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NITROGEN+SYNGAS
ISSUE 364
MARCH-APRIL 2020

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Cover: Fracking rig detail.
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Plant commissioning

Sharing lessons learned from recent projects.

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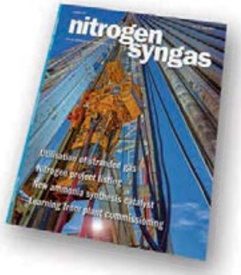
A turn for the worse



What a difference two months can make. When I came to write the editorial for the January/February issue, the talk was all about climate change and sustainable production in the wake of Australia's bushfire crisis, but these days there appears to be only one story that it is obsessing the world, and that of course is the Covid-19 pandemic. The focus of concern has pivoted in recent days and weeks away from China and east Asia, which seem – hopefully – to have weathered the worst of the storm so far, and across to Europe and North America, where some difficult weeks and perhaps months clearly lie ahead.

The shutdown in China's Hubei Province, home to a significant portion of the nation's fertilizer production, especially phosphates, including mono- and diammonium phosphate, has weighed heavily on the ammonia market, slashing Chinese imports for the first quarter and depressing prices more widely. Conversely, the shutdown has also disrupted urea production in China, as well as in Iran, reducing output and exports at the same time that US buyers were looking to cover a shortfall, and raising prices. Methanol has been badly hit by the decline in Chinese industrial production (just reported to be down 13.5% for January and February), as China accounts for half of all methanol demand and an even greater share of the merchant market. Methanol prices had been riding high compared to other syngas derivatives, but have seen a major slump in the past few months.

> Some difficult weeks and perhaps months clearly lie ahead.

Yet as difficult and devastating as Covid-19 may be, ironically there has been just as great an effect on world markets caused by Russia's decision to break ranks on OPEC oil quotas, prompting a similar response from Saudi Arabia, which has sent oil prices tumbling below $30/tonne for West Texas Intermediate for the first time in over 20 years. Both producers presumably hope that they can drive highly geared US shale gas producers out of business, but will also take a great deal of pain themselves in the meantime. The forecast decline in demand caused by reductions in mobility caused by quarantines, including the virtual complete shutdown of the world's air travel, are also playing on oil demand predictions.

Gas prices too are languishing at levels not seen for over a decade, with a glut of supply in the LNG market and Russia and the US both competing for European business, and again a reduction in demand likely from the Covid-19 epidemic. While OPEC discipline may have broken down for the time being, natural gas markets do not even have a body capable of stabilising prices in the same way. Oxford Energy has recently predicted that we may see $2.00/MMBtu natural gas prices in Europe this summer – something that I can't recall even from the halcyon days of the 1990s, and good news for European chemical producers, assuming that they can stay open.

And that remains the great imponderable - with most of the US and Europe on lockdown, certainly for weeks, possibly for months, and possibly to a greater extent than China was, the economic effects of Covid-19 may turn out to be just as if not more far reaching as the immediate health worries, and a global recession may already be a foregone conclusion, with both supply and demand sides of the economy affected. Governments will want to minimise the impact upon agriculture, so demand on the nitrogen side may be more robust than for industrial sectors, but 2020 is shaping up to be a bad year for everyone. For now we must all hope that the quarantines work, and that the northern hemisphere's summer brings better news for us all. ■

Richard Hands, Editor

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MARKET INSIGHT

Alistair Wallace, Head of Fertilizer Research, Argus Media, assesses price trends and the market outlook for nitrogen.

NITROGEN

The ammonia market was dominated by effects of the coronavirus epidemic outbreak during February. Chinese imports for the month fell by 30-40 per cent over volumes seen in January. Yushny f.o.b. ammonia prices remain in the low-$220s/t, with suppliers mainly just covering contracts. The contract price between Yara and its suppliers in the Baltic was agreed at similar levels to January at around $218-220/t f.o.b. There is limited spot demand in Europe to raise prices. Overall, prices were steady in the west of Suez market, but starting to come under pressure in eastern markets, where c.fr rates have been higher.

Weak demand from China as a result of the coronavirus outbreak will likely continue in March, and this is weighing heavily upon Asian delivered prices. Middle East supply is lengthening, but production remains offline in Australia, where Yara's Pilbara fertilizer plant on the Burrup Peninsula has been shut down since mid-November after seawater damage to a cooling tower, and was not expected to be back online for some weeks.

West of Suez, the ammonia market is more balanced, with the US and Europe moving into their regular annual seasonal demand peaks. Overall the second quarter of 2020 looks balanced in terms of supply and demand, but it is to be expected that prices will firm seasonally in the third quarter.

On the urea side, prices rose in February as heavy buying for the US and trader positioning saw most producers sell out early for March. Reduced export availability from China due to concerns over the coronavirus and the associated impact on production also contributed substantially to the price hike. The US almost single-handedly pulled up prices when NOLA prices rose by nearly $40/t to $270/t c.fr. Almost 500,000 tonnes of urea were bought.

With producers heavily committed for March and traders attempting to push up prices before selling long positions, the overall urea market is projected to remain firm during March. Chinese export supply is predicted to remain very low throughout the months of March and April, after the government asked domestic producers to focus on meeting internal fertilizer supply needs in order to mitigate the impact of the coronavirus outbreak. However, Argus believes that much of any increase in global prices has already taken place, and that March will see a slower rate of gain in urea pricing.

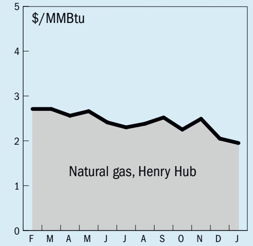
Table 1: **Price indications**

Cash equivalent	mid-Feb	mid-Dec	mid-Oct	mid-Aug
Ammonia ($/t)				
f.o.b. Black Sea	220-223	210-225	225-233	195-215
f.o.b. Caribbean	215	200-215	193-210	170-190
f.o.b. Arab Gulf	215-250	220-235	230-250	190-205
c.fr N.W. Europe	250-285	250-281	250-285	225-265
Urea ($/t)				
f.o.b. bulk Black Sea	212-215	203-220	225-240	245-260
f.o.b. bulk Arab Gulf*	222-235	238-250	244-260	256-270
f.o.b. NOLA barge (metric tonnes)	269	225-240	245	230
f.o.b. bagged China	240-245	252-270	263-280	277-295
DAP ($/t)				
f.o.b. bulk US Gulf	300	268-294	294-303	313-326
UAN (€/tonne)				
f.o.t. ex-tank Rouen, 30%N	146-148	199	200	197

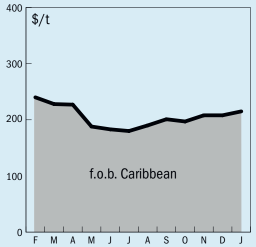
Notes: n.a. price not available at time of going to press.
*n.m. no market * high-end granular*

END OF MONTH SPOT PRICES

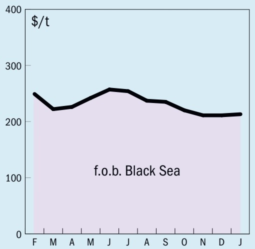
natural gas



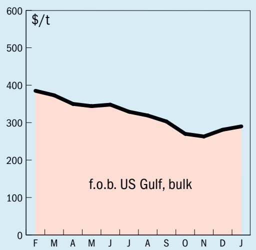
ammonia



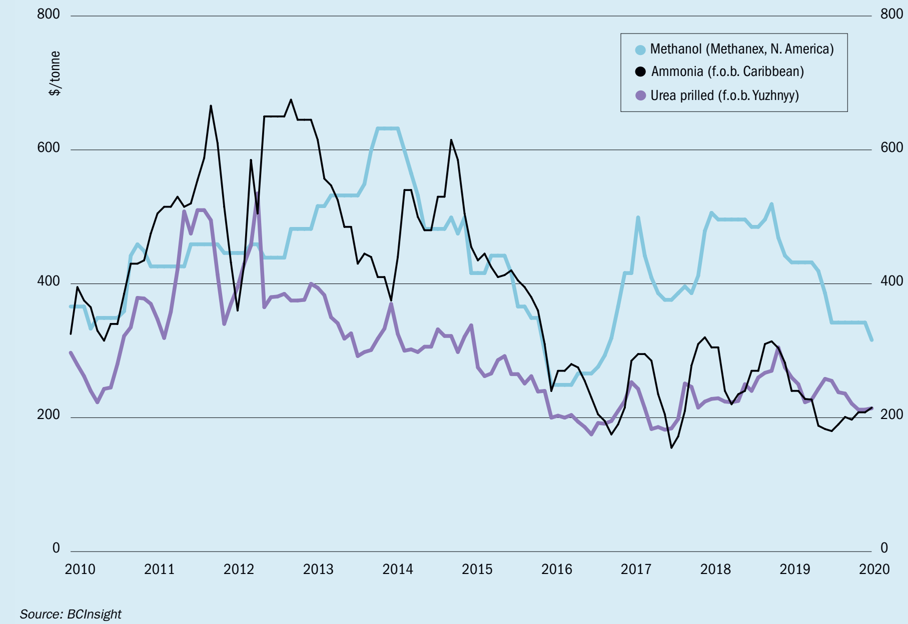
urea



diammonium phosphate



Historical price trends $/tonne



Source: BCInsight

AMMONIA

- The impact of coronavirus on both supply and demand continues to provide considerable uncertainty to the market. With much of Hubei province on lockdown, and a corresponding reduction in ammonia demand for DAP production, Chinese imports appear to be down, pushing more ammonia onto the international market and creating generally bearish sentiment.
- Yara and Mosaic rolled over the Tampa ammonia contract price at $250/tonne c.fr for March, for the third successive month, on the back of lower ammonia demand for MAP/DAP production. However, US agricultural demand is expected to be stronger this year, after ammonia application was halted early last year due to a harsher winter. Up to 96 million acres are expected to be planted to corn in 2020. Nutrien says that it anticipates North American prices will be supported by a surge in demand this spring, and lower offshore imports, and CF Industries also said in a recent results presentation that it expects positive demand for spring ammonia following a poor fall ammonia season.

UREA

- Fewer exports out of China has supported international prices in the short term. Uncertainty over availability appears to be driving buying activity in many markets.
- At the same time, increased US demand has also reduced urea availability west of Suez, with fears of a supply shortfall driving up prices at New Orleans considerably and drawing in urea from Algeria, Russia and Egypt, amongst other places.
- Indian and South American buying is also supporting the urea market, in spite of relatively subdued demand from Europe. There is as yet no sign of any slowdown in buying from key markets such as India due to the unfolding epidemic.
- However, the imminent arrival of the new Dangote urea complex on the market is likely to have a depressing effect on prices in the longer term.

METHANOL

- The potential for disruption to Chinese industrial production caused by the coronavirus outbreak has weighed heavily on the methanol market. China imports 10 million t/a of methanol and its demand, especially for olefins production, is a major factor on setting market prices. The extended New Year shutdown has also crimped Chinese demand.
- Conversely, there have also been worries about the impact of coronavirus on Iran, a major supplier of methanol to China may lead to tighter availability. Iran supply 3.5 million tonnes of methanol to China last year.
- Falling oil prices due to the Russian-Saudi Arabian oil price war are likely to lead to corresponding falls in methanol prices.

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Nitrogen Industry News

NETHERLANDS

Topsoe launches TITAN steam reforming catalyst series

At the Nitrogen+Syngas Conference 2020, held in The Hague, Netherlands, Haldor Topsoe launched its new TITAN™ series of steam reforming catalysts. The company says that the new series, which consists of the RC-67 TITAN and RK-500 TITAN catalysts, offers improved performance and longer catalyst lifetime thanks to the hibonite-rich composition. The addition of titanium promoters adds exceptional mechanical strength while a seven-hole cylindrical shape yields both a very low pressure drop and a high surface area. Pressure drop build-ups in syngas plants can cause unscheduled downtime and cost millions of dollars, while thermal instability during operation can lead to operational risk and reduce plant lifetime. Topsoe says that the catalysts can mitigate these risks, ensuring lower operating costs, increased profit margins, and reduced energy usage.

UNITED STATES

IFA holds first Global Stewardship Conference

From February 3rd to 7th, IFA welcomed 170 leaders from the international fertilizer industry and the wider business community to New York City to discuss innovative stewardship initiatives, learn more about sustainability reporting, get inspired by sustainability programs within the fertilizer industry, and understand expectations from the UN, finance and NGO communities. The IFA Global Stewardship Conference was opened by Mostafa Terrab, IFA and OCP Chairperson, who welcomed CEOs, Safety, Health and Environment experts, agronomists and public affairs professionals from fertilizer producers and distributors from around the world, alongside prominent experts from intergovernmental organizations and NGOs, policymakers, academia, business and engineering to take a comprehensive look at corporate SDG implementation.

The event covered all aspects of industry stewardship. At the level of fertilizer production, innovations and investments in energy and water efficiency, CO_2 and other emission reductions, were presented. With regard to fertilizer application, critical outcomes of the most recent UN reports and resolutions for phosphorus and nitrogen production and application management were examined and the positive contribution of fertilizers in terms of soil health and biodiversity, as were efforts to continuously improve nutrient use efficiency and minimize nutrient losses to the environment in order to help meet challenges facing agrifood systems.

Many of the external speakers saw the fertilizer industry having a crucial role to play in enabling more sustainable agriculture. "Our food system is bankrupting our healthcare system and the fertilizer industry is critical for addressing this," said Roy Steiner, Senior VP of Food at the Rockefeller Foundation, while Ann Tutwiler of the Meridian Institute and SystemIQ explained how agrobiodiversity can mitigate climate change risks and saw the fertilizer industry playing a major role in helping countries to implement it.

With regards to sustainable production, Peter Levi, a leading energy analyst at the International Energy Agency, thanked IFA for its input into the development of a Nitrogen Technology Roadmap, which will outline ways to significantly improve the industry's energy efficiency and reduce its carbon footprint. Following on, the renowned industry analyst Trevor Brown explained how green ammonia is increasingly becoming a contributor to achieving that long-term goal. IFFCO

"As the fertilizer industry takes an increasingly holistic approach to stewardship, we were delighted to have had such prestigious speakers, as well as a wide range of excellent presentations from IFA members from across the world detailing their impressive sustainability initiatives," said IFA Director-General Charlotte Hebebrand.

The event reflected the fertilizer industry's growing focus on sustainability. "Sustainability is business, not something a company does in addition to business," observed Candace Laing, VP of Sustainability & Stakeholder Relations at Nutrien, while for Tip O'Neill, CEO of IRM, it required investment but "represents a huge market opportunity and leads to measurables returns". Ben Pratt, VP of Public Affairs at Mosaic, meanwhile, asserted that the industry cannot afford "to step back from social and environmental responsibilities". Hanane Mourchid, Senior VP of the Sustainability Platform at OCP highlighted the importance of addressing all internal and external stakeholders to spread and raise awareness of the SDGs.

Industry representatives also spoke of the increasing emphasis of the financial community on ESG reporting and called for a harmonized approach to reporting in order to ensure consistent, comparable and meaningful reporting. The sustainable production and application of fertilizers supports sustainable food systems and mitigates climate change. "I am optimistic that through capital deployment, accelerated innovation and courageous leadership, the fertilizer industry will deliver in collaboration with communities and citizens" said Devry Boughner Vorwerk, CEO of DevryBV.

Gulf Coast Ammonia to proceed with world-scale plant

Gulf Coast Ammonia LLC closed project financing for its new 3,600 t/d (1.3 million t/a) world-scale ammonia plant in Texas in January. The company is building at a brownfield site in Texas City, Texas, and says that construction will begin soon with commissioning expected in 1H 2023. Capital for the project is being provided by a joint venture of Starwood Energy Group and Mabanaft GmbH. The plant will purchase hydrogen and nitrogen gases locally as feedstock, leading to significant cost savings by avoiding a reforming section. Haldor Topsoe is licensing its ammonia technology for the project, which will be the world's largest single train ammonia synthesis plant. Gulf Coast says that it has secured long-term offtake contracts for the majority of its production capacity and long-term supply agreements for its feedstock.

Ken Koye, Gulf Coast Ammonia's CEO, said, "I am pleased to have played a leading role in advising on the commercial structuring and development of this significant addition to the development partners' business in North America. I look forward to delivering the completed project and associated infrastructure as a safe, reliable and responsible addition to the industrial base in Texas City. This new world-class facility will meet domestic and global demands for nitrogen-based fertilizers to improve crop production and yields to feed the world's growing population, as well as specialty chemical production on the Texas Gulf Coast."

NORWAY

Vessel to run on ammonia-powered fuel cell

A maritime innovation project looking to install the world's first ammonia-powered fuel cell on a vessel has been awarded €10m funding from the European Union. The ShipFC project is being run by a consortium of 14 European companies and institutions, co-ordinated by the Norwegian cluster organisation NCE Maritime CleanTech, and has been awarded backing from the EU's Research and Innovation programme Horizon 2020 under its Fuel Cells and Hydrogen Joint Undertaking (FCH JU).

The project will see an offshore vessel, Viking Energy, which is owned and operated by Eidesvik and on contract to energy major Equinor, have a large 2MW ammonia fuel cell retrofitted, allowing it to sail solely on the fuel for up to 3,000 hours annually. As such the project aims to demonstrate that long-range zero-emission voyages with high power on larger ships is possible.

The goal is also to ensure that a large fuel cell can deliver total electric power to shipboard systems safely and effectively. This is the first time an ammonia-powered fuel-cell has been installed on a vessel. A significant part of the project will be the scale up of a 100-kilowatt fuel cell to 2 MW. The fuel cell is being tested on land in a parallel project and development and construction will be undertaken by Prototech. Testing will be executed at the Sustainable Energy Norwegian Catapult Centre. The ship-side ammonia system will be supplied by Wärtsilä. The ammonia fuel cell system will be installed in Viking Energy in late 2023.

Norwegian crop nutrition company Yara has been contracted to supply the green ammonia for the project, which will be produced by electrolysis and delivered to Viking Energy containerised to enable easy and safe refuelling. Another part of the ShipFC project will perform studies on three other vessel types, namely offshore construction vessels and two cargo vessel types, to illustrate the ability to transfer this technology to other segments of the shipping industry. The three test cases will look at the ability to transfer the technology to other vessels, which has led to North Sea Shipping, Capital-Executive Ship Management and Star Bulk Ship Management also being part of the consortium.

PHOTO: EIDESVIK

The Vikiing Energy, to be retrofitted with an ammonia fuel cell.

UNITED KINGDOM

Royal Society endorses ammonia for shipping, district heating and storage

Converting high carbon diesel engines in ships to run on clean ammonia would slash carbon emissions, according to a report from the world's oldest scientific institution. The UK-based Royal Society says in a policy briefing published in February that 'green' ammonia could also fuel district heating and provide energy storage. The briefing argues that chilled ammonia made with green electricity can easily be adopted as a fuel, and pumped over existing pipes and distribution infrastructure. Converting marine diesel engines to power bulk cargo carriers would be relatively cheap and simple, researchers suggest. The world's diesel-powered shipping fleets account for 2% of global greenhouse emissions; as much as the entire German economy.

Widely used in fertilizers, explosives, drugs and refrigerants, ammonia has been pondered as a replacement for diesel, but rejected due to its high CO_2 emissions when made conventionally. Ammonia production now accounts for 1.8% of global GHGs, the Royal Society notes. However, the falling costs of green electricity needed to produce ammonia, plus the lower costs of storing carbon dioxide underground from conventional production could open up opportunities for 'green' or 'blue' (conventional production with carbon capture and storage) ammonia. Diesel engine builders are reporting interest in ammonia-powered conversions. One, Man Energy Solutions, hopes to have a new purpose-designed ammonia engine available to shipbuilders by 2024.

BOLIVIA

Urea plant could be moved

The Bolivian government has said that Bolivia's troubled ammonia-urea plant at Bulo Bulo could be moved to a "more profitable" location closer to the Brazilian border. Speaking to local media, hydrocarbons minister Victor Hugo Zamora described the $1 billion project as the "worst political whim" of former president Evo Morales' government. "How are we going to put a plant more than 1,000 km from the principal market, which is Brazil?" state news agency ABI quoted Zamora as saying. However, the local state of Cochabamba's energy and hydrocarbons industrial development director Mario Apaza said in response that the relocation would not be viable due to lack of raw materials, and that the move could cost around 60% of the plant's capital cost.

The plant started up in January 2018, and has a nominal capacity of 1,200 t/d of ammonia and 2,100 t/d of urea, but according to Zamora, the plant has operated at less than 10% of capacity. In 2019, the plant's average urea production was 900 t/d, impacted by the distance to potential markets and poor natural gas supply from declining fields, with no output for 136 days. At the same time, global urea prices have slumped to below $250/t. Losses for 1H 2019 were $6 million. Attempts to improve rail connectivity by building a railway to Montero to

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interconnect with the eastern rail network remain unfinished in spite of having begun work in 2013, meaning that urea must be shipped by truck from the facility. The plant remains closed during revamp work which is expected to last for three months.

AUSTRALIA

Dyno Nobel to pilot renewable ammonia production

Explosives manufacturer Dyno Nobel, part of the Incitec Pivot group, says that it will test the feasibility of manufacturing ammonia using renewable energy at its Moranbah site in Queensland. The company has received a A$980,000 grant from the Australian Renewable Energy Agency (ARENA) to examine the feasibility of renewable hydrogen production at its ammonia, nitric acid and ammonium nitrate facility. The project aims to substitute renewable hydrogen for natural gas as feedstock and simultaneously increase production while reducing CO_2 emissions. The study will be study the scope and cost of the required plant upgrade using methane and renewable hydrogen as alternative feedstocks. Incitec Pivot's Moranbah site is one of six ammonia plants operated by the company, with a capacity of 330,000 t/a of ammonia.

ARENA said in a statement: "The study will evaluate if a feasible project can be developed with hydrogen produced from zero-emission electrolysis and supplied at a price that is cost competitive to alternatives. It will determine the cost of hydrogen electrolysis equipment at industrial scale (of >100 MW) and the strategy to manage electrical and hydrogen supply variability, and determine the economics of solar-only, behind-the-meter power generation for renewable hydrogen production."

NIGERIA

Dangote plant in pre-commissioning phase

Dangote Fertilizer Ltd has begun pre-commissioning of its $2 billion granulated urea fertilizer complex. The urea complex, in the Dangote Free Zone, has a capacity of 3.0 million t/a. The engineering, procurement and supervision contractor for the project is Saipem, with project management consultancy from Tata Consulting Engineers of India. Dangote said in a press statement that virtually all the section of the plant such as the central control room, ammonia and urea bulk storage, cooling tower, power generation plant and granulation plant, have been completed and are going through pre-testing. Gas supply is flowing from the Nigerian Gas Company (NGC) and Chevron Nigeria Ltd (CNL) under a gas sale and purchase agreement to supply 70 MMscf/d of natural gas.


