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Cover: Gothenburg in winter.
Claes Torstensson/iStockphoto.com

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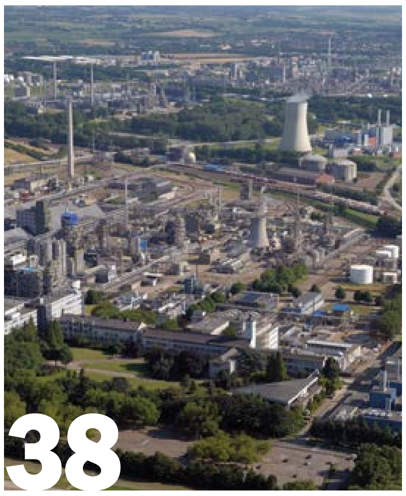
Gas markets

The spread of market liberalisation.



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ANNA 2017

Focus on ammonium nitrate safety.

Read this issue online at: www.nitrogenandsyngas.com

Published by: BCInsight

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REGULARS

Editorial

Yara's vote of confidence in India

On January 13th, Yara finally completed its 100% acquisition of Tata's Babrala urea plant in Uttar Pradesh, India. The sale is the first foreign direct investment in India's domestic nitrogen production industry, and marks an interesting new stage for Yara's penetration of the world's second largest market for nitrogen fertilizers.

The $450 million deal sees Yara inherit one of India's most efficient urea plants, with a capacity of 700,000 t/a of ammonia and 1.2 million t/a of urea, and in some ways one of its most modern – it was completed in 1994 before the moratorium on new plant building which saw only one new urea plant built after 1999. It also has a good track record on safety and the environment.

India's northern state of Uttar Pradesh is also the country's most populous, with 200 million people, and it is also part of India's bread basket, responsible for 13% of the country's agricultural production. The plant supplies urea across the northern belt of agricultural states of Uttar Pradesh, Uttarakhand, Bihar, West Bengal, Punjab and Haryana, and has access to a network of 700 dealers and retailers. Yara says that the acquisition will multiply its fertilizer sales in India almost tenfold, from $40 million per year to $350 million. Prior to the purchase Yara had mainly focused on premium product sales in the west and south of the country. The company says that it now hopes to integrate these operations, giving northern farmers access to Yara's experience with crop nutrition under varied soil and climate conditions and its range of analytical services including soil testing and digital tools like CheckIT, which enables farmers to diagnose nutrient deficiencies in crops. In time it hopes to help to improve fertilizer application practices and productivity, which also fits in with the government's efforts to try and double farm incomes by 2022.

The move can be seen as a vote of confidence in India's heavily regulated urea sector, but it also illustrates some of the difficulties of doing business in India – the sale was first announced in August 2016, but it has taken 18 months to clear regulatory approvals and court sanctions. Yara itself admitted that the Indian market can be a "difficult" one. Terje Knutsen, Yara's EVP, Crop Nutrition, has said that India needs to simplify its registration process for new fertilizer products to allow for new and innovative varieties of speciality fertilizers that will help redress the country's nutrient application imbalance. Urea prices are also still heavily controlled by government and subject to a sometimes byzantine subsidy regime, while demand has been hit by urea's inclusion in the governments Goods and Services Tax (GST) in May 2017. Further regulatory adjustments have come via government moves to try and eke out India's urea supplies by mandating first that it be coated in neem plant oil, and then moving from a 50kg bag size to a 45kg bag size.

India's urea sector is going through a major change at the moment as the Modi government attempts to return India to the self-sufficiency in urea production that it last enjoyed in the 1990s, before it progressively became, as it is today, the world's largest importer of urea. This has been because domestic demand has continued to increase while domestic supply has stayed relatively constant, with only a few revamps at various sites to expand production incrementally. Now, however, there are concerted moves afoot to recondition and re-open long-closed plants and develop major new sites, some of them based on new domestic gas sources (such as the Matix plant in West Bengal, based on coalbed methane) or coal gasification, as at Talcher. All of these projects have presented their own difficulties, however, especially in terms of sourcing feedstock for the projects, with imported liquefied natural gas now looking like the most likely source, and the Indian government continues to struggle with attracting foreign investment and technology.

So will Yara become the trailblazer for new foreign investment in India? Yara has suggested that it might try expanding further via acquisition in India, but its presence there still currently compares unfavourably with the market penetration that it has achieved in, for example, Brazil. However, the attractions of the Indian market continue to be balanced by the difficulty of doing business there. The next few years will be an interesting time for the Indian fertilizer industry. ■

Richard Hands, Editor

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Price trends

MARKET INSIGHT

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

NITROGEN

The nitrogen market faced an unsettled year in 2017, marred with continued oversupply, lacklustre demand and uncertainty over price direction with increased volatility tied to the timing of international buying. A key development that led to the market being weaker than expected was decreased demand from India amid significant stock carryover from 2016, and a new buying strategy by the government Department of Fertilizers. The commissioning of new nitrogen plants around the world further increased the gap between nitrogen supply and demand, and 2018 will see a continuation of this trend with planned plants for 2018 still yet to hit the market, coupled with delayed projects from 2017 yet to start up.

2017 was concluded with NFL's urea import tender on 22nd December, which resulted in the purchase of 387,000 tonnes of urea. Iran is scheduled to supply the entire volume after the country built up high levels of liquidity in anticipation of the tender. Arab Gulf suppliers usually offer significant volumes under Indian tenders. However, producers were largely sold out in late 2017 and as a result did not offer under the December tender. Since then, Sabic has restarted its Safco IV ammonia and urea plant after almost a three-month delay, which will increase availability for any subsequent Indian import tenders in early 2018.

Urea prices increased internationally following the Indian tender, and sentiment remained firm in early January 2018 amid speculation of a new tender in mid-to-late January. Prior to the tender, India's Department of Fertilizers (DoF) claimed to be sufficiently stocked for the rest of the year, after it scrapped its tender on 31 October.

On the supply-side, the Chinese market remains tight due to significant reductions in urea production from gas-based producers over the peak winter heating season, coupled with the longer-term structural rationalisation of the country's coal-based urea oversupply. The average operating rate of urea plants in the country was reported to be 48% in January, making the prospect of international exports slim, and prompting suggestions of import requirements to meet domestic consumption, which is concentrated in the first half of the year. As a result, urea prices in China have been higher than international levels, with prilled prices at $310-320/t f.o.b. and granular at around $290/t f.o.b. at press time, the highest levels in over two years.

Adding further pressure to the Chinese industry is the introduction of a new environment tax on urea plants that was introduced on 1st January this year. The first iteration of claiming the new tax will take place during the period 1st-15th April 2017. Chinese provinces publish environmental tax rates for air and water pollution and these can range significantly based on geography and the local impacts of environmental pollution. Based on Integer's calculations, around 23% of urea capacity is located in areas paying the highest rates of environment taxes, 50% in the medium-tax range and 27% in the low-tax range. Depending on location, the environment tax varies between Rmb 0.20-5.30/t ($0.03-0.82/t).

The implication of the environment tax is that most urea producers will experience higher production costs in 2018. There are also expectations that the environment tax will increase in some provinces in the future, with confirmation already given that Yunnan province will on average double its environment tax rate in 2019. Shuifu Yuntianhua, the gas-based urea plant owned by Yuntianhua Group, will pay Rmb 4.10/t ($0.63/t) in environment tax in 2018, and this will increase to Rmb 9.60/t ($1.50/t) in 2019. The picture is mixed, however, as some Chinese producers that are already managing their emissions will only be charged a small tax. An example is the Henan Xinlianxin plant which is located in a high-tax region but will only pay about Rmb 0.70/t (US$0.10/t) in taxes.

In the ammonia market, supply tightened throughout Q4 2017, as prices moved upwards due to stronger demand in the face of several supply interruptions to key ammonia exporters. Starting in August 2017, consecutive price increases were reported, driving the Yuzhnyy Black Sea ammonia price to $286/t f.o.b. in November 2017, an increase of 49% over the period. The Tampa contract price increased by $118/t between August and November, reaching $317/t c.fr.

The succession of price increases has brought the price of ammonia more in line with the values of other nitrogen products. For much of 2017, ammonia was priced at a discount to urea on a per unit of nitrogen value basis, relative to long term trend values. Historically, the price of ammonia per unit N trades at around 60-80% of the value of urea. This level fundamentally reflects the relative production costs and returns associated with each product, and the relative value to the customer – buyer and seller substitution will result if prices disconnect for a sustained period.