PHOTO: DANGOTE

The new Dangote fertilizer complex under construction.

Dangote Group Executive Director, Strategy, Portfolio Development and Capital Projects, Devakumar Edwin, said that Nigeria would be able to save $500 million from import substitution and provide $400 million from exports of products from the fertilizer plant.

"I am happy that by the time our plant is fully commissioned, the country will become self-sufficient in fertilizer production and even have the capacity to export to other African countries. Right now, farmers are forced to utilise whatever fertilizer that is available as they have no choice; but we need to know that the fertilizer that will work in one state may not be suitable in another state, as they may not have the same soil type and composition. The same fertilizer you use for sorghum may not be the fertilizer you will use for sugar cane," Edwin explained. He added: "By 2020, the Nigerian population is projected to increase to about 207 million, which would lead to increased food requirements. Estimates points out that around five million tonnes of fertilizers are required per year in Nigeria in the next five to seven years - 3.5 million t/a of urea and 1.5 million t/a of NPK, while current production levels in Nigeria [prior to the opening of the Dangote facility] are at 1.6 million t/a."

SAUDI ARABIA

Saipem agrees Saudi joint venture

Saipem has signed a memorandum of understanding with Saudi construction company Abdel Hadi Abdullah Al Qahtani & Sons Company (AHQ). The companies have agreed to form joint venture in Saudi Arabia, combining Saipem's EPC competences and skills with AHQ's knowledge and experience in logistics, construction and supply chain management. The joint venture aims to maximise local value creation and to become a first tier player in the execution of onshore construction and onshore pipeline EPC projects in the Kingdom.

Maurizio Coratella, Chief Operating Officer of the Onshore E&C Division, commented: "Saudi Arabia has been a core market to Saipem from the outset, and our ambition is to maintain our EPC leading role in the country. We are committed to establishing this joint venture together with AHQ with the aim of harnessing synergies to support our key client Saudi Aramco. A central feature of the partnership is the possibility to operate in compliance with the requirements of the IKTVA (In-Kingdom Total Value Added) program launched by Saudi Aramco as an integral part of its contracts to achieve 70% localisation of spending by 2021".

RUSSIA

EuroChem inks credit facility with Roseximbank

EuroChem has closed a $87 million export credit facility with the Russian Export-Import Bank (Roseximbank), in conjunction with the Russian Ministry of Industry and Trade. The loan agreement has a two-year limit and will finance the export of liquid ammonia from the firm's new $1 billion EuroChem Northwest ammonia plant in Kingisepp, to international customers, according to the company. Although most of the ammonia from Kingisepp will be used in EuroChem's own plants in Belgium, Lithuania and Russia, the EuroChem says that around 25% of the plant's output will be sold to other customers in Europe.

UKRAINE

Severodonetsk triples fertilizer output

PrJSC Severodonetsk Azot, part of Dmytro Firtash's Group DF says that it tripled its production of fertilizers in 2019, following the start-up of the company's new UAN unit. Reporting its production for 2019, Severodonetsk said that its output of ammonium nitrate was 371,660 tonnes, sales of ammonia solutions were 1,650 tonnes, and production of non-concentrated nitric acid was 296,200 tonnes.

Chairman of the board Leonid Buhayev said: "The large-scale and important project for us over the year was the start of production at the new UAN liquid fertilizer plant. The result is that we produced twice as many UAN as a year earlier."

As well as its new UAN unit, the company has also overhauled its ammonia refrigeration unit and nitric acid production, steam supply and general communications department.

BAHRAIN

Saipem to conduct feasibility study n expansion plans

Saipem has signed a memorandum of understanding (MoU) with Gulf Petrochemical Industries Company (GPIC) for a feasibility study on three main projects in Bahrain. The first would increase GPIC's daily production of ammonia, urea and methanol by about 15% through debottlenecking and revamping which will also reduce energy consumption and use natural gas. Provisional costing for this is $390 million. The second would be a pre-feasibility study concerning plans to build a new 'mega' ammonia and urea plant, with a capacity of 2,200 t/d of ammonia and 3,400 t/d of urea, expected to cost between $1.6 billion and $2.2 billion. Finally, the third aims to determine the quality of gas feedstock in the oil and gas fields discovered in 2018 off the west coast of the kingdom – now the largest in Bahrain. If developed, these oil and gas projects are estimated to cost $1.65 billion. GPIC is a three-way joint venture between Bahrain's National Oil and Gas Holding Company, Saudi Basic Industries Corporation (SABIC) and Kuwait's PIC.

BRAZIL

Petrobras tries again for Tres Lagoas sale

State oil firm Petrobras has launched a new process to sell the UFN-III urea project at Três Lagoas in Mato Grosso do Sul state. The plant, which has work on which are currently 81% complete, according to Petrobras, will have 2,200 t/d of ammonia and 3,600 t/d of urea capacity when finished. However, a previous attempt to sell the project, as part of Petrobras' huge $30 billion divestment programme, failed to find a buyer when it was cancelled in 2018. Petrobras had begun exclusive negotiations over the unit with Russian firm Acron, but the talks were unsuccessful and were eventually halted after political turbulence following the resignation of Evo Morales as president in Bolivia, which was supposed to supply natural gas for the project.

EGYPT

KIMA commercial production planned for April

Egyptian Chemical Industries (KIMA), said that the company's new plant at Aswan is now fully completed. The complex has a capacity of 900 t/d of ammonia, 1,200 t/d of urea, and 300 t/d of ammonium nitrate (both low and high density). Trial operations have reportedly been successfully concluded, and full scale commercial operation is expected for April 2020. Investment cost is put at $770 million, funded by both debt and equity. ■

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ISSUE 364
MARCH-APRIL 2020

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Syngas News

UNITED KINGDOM

UK awards $36 million to low carbon hydrogen projects

The UK's Department for Business, Energy and Industrial Strategy has awarded £28 million ($36 million) of government funding to five demonstration projects for low carbon hydrogen production, as part of a larger stimulus package to cut industrial carbon emissions. The projects targeted for funding include:

- Dolphyn, which is looking at combining offshore wind power to electrolyse seawater at scale in deep water locations. Hydrogen would be piped from floating combined 10MW wind turbines/water treatment/electrolyser plants to shore. The funding will enable the detailed design of a 2 MW prototype system.
- Gigastack, which aims to demonstrate the delivery of bulk, low-cost zero-carbon hydrogen through gigawatt-scale polymer-electrolyte membrane (PEM) electrolysers. The funding will enable ITM Power to work towards developing a system that uses electricity from Orsted's Hornsea Two offshore wind farm to generate renewable hydrogen for the Phillips 66 Humber Refinery.
- Hyper, which is looking at a low-carbon bulk hydrogen supply through pilot scale demonstration of a sorption enhanced steam reforming process, based on a novel technology invented by the Gas Technology Institute (GTI). This phase of the funding will enable the detailed design and build of the system at Cranfield University.
- Acorn Hydrogen Project. This is the evaluation and development of an advanced reforming process, and includes involvement from Johnson Matthey, who are providing a low-carbon hydrogen technology for evaluation. The proposal is to deliver an energy- and cost-efficient process for hydrogen production from North Sea natural gas, while capturing and sequestering associated CO_2 emissions.

Finally, there is HyNet – a low carbon hydrogen plant being developed by a consortium of Progressive Energy, Essar Oil Ltd, Johnson Matthey and SNC-Lavalin. HyNet will develop a 100,000 Nm3 per hour clean hydrogen production facility for deployment as part of the HyNet Cluster at a 160 acre site owned by Essar Oil at Ellesmere Port near Liverpool, close to the Stanlow refinery, using Johnson Matthey's low-carbon hydrogen technology, which enables carbon capture and storage. ■

Arup joins hydrogen global charter

Arup has signed up to the Hydrogen Global charter. Hydrogen Global was launched in 2019 by the World Energy Council as a platform to promote the deployment of clean hydrogen and hydrogen-based fuels. Stemming from the Council's unparalleled global network of energy experts, Hydrogen Global assembles projects, programmes, and organisations working with hydrogen to raise awareness of the technology across the wider energy community. Arup says that it will draw on its global technical expertise to support the evaluation, application and deployment of effective hydrogen-based solutions to help promote clean hydrogen worldwide.

Chair of the Arup Group, Alan Belfield, said: "Hydrogen can play a critical role in decarbonising energy systems across the world. We are delighted to demonstrate our commitment to the future hydrogen economy by aligning to the World Energy Council's Hydrogen Global charter. It is critical that we embrace all the tools available to mitigate the negative impacts of climate change and the hydrogen economy can play a significant role. Together we can make a positive impact on the industry and enable a better and faster successful energy transition."

Dr Angela Wilkinson, Secretary General of the World Energy Council said: "We are delighted to welcome our partner Arup signing Hydrogen Global's charter. Global demand for energy is rising and there is no quick fix or silver bullet solution to challenges of energy security, equity and affordability and environmental sustainability. New hydrogen pathways can help achieve bolder ambitions for better lives and a healthy planet. Clean hydrogen can reach parts of the global energy system that cannot be electrified."

AUSTRALIA

Ammonia plant to produce renewable hydrogen

Yara Pilbara Fertilisers has been awarded A$1.0 million for a feasibility study to explore the potential to produce renewable hydrogen at industrial scale at its liquid ammonia production facility in the Pilbara, the Australian Renewable Energy Agency (ARENA) has announced. The renewable hydrogen produced at the ammonia plant will displace 30,000 t/a of hydrogen which Yara currently derives from natural gas. The hydrogen will be blended with hydrogen from reforming to produce ammonia with a lower carbon footprint and sold for further processing into domestic and international markets.

In the long term, Yara says that it is aiming to produce hydrogen and ammonia entirely through renewable energy. The study will be the first step on the path to achieving commercial scale production of renewable hydrogen for export. Yara will collaborate with global energy company ENGIE to deliver the feasibility study. ENGIE has a dedicated hydrogen business unit focused on developing industrial-scale renewable-based hydrogen solutions in international markets.

"Yara's project will offer great insight into how Australia's current ammonia producers can transition away from the use of fossil fuels towards renewable alternatives for producing hydrogen while continuing to leverage the substantial export capabilities that those companies have already established," ARENA CEO, Darren Miller, said. "This project will support future investment in renewable hydrogen from our largest producers, which in turn will provide the economies of scale required to produce renewable hydrogen and ammonia at a competitive price for export."

SAUDI ARABIA

Air Products joint venture to build Saudi hydrogen hub

Air Products Qudra has broken ground on its fully integrated industrial gases hub in Jubail, Saudi Arabia. The company is a joint venture between Air Products and Qudra Energy, a subsidiary of Saudi development and investment company Vision Invest. The industrial gases hub will produce 414 t/d of hydrogen using steam reforming. The project will also include Saudi Arabia's second hydrogen fuelling station, an air separation unit to produce oxygen and nitrogen, and a hydrogen pressure swing adsorption (PSA) unit to recover hydrogen from industrial off-gases, as well as the installation of pipeline networks to transport industrial gases to refining and chemical customers around the region, Air Products said. The hydrogen plant will be of identical size to a plant Air Products announced earlier for the US Gulf Coast of Texas. The Saudi industrial gases facility is due to begin operations in 2023.

Dr. Samir Serhan, Chairman of Air Products Qudra and Executive Vice-President for Air Products, said, "The investment we are making in Jubail is a continuation of our mission to bring world-class technology, on-site solutions, leading project execution and operational leadership for large-scale energy and environmental projects throughout the Middle East region."

TRINIDAD & TOBAGO

Gas price discussions get serious

Methanex has managed to agree a two month extension of its natural gas supply contract with the National Gas Company of Trinidad & Tobago (NGC) for its Titan methanol plant, following the one month extension it secured to cover supplies during January. CEO John Floren said that the company is continuing to try and work towards a long term gas contract with NGC. Methanex is working on the assumption of an 85% operating rate for its Trinidad plants, assuming that a gas supply can be secured. However, the company has also said that it would consider closing the Titan plant rather than sign an unprofitable deal with NGC. In an investor conference call, Floren said:

"Well, I think we're going to pay a higher price for gas in Trinidad. You know we want to pay a price where we can still earn EBITA and invest in the plant, so it's usually a round price. So when you have these negotiations, that sliding scale with methanol will continue to be in place and we just want to be able to make sure we can survive in the low end of the cycle and do well at the high end of the cycle." NGC typically sells gas with a price escalator mechanism tied to end product prices.

Methanex's Titan plant has a capacity of 875,000 t/a of methanol. The company also operates the 1.7 million t/a Atlas unit at the same site.

FRANCE

France launches wind-powered hydrogen plant

Start-up company Lhyfe has raised €8 million to build France's first wind-powered hydrogen plant in northwest France, with plans to deploy its concept to offshore wind by 2025. The electricity will be generated at an eight turbine offshore wind project at Bouin, 50 km southwest of Nantes, and used to electrolyse water for 300 kg/d of hydrogen production. The hydrogen will be delivered to the nearby town of La Roche-sur-Yon, where a hydrogen station will be installed to fuel the town's newly-converted fleet of hydrogen-powered buses and refuse collectors.

PHOTO: METHANEX

Methanex plant, Trinidad.

SWEDEN

Biomethanol for diesel production

Swedish forest-owner association Södra has made its first delivery of biomethanol from its new unit based at Södra's pulp mill in Mönsterås. The plant uses forest biomass as feedstock. The company made the decision to invest in such a commercial production facility in 2017. The facility recovers 5,000 t/a of methanol from a Kraft mill using Andritz technology. The methanol will then be used for biodiesel production using Danish canola.

BELGIUM

Belgium also looking to wind-powered hydrogen

Belgium is looking to use hydrogen produced by electrolysis as a way of capturing surplus energy from wind turbines when this cannot be absorbed by the local electricity grid. The project, at Ostend on the North Sea coast, will be fuelled by offshore wind turbines. Belgium's offshore wind generation is due to reach 2 GW of capacity by the end of 2020. However, the turbines' production peaks rarely coincide with consumer demand peaks, meaning that "there is an opportunity to compensate for the discontinuity between production and consumption," taccording to the project's backers. A 50 MW demonstration electrolyser is due for completion in 2022, before a full-scale plant is ramped up in 2025. The final stage of the project aims to reduce CO_2 levels by between 500,000 and one million tonnes of CO_2 per year.

BOTSWANA

Government renews push for CTL plant

Reuters reports that Botswana is looking to push development of a $4 billion coal to liquids (CTL) plant in the country. Developer state-owned Botswana Oil Ltd issued a tender seeking investors three years ago, but has made no real progress since then. However, Lefoko Maxwell Moagi, minister of mineral resources, green technology and energy security, says that the development will now be "accelerated", looking towards completion in 2025. Botswana has Africa's largest coal reserves at 212 billion tonnes. The government says that it has had preliminary discussions with Sasol over the latter's CTL technology. ■

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People

Clariant has announced that **Stephan Lynen** will be appointed chief financial officer (CFO) of the company as of April 1st, 2020. Lynen is currently head of the Clariant's Additives business unit, and has served with the company for more than 20 years in various international general management and business roles. He will succeed **Patrick Jany** who will be leaving to pursue a career opportunity outside of Clariant as CFO of A.P. Moller-Maersk, a global leader in shipping services.

"We are very pleased that Stephan Lynen will join the executive committee as CFO of Clariant," said Hariolf Kottmann, Executive Chairman of Clariant. "With his vast business experience, his general management skills and his vast expertise in finance, he has the perfect profile for this important role. Drawing on his outstanding ability in strategy implementation and his broad knowledge of our customers, he will play a leading role in shaping the Clariant of the future. At the same time, we very much regret Patrick Jany's decision to leave Clariant. Patrick Jany has been with our company for 25 years and has played a major role in our success story. He joined Clariant after a successful career at Sandoz, and has helped shape the development of our company from the very beginning. We wish him all the best for his future endeavors as CFO of A.P. Moller-Maersk."

During Patrick Jany's tenure as CFO since 2006, Clariant has gone through several structural changes, including a fundamental restructuring of the company, the acquisition of Süd-Chemie and recently the repositioning of the company.

Clariant's board of directors has also proposed **Nader Ibrahim Alwehibi** and **Thilo Mannhardt** for election to the board at its Annual General Meeting. The nominees will replace current board members **Khaled Homza A. Nahas** and **Carlo G. Soave**. Alwehibi, an insurance expert, is a member of SABIC's board of directors and serves on its Audit and Risk and Sustainability Committees. Mannhardt, who has lived in Latin America for many years, holds several board memberships in Brazil and has many years of experience as a management consultant and CEO of a listed Brazilian chemical and pharmaceutical company.

Charlotte Hebebrand, Director General of the International Fertilizer Industry Association (IFA), will end her term with the organisation on May 1st. IFA's Senior Director of the Agriculture Service, **Patrick Heffer**, will serve as interim Director General as of 1 May, until a new permanent Director General can be proposed by IFA's Board of Directors and approved by the membership at the organisation's General Meeting, with the aim of having a new person in place by July.

In a farewell letter to IFA's membership, Charlotte said that it had been "a tremendous privilege" to work with IFA since joining the association in September 2012. "I will forever be grateful for the trust you placed in me, for your engagement to both build and implement IFA's strategic objectives, and for all the support you have provided to IFA," she said. The board of directors of Haldor Topsoe has announced the appointment of **Roeland Baan** as the company's new Chief Executive Officer (CEO) as from June 1st, 2020. Baan takes over from **Bjerne S. Clausen**, who will retire in June after more than 40 years with the company, including more than eight years as CEO. Since 2016, Roeland Baan has been President and CEO of the global stainless steel company Outokumpu. Previously, he held a wide range of global CEO and executive vice president (EVP) positions at Aleris International, Arcelor Mittal, SHV NV and Shell. He is Vice Chairman of the International Stainless Steel Forum and member of the Executive Committee of Eurofer. He also serves as a supervisory board member of SBM Offshore NV and as an independent board member of Norsk Hydro ASA. Mr. Baan is a citizen of The Netherlands and holds a MSc in Economics from Vrije Universiteit Amsterdam.

Bjerne S. Clausen commented: "I have had an amazing journey here at Topsoe, worked on a vast variety of exciting projects, worked with some of the sharpest brains in the field of catalysis and chemistry, and met customers and partners around the globe. I cannot imagine a more rewarding career. I welcome Roeland Baan to the company. He has come to a great company with dedicated and passionate colleagues."

The Agricultural Industries Confederation (AIC) has appointed **Andrew Pearson** as its Policy Manager. His role will involve working across all five sectors of AIC, analysing the latest information and data in order to develop solutions for the most pressing issues facing agri-supply businesses and UK agriculture. Taking over from **Dave Freeman**, Andrew brings extensive experience and expertise from his time as a land quality and estates manager for over seven years, and work as a Contaminated Land Officer and Environmental Health Technician. ■

Calendar 2020

APRIL

20-22 CANCELLED
IFA 88th Annual Conference,
NEW DELHI, India
Contact: IFA Conference Service,
49 Avenue d'Iena, Paris, F75116, France
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

MAY

20-22
IFS Technical Conference,
THE HAGUE, Netherlands
Contact: International Fertiliser Society,
PO Box 12220, Colchester, CO1 9PR, UK
Tel: +44 (0)1206 851 819
Fax: +44 (0)1206 851 819
Email: secretary@fertiliser-society.org

27-28
Syngas Nitrogen Russia and CIS,
MOSCOW, Russia
Contact: Milana Stavnaya,
Programme producer, Vostock Capital
Tel: +7 499 505 1 505
Email: MStavnaya@vostockcapital.com

28-29
NH3 Event, ROTTERDAM, Netherlands
Contact: NH3 Event Europe
Tel: +31 10 4267275
Email: info@nh3event.com

JUNE

2-4
Nitrogen+Syngas USA,
TULSA, Oklahoma, USA
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Fax: +44 (0) 20 7903 2172
Email: conferences@crugroup.com

11-12
IMPCA European Mini-Conference,
PORTO, Portugal
Contact: International Methanol Producers and Consumers Association, Belgium
Tel: +32 (0)2 741 86 83
Email: info@impca.eu

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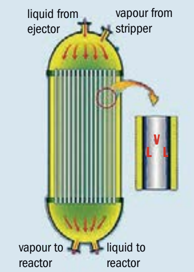
Plant Manager+

Problem No. 59 Troubleshooting the condensation capacity of a falling film HPCC

The falling film high pressure carbamate condenser (HPCC) was the first type of high pressure carbamate condenser applied in urea stripping plants. Did you know that the first Snamprogetti stripping plants also had falling film carbamate condensers? In 1978 Mr Umberto Zardi, later founder of Casale, invented the horizontal kettle type condenser for Snamprogetti urea plants.

The process performance (read condensation capacity) of falling film high pressure carbamate condensers in a urea synthesis section depends on many factors, amongst others synthesis pressure, N/C and H/C ratios, inert content on the process side and steam side, circulation rate on the steam side, etc. Calculations on the process side are limited and not much actual operating data is available.

This makes it difficult to troubleshoot a falling film high pressure carbamate condenser that lacks condensation capacity. And that is exactly the topic of this round table discussion.



Muhammad Farooq of SAFCO in Saudi Arabia starts the round table discussion which refers to an issue he faced in his earlier job: We have two carbamate condensers in parallel in our urea synthesis section. We are experiencing the problem of a low heat-transfer coefficient despite conducting chemical cleaning. Due to low condensation capacity we have synthesis section pressure hikes in the loop.

Please note that if we decrease the steam flow/pressure to the urea stripper, it increases the residual ammonia at the outlet of the stripper. Increasing steam pressure also results in a decrease in condensation capacity at the HPCC as the stripper steam condensate flows on the shell side.

We control the synthesis pressure at around 146 kg/cm² as per design of our licensor. What measures are available to overcome this problem?

Mark Brouwer of UreaKnowHow.com, the Netherlands asks for some clarifications:

- Are we talking about the TEC ACES process?
- Do you have this problem in both HPCCs?
- Are all tubes available or are some tubes plugged?
- Is there any chance of inert build up on the steam side?

Muhammad replies:

- Yes our plant is basically TEC ACES but after carrying out a revamp in 2010, it was changed to the Stamicarbon process.
- The problem exists with both HPCCs. We have diverted the maximum liquid ammonia to increase the conldensation capacity at the inlets of both HPCCs.
- There are no plugged tubes in the HPCCs, both are in very good condition after 15 years of operation.
- How do we check the inert content on the steam/condensate side? Tube side inerts are in range as we analyse gases at the washing column exit.

Mark comes back with a suggestion and some more questions: You could open the inert vent on the steam side and see if the situation improves. But as both HPCCs suffer the problem and one HPCC has steam on the shell side and the other carbamate (am I right?), the problem seems to be on the tube side. Did it change suddenly or slowly and since when? Has there been any change in process conditions?