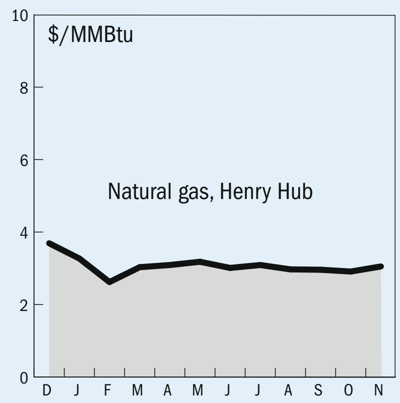
Table 1: **Price indications**

Cash equivalent	mid-Nov	mid-Sept	mid-July	mid-May
Ammonia ($/t)				
f.o.b. Caribbean	270	200	205	285
f.o.b. Arab Gulf	280-330	230-260	180-190	295
c.fr N.W. Europe	305-340	240-260	230-250	325
c.fr India	310-360	240-270	209-240	340
Urea ($/t)				
f.o.b. bulk Black Sea	240-250	224-234	181-190	175
f.o.b. bulk Arab Gulf*	259-264	227-232	153-187	176
f.o.b. bulk Caribbean (granular)	250-260	190-198	160-183	210
f.o.b. bagged China	268-272	248-255	207-212	210
DAP ($/t)				
f.o.b. bulk US Gulf	375	333-337	344	355
UAN (€/t)				
f.o.t. ex-tank Rouen, 30%N	159-164	141-143	133-137	157

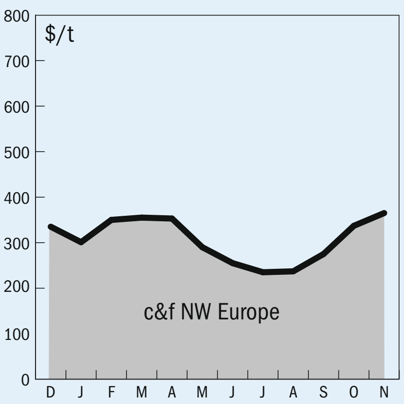
Notes: n.a. price not available at time of going to press
*n.m. no market * high-end granular*
Source: Fertilizer Week

END OF MONTH SPOT PRICES

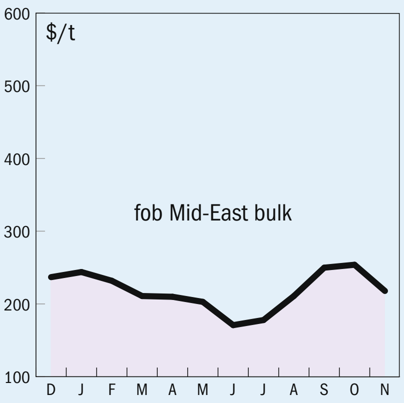
natural gas



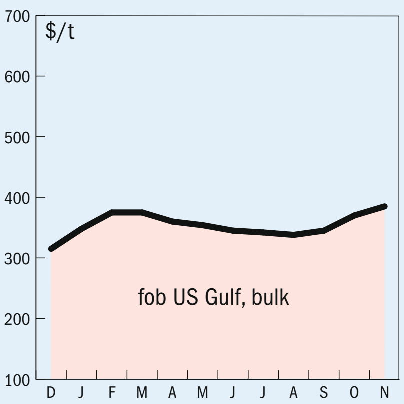
ammonia



urea



diammonium phosphate



MARKET INSIGHT

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

METHANOL

Methanol prices rose in December, with global operating rates down to about 68% of total capacity or 80% of effective capacity. In the Americas, the official posted reference prices for January are $1.44/gal for Methanex (up $0.20/gal from December) and $1.42/gal for Southern Chemical Co. (up 20/gal from December), equivalent to $479/t and $472/t respectively. Month-on-month weighted average spot prices in the US Gulf for December increased by $0.12/gal from November to $1.065/gal (nominal $354/t). IHS Markit Chemical's contract net transaction price for January is officially posted at $1.43/gal (nominal $476/t).

Supply was up from Trinidad, with 93% availability from those plants still running, or about 79% of the total capacity in December. Further south, Methanex's Chilean unit ran at about 50% capacity during December as gas availability improved during the southern summer. In the US, Eastman's methanol plant at Kingsport was down during December after an explosion in the gasification section in early October led to a shutdown. The unit has now completed repairs and will be restarting soon.

US methanol demand improved slightly in December, boosted by demand for winter applications consuming methanol into windshield wash, anti-freeze and downhole/pipeline applications. Demand into MTBE is set to slow down due to turnarounds in January.