Muhammad replies: The shell side of both HPCCs contain steam condensate. The problem of synthesis pressure greater than 146kg/cm² is observed when the plant load is increased by more than 90%. The carbamate condenser bottom temperatures are below design. The change is consistent. The major change in the process is that with TEC we were operating at a N/C ratio = 4, while now it is lower.

Mark asks further: Could inert pressure be higher on the process side? Are several synthesis temperatures on the lower side?

Muhammad Kashif Naseem of SAFCO in Saudi also has some questions: Please share your N/C ratio, generated steam pressure and top/bottom temperature.

Muhammad replies: You will find some of the answers below: The steam pressure at low load operation is already on the low side (3.8 kg/cm² against design 3.5 at 100% load), N/C =3.1, reactor top/bottom =185.2/172.8°C against design =183.3/173.5°C. The inert level is under control and we don't believe it is the inerts that are increasing the system pressure.

Easa Norozipour of Khorasan Petrochemical Company in Iran asks further: Did you change the stripper or is the stripper still as per TEC license. I think if you didn't change the stripper as per Stamicarbon license and the N/C ratio is decreased, the main cause must be the new N/C ratio.

A second cause may be a mechanical problem like damage to the distributor in the top of the HPCC.

Muhammad Kashif Naseem shares his experiences: The data provided is very brief but it seems that the condensation rate across the HPCC is too low and the carbamate solution has a high density.

Muhammad responds to comments: We did change the stripper as per Stamicarbon recommendations and our N/C ratio is as per the licensor. We checked both HPCCs during our annual turnaround and both were found to be normal. What is your viewpoint as regards the heat load generated at the stripper and requirements to be absorbed by the HPCC?

A far as operation is concerned, it is ok, however for better optimisation of process parameters we need countermeasures to overcome the condensation capacity and want to benefit from revamping expertise.

Majid Mohammadian of OCI Nitrogen in The Netherlands joins the discussion: In typical HPCC Stamicarbon urea plants the synthesis pressure transmitter is in the HP scrubber overflow line, in a pool condenser type it is located in the ammonia inlet to the pool condenser and in your plant it is in ammonia inlet to the reactor, so the normal synthesis pressure in your case should be higher than the original Stamicarbon plants let say something around 148 to 150 kg/cm². I think it might be possible to increase the plant capacity with normal synthesis pressure of about 148 to 150 kg/cm².

Mark provides a further suggestion: Did you compare the overall heat transfer coefficient (U) before and after the revamp? A reasonably accurate (but certainly good for comparison purposes) value of U can be calculated via:

$$Q = U \times A \times (T_{process} - T_{steam})$$

T_{steam} is the saturation temperature of the steam at the operating steam pressure and $Q = Flow_{LP\ steam} \times dH_{evap}$

Farzan Bashir of Fauji Fertilizer Company in Pakistan shares his experience: Please check that your steam header pressure is in range, because in case of higher steam header pressure there will be less condensation in the HPCC.

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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Africa's fertilizer renaissance

Indorama's fertilizer plant at Port Harcourt, Nigeria.

PHOTO: INDORAMA ELEME

New ammonia and urea plants in Nigeria and Ethiopia are part of a wave of new capacity in Sub-Saharan Africa, and may help pull up regional demand from its current low base level.

While Africa has for a variety of reasons often been behind the curve in terms of the developments in both industry and agriculture that have been seen in, for example South America or South or Southeast Asia, there are hopeful signs that that may be changing. Some of this is coming on the back of a wave of new resource development in the region that peace and more stable economic conditions have allowed. Gas exploration and production is expanding rapidly, and Africa is now the last major region where there is large scale 'stranded' gas suitable for export-oriented nitrogen capacity, although political risk and poor infrastructure remain barriers to development.

Gas

Key to the success of any ammonia and downstream urea or other project is securing a supply of feedstock, and that usually means natural gas. African natural gas production is currently concentrated in the north of the continent, especially Egypt and Algeria, where most of the Africa's ammonia/urea capacity is based, while Sub-Saharan Africa represents only one third of the continent's gas output. Sub-Saharan Africa's natural gas production was estimated at 75.9 bcm in 2018, as against 236.6 bcm for the whole of Africa. Within that figure, the output for the region is dominated by Nigerian gas production, which reached 49.2 bcm that year, representing 65% of Sub-Saharan production. Other significant regional producers are Angola and Mozambique, with smaller volumes coming from the Republic of Congo, Tanzania, Côte d'Ivoire and Equatorial Guinea – Table 1 shows production and consumption figures for Africa's leading producers and consumers.

However, while Sub-Saharan African gas production outside of Nigeria remains currently fairly small, the region has seen a number of new gas discoveries in recent years, and has become a major focus for international oil and gas companies in the past decade, who have seen themselves shut out of some major markets such as Saudi Arabia by national oil companies. So while Sub-Saharan Africa has only 2% of the world's gas production, it is the focus of up to 30% of the exploration and development efforts by major producers.

Prior to this, the focus had been on oil development, and associated gas was seen mainly as an inconvenience and often flared. However, the development of an international market for gas via liquefied natural gas (LNG) trade saw LNG plants beginning to be developed in the region, first in Nigeria in 1999, followed more recently by Equatorial Guinea (2007), Angola (2013) and Cameroon (2018). Interest gathered pace in East Africa from 2009, following major gas discoveries in Mozambique and Tanzania, and LNG projects are slated for these countries too.

Adding to the buzz of activity in Africa's gas sector is growing domestic use of gas as countries begin to industrialise. Sub-Saharan African economies are transitioning to gas, and requiring more gas to feed gas-fired power generation, in addition to rapid progress in renewable energy. And this trend will be boosted by rapidly growing populations. Africa's population is among the fastest growing and youngest in the world. One in two people added to the world's population between today and 2040 will be African, and the continent is on course to become the world's most populous region by 2023, overtaking China and India.

LNG

Gas development in Sub-Saharan Africa has been spearheaded by LNG export projects. Nigeria is the biggest and longest established player here, exporting 27.8 bcm of gas in 2018 (20.5 million t/a of LNG). Angola followed at 5.2 bcm (3.8 million tonnes). Since 2007 Equatorial Guinea has operated a 3.7 million t/a LNG plant at Bioko Island, and has recently found new gas fields to extend the operating life of the plant. Most recently, in Cameroon, Golar LNG started operations via a 1.2 million t/a capacity floating LNG (FLNG) platform in 2018, although so far only two of the four trains in the vessel are operational, with the third likely to become so this year.

Development is accelerating, however: joining these established projects are several new ones. In late December 2019 Nigeria made a final investment decision to go ahead with a major expansion of its Bonny LNG plant via a new 7th train which will increase capacity by 4.2 million t/a, as well as debottlenecking of existing capacity to add a further 3.4 million t/a. Overall, Nigeria's LNG capacity will increase by 35% to just over 30 million t/a by 2024. Train 7 will cost $6.5 billion to build, with another $5 billion to be spent on wells and pipelines needed to supply the plant, according to Nigeria LNG (NLNG).

Mozambique has a huge series of investments in the pipeline, beginning with the Mozambique LNG Project, which is being developed by a consortium including Total, Mitsui & Co, ONGC, ENH, Bharat PetroResources, PTTEP and Oil India Ltd – Total bought out Andarko's 26.5% share in the project in September 2019 for $3.9 billion – a sign of how seriously the project is being taken. Initial plans call for two 6.4 million t/a liquefaction trains with associated jetty and infrastructure at a cost of $20 billion. A final investment decision was taken in June 2019 and construction began in August, with production scheduled to begin in 2024.

Close behind it is ExxonMobil's Rovuma LNG project, jointly being developed with Eni, which is to consist of two 7.6 million t/a liquefaction trains on the Afungi Peninsula at a cost of $22 billion. Construction of onshore facilities has been awarded to a consortium led by Japan's JGC, TechnipFMC and Fluor. Production is expected to begin in 2024/25. Exxon said it would make a final investment decision in early 2020, although it remains unclear what effect the current collapse in oil prices may have on that. As part of the Coral gas field development which will feed Rovuma, Eni is also developing an $8 billion "ultra-deep water" floating LNG project for the field, with a production vessel with a capacity of 3.4 million t/a of LNG. Construction of the vessel began in September 2018, and first gas is due in 2022.

As well as LNG, Shell is considering a 68,000 bbl/d gas to liquids plant at Afungi in Mozambique, and is due to make a final investment decision next year. In Tanzania, Shell has also been developing a $30 billion, 10 million t/a LNG project, but this has been held up for years due to regulatory delays, land acquisition and

Table 1: **African gas production/consumption, 2018, billion cubic metres**

Country	Production	Consumption	Proved reserves
Algeria	92.3	42.7	4,300
Angola	7.0	0.8	420
Congo Brazzaville	1.4	1.4	110
Cote D'Ivoire	2.6	2.6	22
Egypt	58.6	59.6	2,100
Equatorial Guinea	7.8	2.3	42
Ghana	0.9	1.2	58
Libya	9.8	4.8	1,400
Mozambique	5.3	1.8	190
Nigeria	49.2	17.2	5,600
South Africa	1.3	4.5	n.a.
Sudan	0	0	85
Tanzania	3.1	3.1	37
Total	**236.6**	**150.0**	**14,400**

Source: BP

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hydrocarbon legislation. The government is currently saying that construction will begin in 2022 and gas will be flowing by 2028, although the timetable remains very uncertain.

Meanwhile, on the maritime border of Mauritania and Senegal, the Tortue Ahmeyim project is a field development operated by BP. BP has recently awarded TechnipFMC a large contract, between $500 million and $1 billion, to build an FPSO unit to be deployed for phase 1 of the project in 2022. Front end engineering and design for Phases 2 and 3 have begun for the onshore facility, which is due to be in production during 2024.

However, a second floating LNG project for Cameroon is looking doubtful, and the other projects are all subject to potential cost inflation, and regulatory and other political risks.

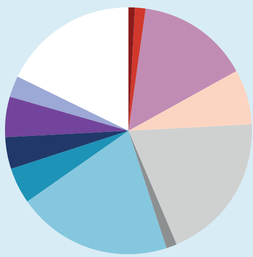
Other feedstocks

Gas developments have led to a flurry of fertilizer plant feasibility studies, but previously much of the region's fertilizer production have been based on coal and renewables. Sub-Saharan Africa's nitrogen industry began in South Africa based on ammonia from coal gasification using Sasol technology. Today Sasol operates a 300,000 t/a plant at Sasolburg and two trains at Secunda with another 250,000 t/a, all based on coal gasification. From this AEL manufactures ammonium nitrate for explosives use using ammonia sourced from Sasol, as does mining company Omnia, which has nitric acid, AN and CAN facilities at Sasolburg. Omnia has expanded production at Sasolburg, adding a 330,000 t/a nitric acid and ammonium nitrate plant.

Zambia likewise developed coal-based capacity, including 100,000 t/a of ammonia production at Kafue, operated by Nitrogen Chemicals of Zambia (NCZ), as well as downstream nitric acid, ammonium nitrate and ammonium sulphate production. Most of this capacity has been closed down, but the AN plant was re-started in 2013 using ammonia imported from South Africa.

On the renewables side, Zimbabwe operated an electrolysis-based ammonia plant at Kwekwe using electricity from the Kariba Dam, but this closed in 2015 due to the high electricity costs involved. Sable Chemicals continues to run nitric acid and ammonium nitrate production at the site using ammonia imported from South Africa, and briefly considered switching to a coal gasification feed. Now however the company is instead looking at a new solar farm, initially of 50 MW to become operational in 2021, but eventually expanding to 150 MW to run electrolysis for ammonia production.

Fig. 1: **Total nitrogen consumption in sub-Saharan Africa, 2017, '000 tonnes N**



Cameroon	25
Cote d'Ivoire	32
Ethiopia	343
Kenya	168
Nigeria	455
Senegal	37
South Africa	470
Sudan	112
Tanzania	97
Zambia	126
Zimbabwe	65
Others	412
Total	**2,342**

Source: IFA

Nigeria

Nigeria has had a long history of domestic nitrogen production, beginning in 1987 with the National Fertilizer Company of Nigeria (Nafcon) plant, which operated 500,000 t/a of gas-based ammonia-urea production at Onne, near Port Harcourt in the east of Nigeria. The company suffered from financial and operating problems throughout the 1990s however, and Nafcon was sold on in 2005 to Egypt's OCI group, becoming Notore Chemical Industries. Notore refurbished the plant and reopened it in 2010. A subsequent debottlenecking project increased capacity to 430,000 t/a of ammonia and 750,000 t/a of urea in 2013.

Several projects to build new nitrogen capacity followed, but delays in gas allocations and difficult financing slowed development. The first new project to be commissioned was the Indorama Eleme Fertilizer and Chemicals Ltd facility at Port Harcourt, River State, developed by Indonesian chemical giant Indorama Corp. Toyo Engineering and Daweoo Nigeria built the plant using KBR ammonia technology for the 2,300 t/d ammonia plant and a Toyo license for the 4,000 t/d urea plant. The facility was commissioned in 2016, and since then Indorama has approved the construction of a second, identical ammonia-urea train. Construction is under way, with completion scheduled for 2021.

Outside of Indorama, the major development has been the $2 billion Dangote complex in the Lekki Free Trade Zone east of the capital, Lagos, next to a refinery and petrochemical plant run by the same company. The Dangote project has been a huge one, consisting of two 2,200 t/d Topsoe-designed ammonia plants feeding two 3,850 t/d Saipem urea plants, for a total of 2.5 million t/a of urea capacity. While completion of a gas supply pipeline pushed start-up back from 2019, the plant is now reported to be in commissioning and due to be on-stream this year.

The Dangote complex takes Nigeria's urea capacity to 4.5 million t/a and Indorama will make that 5.8 million t/a. This is considerably ahead of domestic consumption, although that has been rising as more fertilizer becomes available. Nigeria consumed 550,000 t/a of urea in 2016, but after the Indorama plant started up this rose to 750,000 t/a in 2017. Nevertheless, both Indorama and Dangote rely upon export sales.

Other projects

There have been a number of other nitrogen schemes proposed for the region, but outside of Nigeria actual concrete developments have been scarcer. An Indian project for a 1.2 million t/a urea plant in Ghana was cancelled in 2014 after the government could not guarantee gas supplies, and another Indian project in Gabon was cancelled the same year. Plans have also been floated for ammonia-urea plants in Cameroon, Tanzania, Mozambique and Angola, but so far none have made it past the design stage. In Ethiopia, a 300,000 t/a coal-based urea plant that was to have formed part of a fertilizer complex being developed with Chinese assistance at Yayu remains only 45% complete after nine years. The project has been mired in corruption allegations and last year the government dismissed the nation's military-linked Metals & Engineering Corp. from overseeing the project and handed it to Morocco's OCP. OCP has bigger plans for Ethiopia, though, and in 2016 engaged Tecnimont for a feasibility study on a huge $3.7 billion fertilizer complex for Dire Dawa in the east of Ethiopia, to include two 1,500 t/d gas-based ammonia plants and a 3,200 t/d urea unit as well as NPK production. Work has reportedly begun at the site at Dire Dawa, and completion is expected some time in 2023 or 2024, according to OCP.

OCP has been increasing its presence in Africa and the company is working on a number of bulk blending plants across the region and phosphate capacity in Senegal. In Nigeria, it signed off late last year on developing a 750,000 t/a ammonia plant which it would use for downstream diammonium phosphate (DAP) production using phosphoric acid shipped from Morocco.

Fertilizer demand

While many of the ammonia-urea projects have been at coastal locations aimed at export markets, the hope has always been that a greater regional supply of fertilizers will also help boost demand there. Africa, especially Sub-Saharan Africa, is a relatively minor consumer of fertiliser, and five countries (Ethiopia, Kenya, Nigeria, South Africa and Zambia) account for almost two-thirds of consumption (see Figure 1). African leaders adopted the Abuja Declaration in 2006, calling for increasing average fertilizer use in sub-Saharan Africa (SSA) from less than 10 kilograms per hectare (kg/ha) to at least 50 kg/ha by 2015. However, this goal was missed by a considerable margin: by 2018, the application rate was still only 17 kg/ha in Africa, compared to a global average of 140 kg/ha.

The region has vast amounts of arable land and extensive agricultural production (albeit with low yields) but soil fertility is low – the major increase in food production that the region needs to feed its projected population increase over the next 20 years will need to come from increased fertilizer use. The main barrier to this is that 70% of farmers in the region are smallholders and fertilizer is often too expensive without government subsidy because prices are boosted by poor transportation infrastructure. Some of this is because ports are often not able to handle larger vessels, so capacity to handle fertilizer shipments is limited, and here developing local fertilizer capacity can help, but poor road and rail infrastructure are also major problems.

There are however encouraging signs that this is changing. Fertilizer consumption is rising in the region, at a faster rate than anywhere else in the world – albeit from a small base. IFA is predicting 4.5% year on year increase in African nitrogen demand over the next five years, as compared to an average global demand increase of just 1.3%. This will add 800,000 tonnes N of nitrogen demand in Africa between 2018 and 2023 – equivalent to 1.7 million t/a of urea. Of course, at the same time, urea capacity is projected to increase by nearly 5 million t/a, assuming no project slippages (although half of that is represented by Dangote – currently commissioning), and so for the time being African producers will need to find markets in India, South America and possibly even further afield for their urea.

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ISSUE 364
MARCH-APRIL 2020

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Monetising 'challenged' gas resources

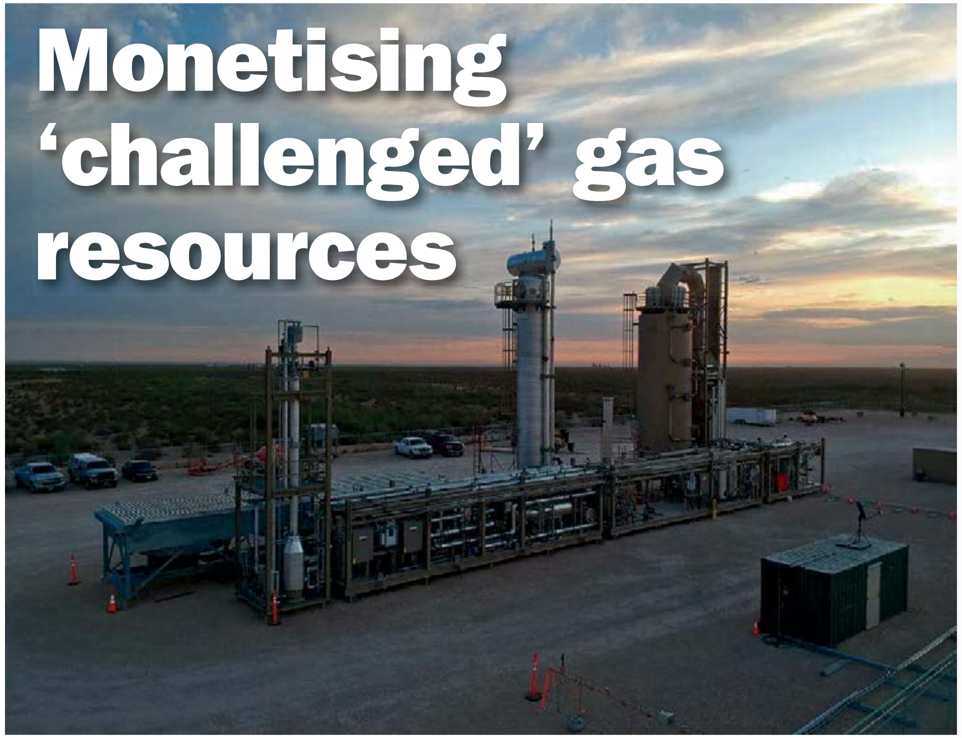


PHOTO: GREYROCK

The Global Gas Flaring Reduction Partnership (GGFR) is a World Bank sponsored programme to end wasteful and CO_2-intensive flaring of natural gas from oil production and stranded shale wells, and has been looking to small-scale methanol and GTL projects as a way of utilising this gas for productive ends.

Above: Greyrock's M-class plant installed at Permian, Texas.

During the 1990s and early 2000s, the watchword of the methanol and to a lesser extent the ammonia/urea industries was 'stranded' natural gas. In essence, this meant large untapped reserves of natural gas in remote locations, where there was no pipeline infrastructure to carry the gas to market, 'stranding' the gas without a way of monetising it. If this could be coupled with a coastal location, for ease of export of product, then in theory natural gas could be had at a very cheap price, as there was no competing use for it, and large export-oriented syngas-based plants could monetise the natural gas, bringing benefits both for the gas reserve owner and the operating company. This became the economic basis for a wholesale shift in the ammonia-urea and methanol industries, away from established producing locations based on old heavy industry, such as Europe, Japan/Korea and the United States, and towards places with ample gas reserves but no other use for them, including the Middle East in particular, but also places such as Trinidad, North Africa, Russia and the FSU and parts of southeast Asia. The AMPCO methanol plant in Equatorial Guinea is another example of this.

Since then, the gas industry has changed dramatically. The development of a large-scale global market for liquefied natural gas (LNG) has meant that any gas reserve near a coast that is large enough to be able to sustain LNG production and an export terminal for vessels can now participate in a global gas market and find a buyer. Pipeline infrastructure has also expanded considerably, connecting up once remote locations, although gas export from some places (such as Central Asia) remains constrained by pipeline capacity. Furthermore, the rapid growth of cities and industries in developing parts of the world has led to a huge increase in demand for gas for heating and especially electricity production. This has been the case in, for example, the Middle East, where shortages of gas mean that countries that were once considered stranded gas producers, like Kuwait, Bahrain or parts of the UAE are now gas importers, while Saudi Arabia and the UAE have had to turn to exploiting increasingly difficult and more expensive sour gas reserves to generate power. In other places, such as Trinidad, maturing of gas fields has reduced the availability of local gas and led to rationing of supply to ammonia and methanol producers.

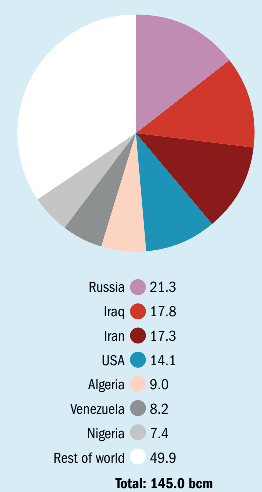
All of this has meant that 'stranded' natural gas in the way that it was understood 20 years ago has largely disappeared, with the exception of some large deposits still being found and exploited around the coast of Africa, which are described in our article elsewhere in this issue. However, this has not ended the issue of stranded gas, merely forced those looking to exploit it to turn towards smaller scales and niches. There are still many gas resources which go to waste because they cannot be captured and turned into useful, more easily transportable products. In particular, there is still widespread flaring of gas, often associated gas from oil production in remote area or as part of shale drilling. In 2018, it was estimated that 145 billion cubic metres of gas were flared, equivalent to 3.6% of all global gas production that year. Particular culprits were Russia, Iraq, Iran and the United States, as Figure 1 shows. As can be seen, the top seven countries were responsible for two thirds of all gas flaring. Associated gas represents about 20% of all gas production, but World Bank figures suggest that of that gas, only 27% is currently utilised – 58% is reinjected, and 15% flared. The potential gas available for use is thus even greater than the 145 bcm that is flared per year – reinjected gas represents another 455 bcm.

The Global Gas Flaring Reduction Partnership (GGFR)

As well as being a wasteful use of resources, flaring gas also contributes to climate change by releasing millions of tons of CO_2 to the atmosphere. The World Bank estimates that more than 300 million t/a of CO_2 are emitted to the atmosphere as a result of gas flaring, and could instead, for example, generate 750 million MWh of electricity – more than that currently used by the whole continent of Africa. The Bank has therefore tried to claim a leadership role in gas flaring reduction through its Global Gas Flaring Reduction Partnership (GGFR), a public-private initiative comprising international and national oil companies, national and regional governments, and international institutions. GGFR works to increase use of natural gas associated with oil production by helping remove technical and regulatory barriers to flaring reduction, conducting research, disseminating best practices, and developing country-specific gas flaring reduction programmes.

Participating national governments include Algeria, Azerbaijan, Cameroon, Indonesia, Iraq, Kazakhstan, Kuwait, Mexico, Nigeria, Norway, Qatar and Uzbekistan, as well as the Canadian province of Alberta and the Russian district of Khanty-Mansiysk. Corporate partners include BP, Chevron, Eni, Equinor, ExxonMobil, Occidental, Pemex, Qatar Petroleum, Saudi Aramco, Shell, SOCAR and Sonatrach. GGFR continues to urge governments, oil companies, and development institutions around the world to help reduce flaring, via initiatives such as its "Zero Routine Flaring by 2030" programme.

Fig. 1: **Flared natural gas, 2018**



Source: GGFR

Gas utilisation

At the core of GGFR is a quest to provide alternatives to gas flaring. To this end, it monitors and advises on technologies which can be used by companies to use the gas that they are flaring. The most common use for natural gas worldwide is electricity production. However, gas flaring often takes place in locations which are not only too remote to justify gas pipeline linkages, but also electricity grid connections, and which may not produce sufficient gas for a long enough period to justify construction of a large scale gas-fired power plant. Small-scale gas turbines are available, but tend to still have a significant minimum throughput requirement (>10 million scf/d at the very lowest, and often an order of magnitude more).

GGFR has considered two other main technology routes to gas utilisation. The first onward transport, as either small scale LNG or as compressed natural gas (CNG); the latter tends to be far cheaper for small volumes (less than about 5 million scf/d) and transport over shorter distances (<700 km), and can be supplied at around \$3.60-4.60/MMBtu delivered cost (without any value assigned to the gas itself). Much depends upon the availability of a local market. Mini-LNG costs tended to be much higher, starting at \$9.00/MMBtu (for liquefaction and transportation costs oinly), a level unlikely to be competitive with most gas markets[1].

The second major route that GGFR has considered is small-scale gas conversion to chemicals, and this of course tends to require a syngas intermediate step.

Chemical options

GGFR looks at two main downstream chemical options for dealing with stranded associated gas; methanol production and Fischer Tropsch (F-T) gas to liquids conversion. The technologies are considered across three separate scales; 'small scale' production, based on 10 million scf/d of feed gas or more; 'mini-scale' production, based on 1-10 million scf/d of gas feed; and 'micro-scale' production, based on 100,000 – 1 million scf/d of gas feed[2]. In its most recent GTL technology bulletin, published in September 2019, GGFR listed those companies still involved in working on methanol or GTL downstream options for flared gas[3], and the scale of

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ISSUE 364
MARCH-APRIL 2020
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Table 1: **Small-scale GTL and other technology offerings**

Product	Company	Micro-GTL	Mini-GTL	Small-Scale
Methanol blend	GasTechno	X		
Methanol	Maverick Synfuels	X	X	
Methanol	Topsoe/MPS		X	
Methanol, gasoline	Primus GE		X	
Oil, diesel, methanol	BgtL	X		
FT: diesel	Greyrock	X	X	X
FT: oil, diesel	EFT	X	X	
FT: diesel, gasoline, jet	INFRA		X	
FT: diesel, oil	CompactGTL			X

Source: GGFR

their technology offerings, and these are summarised in Table 1.

CompactGTL and Velocys

The path of using flared gas to produce chemicals has not been a smooth one, however, as illustrated by two UK-based companies who had looked to be the most promising candidates a few years ago; CompactGTL and Velocys, both offer F-T GTL technologies based on a compact modular steam methane reforming technology using mini-channel reactors to generate syngas which is then Fischer-Tropsch processed into what CompactGTL describes as syncrude – a mix of waxes, naphtha and middle distillates and which, with the addition of a hydroprocessing module, can produce synthetic diesel with zero sulphur content.

CompactGTL built a demonstrator plant in Brazil in conjunction with Petrobras in 2008, and a pilot plant at Wilton in the UK the same year. However, Velocys, based like CompactGTL in Oxford, UK, claimed that the CompactGTL process was too similar to its own, and this led to a patent infringement lawsuit in 2014 which went in Velocys' favour. After the settlement, CompactGTL faced receivership, and was bought out by its then non-executive chairman, former BP boss Tony Hayward, together with investment banker Ian Hannam, and the company then signed an agreement with the government of Kazakhstan to build a 2,500 bbl/d GTL plant based on flared associated gas. The Kazakh government postponed a final investment decision on the project, and though CompactGTL continues to trade, there have been no further updates since 2015. Likewise plans to build larger units in Brazil to tackle flared gas have been shelved following Petrobras' difficulties and its need to sell off various of its operations to raise cash.

Velocys, meanwhile, completed a small-scale (200 bbl/d) GTL unit in Oklahoma with ENVIA in 2014, based on landfill gas, but operations at the unit were suspended in 2018 following a coolant leak and ENVIA bought out Velocys' interest. The company is still involved in two projects, a 60,000 t/a GTL unit in Mississippi based on gasified biomass, and a 30,000 t/a GTL unit in the UK to produce jet fuel from gasified waste, but it is no longer looking at dealing with stranded natural gas as a feedstock.

Greyrock

Into the gap left by Velocys and CompactGTL has stepped US-based Greyrock. Greyrock offers a series of modular plants at different scales: M50, M100, P450, P2500 and P5000, with the number being the approximate output in terms of barrels/day ('M' means a moveable, skid-mounted unit). The process is based around a proprietary catalyst ('Greycat') that converts syngas into synthetic fuels without a wax component by preventing longer chain hydrocarbon formation. The company is currently involved in four projects, in the US, Canada, Mexico and the Democratic Republic of Congo to deploy its technology to produce liquid fuels from flared gas. Financing was secured and construction work began on the joint venture Canadian plant, based near Carseland, Alberta, 60 km east of Calgary, in May 2019. The facility is a 500 bbl/d unit, based on flared gas, and is due to begin commercial production soon. In the US, Greyrock has sold an M50 (50 bbl/d, 500,000 scf/d of gas feed) plant to Advantage Midstream, who will own and operate the unit in Jackson County, Colorado, and delivered another M-class plant to Permian, Texas.

EFT

Emerging Fuels Technologies (EFT) offers a micro-scale (25 bbl/d) skid-mounted modular GTL plant which it calls *Flare Buster 25*, based on its proprietary Advanced Fixed Bed (AFB) Fischer-Tropsch reactor/catalyst system. The principals in the company, Kenneth and Mark Agree, were the founders of the Syntroleum corporation. EFT has also licensed its technology to the 1,100 bbl/d Juniper GTL project in Texas, which aims to convert an existing steam reformer into a GTL plant. That project had reached the construction stage but work was halted in May 2019. However, a new investor, Calumet, came on board in October and the project still seems to be in development.

Meanwhile, EFT has recently qualified two US manufacturers to build its *Flare Buster 25* plants, and says that it expects to do likewise with more manufacturers on a global basis. The cost of one of the modular units is reportedly $4 million. The company is also working with Black and Veatch and NiQuan on rescuing the Point a Pierre GTL plant in Trinidad, which remains 85% complete.

GasTechno

GasTechno is the brainchild of Walter Briedenstein, who literally built a small-scale methanol plant in his garage in Michigan in 2010, converting methane directly into methanol via a patented direct homogenous partial oxidation process. This had scaled to a demonstrator unit by 2013, working off a flared gas site nearby, and a small-scale *Mini-GTL 300* commercial unit began operation in 2018 in North Dakota, and another in Utah. The '*Methanol in a Box*' process generates an alcohol blend and requires a distillation unit to produce pure methanol. GasTechno currently offer an M-300 and an M-700 unit converting 300,000 scf/d or 700,000 scf/d respectively, for $1.5 million for the smaller plant and $2.5 million for the larger.

INFRA

INFRA developed its own Fischer-Tropsch catalyst which, like Greyrock, produces synthetic fuels without the wax component. It claims that the product stream is 65% diesel and 35% naphtha. The company installed a 100 bbl/d demonstration plant in Wharton, Texas in 2016, but commissioning and start-up ended slipping, reportedly due to issues with the front end syngas section (which did not use INFRA's technology) which was unable to produce syngas in the correct ratio to start the F-T section. In July 2019 INFRA sold the Wharton plant to Greenway Technologies, who aim to use their own patented syngas generation technology to run the plant.

In the meanwhile, the company is continuing to look to project opportunities, and is currently in front end engineering and design work for a 450 bbl/d unit in Russia to produce winter diesel fuel and high-octane gasoline from the natural gas of the Vasylkovskoye gas condensate field. In September 2019 INFRA announced a partnership with GasTechno to jointly market methanol and GTL solutions.

Primus Green Energy

Primus Green Energy has its own *STG* (syngas to gasoline) technology, offering either methanol or synthetic gasoline as an end product – the gasoline is produced via a methanol intermediate step. The company built a demonstrator unit in New Jersey and had been looking to build a series of 160 t/d methanol plants in North America each converting around 6 million scf/d of gas. At the moment, however, the company's only active project is a 2,800 bbl/d natural gas to gasoline unit for Texas. Front end engineering and design on the project began in December 2019 in conjunction with an un-named joint venture partner, and is expected to be complete in mid-2020.

Maverick Synfuels

Maverick Synfuels offers its *Oasis* skid-mounted modular methanol production technology, at sizes ranging from 25 t/d (800,000 scf/d equivalent) to 100 t/d methanol (3 million scf/d gas equivalent). The company had been looking to develop a 100 t/d installation at Prudhoe Bay in Alaska, but the project has been quiet for the past 18 months.

Haldor Topsoe

Finally, also looking to get in on the small-scale modular plant market, Haldor Topsoe has developed its *MeOH-To-Go* concept in conjunction with specialist EPC firm Modular Plant Solutions. Topsoe currently offers a single modular plant size of 215 t/d methanol capacity, requiring 7.1 million scf/d of natural gas, using the company's heat exchange convection reformer (HTCR) technology. Topsoe says that this scheme is suited for small scale production as it is steam neutral and lower cost than conventional reformers, and it has been used for some years for small scale hydrogen production. We are not aware of any commercial projects as yet for this technology.

Summary

Flared natural gas is a big issue from both an environmental and economic perspective. There are a number of strategies for reducing it, including pumping associated gas back into an oil well, converting the gas to compressed natural gas (CNG) for sale, or small-scale power generation. Producing a useful co-product, be it methanol or synthetic gasoline or diesel is a potentially attractive option if the cost of installation and operation is right.

"At such small scales, achieving economies of scale is difficult..."

However, the world of small-scale GTL and methanol production is a fast-moving one. Companies are themselves often quite small scale and can find the financial and technical challenges of proving their concept via a working demonstrator unit and then securing new orders challenging. The failure of a single project, such as ENVIA's Oklahoma plant, can spell disaster for a technology licensing company. For this reason a number of companies in the field have come and gone, and some other technologies not mentioned here appear to be in abeyance, at least as regards developing units for dealing with flared/stranded gas (a number of other companies are still involved in dealing with e.g. waste or biomass gasification or small-scale production using electrolysis). Indeed, it is small-scale production based on electrolysis that seems to be grabbing much of the attention at the moment.

Even so, some companies do now seem to be developing viable technologies and business models for small-scale plants based on flared/stranded gas, and establishing themselves in the field. As detailed above, Greyrock has had a number of notable successes, and GasTechno and EFT also appear to be making headway. It is possible as the field develops that we will see more of the established players moving into the world of modular small-scale plants aimed at stranded or flared gas utilisation, as Haldor Topsoe has done. These plant scales are often already available – on the ammonia side, for example, thyssenkrupp Industrial Solutions offers plants of capacities down to 250-500 t/d, and Casale offers via its A60 flowsheet ammonia plants as small as 50-300 t/d capacity. Johnson Matthey's Compact Reforming technology was used for a 300 bbl/d GTL plant at Nikiski, Alaska in 2001. The issue has generally been one of cost – at such small scales, achieving economies of scale is difficult and so such plants often depend for their economics upon very cheap feedstock – one reason for the concentration on waste or biomass gasification. Large scale production of small modular units could bring down per unit cost, but at the moment the market does not appear to exist for so many plants.

Furthermore, as the GGFR itself admits in a recent report, oil and gas producers are often not used to and hence not comfortable with on-site petrochemical production, and there is an education process that must go alongside technical and economic issues – selling the chemical unit as a 'black box' that the producer does not need to worry about.

Nevertheless, most governments are making efforts and commitments to reduce flaring as part of their ambitions to tackle emissions. Government pressure on oil and gas producers to deal with flared gas could yet be the impetus that the field needs for more widespread adoption of small-scale chemical production. ■

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ISSUE 364
MARCH-APRIL 2020

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Nitrogen project listing 2020

Nitrogen+Syngas's annual listing of new ammonia, urea, nitric acid and ammonium nitrate plants shows that the key areas for new project developments are Egypt, India, Nigeria and Russia. The timing of new Iranian capacity remains subject to external sanctions, while other significant projects are under way in China, Brunei and Uzbekistan, and the new ammonia plant for Ma'aden in Ras Al Khair to produce diammonium phosphate. Currently however the number of new projects scheduled for beyond 2021 is relatively small, although a number of the current batch of projects are likely to slip.

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
AUSTRALIA							
SNC Lavalin	Haldor Topsoe	Perdaman	Karratha, WA	Ammonia	3.500	CA	2024
SNC Lavalin	Stamicarbon	Perdaman	Karratha, WA	Urea	6,000	CA	2024
AZERBAIJAN							
Samsung	Haldor Topsoe	SOCAR	Sumgait	Ammonia	1,200	C	2019
Samsung	Stamicarbon	SOCAR	Sumgait	Urea	2,000	C	2019
n.a.	n.a.	SOCAR	Sumgait	Ammonia	1,200	P	n.a.
n.a.	n.a.	SOCAR	Sumgait	Urea	2,000	P	n.a.
BAHRAIN							
Saipem	n.a.	GPIC	Sitra	Ammonia	2,200	FS	n.a.
Saipem	n.a.	GPIC	Sitra	Urea	3,400	FS	n.a.
BANGLADESH							
MHI	Haldor Topsoe	BCIC	Ghorasal	Ammonia	1,600	BE	2022
MHI, CNCIC	Saipem, TKFT	BCIC	Ghorasal	Urea	2,800	BE	2022
BELARUS							
thyssenkrupp I.S.	thyssenkrupp I.S.	Grodno Azot	Grodno	Nitric acid	1,200	UC	n.a.
thyssenkrupp I.S.	thyssenkrupp I.S.	Grodno Azot	Grodno	UAN	3,395	UC	n.a.
BRUNEI							
thyssenkrupp I.S.	thyssenkrupp I.S.	Brunei Fertilizer Ind.	Sungai Liang	Ammonia	2,200	UC	2021
thyssenkrupp I.S.	Stamicarbon, TKFT	Brunei Fertilizer Ind.	Sungai Liang	Urea	3,900	UC	2021
CANADA							
Black & Veatch	Stamicarbon	Nutrien	Carseland, AB	Urea	+300	RE	2021
CHINA							
n.a.	Casale	Hubei Yunhuaan Chem Co	Wuxue	Ammonia	1,200	UC	2020
n.a.	Casale	Hubei Sanning Chem Co	Yichang, Hubei	Ammonia	2,020	UC	2020
n.a.	Casale	Yichang Xingxing	Yichang, Hubei	Ammonia	1,250	UC	2020
n.a.	Casale	Hubei Yihua Fert	Yichang, Hubei	Ammonia	1,820	UC	2020
n.a.	Casale	Fujian Shen Yuan	Fuzhou	Ammonia	1,200	UC	2021
n.a.	Casale	Henan Xinlianxin	Xinjiang	Ammonia	2,000	UC	2021
n.a.	Casale	Jiangsu Jinmei	Xuzhou	Ammonia	2,000	UC	2022
n.a.	Casale	Chongqing Yihua	Chongqing	Ammonia	900	UC	900
Hualu Engineering	Stamicarbon	Jiujiang Xinlianxin	Jiujiang, Jiangxi	Urea	2,330	UC	2020
Wuhuan Engineering	Stamicarbon	Hubei Sanning	Hubei	Urea	2,330	UC	2022

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1 t/d of natural gas = 1,400 Nm^3/d

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Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
EGYPT							
Tecnimont	KBR	Kima	Aswan	Ammonia	1,200	C	2020
Tecnimont	Stamicarbon	Kima	Aswan	Urea	1,575	C	2020
thyssenkrupp I.S.	thyssenkrupp I.S.	NCIC	Ain Sokhna	Ammonia	1,200	UC	2022
thyssenkrupp I.S.	Stamicarbon, TKFT	NCIC	Ain Sokhna	Urea	1,050	UC	2022
thyssenkrupp I.S.	thyssenkrupp I.S.	NCIC	Ain Sokhna	Nitric acid	500	UC	2022
thyssenkrupp I.S.	thyssenkrupp I.S.	NCIC	Ain Sokhna	Ammonium nitrate	635	UC	2022
thyssenkrupp I.S.	thyssenkrupp I.S.	NCIC	Ain Sokhna	CAN	835	UC	2022
n.a.	n.a.	El Nasr Fertilizers	Ataka	Ammonia	1,200	P	n.a.
GABON							
MHI	thyssenkrupp I.S.	Olam Intl	Port Gentil	Urea	3,850	DE	On Hold
HUNGARY							
n.a.	Casale	BorsodChem	Kazincbarcika	Nitric acid	660	UC	2021
INDIA							
TEC	KBR	Chambal Fert & Chem	Gadepan	Ammonia	2,200	C	2019
TEC	TEC	Chambal Fert & Chem	Gadepan	Urea	2 x 2,000	C	2019
Engineers India Ltd	Haldor Topsoe	RCFL	Ramagundam	Ammonia	2,200	C	2020
Engineers India Ltd	Saipem	RCFL	Ramagundam	Urea	3,850	C	2020
n.a.	Casale	Zuari AgroChem	Goa	Ammonia	1,050	RE	2020
TechnipFMC/L&T	Haldor Topsoe	HURL	Sindri	Ammonia	2,200	UC	2021
TechnipFMC/L&T	Saipem	HURL	Sindri	Urea	3,850	UC	2021
TechnipFMC/L&T	Haldor Topsoe	HURL	Barauni	Ammonia	2,200	UC	2021
TechnipFMC/L&T	Saipem	HURL	Barauni	Urea	3,850	UC	2021
n.a.	KBR	HURL	Gorakhpur	Ammonia	2,420	UC	2021
n.a.	TEC	HURL	Gorakhpur	Urea	3,850	UC	2021
n.a.	Casale	Deepak Fertilizers	Paradip	Nitric acid	970	BE	2021
n.a.	KBR	Deepak Fertilizers	Taloja	Ammonia	1,500	UC	n.a.
Wuhuan Engineering	KBR	Talcher Fertilizers	Talcher	Ammonia	2,200	DE	2023
Wuhuan Engineering	Stamicarbon	Talcher Fertilizers	Talcher	Urea	3,850	DE	2023
INDONESIA							
n.a.	thyssenkrupp I.S.	Bakrie	Kalimantan	Nitric acid	750	DE	On hold
n.a.	thyssenkrupp I.S.	Bakrie	Kalimantan	Ammonium nitrate	900	DE	On hold
IRAN							
PIDEC	Casale	Masjid Soleyman	Masjid Soleyman	Ammonia	2,050	UC	On Hold
PIDEC	n.a.	Masjid Soleyman	Masjid Soleyman	Urea	3,250	UC	On Hold
Hampa	Casale	Zanjan Petrochemical	Zanjan	Ammonia	2,050	UC	2021
Hampa	Stamicarbon	Zanjan Petrochemical	Zanjan	Urea	3,250	UC	2021
Namvaran	KBR	Kermanshah Petchem	Kermanshah	Ammonia	2,400	UC	On Hold
Namvaran	Stamicarbon	Kermanshah Petchem	Kermanshah	Urea	4,000	UC	On Hold
PIDEC	Haldor Topsoe	Hengan Petrochemical	Assaluyeh	Ammonia	2,050	UC	2021
PIDEC	Saipem, TKFT	Hengam Petrochemical	Assalyueh	Urea	3,500	UC	2021
NETHERLANDS							
OCI Nitrogen	Stamicarbon	OCI Nitrogen	Geleen	Urea	n.a.	RE	2020

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NIGERIA							
TEC	KBR	Indorama	Port Harcourt	Ammonia	2,300	UC	2021
TEC	TEC	Indorama	Port Harcourt	Urea	4,000	UC	2021
Saipem	Haldor Topsoe	Dangote Fertilizer Ltd	Agenbode	Ammonia	2 x 2,200	UC	2020
Saipem	Saipem/TKFT	Dangote Fertilizer Ltd	Agenbode	Urea	2 x 3,850	UC	2020
n.a.	n.a.	OCP	n.a.	Ammonia	3,300	P	n.a.
OMAN							
SNC Lavalin	Linde/Haldor Topsoe	Salalah Methanol	Salalah	Ammonia	1,000	UC	2020
POLAND							
thyssenkrupp I.S.	thyssenkrupp I.S.	Grupa Azoty	Pulawy	Nitric acid	1,000	UC	2021
thyssenkrupp I.S.	thyssenkrupp I.S.	Grupa Azoty	Pulawy	Ammonium nitrate	1,300	UC	2021
thyssenkrupp I.S.	thyssenkrupp I.S.	Anwil SA	Wloclawek	Nitric acid	1,265	UC	2022
thyssenkrupp I.S.	thyssenkrupp I.S.	Anwil SA	Wloclawek	Ammonium nitrate	1,200	UC	2022
RUSSIA							
Tecnimont	Stamicarbon	KuibishevAzot	Togliatti	Urea	1,500	UC	2021
GIAP	Casale	KuibishevAzot	Togliatti	Nitric acid	1,350	UC	2021
GIAP	Casale	KuibishevAzot	Togliatti	Ammonium nitrate	1,500	UC	2021
NIIK	Casale	JSC Metafrax	Gubakha	Ammonia	1,000	UC	2020
NIIK	Casale/MHI	JSC Metafrax	Gubakha	Urea	1,700	UC	2021
Casale	Casale	Togliatti Azot	Togliatti	Urea	2,200	UC	2021
Tecnimont	KBR	EuroChem	Kingisepp	Ammonia	2,700	C	2019
Tecnimont	KBR	EuroChem	Nevynnomyssk	Ammonia	3,300	UC	n.a.
Tecnimont	n.a.	EuroChem	Kingisepp	Ammonia	3,000	FS	n.a.
Tecnimont	n.a.	EuroChem	Kingisepp	Urea	4,000	FS	n.a.
Uralchem	Stamicarbon	Uralchem	Perm	Urea	+900	RE	2020
n.a.	KBR	Kemerovo Azot	Kemerovo	Nitric acid	500	DE	2021
NIIK	Stamicarbon	Acron	Novgorod	Urea	2,000	UC	2020
CNCCC	Haldor Topsoe	ShchekinoAzot	Pervomayskyy, Tula	Ammonia	1,500	DE	2022
CNCCC	Stamicarbon	ShchekinoAzot	Pervomayskyy, Tula	Urea	2,000	DE	2022
SAUDI ARABIA							
Al Jubail Fert Co	Stamicarbon	Al Jubail Fert Co	Al Bayroni	Urea	n.a.	C	2019
Daelim	thyssenkrupp I.S.	Ma'aden	Ras al Khair	Ammonia	3,300	UC	2022
TRINIDAD & TOBAGO							
n.a.	Casale	PCS Nitrogen	Point Lisas	Ammonia	1,600	RE	2020
UNITED KINGDOM							
n.a.	JM	CF Industries	Billingham	Ammonia	1,500	RE	2020
UNITED STATES							
n.a.	Haldor Topsoe	Gulf Coast Ammonia	Texas City, TX	Ammonia	3,600	DE	2023
Black & Veatch	Stamicarbon	Koch Nitrogen	Enid, OK	Urea	+600	RE	2022
PCS Nitrogen	Stamicarbon	PCS Nitrogen	Augusta, GA	Urea	+250	RE	2020
UZBEKISTAN							
MHI	Haldor Topsoe	NavoijAzot	Navoij	Ammonia	2,000	UC	2020
MHI	Saipem, TKFT	NavoijAzot	Navoij	Urea	1,750	UC	2020
n.a.	Casale	NavoijAzot	Navoij	Nitric acid	1,500	UC	2020

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Nitrogen + Syngas 2020

PHOTO: NAPA/SHUTTERSTOCK.COM

This year's Nitrogen + Syngas conference was held from 17-19 February in The Hague, Netherlands.