European spot prices (T2 f.o.b. Rotterdam) for December were up €38/t from November at €314/t. Methanex posted its 1Q 2018 West European Contract Price at €380/t, f.o.b. Rotterdam T2, an increase of €50 on the previous quarter, and the 1Q 2018 West European Contract Price was settled the same rate, up €62/t from 4Q 2017. The ongoing suspension of duty on methanol arriving into the EU implemented by the European Commission is likely to remain for the foreseeable future.

Supply from Saudi Arabia was down - Ar Razi III restarted after experiencing unexpected operating issues in the first half of November, but lines II and IV were offline in December. European demand softened in December as is typical towards the end of the year but has been healthy during 2017, supported by good demand for formaldehyde, silicones and MMA. In the acetic acid market, the ongoing outage at Eastman at Kingsport, US, increased demand for exports out of Europe, keeping domestic European operating rates at healthy levels for December.

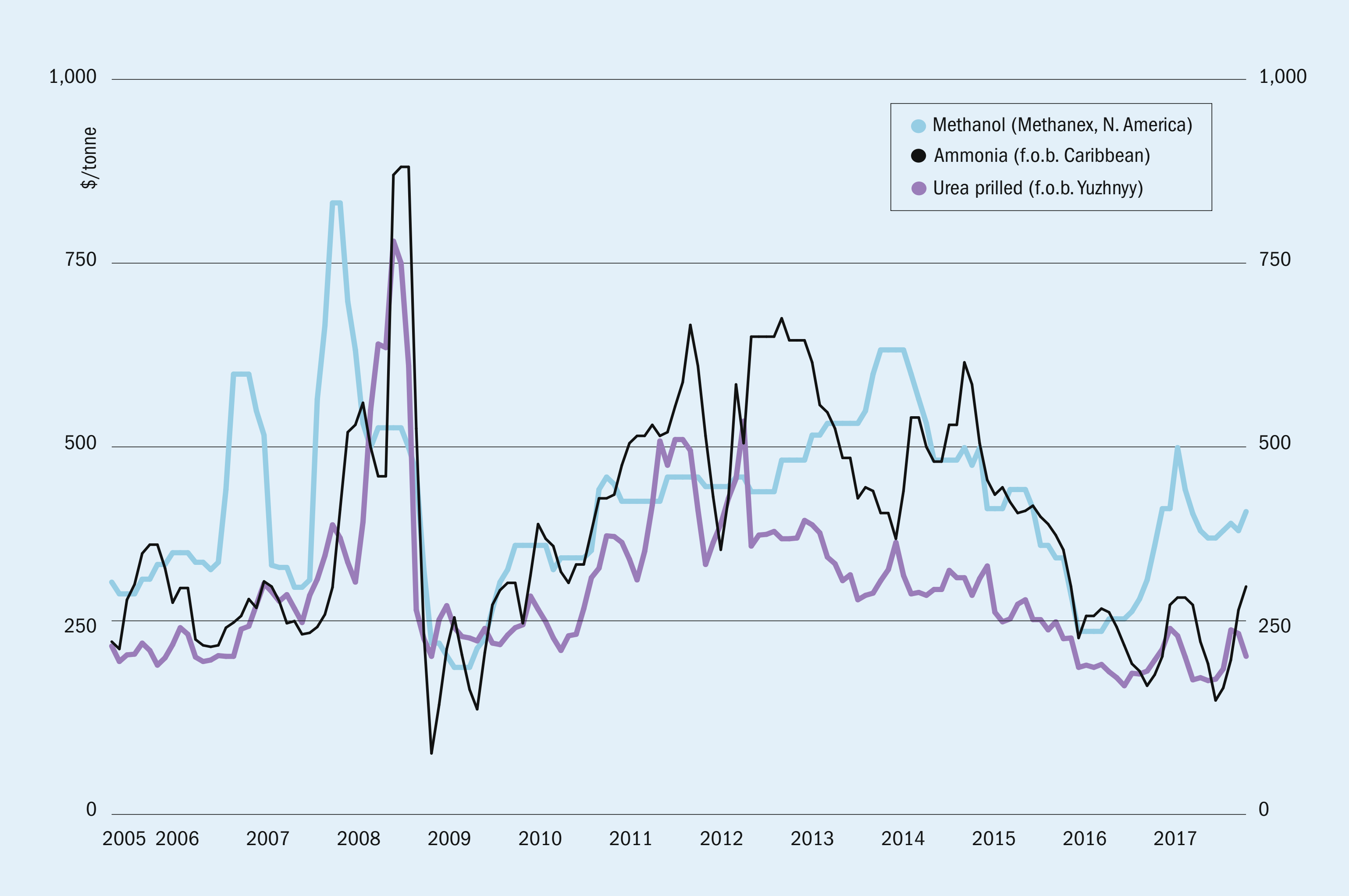
In India, port prices started the month at an average of $337.5/t c.fr T1 and finished the month $82.5 higher at $420/t. The price increase was due to higher prices in China and operational issues in Saudi Arabia. Demand remained constrained and extreme volatility in prices discouraged liquidity.