In spite of some slight nerves about coronavirus, CRU's annual Nitrogen + Syngas conference went ahead in the middle of February at The Hague, and may have proved to be the last major industry gathering for some months. Attendance was brisk, and this year the exhibition had grown to a size that necessitated a move to a purpose built conference centre rather than a hotel, in this case the World Forum.

The meeting began with a morning of technical showcases on the Monday, short 15 minute presentations covering measurement and analysis, boilers, reforming and materials development.

Market papers

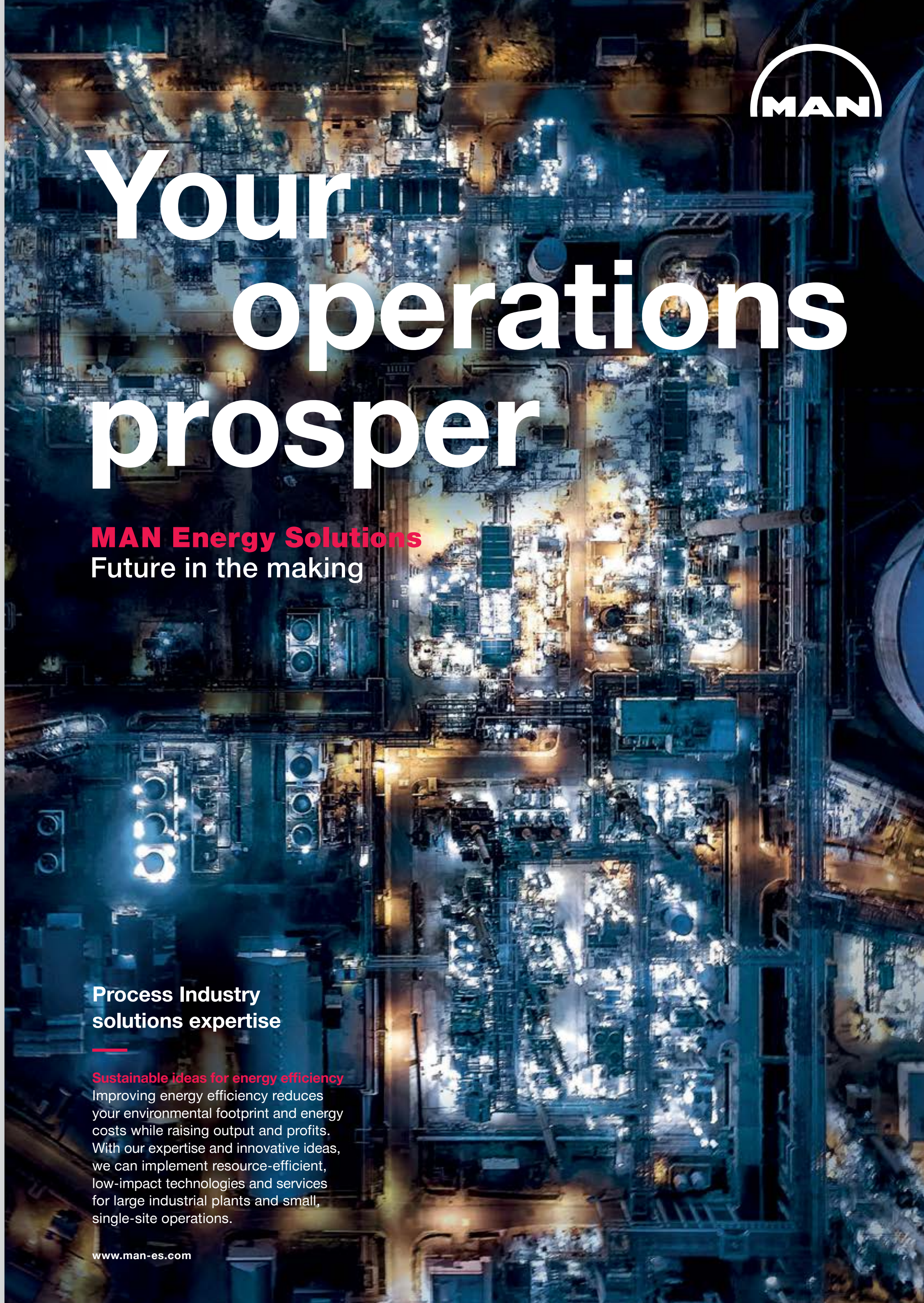
The additional of the technical showcases meant that the keynote plenary session was pushed back to Monday afternoon. Following the usual welcome from conference organiser Amanda Whicher, CRU's chief nitrogen analyst Laura Cross began with an overview of the global nitrogen market. Last year had seen some surprises, including China exporting 4.7 million tonnes of urea, far more than the 2.9 million tonnes expected, and India importing a huge 9.7 million tonnes – the latter drawing out most of those additional Chinese tonnes. India had faced subsidy issues at its naphtha-based urea plants and technical issues at some others, and so needed to import more in spite of the start-up of the new 1.3 million t/a Gadepan plant. Although three more new urea plants are on the 2023 time horizon, India is still expected to import 6.8 million t/a in 2020 and 2021, and could be higher if domestic production issues continue or the new plants face delays.

Demand fundamentals look strong, with the US returning to higher application levels and forecast demand increases in Brazil as Petrobras leaves the market which will offset falling Chinese demand. Changes to Indian subsidy rates in the April budget could still cause some change to this however. Overall CRU predicts urea demand will rise from 162 million t/a in 2018 to 178 million t/a in 2023, with South and Southeast Asia, and Central and South America the major sources of new demand, but African demand is also rising rapidly, and more demand is expected in North America and Europe.

China continues to switch from expensive and less efficient anthracite coal-based urea production to bituminous, with 9 million t/a of new capacity coming onstream at the same time that 13 million t/d of older capacity closes. Exports are likely to continue to fall, depending on industrial sector demand and global prices.

A low cost wave of new export capacity is on the horizon, in Nigeria and Brunei, but will be offset by Chinese closures, though China will remain the marginal producer.

Keshni Sritharan of CRU followed with a paper on energy markets. Geopolitics were leading to market volatility, she said, with oil prices falling as economic fears of a global slowdown triumph over supply cutbacks (cutbacks which, as we have seen very recently, have since been reversed). Coronavirus, the US-Chinese trade war and



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Iranian drone strikes on Saudi Arabia are all weighing on oil markets.

On the gas front, oil and gas prices are steadily decoupling in Europe, and though they remain linked in Asia Pacific, a shift to market pricing is expected over the coming years. However, regulated pricing still predominates in Eurasia, South America, Africa and the Middle East. The lowest gas cost regions – North America, Russia, the Middle East and Africa continue to see the most investments in new ammonia-urea capacity. Russia in particular has benefitted from the weak rouble and is seeing new capacity investments. Gas prices are at decade lows, with Henry Hub prices dragging indicators and markets down. But US LNG suppliers are not making money at current prices and cutbacks and a price recovery were expected. CRU was forecasting a gas price floor in late 2020/early 2021, by which time European prices could have fallen as low as \$2.00/MMBtu.

Sustainable production

As the effects of climate change become more pronounced, there is increasing recognition in the industry that more needs to be done to help tackle emissions of CO_2 and CO_2-equivalent gases, and a number of papers covered this topic. A German government-funded programme to help producers deal with nitrous oxide emissions from nitric acid production was the topic of Volker Schmidt of the German Company for International Cooperation (GIZ). N_2O emissions from nitric acid plants have become a focus for regulators because they offer a relatively cheap way of abating emissions in terms of CO_2-equivalence. There is a relatively centralised global industry – only 580 plants – and a high potential impact: 1.7 gigatonnes of CO_2 emissions which could occur between 2021 and 2030 if not abated. At the COP-21 summit in 2015, the German government launched an initiative to try and reduce these emissions worldwide, with euro 70 million of federal funding. It comprises a grants programme for remediation technologies, administered by GIZ, and a National Climate Change Action Group auctions programme implemented by the World Bank. The initiative covers secondary and tertiary N_2O emissions reduction and is technology neutral – the final decision is down to the plant operator, though competitive tendering is required. Of the 580 plants worldwide, 100 plants in 30 countries are eligible for financial support. The grants application deadline has been extended to December 2020, and the NACAP auction programme to 2025.

John Pach of JM showcased what his own company was involved in as regards sustainable nitrogen and methanol production. With some questions over the short-term scalability of 'green'/renewable hydrogen production, he suggested that 'blue' production – conventional production using carbon capture and storage (CCS) was vital to deliver scalable CO_2 reductions in the short to medium term. CCS of course presents challenges – large gas volumes with low partial pressures of CO_2 requiring a large flow of absorption solution and higher capex. The solution is to design hydrogen plants differently. For example, JM's LCH (leading concept for hydrogen) process uses a gas heated and autothermal reformer and generates no flue gas stream. All of the CO_2 is contained at pressure and easier to remove for lower capex and opex. Compared to a CCS add-on to a conventional plant, LCH+CCS can deliver 40% lower capex and 15% less CO_2 as well as 15% more nitrogen gas efficiency. It has been selected for the Hynet project in the UK (see Syngas News, this issue); a 330 MW hydrogen plant (equivalent to 1,000 t/d of hydrogen) and the Acorn project in Scotland (250 MW hydrogen).

Stephan Buss of thyssenkrupp Industrial Solutions described some other ways that plants could be made "fit for the future". He also focused on NOx emissions; a typical nitric acid plant emits NOx at about 150 ppmv. Low NOx burners can reduce this to 50 ppmv, and the addition of tertiary selective catalytic or non-catalytic reduction (SCR/SNCR) using ammonia can reduce this to 5 ppmv or below. tkIS has its own Envinox system for post-combustion cleanup, which reduces NOx emissions to below 10 ppmv, and which removes 99% of all nitrous oxide emissions above 430°C. For lower temperature operations (>315°C), a different set-up is required, which can reduce NOx to virtually zero with moderate hydrocarbon feed consumption. Other innovations Stephan covered included digitisation, either model driven ('digital twin' plants) or data driven, via neural networks.

Joey Dobree of Stamicarbon looked at the possibility of producing nitrates from renewable energy. Of course this means water electrolysis to generate hydrogen for ammonia production, and Stamicarbon's parent Maire Tecnimont has been able to partner with other technology developers, such as Siemens for electrolysers. Joey considered the case of a 100,000 t/a CAN plant based on renewable ammonia. Of course the economics are very location dependent, but he said that, for example, inland Kenya or elsewhere in southern Africa has a combination of high solar flux, and remote locations which can make importing fertilizers expensive. At such a site an electrolysis-based plant is already competitive today, he argued, and as the cost of electrolysis comes down, and with the additions of carbon taxes or government incentives, it could easily become competitive elsewhere.

Catalyst developments

Several companies reported new catalyst developments. Haldor Topsoe launched its new *TITAN* reforming catalyst series, based on hibonite calcium aluminate support which the company says is more stable under reforming conditions. A full discussion of the catalyst can be found in the article in our previous issue, *Nitrogen+Syngas* 363, Jan-Feb 2020, pp59-61.

Matthew Wilson of Johnson Matthey updated delegates on progress with JM's new *Catacel* engineered metal support structure for catalysts, which coats metal 'fans' that are then stacked in catalyst tubes, offering a 10-20% lower pressure drop and greater long-term structural integrity, as well as a higher surface area for greater reactivity and heat transfer. It has now been used in a number of revamping operations, and has allowed increased throughput – a hydrogen plant at a refinery saw a 17% increase, for example. It can be changed during a standard maintenance shutdown, although some debottlenecking may be required in associated production units to allow for higher throughput. In new plant designs, thinner, shorter reformer tubes could instead be used, lowering the capex of the reformer box. It can also be used in a hybrid tube filling, with the top half packed with *Catacel* for higher activity and the bottom half conventional catalyst for robustness and economy.

Christian Berchtold of Clariant and Sergio Panza of Casale presented a refinement of Clariant's AmoMax ammonia synthesis catalyst; *AmoMax-Casale*, with higher activity at higher temperatures and increased resistance to poisoning and long term stability. A fuller discussion of the technology can be found in our article on pages 44-48 this issue.

Linde and BASF have been engaged in collaborative research on reforming, and Klemens Wawrzinek and Virginie Lanver described the result of their companies' work. BASF has developed a new catalyst – *Synspire G1-110* – for reforming in low steam and high CO_2 conditions, featuring a unique metal oxide carrier which prevents carbon accumulation and catalyst deactivation. This is a feature of Linde's new *Dryref* 'dry' reforming process, allowing it to operate at a lower steam: carbon ratio and avoid the necessity of a pre-reformer. CO_2 is recycled to the reformer and can be supplemented by additional CO_2 to control reforming conditions. The companies claim a 3-5% reduction in operating expenditure as well as a lower CO_2 footprint.

Finally, in a similar catalyst/process technology joint development Stefan Gebert of Clariant and Stephane Walspurger of TechnipFMC jointly introduced a recuperative reforming innovation called *EARTH* – the Enhanced Annular Reforming Tube for Hydrogen. The aim is to generate energy efficiency improvements in reforming which lower CO_2 emissions. Like JM's *Catacel*, it uses a structured metal foil catalyst support which gives high surface area and heat transfer, while the recuperative reforming tube reduces fired heat demand via internal heat recovery. The tubes are available as a retrofit for existing plants as a drop-in insert consisting of the structured reforming catalyst and concentric internal heat transfer tubes. From a plant reference already in operation, the companies claim 10% higher efficiency and 10% lower CO_2 footprint, albeit with 50% lower steam export.

Reforming

Outside of the catalytic arena, a number of papers dealt with other issues in reforming. Hadj Ali Gueniche of Zohn Zink Hamworthy Combustion showcased a laser reformer monitoring system called *ZoloSCAN* which, tied into a process monitoring software suite, can allow real time balancing of gas flows in the reformer by adjustment of the burners.

Daniel Znidersic of BD Energy Systems and Jeffrey Bolesbrusch of Blasch Precision Ceramics showed how the installation of Blasch's *Stablox* modular reformer tunnels at the bottom of a reformer can transport flue gas out of the radiant section in a uniform way, avoiding turbulence and hot spots at the bottom of reformer tubes. The *Stablox* do not require mortar – a potential point of failure in conventional systems – and feature inserts allowing fine tuning of reformer flue gas flow.

Soren Gyde Thomsen of Haldor Topsoe shared some operator experiences with Topsoe's heat exchange reformer in ammonia plants, including a revamp at PetroVietnam's Phy My plant that delivered a 20% capacity increase, and a new HTER reformer as part of a 1,600 t/d plant for Duslo in the Czech Republic.

Urea plant operations

In the conference's urea section, a number of case studies described operator experiences. Some, concerning plant start-up and commissioning, are covered in more detail in our article elsewhere in this issue (pp34-42). Others included NIIK's work on revamping Acron's urea plant in Russia, and Koch Agronomic Services expanding its product portfolio at Enid, Oklahoma via the addition of a new plant section integrating urease and nitrification inhibitors into its urea granules. GPIC, in conjunction with thyssenkrupp Fertilizer Technology, showed the results of using tkFT's new advanced spray nozzles in their urea plant's granulation section, while Pakistan's Fauji Fertilizer Company covered modifications to the foundation of a heat exchanger in their urea plant.

Melamine

Two papers also looked at melamine production. The first, by Casale, described the first installation of Casale's new Low Energy Melamine (LEM) process, for Gujarat State Fertilizers and Chemicals (GSFC) in India. The installation uses CO_2 and ammonia from the ammonia plant rather than urea as a feedstock and so has its own integrated urea synthesis and melamine sections. The plant was commissioned in January 2019 and achieved capacity in April.

The second paper, by Eurotecnica, considered some of the advantages of adding a melamine section to a fertilizer plant, including the rapidly growing market for melamine and downstream resins, and the fact that existing prilling or granulation plant capacity may limit any increase in production from a urea plant, allowing excess urea to be used for melamine production instead. ■

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Learning from successful plant commissioning


PHOTO: KBR

Lessons can be learned from the challenges faced during the construction, commissioning and start-up phases of major projects. In this article challenges and experiences are shared from the recent successful commissioning of ammonia and urea plants around the world, including projects in Indonesia, India, Egypt and the Middle East.

Above: Overview of the PAU ammonia plant and ship loading.

World's first KBR Purifierplus™ ammonia plant in Indonesia

In 2018, PT Panca Amara Utama (PAU) successfully commissioned its 700,000 t/a ammonia plant located at Central Sulawesi, Indonesia. It is one of the biggest industrial projects in eastern Indonesia, supporting the government's directive to increase domestic value addition and stimulate the local economy. The ammonia plant was specially designed to create a state-of-the-art facility with low natural gas consumption, high efficiency, and high reliability.

PAU ammonia plant is the first in the world to use KBR's Purifier™ technology in combination with the KRES™ technology (namely KBR Purifierplus™) in one plant[1].

KRES™ technology has been successfully implemented in various existing plant revamps for capacity increase, energy reduction or natural gas saving, while Purifier™ technology has been successfully used in both grassroots plants around the world since 1966 as well as for existing plant revamps. PAU is the first grassroots plant used Purifierplus™ technology, which makes this plant unique.

Commissioning of the PAU ammonia plant was successfully completed in August, 2018 with one of the lowest energy and natural gas consumption figures per tonne of ammonia.

Challenges and lesson learned

Successful commissioning of an ammonia plant requires careful planning and utilisation of lessons learned from other successful start-ups. Below are some of the main challenges and lessons learned during the plant commissioning and start-up of the PAU plant.

Prevention of solution foaming in the CO_2 removal system

Key to trouble-free, quick start-up and stable operation of the OASE white CO_2 removal system is the effective prevention of the foaming of the OASE solution. Solution foaming can lead to significant operational upsets, and may cause damage to column internals, solution pumps, and heat exchangers in the system. It may also damage downstream equipment and catalyst due to solution being carried over to methanator. Hence, it is vitally important to ensure removal of the foaming causing agents, such as grease, oil, dust and fine particles from the system.

Following KBR advice, in the pre-commissioning phase, a very thorough cleaning and degreasing of the system was performed. The fact that degreased packings were procured also helped the cause. In the commissioning phase, two other important steps were carried out before process feed introduction to the system:

- Performance of a passivation step to form a magnetite layer (Fe_3O_4) that protects the carbon steel surfaces from corrosion;
- LTS catalyst de-dusting to prevent fine particles from entering the system.

Continuous filtration of the recirculating OASE solution was maintained during start-up and normal operation.

To prevent foaming, tests were carried out twice a shift on the recirculating OASE solution and adjustments were made accordingly to the anti-foam injection program which comprised continuous injection using the installed anti-foam injection pump skid and also e ach shift "shot" dosing using the installed "shot pots".

Because of these measures, the PAU OASE White CO_2 removal system has been running very smoothly and no foaming problems have been encountered since initial start-up.

CO_2 ingression into the N_2 plant

During start-up and soon after the ammonia plant was producing CO_2, the OSBL cryogenic nitrogen plant tripped several times due to icing caused by high CO_2 content in the outlet stream of the molecular sieve dryers to the cryogenic section of the plant.

It was observed that, due to prevailing wind conditions, the CO_2 vent from the ammonia OASE system was settling towards the air suction intake of the nitrogen plant compressor. CO_2 mapping around the plant confirmed the phenomenon. During mapping, it was observed that the CO_2 level in the area of the process air compressor was unaffected. As a solution, an additional air feed line for the nitrogen plant was taken from the process air compressor of the ammonia plant. CO_2 mapping is carried out on a regular basis and air is sourced from the process air compressor if needed. As a result, the nitrogen plant had been running normally.

This problem could have been avoided if proper dispersion modelling had been carried out by the detailed engineering contractor before finalising the layout of the units in the plant.

Oil ingression into the dry gas seal of refrigerant compressor

During commissioning of the refrigerant compressor, lube oil leaked into the dry gas seal of the compressor due to failure of the nitrogen supply (separation gas) to the bearing housing. Spare dry gas seals were installed and the plant was re-started. Nitrogen backup with a battery of nitrogen cylinders was subsequently provided.