In China, MTO affordability worsened and operating rates declined in December as methanol prices increased further. Asian prices in December traded $43/t higher, in an average range of $383-430/t, c.fr; Chinese prices were up $52/t in a range of $375-420/t, c.fr. Methanex's posted APCP for January is $470/t, up $40/t from December. Chinese MTO plants ran at an average of 73% capacity. Chinese methanol capacity utilisation was down from November's level, at around 52% of nameplate capacity, or around 67% of effective capacity. A new 1.0 million t/a coal-based methanol unit, Hualu Hengsheng commissioned its unit at the end of September, and ran normally during December. Inner Mongolia Donghua, Gansu Huating and Shandong Minshui re-started in early November after turnarounds and operated during December. Some coking gas-based methanol producers in north China and coal-based methanol plants in Northwest China were still affected by the environmental pollution controls with the winter season approaching, and the natural gas-based methanol plants in Southwest China were also affected by seasonal natural gas restrictions.

In Southeast Asia, supply improved in December with several plants resuming production. KMI shut down for a regular turnaround in November, and restarted at the end of December. Petronas's larger unit resumed production after nearly three weeks offline, and its smaller unit had a short product outage in the final month of the year, but restarted quickly. The company's larger unit will have a turnaround in the second quarter of 2018. BMC in Brunei has resumed production after a short shutdown early in December. ■

Market outlook

Historical price trends $/tonne



Source: BCInsight

AMMONIA

- The ammonia market is expected to be temporarily tight in the opening weeks of January amid steady demand in the US coupled with some residual supply shortages following on from plant shutdowns in December 2017.
- Beyond this, ammonia prices are expected to decrease as several key exporting plants restart and the market returns to a state of oversupply.
- This price weakness relative to downstream nitrogen products is expected to encourage nitrogen producers with flexible capacity to switch to better margin products such as urea and nitrates, which would bring merchant ammonia supply back into balance.

UREA

- Following the Indian tender announcements, firmer urea prices are expected to carry over into the first months of 2018, particularly in light of dramatically reduced export potential from Chinese producers, and speculation of import requirements which would bolster international price sentiment.
- New Chinese environmental taxes are affecting urea producers, with most urea producers having higher production costs in 2018. This is compounding issues caused by shutdowns to gas-based plants due to lack of availability over winter, and rationalisation of coal-based urea capacity. Low Chinese operating rates are likely to lead to increased imports to meet domestic consumption.
- Spring demand in North America and Europe is expected to stimulate urea prices further, however this will be offset by new capacity expansions hitting the market.
- The timing of commissioning of these new projects will be a key price influence in 2018, with start-ups at plants including Koch's Enid expansion and the new Bolivian Bulo Bulo plant having a pivotal impact on sourcing options for key urea buyers.

METHANOL

- Methanol prices rose in December after some operating issues in the Middle East and the outage at Kingsport's plant in the US, together with strong demand in the US.
- Higher prices in China have started to impact on the affordability of olefins from methanol to olefins plans, and the shutdown of several MTO units is likely to lead to a drop in demand for merchant methanol into China in 1Q 2017.
- However, Chinese producers are also being affected by government crackdowns on environmental pollution from coal-based plants, while natural gas-based producers are suffering from gas shortages as gas is diverted preferentially to residential consumers.
- The net effect of this on Chinese methanol demand is hard to gauge. The impact of Chinese MTO buying on the market has been to significantly increase volatility, and this is likely to have a knock-on impact on, e.g. European price settlements.