Delay in completing cleaning of the lube oil systems

Cleaning of the lube oil system for the major compressors, process air compressor, refrigerant compressor, and syngas compressor was prolonged and led to a delay in the plant commissioning. Cleaning of the air compressor lube oil took nearly nine months, as did the cleaning of the lube oil of the syngas and refrigerant compressors, which shared a common oil system.

The problem could have been avoided if proper pickling and air blowing of the lube oil piping was done before starting the flushing activity.

Erratic readings from steam flow transmitters

After completion of the nitrogen circulation heating and starting initial steam introduction to the primary reformer and KRES, it was found that all of the steam flow transmitters were showing different readings. It was observed that the impulse line tapping of the flow transmitters had not been installed as per KBR standard. The problem was resolved after the layout of the impulse line was modified from a 45° angle to horizontal as per KBR recommendations.

Delay of air blowing due to damage to auxilliary boiler

Two auxiliary boilers were provided to meet the ammonia plant start-up and commissioning steam requirement. However, during commissioning, tube leakage was observed in one boiler, causing a delay to the commissioning of the process air compressor, which in turn delayed other commissioning activities like air blowing of the plant pipelines.

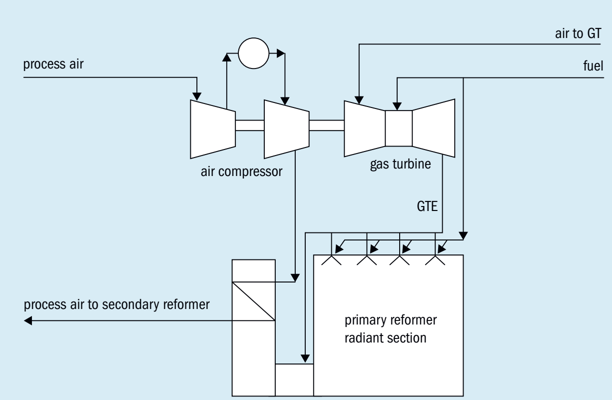
Underperformance of methanator effluent water cooler

During start-up, it was found that the methanator effluent water cooler was underperforming and the process outlet temperature was about 12-15°C above design. Upon investigation it was concluded that the problem was caused by a fabrication defect – part of the internal partition plate was missing and led to bypass of the synthesis gas. The underperformance of this exchanger led to increased load for the downstream chiller and on the refrigerant compressor.

Repairs were done by the manufacturer, which involved extending the partition plate. However, the problem has not been fully resolved as the hot gas outlet temperature is still (approximately 6-7°C) hotter than design.

Despite the problems encountered, the PAU ammonia plant successfully demonstrated that its performance was better

Fig. 1: **Gas turbine driven air compressor for CFCL plant**



Source: KBR

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NITROGEN+SYNGAS
ISSUE 364
MARCH-APRIL 2020

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than the guarantees and design in terms of energy consumption, ammonia production capacity and product quality.

KBR world's lowest energy ammonia plant at CFCL, India

To meet the demand for urea in India, in January 2019, Chambal Fertilisers and Chemical Ltd (CFCL) successfully commissioned its third ammonia/urea plant (G3AU Project) with a capacity of 2,200 t/d ammonia and 4,000 t/d urea at its existing facilities at Gadepan (Kota, Rajasthan) in India[2]. Since commissioning the new ammonia/urea plant, CFCL has now become India's largest production capacity of urea at one location.

Due to the high cost of natural gas in India, CFCL wanted the new plant to have lowest possible energy consumption. CFCL also desired the plant to be self-sufficient in terms of MP steam. It was therefore decided that the process air compressor would be driven by a gas turbine and the hot gas turbine exhaust would be used as preheated combustion air for the primary reformer (Fig. 1). This configuration improves the thermal efficiency of the gas turbine from around 30% to over 95%, allows more steam export to the urea plant for its turbine-driven CO_2 compressor and also eliminates the requirement of the forced draft fan and combustion air preheater. Due to its unique features, the ammonia plant has become the world's lowest energy plant using KBR's Purifier™ ammonia technology.

Project execution

The lump sum contracts for engineering, procurement and construction (EPC) for the development of the entire facility i.e. ammonia/urea/OSBL were awarded to TOYO. TOYO in turn awarded contracts for the ammonia plant license, basic engineering design packages, and supply of licensor's proprietary equipment to KBR.

To ensure safety, quality and consistency of the overall plant design, KBR also supported TOYO/CFCL in the activities, such as review of the critical documents, critical equipment inspections, participation in Hazop, 3D model reviews, supervision during catalyst loading of the reformer, ammonia converter etc.

KBR also provided pre-commissioning, commissioning and start-up advisory services with 24x7 coverage for safe, fast and efficient start-up of the ammonia plant.

Throughout all phases of the project, CFCL, KBR and Toyo worked together for the common goal of design and construction of a safe, reliable and energy efficient world class ammonia plant.

Challenges and lesson learned

Several challenges were faced during the commissioning and start-up of the plant.

Purifier outlet valve stuck

A high pressure drop of 5 kg/cm² was observed between the expander outlet pressure and syngas suction pressure during a start-up, after plant tripping. Upon checking, a high pressure drop was observed across purifier outlet valve, while the valve stem was in full open condition. This was creating a load limitation due to lower syngas compressor suction pressure.

During a short shutdown of the plant, the purifier outlet valve was replaced with a manual isolation valve. Upon checking the replaced valve it was found that the disc was disconnected from the stem and the valve was stuck at 40% open position, which was creating a high pressure drop.

Leakage from expander flange

The purifier was checked for any leakage at 30 kg/cm²g with syngas before start-up and no leakage was detected at that time. After commissioning the purifier, a minor hydrogen leak was observed from the sample point of the expander duct during routine checking of leaks in plant. The hydrogen concentration was in the range of approximately 4% and reduced to about 2% after increasing the nitrogen flow to the duct. The nitrogen hose was provided at the vent point to avoid an explosive mixture.

To reduce the leak from the flange in the expander compartment, the syngas compressor suction pressure was reduced by 1.0 kg/cm² compared to design, which increased the load on the syngas turbine.

Expander bypass valve operation

During stroke checking of the expander bypass valve, it was observed that valve operation was not smooth. The vendor checked and found that due to the actuator weight, the valve stem had bent (Fig. 2). During installation of the valve, the support for the valve actuator was not installed properly which led to the bending of the valve stem. The valve stem was replaced and valve operation returned to normal.

Oil Ingress to synthesis gas compressor dry gas seal

During start-up of the plant, after tripping, a small amount of lube oil was observed from the syngas compressor LP stage NDE side dry gas seal drain. A probable reason for the oil ingress was no backup of nitrogen from the existing nitrogen plant. Later on nitrogen backup was provided with a battery of nitrogen cylinders.

Heat leak from air compressor anti-surge valve

The ammonia plant tripped due to low air flow to the secondary reformer actuation. It was observed that initially the anti-surge valve opened which led to low process air flow to the secondary reformer and finally a full plant trip on the MP steam header fluctuation.

The root cause for the anti-surge valve malfunctioning was a heat leak from the control valve body. Proper insulation of the valve body was carried out to avoid the heat leak to instruments.

Cooling water high pressure drop

Lean cooler 108-C is a plate type heat exchanger which cools lean solution using cooling water as the cooling medium. During commissioning, it was observed that cooling water flow through the lean cooler was lower than design due to high pressure drop across the plates. The matter was discussed with the vendor and the problem was resolved by replacing the wrong type of plates with the correct type as well as installing 20% additional plates.

The CFCL plant was successfully commissioned and became the world's lowest energy ammonia plant despite the problems listed above.

PHOTO: KBR

Fig. 2: Bend in valve stem.

COMMISSIONING AND START-UP

PHOTO: tkIS

Fig. 3: ENPC ammonia/urea complex (view by night on train 1 including ammonia storage tank and the adjacent new Damietta harbour.

ENPC ammonia/urea project in Egypt

In 2016, the two train ammonia/urea fertilizer complex ENPC, owned by ENPC (Egyptian Nitrogen Products Company) was successfully commissioned[3]. The complex is located in New Damietta (Egypt) near the Mediterranean Sea (see Fig. 3).

The ENPC complex consists of:

- 2 x 1,200 t/d ammonia plant (Uhde process with Johnson Matthey catalysts, UOP Benfield CO_2 removal);
- 2 x 1,925 t/d urea plant (based on Stamicarbon synthesis and Stamicarbon granulation);
- all offsite and utility facilities, including 72,500 t urea storage.

In this project, thyssenkrupp Industrial Solutions (tkIS) was the EPC contractor, supplying its Uhde® technology and having the responsibility for engineering, procurement, construction and also for the commissioning and start-up of the entire complex.

Project history

In total the ENPC project had a running time of 9½ years from date of contract signature until the achievement of provisional acceptance. Three stoppages and one site relocation in between were the main reason for the long project time.

The last stoppage fell in the phase of precommissioning of train 1 (see Table 1, "2nd suspension").

Challenges during (pre-)commissioning

The main (pre-)commissioning challenge for the ENPC project was a 27-month project suspension due to political unrest.

The first (pre-)commissioning started in August 2011 and was interrupted shortly after by the suspension in November 2011, when all activities on site had to be stopped.

After resuming the project in February 2014, first with detailed inspections of the condition of the complex, construction resumed followed by first (pre-)commissioning activities in July 2014.

All previous (pre-)commissioning activities had to be repeated in addition to an intensive cleaning and repair effort for all affected sub-systems, which suffered during the suspension period.

Interruption of first (pre-)commissioning phase

In September 2011 the (pre-)commissioning started with air blowing of the interconnecting piping network between the battery limits and the two trains as well as for the fuel gas system. In parallel, pre-commissioning by water flushing for some utility systems was ongoing. The events mentioned here are discussed in more depth in reference 3.

In early November 2011 the site had to be left suddenly due to civil unrest in context with the "Arabian Spring" and unfinished sub-systems of train 1 had to be left in their current condition. For example:

- The cooling water system was filled with untreated town water for initial flushing.
- The boiler feed water system in the utilities and in the ammonia plant partly filled with demineralised water. Parts of the system were exposed to a seashore atmosphere due to dismantling of control valves for flushing activities.
- Fuel and feed gas system were exposed to a seashore atmosphere. Water from air humidity condensed inside the piping causing corrosion.

Preservation and conservation measures

The site was inaccessible for around six weeks, until mid December 2011. When the tkIS project team returned to site in December 2011, after an initial inspection of the conditions on site, no further site activities were possible until the civil unrest outside the complex ceased.

Preservation procedures were prepared based on the assumption of a stoppage of all further site activities for a few months. Due to the situation in the country, only a few activities could be done in order to minimise damage to train 1.

- Only a few equipment items could be filled with clean water with pH control or filled with nitrogen.
- Several sub-systems filled with water from the hydrostatic testing could not be emptied, e.g. ammonia refrigeration system train 1.
- The shafts of the major turbines and compressors were not turned at regular intervals as requested by the vendor (once per week)

NITROGEN+SYNGAS
ISSUE 364
MARCH-APRIL 2020

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Table 1: **ENPC project timeline**

Date	Event	Comments
19 April 2007	Date of Contract	
August 2007	First site stoppage	Political interference
December 2007 – January 2008	Second site stoppage	Political interference
April 2008 – August 2009	First suspension Third site stoppage, relocation from "old"-site to current site within harbour of Damietta	Political interference
15 October 2009	Recommencement date (new site)	
10 November 2011	2nd Suspension	Civil unrest
17 February 2014	Suspension lifting	
8-15 June 2015	First ammonia and urea product train 1	
18-26 December 2015	First ammonia and urea product train 2	
March 2016	Performance test train 1	
May 2016	Performance test train 2	
13 November 2016	Provisional acceptance (PAC)	

Source: tkIS

Second (pre-)commissioning phase

After tkIS' return to site in February 2014, inspection, preparation and first construction activities took place between March and July 2014. In July 2014 the (pre-)commissioning activities resumed with the interconnecting system between both trains and the plant and instrument air system of train 1.

The (pre-)commissioning and start-up phase for train 1 was a success without major safety incidents with all parties following the strict safety protocols.

Major rotating equipment like e.g. the synthesis gas compressor were specially inspected and repaired after the suspension involving the vendor specialists, as well as specialists from tkIS and ENPC.

During (pre-)commissioning of the first train the second train was still under construction, which allowed replacement of defects in train 1 by utilising the corresponding parts from the identical second train, if in usable condition.

The (pre-)commissioning activities for the gas-containing sub-systems in train 1 went smoothly. Major damage was mainly detected for control valves, flanges and gaskets, e.g. lens gaskets. Whenever possible the damaged parts were repaired, e.g. resurfacing of lens gaskets. Air blowing was repeated several times to remove all the accumulated dirt and rust in the system. The effort required for pipe cleaning was approximately two to three times higher than for projects without interruption.

For the water containing sub-systems the situation was different. Since several of the sub-systems were filled with water during the suspension and were partly exposed to the seashore atmosphere, a much higher amount of damage was found during the construction and (pre-)commissioning phase. In particular, carbon steel piping, e.g. in the cooling water system, was heavily affected. Several parts of the piping had to be replaced after intensive inspections. Besides the cooling water system, the ammonia refrigeration system also showed a high amount of corrosion.

Unfortunately, during the commissioning phase, while synthesis gas was introduced into the ammonia synthesis loop under pressure, a leakage in the gas cooler downstream of the gas/gas heat exchanger was detected. The gas cooler is a shell-and-tube heat exchanger in which the ammonia containing synthesis gas is cooled down with cooling water.

After the detection of the leakage the ammonia synthesis was immediately depressurised and purged with nitrogen over several days with continuous hazardous gas monitoring.

During the following inspection of the heat exchanger by endoscopy and eddy current several leakages in the tubes were detected, requiring urgent replacement of the complete gas cooler. The inquiry and purchasing of a replacement heat exchanger would have taken several months, jeopardising the complete project schedule. However, by lucky coincidence a replacement gas cooler with the same specification was found at another ammonia producer, and because of the good cooperation between companies it was quickly transferred to ENPC.

The replacement of the gas cooler was thus executed in a very short period of seven days, considering the difficulty of keeping a positive nitrogen pressure in the ammonia catalyst beds and cutting the attached piping to the heat exchanger. A detailed safety analysis including a safety area with limited access was implemented around the heat exchanger. During the replacement of the heat exchanger all safety rules were strictly followed and there were no safety incidents or near misses. In summary, it was a remarkable effort considering the time criticality and difficulty of the job.

For the ammonia refrigeration system (having been filled with water during the interruption period), the situation was quite different. During the (pre-)commissioning phase leakages in the sub-systems of the ammonia refrigeration were detected. On the contrary to the cooling water system, it was not possible to replace affected parts of the piping system one after another later during operation since the operating media is hazardous ammonia. Consequently, the affected sub-systems were carefully emptied, inspected and corroded parts exchanged. Since it was not possible to inspect the complete ammonia refrigeration system in detail due to its size and the fact that most of the system had already been covered by cold insulation foaming, a job safety analysis had been executed in which it was decided to implement a safety area around the ammonia refrigeration system (including affected systems like the ammonia synthesis loop) with only limited access. During the initial filling of the refrigeration system with ammonia and the start-up of the system the plant was evacuated and all points were observed over weeks to detect any possible leakages and defects in the piping. Except for the previously found leakages, no additional ones were found. The safety area around the refrigeration system was kept for a longer time period until the plant was in a steady and stable operation mode.

In addition to the damage found in the mechanical systems of the plant resulting from the suspension period, the stored catalyst material and packing material also showed significant signs of corrosion. In case of the primary reformer catalyst and the packing material of the CO_2 removal unit, the material had to be spread out over a wide area and sorted manually.

Shortly before starting the reduction of the ammonia synthesis catalyst in train 1, several leakages occurred in the ammonia synthesis loop and at the synthesis gas compressor. In particular, damaged lens gasket surfaces of quench valves directly at the converter pressure shell caused several delays due to the complicated re-machining of the surfaces at elevated heights. Therefore, the ammonia synthesis loop had to be depressurised and purged over several days.

Case studies

The following case studies discuss three different challenges faced by thyssenkrupp Industrial Solutions and their successful solutions during the commissioning of ammonia and urea plants.

False readings from synthesis gas moisture analyser

This case study refers to an ammonia plant where a synthesis gas drying unit is installed between the stages of the synthesis gas compressor. In this drying unit the makeup synthesis gas is passed through molecular sieves in order to remove remaining water vapour before the gas enters the ammonia converter.

According to the operating procedure from the ammonia catalyst supplier, the water content of the gas entering the converter should be kept as low as possible to avoid catalyst deactivation. Typically, the desired value in this particular application is less than 1 ppmv moisture.

During the recent commissioning of an ammonia plant in the Middle East the synthesis drying unit was put online. At the same time, the moisture analyser reading downstream of the drying unit was swinging with an amplitude of up to 200 ppmv. This meant that there were severe concerns about feeding the synthesis gas into the ammonia converter. A calibration of the moisture analyser was done, but the periodically high reading remained unchanged.

On the fourth day of the synthesis drying unit being online a pattern in the moisture reading was noticed. A peak in moisture reading was observed daily at noon, which coincidently is the time with the highest ambient temperature.

An effect on the moisture reading due to high levels of sun radiation was expected. Sun shades were installed and the analyser box was continuously purged with plant air which acts as a coolant in the analyser box.

With this arrangement the moisture reading became stable and commissioning of the ammonia synthesis unit could continue without any fear of deactivating the catalyst.

It was later learned that this cyclic effect is defined by the so-called "diurnal effect" and is typical for analyser systems which are located in outdoor locations. This effect is a real moisture change in the process sample system, associated process piping and vessels.

The polar nature of the water molecule allows it to adsorb to all surfaces with a full or partial ionic charge, like iron oxides on the inside of process piping or equipment. The equilibrium of the adsorption depends on the temperature.

During nighttime, due to lower temperatures, water molecules are adsorbed onto the inner pipe wall in equilibrium. This adsorbed water leaves the pipe wall as it heats up during the day time and enters the gas system.

The moisture analyser reading was influenced by the swinging ambient temperature within the analyser box. As soon as the temperature in the analyser box was stabilised by plant air purging no more fluctuations were observed.

The lesson learned from this incident is that the moisture analyser reading can be influenced by environmental conditions and that an appropriate arrangement should be considered to avoid analyser box temperature fluctuation.

Adjustment of biuret content of urea product

Urea product contains biuret, typically up to 0.9-1.2 wt-%. As biuret is a plant poison and the marketability of granulated urea product is somewhat limited when containing higher amounts of biuret the intention is to reduce biuret to a minimum.

In 2013, thyssenkrupp Industrial Solutions (tkIS) commissioned a urea plant using the Stamicarbon LAUNCH MELT™ technology for synthesis and the UFT® Fluid Bed Granulation technology licensed by thyssenkrupp Fertilizer Technology (tkFT). While maintaining the other product qualities, a significantly lower than 1.0 wt-% biuret in the solid product seemed nearly impossible to achieve.

It is well known that biuret formation increases at high temperatures and concentration as well as residence time while the urea is liquid. These conditions are found in the recirculation and evaporation section. Consequently, the residence time can be reduced by minimising the liquid levels in the rectifying column outlet, the flash vessel, and in the urea solution tank. By doing so, the biuret content decreased but still remained above the required value. Beside the evaporation section, high temperatures also occur in the HP section of the synthesis. However, the high temperatures in the HP section are required in order to achieve sufficient reaction progress. Consequently, it was decided to focus on the evaporation section and reduce the temperature of the urea melt using different approaches. tkIS urea plants are equipped with level control at the evaporator shell side which allows partial submersion of the tubes with condensate. While parts of the tubes are submerged, the area of heat transfer is reduced leading to a reduction in the residence time of liquid urea in contact with the hot inner tube surface. The steam supply to the evaporators is equipped with pressure control valves, allowing the shell side temperature to be adjusted. Reducing the steam pressure also reduced the temperatures which the liquid urea is exposed to. By increasing the vacuum in both stages of the evaporation, the melt temperature in the outlet could be reduced by some 1-3 K. Further reduction of the temperature was not possible because the melt temperature came closer to the crystallisation point. Still there was the possibility to shift the load from the first to the second stage and the other way around in order to try and find the optimum for the biuret formation. Unfortunately, despite all optimisation performed in the evaporation section, the biuret content remains above the required value.

In order to search for the cause of the unexpected high biuret content the parties involved decided to increase the location of samples taken in the recirculation and evaporation section. The sample analysis

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did not show essential changes in biuret content in the urea melt and urea solution sections of the plant. Consequently, tkIS engineers requested to widen the field of samples taken to include the upstream high pressure equipment. By doing so, the location of urea solution with the highest biuret increase was finally detected and was found to be the liquid outlet of the HP heat exchanger.

Within the HP heat exchanger, unconverted free ammonia is stripped by means of heat and CO_2 introduced countercurrently. The higher the stripping efficiency, the higher the urea concentration in the solution from the stripper section. The stripping efficiency is the ratio between the number of moles of ammonia that have contributed to the conversion of urea and the total number of moles of ammonia in a reaction system.

In synthesis plants using Stamicarbon license, the stripping efficiency typically reaches 78-80%. The higher the stripping efficiency, the less unconverted ammonia leaves the HP heat exchanger with the liquid outlet which subsequently leads to a reduced load in the low pressure section.

Back in the urea plant under examination, the stripping efficiency was found to be 83% which is quite high. On the one side, the HP heat exchanger is able to handle higher capacities, while on the other side, it removed too much free ammonia which inhibits biuret formation. Consequently, a sufficient amount of free ammonia needs to be present in the liquid phase to decrease the biuret content.

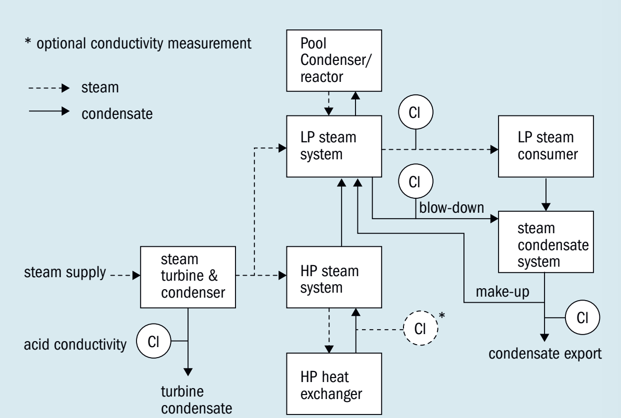
After reducing the stripping efficiency of the HP heat exchanger to below 80 % by adjusting the steam pressure on the shell side, the biuret in the solid product dropped below the required value.

The commissioning of the plant showed once more that it is not always the typical factors which have to be considered and a complete analysis needs to be performed. Good cooperation between all partners, contractor, licensor Stamicarbon and plant operator, under the pressure of time as well as experience in engineering and commissioning were essential to find the right plant parameters in order to produce high quality fertilizer grade urea.

High conductivity readings during start-up and commissioning

In a urea synthesis plant, the HP synthesis equipment is most vital for the operation of the plant. The synthesis is operated under severe process conditions and the synthesis solution contains amongst others carbamate, which is highly corrosive. This combination leads to challenging requirements for the used material in the urea synthesis. For the Stamicarbon urea process applied by thyssenkrupp Industrial Solutions (tkIS) the specifically developed duplex steel Safurex® is used as liner on the carbon steel pressure carrier for the HP synthesis equipment to withstand these harsh process conditions. A part of the HP synthesis equipment is energetically integrated to the carbon steel steam system of the urea plant via tube bundles. Here, MP steam is used as a heat source in one equipment and LP steam is generated in the tube bundle of another equipment. Even though a material failure of the tubes is very unlikely and had not yet occurred for Safurex® tubes, the effect thereof would be very severe. In the case of a tube leak, the whole carbon steel steam system could be contaminated with highly corrosive carbamate solution which would eventually lead to a release of ammonia via steam vent or steam condensate export. In case of a tube rupture, the whole hold up of the synthesis could be emptied from the synthesis into the steam system and additionally the design pressure of the steam system could be exceeded. That is why safety valves are installed in the steam system for this case, which release the synthesis solution in case of a tube rupture into a dedicated collection system.

Fig. 4: Simplified set-up of a urea plant's steam and condensate system



Source: tkIS

In both cases carbamate in the steam system can easily be detected as an increase of conductivity, which is why tkIS plants are provided with online conductivity analysers to closely monitor this parameter as shown in Fig. 4. This allows the detection of any leakage into the steam system or tube failure very early and prevents ammonia release to the atmosphere by blocking in the entire steam system.

However, a detected increase in conductivity is not necessarily correlated to a failure of an HP urea equipment as shown by the following two examples which occurred during the commissioning of tkIS urea plants. Both times, the conductivity analysers gave similar indications, but in the end there were completely different reasons for this and none included a failure of the HP equipment:

The first case happened during the commissioning of a urea plant in 2011. The analyser on the steam side of the HP heat exchanger showed a rapid increase of conductivity. Subsequently, the conductivity in the downstream systems increased as well. First a tube leakage in the HP heat exchanger was assumed, but the measured conductivity was much lower than could usually be expected for that case. Additionally, the laboratory analysis showed only an increase of the ammonia concentration and no increase in carbon dioxide concentration, which is expected in case of a tube leakage. Together with our client it was decided to keep the synthesis in operation as long as the conductivity stayed below a certain threshold while, in parallel, a root-cause-analysis was carried out.

After extensive sampling, it was found that the reason for the conductivity increase was not within the urea plant, but a consequence of a leaking heat exchanger in the upstream ammonia plant which provides steam to the urea plant. The conductivity analyser at the turbine condenser of the CO_2 compressor turbine inside the urea plant did not indicate contamination of the inlet steam, because it was just measuring the acid conductivity and was unable to detect ammonia.

The second case happened during first start-up of a urea plant in 2017. A while after feed-in, the conductivity in the LP steam system started to increase. A consecutive increase of the conductivity in the condensate blow-down and after that in the condensate system could be detected within 15 minutes. The steam system was blocked-in by an automatic plant-trip and it was decided to consequently block in the whole urea synthesis. Lab samples which were taken immediately after plant shutdown confirmed the high conductivity and showed that ammonia as well as carbon dioxide were present in the steam and condensate system. Considering the lab results and because there was no increased conductivity in the condensate of the steam turbine – unlike the first case, here total conductivity was measured and not only acid conductivity – a cause outside of the urea plant could be excluded. The sequence of the conductivity increase detected by the online analysers together with the ammonia and carbon dioxide in the steam system implied that there had been a failure of one of the HP equipment. To inspect the HP synthesis equipment, it had to be drained, purged, flushed and cooled down in order to enter it, which was a time consuming procedure. But inspection and leakage test of both equipment, including a huge number of the combined almost 4,000 tubes, showed no failure. So the search was extended to all non-HP equipment connected to the steam system, which operates at higher pressure than the steam system. Here backflow would theoretically be possible in case of a material failure.

Normal process conditions are required to detect leakages in the LP equipment downstream of the synthesis, therefore it was decided to restart the plant and locate the leakage with an extended sampling schedule and some additional sampling points for manual sampling. Again, a conductivity increase was detected by the online monitors. However, with the additional sampling, the source of the carbamate contamination could successfully be attributed to the low pressure carbamate condenser (LPCC). This LPCC is operated by tempered cooling water of a closed cooling loop filled with steam condensate with a bleed stream to the steam condensate system. Thus, a leak to a cooling system was the reason for the high conductivity in the steam system. After the repair of the condenser and re-start of the plant, no further issues with the conductivity in the steam and condensate system occurred.

The sequence of conductivity increase detected by the online analysers had not been reflecting the real sequence in the second case. The incorrect sequence was a consequence of different response times of the online conductivity analysers, due to different lengths of sampling tubing.

Both cases show that similar indications of process parameters are not necessarily caused by similar failures. Experience in engineering as well as in commissioning was the key success factor to find the root cause of the defects in due time for both cases enabling rectification and ensuring commissioning in time.

1,725 t/d urea project in Indonesia for Petrokimia Gresik

PT Petrokimia Gresik (PG) in Indonesia has been producing ammonia (1,350 t/d) and urea (1,400 t/d) for more than 20 years and in the past two decades has also intensely developed its NPK fertilizer production, which has become one of its core businesses.

Recently, the demand for NPK fertilizer has increased significantly, exceeding PG's production capability. The demand for urea has also grown to approximately 1,100,100 t/a in East Java province of Indonesia, while PG was only able to supply 460,000 t/a of urea. In addition to this, most of the ammonia used as a raw material for NPK fertilizer production was imported and its high price had a big impact on the production cost of the fertilizers. For these reasons, PG decided to build a new ammonia and urea plant, to meet the increased demand and to reduce production costs[4].

The new project (Ammonia Urea 1B Project) consists of 2,000 t/d of ammonia and 1,725 t/d of prilled urea. Wuhuan Engineering Co., Ltd. (WEC) and PT Adhi Karya (ADHI) were awarded the EPC contract on a lump sum turnkey (LSTK) basis utilising technology licenses from KBR and Toyo Engineering Corporation (TOYO).

WEC, the EPC consortium leader, had the overall responsibility for the ammonia and urea plant, while ADHI's scope was the utility units including urea product handling facilities. The service relating to the outside battery limit of this project (i.e. raw water supply, liquid ammonia storage, offsite piping, steam supply, and electricity supply) was the scope of other independent utility suppliers.

PHOTO: TOYO

Petrokimia Gresik's new 1,725 t/d urea plant, Indonesia.

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Initial start-up

During the initial start-up, a leakage from the lining of the reactor occurred unexpectedly due to a minor weld imperfection of a weld line between lining plates which cannot be detected by conventional non-destructive testing during manufacturing. Therefore, the urea plant was shut down immediately for repair. TOYO concentrated intensively on its repairing work and the urea plant was ready for start-up again in ten days. To avoid the recurrence of this problem, TOYO developed a special NDT for inspection of weld lines, which has already been applied in current on-going projects.

After the successful repair, from start-up it took only seven hours from raw material feed to the urea plant until first urea production. The readiness test was then performed in line with the requirement of EPC contract to ensure the urea plant could run at minimum 80% load, which was successfully completed in June 2018. However, after the readiness test, it was decided to shut down the urea plant for 19 days. During this period, all pending items were resolved.

Following the shutdown the urea plant was put back into service and the performance test was conducted at 100% load for a period of one week to confirm all the guaranteed figures specified in EPC contract, such as the consumption of raw material and utility, the product quality, etc. A demonstration test was then carried out at 110% and 115% load plant load. The urea plant was quite stable even at such high plant capacity.

Plant performance

Since commercial operation of the plant started in August 2018, the plant reliability has been confirmed and the plant has been running almost continuously at 110% capacity and finally achieved 120%. After one-year operation from the handover, the first turnaround was conducted in July 2019. All equipment was carefully checked and the critical equipment was free from any damage.

Project challenges

Every project has its own characteristics and challenges. Some of the major challenges faced in this project are detailed below.

Plant location near residential area

The dedicated area given to build this plant was in close proximity (approx. 300 m distance) to a residential area. No activities had any impact on the neighbourhood. Steam blowing was problematic resulting in many complaints due to its noise and heat exposure. To minimise the complaints, steam blowing had to be conducted during daytime only, which prolonged the activity, beyond the original plan. Close coordination among all the parties was required to prevent any activities being cause for complaint. Furthermore, as the emission of process fluid to the atmosphere also directly impacts the residents, a flare was installed to overcome it.

PG's young and inexperienced personnel

PG's main personnel involved in this project were relatively young – most were below 25 years old with less than two years job experience. Therefore, PG hired a senior, retired, former employee of PG to transfer expertise and support the inexperienced personnel. PG also employed some technical experts from third parties who had extensive experience in the construction of grass-roots ammonia and urea projects. Their coaching and leadership significantly raised the knowledge of the young personnel to a higher level.

PG also utilised TOYO's operating training simulator (OTS), which proved very useful to operators, speeding up the time to become familiar with the operation and to learn the basic operational philosophy of the urea plant. OTS's interface was very similar to the real HMI and young operators were able to simulate operating the real plant under various situations: start-up, shut down, normal operation, and even abnormal conditions. The more they utilised the OTS, the more experience they gained.

Safety awareness

Since safety is the first priority for all activities, the close meeting was always held to discuss the concrete work plan, and it was briefed again at the site among all parties. Despite strict supervision by PG, some workers still broke rules, for example, there was a case where a worker took off his safety protection because he felt uncomfortable wearing it while working. Each work area leader, who was a role model for the workforce, had the strong mandate to ensure workers obeyed the rules.

Change of government regulation

Government regulation was one of the biggest uncertainties in the project execution stage. Changing of the regulation related to "the import of steel and alloy", "the custom clearance", and "the labour law" caused three months delay to the project schedule. In the end, the EPC contract was revised to extend the period of the project by eight months, taking all unexpected circumstances into account.

Quality control (QC) of manufactured equipment

The competent and experienced inspectors, hired by PG from a third party, played an important role ensuring that the quality of the equipment satisfied the requirements based on international codes and standard. Most of the inspection activities were performed by them and no defects were observed throughout the project.

Supply of electricity and steam

The supply of electric power and steam for the plant was out of scope in this project, which means it was supplied from outside plants built newly by other independent utility suppliers. The project to build new power and steam plants commenced at the same time as this project, but unfortunately progress of their project was delayed. The overall project schedule also had to be delayed because each activity related to steam and power was suspended due to this reason. To minimise the delay, PG decided to shutdown PG's existing plants in sacrifice, and transfer steam and power to the new ammonia and urea plant. ■

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Evolution of a new NH_3 synthesis catalyst

AmoMax®-Casale is a new ammonia synthesis catalyst jointly developed by Casale and Clariant. Retaining the same superior resistance to ageing, poisoning and mechanical strength as the well-known wustite-based catalyst, AmoMax® 10, the new catalyst is significantly more active. **C. Berchthold** of Clariant and **S. Panza** of Casale explain the advantages of AmoMax®-Casale and share the start-up experience of the first commercial reference.

Catalyst development

Catalytic ammonia synthesis from hydrogen and nitrogen represents one of the most important industrial reactions today. The catalyst used in this reaction is made from iron oxide with small amounts of other oxides added as promoters to enhance activity and stability. Despite the Haber-Bosch process being more than 100 years old, only incremental improvements have been achieved until recently. Combining the catalyst expertise of Clariant and the engineering knowledge of Casale, a breakthrough has been realised leading to the new ammonia synthesis catalyst AmoMax®-Casale.

The new catalyst is based on Clariant's successful catalyst AmoMax 10 with more than 100 references worldwide and is customised for Casale reactors (patent pending) with significantly improved activity compared to state-of-the-art iron-based catalysts. When introducing a new catalyst to the market, performance evaluation is of utmost importance. Simple catalytic tests in powder form are not representative enough for industrial applications and are only suitable for screening purposes. Therefore, a precise and rigorous methodology must be applied.

Materials and methods

To reliably validate a new catalyst, laboratory-scale tests should be representative of the industrial catalyst. Thus, catalytic and mechanical tests are performed with the final form and shape of the catalyst. During catalytic tests, the temperature profile in the catalyst bed is measured and correlated with the heat exchange between oven and reactor. Subsequently, systematic modelling of the obtained data is applied to understand the performance of the catalyst under industrial conditions. The information acquired is used to compare the new catalyst with the best available state-of-the-art catalyst technology. In case of the superior activity of the new catalyst, as a next step, in-depth mechanical stability characterisations are performed to confirm the robustness of the catalyst. This includes simulations and experiments of friction between the catalyst pellets/granules and the walls of the reactor, crush strength and simulations of start-up/shut-down of industrial reactors. If the catalyst passes all the mechanical tests, proof of concept is achieved, and it is considered ready for scale-up. Transferring the catalyst recipe from lab to production scale is a highly complex process with numerous important parameters, which must be considered by the catalyst manufacturer. After a successful scale-up, the catalyst is prepared for shipment. To ensure it maintains its mechanical integrity and activity after transport from the production site to the plant, samples are taken during transportation, sent to different analytical laboratories and precisely analysed. The catalyst is then validated with the same catalytic and mechanical tests applied during the proof of concept phase. If all parameters are confirmed, the catalyst is finally ready for the market.

Fig. 1: **Catalyst performance comparison**

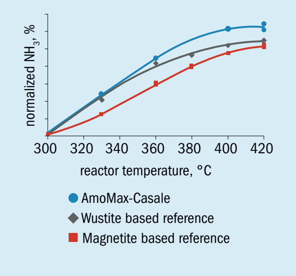
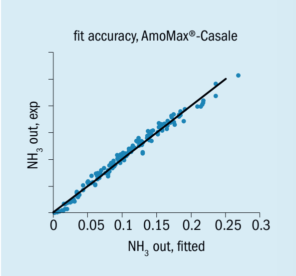


Fig. 2: **Simulated and experimental data**



Performance tests

Activity

Laboratory results for the catalytic activity are reported in Fig. 1. The test conditions were:

- Tubular reactor, tests performed on granules
- Pressure: 150 bar and $H_2 : N_2 = 3$
- Temperature: 300, 330, 360, 380, 400 and 420°C

The results show how the new AmoMax®-Casale outperforms magnetite and wustite-based state-of-the-art ammonia synthesis catalysts over the whole relevant temperature range. In particular, the gap between AmoMax®-Casale and standard magnetite catalyst is drastically increased.

Based on the test results a kinetic model was created which fits very well with the experimental data (see Fig. 2).

Fig. 3: **Poison resistance in different oxygen concentrations**

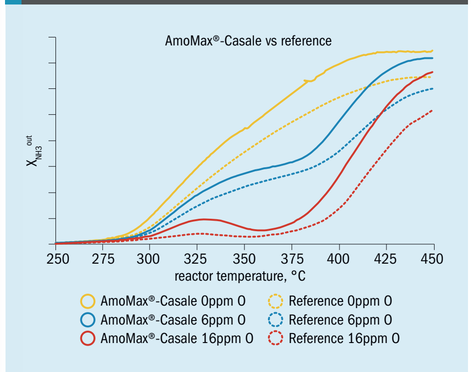
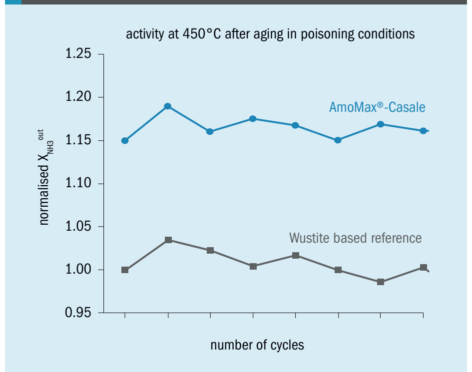


Fig. 4: **Stability after aging in poisoning conditions**



Poison resistance

The performance with different O_2 concentrations in the feed was tested at different temperatures with the following results:

- The oxygen poisoning behaviour of the new catalyst is similar to the reference catalyst at all measured O_2 concentrations (compare dotted versus full line)
- The deactivation observed due to oxygen poisoning corresponds to observations in commercial plants.
- Despite the higher activity, AmoMax®-Casale offers superior performance regardless of oxygen concentration (Fig. 3).

Stability

AmoMax-Casale shows an extraordinary stability in poisoning conditions. The performance was tested after each poisoning treatment and the activity was measured over time at fixed testing conditions without oxygen poisoning and after a stabilisation period.

As shown in Fig. 4 AmoMax®-Casale has proven to be very stable compared to wustite-based reference catalyst.

Mechanical tests

In addition, Casale and Clariant performed tests to assess the mechanical suitability of AmoMax®-Casale; in particular the main targets were to identify the intrinsic properties of the catalyst and how the catalyst would behave inside the Casale internals.

The tests performed to mechanically qualify the AmoMax®-Casale were:

Crushing strength properties in Casale internals: AmoMax®-Casale has been tested with an in-house tool (the so-called "Casale wall tester", see Fig. 5) to assess the amount of powder produced due to friction of the catalyst with the Casale collectors. The AmoMax®-Casale crushing tendency has been compared with standard wustite and magnetite catalyst and no significant differences were found.

Pressure drop: a test unit was set up to assess the pressure drop generated by the new catalyst and compared with standard catalysts used as references with the aim to evaluate the pressure drop result inside an axial-radial bed. The results obtained were in line with expectations and with the industrial pressure drop achievable in an industrial converter with a converter based on standard catalyst.

Shear stress test: basically, this test is designed to apply stress to a test sample so that it experiences a sliding failure along a plane that is parallel to the forces applied. Therefore, this test is important in order to assess the effect of the catalyst on the Casale internals; after several tests the parallel stresses created on the internal surface are comparable to the ones measured with standard catalyst.

Fig. 5: Casale wall tester.

Casale internals design philosophy

Depending on the project type (new converter or revamping of an existing reactor), Casale can approach the ammonia synthesis converter in different ways.

In general, for a new pressure vessel the main goals are:

- full exploitation of catalyst;
- high reliability;
- highest catalyst volume filling efficiency to reduce the final pressure vessel sizes;
- easy access to internal baskets for maintenance or catalyst replacement.

For revamping, considering the possible physical constraints of the existing pressure vessel, the target is to provide the most efficient thermodynamic configuration combined with the maximum catalyst volume filling efficiency; reliability is another important target, while access to

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the internal baskets is determined by the existing pressure vessel configuration.

For a new converter Casale usually adopts the well-known configuration based on three catalytic beds with interchangers between the first and second bed and between the second and third bed, coupled with the use of Casale patented axial-radial internals.

In case of revamping the most frequent configuration is three catalytic beds with one or two interchangers; retrofitting an existing converter with Casale internals often means increasing the installed catalytic volume compared to the previous design.

The installation of a bottom exchanger is also quite common especially for revamps or the installation of a new pressure vessel in an existing synthesis loop.

In general, the higher efficiency of Casale internals together with the well-known Casale cold-wall design allows the converter to operate at a lower thermal level, thus improving its expected lifetime. Independent control of each of the three beds temperatures is foreseen since it is essential to obtain optimum operation of the converter at all times, i.e. with new as well as aged catalyst and at different plant loads, for maximum energy saving and thus highest return on the converter retrofit investment.

The new converter internal features are:

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

The catalyst beds have two cylindrical walls, one external (near the cartridge wall) and one internal, to contain and support the catalyst mass providing mechanical strength and to provide uniform gas distribution throughout the whole bed volume in order to get the best catalyst performance. Each of the three axial-radial baskets is designed with an open top catalyst bed, which has the following advantages compared to conventional radial designs:

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

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

The material selection is performed to minimise or avoid high temperature Hydrogen attack and nitriding phenomena, that would affect the reliability and the life of the installed pressure vessel and internals as well.

The axial-radial flow pattern in the catalyst, results in an empty cylindrical core around the converter centreline, which is the ideal location for the interbed heat exchangers. To save costly converter space, Casale adopts a special design that allows high heat transfer rates to be obtained with comparatively low pressure drop and eliminates vibration problems. The bottoms of the removable baskets are inverted dished heads. Besides simplifying the sealing problems, this arrangement allows better utilisation of the converter volume (i.e. more catalyst can be packed in these baskets).

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

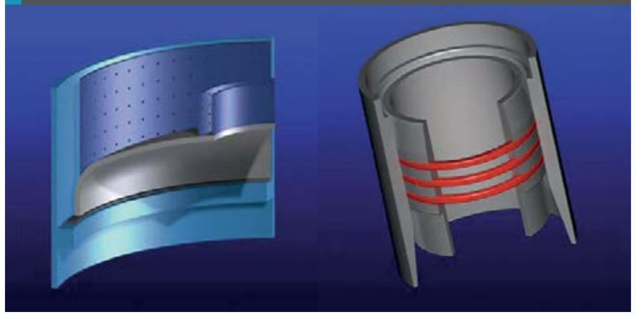

Fig. 7: Cartridge lift and installation inside converter.

Fig. 8: **New pressure vessel**

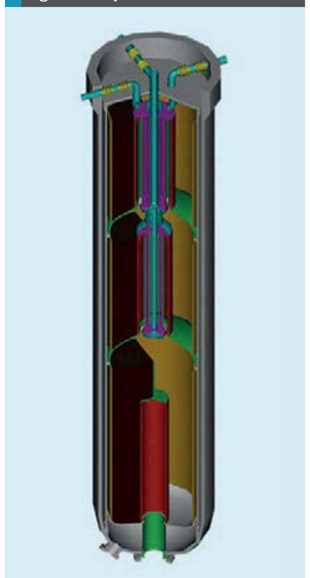

Fig. 9: Catalyst dense loading.

The different interconnected metal parts, which combined constitute the internals, reach very different steady state temperatures in an operating converter. To cope with different thermal expansions, Casale only uses bellows expansion joints where they are easily accessible for assembly and disassembly (i.e. at the reactor top). For converter inner parts, since they are not easily accessible, Casale patented elastic seal rings are used (Fig. 6). In this way it is possible to reduce internal leakages with smaller axial dimensions and shorter length.

Casale internals installation

In case of converter pressure vessels with a fully open top configuration, this is unbolted to unload catalyst and remove the existing cartridge. The pressure vessel is then inspected, the stud bolts and gaskets seating surface are protected. A new cartridge is then lifted (Fig. 7) and installed inside the pressure vessel (Fig. 8). The expansion joint assembly on the converter outlet nozzle is installed and welded up to the cartridge bottom pipe, then the cartridge top cover is removed. After removal of the protection screen and lifting of the first bed basket, it is possible to unbolt and remove thermowell pipes.

To ensure a proper reading during converter operation, water moisture and dirt must be prevented from infiltrating the inside of the thermowell pipes: special care is therefore taken to plug and seal the thermowell pipes openings. Internal heat exchangers are already welded and in position inside the new cartridge; they are never normally removed during cartridge installation. Using the same procedure as for the first bed, the second bed basket is removed, and catalyst loading is started in the third bed.

Special attention must be given during catalyst loading to preserve catalyst activity and the integrity of the converter internals. Oxidised catalyst is completely unreduced and does not present any risk of reactions with ambient air; conversely, pre-reduced and stabilised (RS) catalyst is obtained by the complete reduction of oxidised catalyst followed by skin oxidation for safe handling and storage. Reduced and stabilised catalyst can react with air even at ambient temperature; if such a reaction occurs, the temperature can easily rise since the oxidation reaction is exothermic, causing both catalyst and converter internals damage. For these reasons, pre-reduced catalyst loading (converter first bed) must be performed under a nitrogen atmosphere. Special nitrogen connections are used to flush the converter and a temporary cartridge closure cover and polyethylene sheet are used to cover all areas were catalyst is handled.

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

Catalyst loading is performed by using a dense loader (Fig. 9). The amount of catalyst loaded is recorded while regularly monitoring (every 1,250 mm) catalyst distribution and bulk density (loaded catalyst weight and height are required) to maximise loaded catalyst bulk density.

After the third bed catalyst loading is completed, a relevant top protection screen is re-installed together with second bed and gaskets. Catalyst loading on the second and first bed proceeds as described for the third bed. Thermowell pipes and relevant stuffing boxes are also re-installed. During first bed loading, the bed temperature is carefully monitored to ensure that no oxidation is occurring.

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

All welds are 100% checked by dye penetrant test to ensure maximum reliability of internals. Installation of the new converter internals are accomplished smoothly in less than 15 days for a new converter, with no impact on plant scheduled shutdown time.

Fig. 10: **Revamping of a bottle shape converter**

AmoMax®-casale operation in casale converters

As discussed previously AmoMax®-Casale catalyst provides up to 30% higher activity compared with the standard wustite based catalyst available on the market (reference catalyst). The combination and synergy of this catalyst with the best ammonia converter technology provided by Casale offers an unmatchable design with the highest possible attainable performances, in terms of lower synloop operating pressure and higher ammonia conversion.

These benefits can be easily converted into energy savings, lower natural gas specific consumption or higher production if the limitation to a plant load increase is provided by the synthesis loop.

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ISSUE 364
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Table 1: **New converter catalyst comparison**

	Reference catalyst	AmoMax®-Casale
Internals	Casale	Casale
Production, t/d	1,655	1,655
Operating pressure, kg/cm²g*	140	134.5
Ammonia outlet, mol-%	17.7	18.4
Energy saving, kcal/tonne	–	>25,000

**Outlet converter*

Table 2: **Benefits of AmoMax®-Casale in GIAP revamped converter**

	Pre-revamping	Reference catalyst	AmoMax®-Casale
Internals	Other licensor	Casale	Casale
Production, t/d	1,400	1,870	1,870
Operating pressure, kg/cm²g*	249	231.4	223.7
Ammonia outlet, mol-%	14.5	17.0	18.8
Chiller duties, Gcal/h	7.2	9.5	8.6
Loop Circulation, kmol/h**	35,700	38,100	34,100
Energy saving, kcal/tonne	–	163,000	>210,000

**Outlet converter ** inlet ammonia converter*

Table 3: **Benefits of AmoMax®-Casale in TEC revamped converter**

	Reference catalyst	AmoMax®-Casale
Internals	Casale	Casale
Production, t/d	2,100	2,100
Operating pressure, kg/cm²g*	226.1	217.4
Ammonia outlet, mol-%	20.7	21.7
Energy saving, kcal/tonne	-	>45,000

**Outlet converter*

In case of a new converter, AmoMax®-Casale can be used in all designed beds boosting the performances and the expected life, a different layout could foresee a first bed based on standard catalyst (this bed is working with fresh and unreacted gas).

A new converter based on AmoMax®-Casale catalyst and Casale internals to be installed in a new synthesis loop would have a smaller pressure vessel or a lower synloop circulation and therefore smaller equipment sizes with reduction of the relevant capex.

For ammonia synthesis converter revamping, as AmoMax®-Casale is more efficient than the standard reference catalyst, its logical application is in the last bed of an existing converter. Often the application of AmoMax®-Casale is also offered starting from the second bed of an ammonia synthesis converter. The application of AmoMax®-Casale in the first bed is not normally required for ammonia synthesis converter revamping as this basket is working with a very fresh gas (low ammonia concentration) and therefore the differences with a standard catalyst are not so significant.

Table 1 compares the performances of a new ammonia synthesis converter pressure vessel designed with Casale internals and operated with standard wustite based catalyst available on the market (reference catalyst) or AmoMax®-Casale catalyst, based on the following boundary conditions:

- same catalyst life:
- same Casale internals;
- same new pressure vessel;
- AmoMax®-Casale loaded in the second and third catalytic beds.

Therefore, with an optimised ammonia converter internals configuration and based on the latest Casale technological improvements the AmoMax®-Casale catalyst is able to provide an enhancement of the overall synloop performance.

The installation of this new catalyst in a revamped converter (Fig. 10) can be even more effective considering that very often, an existing converter is working in conditions far from the original ones, and therefore with a design and configuration that may no longer be optimised for the current operation.

Consider, for example, two different design configurations, a GIAP bottle shape and a TEC bottle shape, based on the following:

- same catalyst life:
- Casale or competitor internals;
- existing pressure vessel;
- AmoMax®-Casale loaded in the second and third catalytic beds.

The benefits of AmoMax®-Casale in the revamped converters are presented in Tables 2 and 3.

The performances improvements in terms of energy savings and capacity increase are quite remarkable especially if compared with ammonia synthesis converter design different to Casale.

Conclusions

In a joint multidisciplinary effort involving process engineers, scientists, modelling engineers, and fluid dynamic engineers, Casale and Clariant have created a new ammonia synthesis catalyst and made it ready for the market in less than three years.

AmoMax®-Casale provides the following benefits to ammonia plants:

- Casale engineering adapted and optimised to use the newly developed catalyst;
- new catalyst efficiency index up to 30% more than wustite-based reference;
- higher tolerance towards poisoning and aging compared to wustite-based reference;
- Energy savings, lower natural gas specific consumption or higher production if the limitation to a plant load increase is provided by the synthesis loop.

AmoMax®-Casale has been successfully installed and started up in the first large scale ammonia plant in the Americas. ■

Finding solutions to problems in urea equipment

Schoeller-Bleckmann Nitec (SBN), an experienced manufacturer of high pressure equipment for ammonia and urea plants for many years, also helps customers when things go wrong. SBN has come to the aid of operators on numerous occasions, helping them return their plant to operation as soon as possible when a problem occurs. **R. Bunzl** discusses SBN's approach to finding solutions to a number of exceptional problems in urea equipment.

SBN, part of the Christof Group, is a manufacturer of high pressure equipment for ammonia and urea plants. Over the past 20 years, SBN has manufactured more than 200 heat exchangers and reactors for high pressure urea synthesis. SBN is based in Ternitz, Austria, where there is a very experienced team in the workshop, mechanical and design engineers, welding engineers and non-destructive testing specialists, all contributing to the decades of experience and success of SBN.

Having manufactured so many vessels for urea plants, with many still in constant operation, SBN also gets involved when there are incidents during operation of these vessels. If, for whatever reason, a problem occurs, SBN is often called upon by the operators for immediate help in order to return the plant to operation as soon as possible.

This article describes several exceptional problems for which SBN has been approached to help.

Repair of a Pool Condenser tubesheet

The Pool Condenser is a horizontal shell-and-tube heat exchanger in the high pressure synthesis section of a urea plant. On the shell side, ammonia and carbon dioxide react to form carbamate and urea. The reaction heat is removed by passing steam condensate through the U-bundle.

Fig. 1: Bent U-bundle and stay rods.

In this Pool Condenser the carbon steel tubesheet was severely affected due to flow accelerated corrosion (FAC), which created a large cavity. The cavity grew over a period of months and remained undetected until finally a sudden increase in conductivity triggered an alarm indicating a leakage. The plant was shut down and the Pool Condenser opened for inspection.

With the help of a video endoscope the inside of the tubesheet was inspected and the cavity was found. A severely deformed and buckled tube bundle was also discovered (Fig. 1). Fig. 2 shows a schematic of the cavity in the tubesheet.

The vessel damage meant the plant could not continue operating, so SBN was contacted by the client for a repair solution that would enable the plant to return to operation as soon as possible.

After a detailed study of different repair solutions, and taking into consideration technical and commercial aspects, it was decided to do a temporary repair of the damaged tubesheet and in parallel manufacture a new Pool Condenser.

The idea was to keep the tube bundle and weld overlay of the tubesheet,

Fig. 2: **Schematic representation of the cavity in the tubesheet**

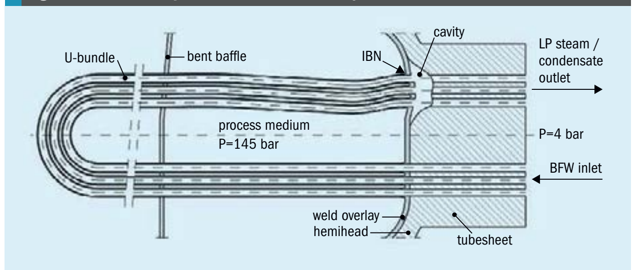

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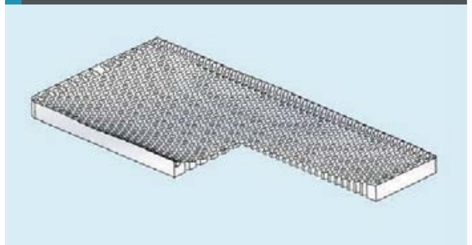
Fig. 3: CS part of tubesheet removed for weld overlay inspection.

Fig. 4: **Support plate for deformed weld overlay**



although deformed and sufficiently damaged that a leak occurred, but to repair the tubesheet as its mechanical integrity was the biggest concern. Since the damaged weld overlay was beyond repair, it was clear from the beginning that any repair could only be temporary and, due to the deformation of the overlay, additional leaks could still occur after the repair.

The repair was therefore only to keep the plant in operation until the new Pool Condenser arrived on site.

The repair method entailed completely removing the carbon steel of the tubesheet from the opposite side of the bundle in the area of the damage, but leaving the overlay untouched.The overlay could then be inspected and the amount of damage and cracks finally assessed.

Fig. 3 shows the CS part of the tubesheet removed to allow inspection of the weld overlay.

As expected, the overlay was severely deformed. It was clear that the three-dimensional shape of the deformation had to be recorded and a support plate with exactly the negative shape of the deformation needed to be installed. This support plate would avoid additional deformation after start-up of the vessel due to the pressure on the overlay from shell side.

To make this possible a 3D-laser scan of the deformed overlay was performed. The data were then used to exactly machine the same contour.

Fig. 4 shows the support plate for the deformed weld overlay.

After supporting the existing weld overlay the mechanical integrity of the tubesheet needed to be restored.

The solution was to close the cut-out in multilayer design. Since the tubesheet was bending due to the higher pressure on the shell side, the shear forces between the layers needed to be addressed. This was done with the help of high strength duplex sleeves, which also protected the carbon steel.

Fig. 5 shows a drawing of the repair. The repair was completed within the estimated and contractually agreed time of four months.

The repaired Pool Condenser was in operation for more than one year without any problems or unplanned shutdowns.

Re-design of a gasket seat

In the past, double cone gaskets were used by some companies as a standard gasket solution for manway covers in high pressure urea vessels. Some of these vessels are still in operation today.

Double cone gaskets need to be pre-tensioned to have contact on the conical face with the vessel wall. Additionally, thin layers of aluminium foils are used to improve initial sealing. Upon application of pressure it expands and is pressed further against the vessel wall to seal it.

A client of SBN operates a urea reactor, designed in the 1980s, with a double cone gasket. The client experienced leakages every few years, especially after longer plant shutdowns (without opening the vessel). Although the gasket is replaced every time, the leakage still occurs frequently.

It is assumed that these leakages occured due to slight corrosion effects and imperfect gasket surface geometry. SBN was asked what could be done to avoid these leakages and associated unplanned shutdowns.

SBN's recommendation was to change the gasket type to the standard gasket system commonly used today. This is a serrated gasket made of urea resistant steel covered by a PTFE envelope.

This gasket is well proven and reliable. Due to the PTFE envelope, which is pressed by the serrated steel against the flange face, the sealing system is unaffected by pressure variations in the vessel.

Fig. 5: **Pool Condenser tubesheet repair**

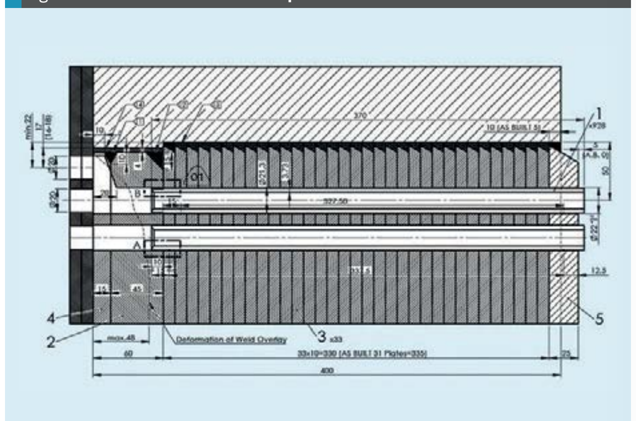


Fig. 6: SBN welder working on site.

Fig. 7: Damage behind the lining of a HP scrubber.

In this specific case two different options for changing the gasket design to a new modern solution were possible.

The first option was to manufacture a new cover with the necessary geometry and additionally machine the existing manhole on-site with a transportable device. Afterwards, a solid gasket ring could be welded into the manhole. Finally, all open carbon steel parts need to be covered again by overlay welding with a urea resistant steel like 25-22-2.

A second option was also possible, since the original vessel had a multilayer shell design. Here, the multilayer design is a big advantage. Since no post-weld heat treatment is necessary when welding forgings to a multilayer shell, the complete manhole can be manufactured in the SBN workshop together with a new cover. The original flange is cut at the connection to the multilayer and the new one is welded on. This also reduces shutdown time of the plant during the change of the gasket seat.

After welding, the seam needs to be checked. Normally such seams are Xrayed in a workshop. But on-site, due to the restriction of all radiography, this becomes virtually possible. In such cases ultrasonic testing like UT-TOFD and phased array can be used. This is also covered by all major pressure vessel codes like EN 13445, AD-2000 or ASME. SBN has the equipment and experience to use this NDT technique on site.

Re-lining of a HP scrubber

During a shutdown and inspection of the HP equipment a client of SBN recognised severe cracks over several square metres of the lining in a scrubber. It was clear that it needed to be replaced before it could go back into operation. After removal of the lining in the affected zone it could also be seen that even the carbon steel behind was already severely damaged.

Fig. 7 shows damage in a HP scrubber sphere behind the lining.

The damaged area was located in the sphere. The manufacture of spherical lining is much more complicated than lining for a cylindrical shell. This is the reason why many vessel manufacturers only do overlay welding in spherical formed sections of their vessels, and not lining.

SBN has extensive experience in manufacturing spherical vessels for urea plants with lining. The re-lining of existing vessels has also been performed many times.

Fig. 8: Forming of a spherical lining segment on a press.

Fig. 9: Packing lining material for air transport.

NITROGEN+SYNGAS
ISSUE 364
MARCH-APRIL 2020

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Fig. 10: **3D CAD model of steel structure to accomodate the HP stripper**

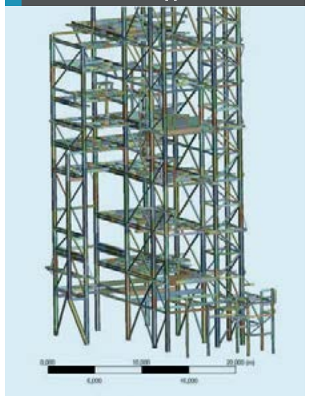


Fig. 11: **Finite element analysis result for local beams in steel structure to support the HP stripper**

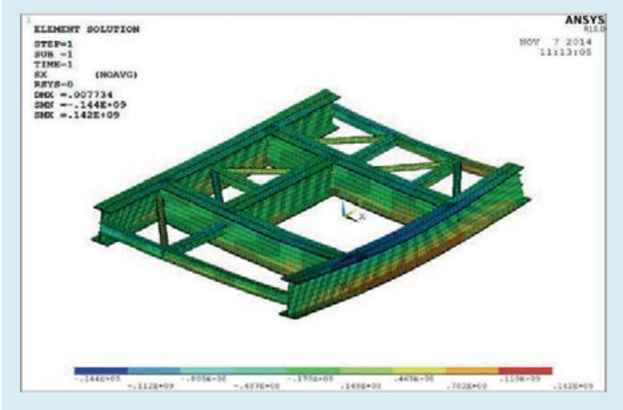
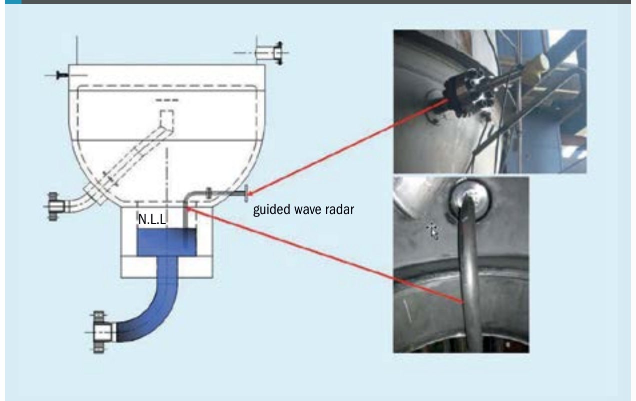


Fig. 12: Opening in steel structure allowing access to the HP stripper.

Fig. 13: **Level measurement by radar in the bottom of the HP urea stripper**



For manufacturing a spherical lining the plates need to be first cut to size and then pre-formed on a press.

Fig. 8 shows the forming of a spherical lining segment on a press.

Forming requires a lot of experience and very skilful press operators to shape the segments. The segments need to be placed in the vessel several times during the forming process to check the shape. Only when the shape fits almost perfectly with the vessel can the lining be installed. Otherwise the gap between the lining and the carbon steel after welding the lining to the vessel may be too big. In this case the lining could crack when pressure is applied to the vessel.

In case of manufacturing re-lining material for an existing vessel there is of course no possibility to check the shape with the help of the real vessel. Therefore, a wooden model with the same shape as the existing vessel is built which can be used during forming.

Since in such cases the shutdown times of the plant during the repair are one of the biggest concerns of the plant operators, SBN delivers the re-lining material in the quickest possible way. SBN has material of different urea resistant steel grades in different thicknesses in stock for such emergencies.

Fig. 9 shows packing of lining material for air transport.

Change of steel structure

SBN manufactures several replacement vessels a year for the high pressure urea synthesis section. Sometimes clients need just a replacement in kind with identical vessel dimensions and design. But for good reasons such a replacement is always an opportunity to increase plant capacity.

For the replacement of a HP stripper a client wanted to increase the capacity as much as possible. The heat exchanger part of the stripper, with its effective tube surface area, defines the capacity of the vessel. After re-calculations by a licensor

Fig. 14: Drilling of hole in existing vessel for installation of new radar nozzle.

Fig. 15: Installed radar stand pipe – view from inside the vessel.

Fig. 16: Installed radar – external view with heat tracing.

it was decided to increase the number of tubes in the stripper. When SBN did the mechanical design of the vessel the client was informed about the new dimensions necessary to house the increased number of tubes. The client wasn't aware of the increased size and weight and wasn't prepared to change the steel structure where the stripper needed to be placed.

To support the client and not to jeopardise the shutdown date SBN evaluated the steel structure and developed suitable options for local but effective reinforcements.

To do so SBN built the steel structure based on old as-built documentation in a CAD program.

Fig. 10 shows a 3D CAD model of the steel structure to accommodate the HP stripper.

This model was used to perform different kinds of finite element analysis (FEA). First of all certain beams needed to be removed or replaced to increase the space necessary for the bigger vessel. Additionally the weight of the new stripper was increased and therefore especially the beams close to the stripper supports needed to be checked for their stresses and deformation.

Fig. 11 shows the FEA calculation result of local beams in the steel structure to support the HP stripper.

The complete structure also needed to be checked in terms of stability to avoid buckling. Especially during removal and installation of the stripper some beams needed to be removed to go in and out. This is the most dangerous load case and if not properly checked, there was the risk that the complete structure could collapse.

Fig. 12 shows an opening in the steel structure allowing entry into and out of the HP stripper with the help of a mobile crane.

With these calculations SBN was able to support the client. SBN also prepared drawings for the necessary changes in the steel structure. The material itself and the erection work on the steel structure was organised by the client.

The stripper was finally installed without any problems.

Change of level measurement system

In different locations in the high pressure urea synthesis section it is necessary to control the level of liquid for efficient operation of the plant. Due to the high pressure and temperature as well as the aggressive medium, level measurement is no easy task in these vessels.

Traditionally this has been done by using a radioactive source and a detector. For health and safety reasons this is very problematic and a radar level measurement system is now available on the market.

Unfortunately for existing vessels this radar measurement cannot be just placed onto the old nozzles for the radioactive source, a new nozzle is necessary.

Fig. 13 shows level measurement by radar in the bottom of a HP urea stripper.

SBN can install new nozzles on site by drilling a hole into the vessel wall (Fig. 14) and welding in the new nozzle. The fact that these vessels are lined makes the task more complicated.

After drilling and welding in the new nozzle the corrosion protective lining and weld overlay needs to be closed again to avoid leakage and damage.

Fig. 15 shows a view from inside the vessel of an installed radar stand pipe. In addition to the machining and welding work, non-destructive testing is also necessary. This can also be performed by SBN.

The radar measurement nozzles need to be heat traced to avoid problems later on due to cold spots and related corrosion problems.

SBN has successfully completed on-site radar nozzle installations several times. Typically only 1-2 weeks of shutdown time are needed to install the nozzle. Fig. 16 shows an installed radar nozzle from the outside with heat tracing. ■

NITROGEN+SYNGAS
ISSUE 364
MARCH-APRIL 2020

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Subscription rates:
GBP 425; USD 850; EUR 655

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

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ISSN: 1750-6891

Design and production:
JOHN CREEK, DANI HART

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www.fsc.org Cert no. SA-COC-001904
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Printed in England by:
Buxton Press Ltd
Palace Road, Buxton, Derbyshire, SK17 6AE

BCInsight

Published by: BCInsight Ltd
China Works, Unit 102,
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