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Nitrogen Industry News

CHINA

Gas shortage leads to ammonia shutdowns

Yunnan Yuntianhua Co said that it had idled a 500,000 t/a ammonia plant and associated downstream 800,000 t/a urea line at its Yunnan Shuifu subsidiary in early December due to natural gas shortages. As China's winter heating crisis deepens, gas producers have suspended gas supplies to major industrial consumers in southwestern regions, the company said. Yuntianhua added that it does not expect to re-start the plant before 2018, and will book a $3.8 million loss due to the disruption. Shortages of gas have lead at least one state natural gas producer to divert supplies to China's north for residential heating use; PetroChina has sent 5-10 million cubic metres of gas from the southern provinces of Zhejiang, Fujian and Guangdong province to help relieve shortages in northern China. The shortages have been exacerbated by a number of industries switching to using gas from coal to run their plants this year, in line with China's push for cleaner air and environmental protection. The gas deficit this winter is expected reach 10.5 billion cubic metres, representing 10%-20% of the total requirement.

The government of Hebei announced on November 28th an orange warning (severe shortage) of gas supply in the province, with chemical producers targeted first for cuts. Other provinces such as Henan, Shandong, Anhui and Hubei have taken similar measures. Henan-based Zhongyuan Dahua shut its 600,000 t/a ammonia/urea plants on November 27th and Chongqing-based Jianfeng Chemicals cut the operating rate at its 1.4 million tonne/year urea plant to 50% in November and 0% in December. PetroChina Daqing also shut down its 800,000 t/a urea plant was in mid-November.

Taken on top of previous restrictions on coal-based ammonia-urea plants aimed at tackling pollution in urban areas, the gas curtailments have led to the price of urea rising to its highest level for four years in China. Chinese urea exports are expected to be half in 2017 of the 8.9 million tonnes seen in 2016. China produced 62 million tonnes of urea last year, of which 28% from gas-based plants.

Stamicarbon to build new urea plant

Jiujiang Xinlianxin Fertilizer Co., Ltd (XLX) has awarded Tecnimont subsidiary Stamicarbon contracts for technology licensing and delivery of proprietary equipment for a new ultra-low energy urea plant to be built in Jiujiang, Jiangxi. This grass root project follows a smaller revamp project between the parties in 2016.

The scope of the project comprises the license, the process design package, delivery of proprietary high pressure equipment in *Safurex*® and associated services for both the urea melt plant and the finishing by prilling. The urea plant is based on Stamicarbon's *LAUNCH MELT*™ ultra-low energy design with a pool reactor. Plant start-up is planned for the end of 2020. The company says that this new technology has improved heat integration which leads to a 40% reduction in steam consumption and consequent very significant reduction in energy cost and operating expense, and also reduces the carbon footprint substantially in comparison with other types of urea plants. It can also be used as a revamp tool for both CO_2 stripping and conventional urea plants.

"Energy efficiency will become more and more important in many countries. This project is a major step in implementing innovative energy efficient technologies and it will pave the way for many other projects. We look forward to the successful cooperation with this main fertilizer producer in China", said Pejman Djavdan, CEO of Stamicarbon.

AZERBAIJAN

SOCAR set for 1H 2018 commissioning

Construction of the ammonia-urea plant for Azerbaijan's state oil company SOCAR is now 98% complete, according to plant director Khayal Jafarov, and commissioning is due in the first half of 2018. Speaking to a conference in Baku, he said that engineering work and equipment procurement is complete, construction 95% complete, and equipment installation 92% complete. All construction work was on course to be finished by the end of December 2017. The plant will produce 1,200 t/d of ammonia and 2,000 t/d of urea. Around 25% of this will be sold domestically, with the remainder exported to Turkey, Georgia and into the Black Sea and Mediterranean markets.

Samsung Engineering has been the lead EPC contractor, with ammonia licenses supplied by Haldor Topsoe and urea license from Stamicarbon. Finance has come from the Export-Import Bank of South Korea (€251 million) a further €249 million being loaned by UniCredit of Italy, Societe Generale and Deutsche Bank.

INDIA

MMTC and STC merger decision expected soon

The Indian cabinet is to consider a plan to merge state-owned trading companies Metals and Minerals Trading Corporation of India (MMTC) and the State Trading Corporation of India Ltd (STC) into one huge trading company that will also be allowed to operate independently. It follows a similar approval for massive state oil companies Hindustan Petroleum Company Ltd (HPCL) and Oil and Natural Gas Company of India (ONGC).

MMTC and STC, together with a third entity, the Project & Equipment Corporation of India (PEC), are collectively responsible for most of India's imports and exports of key commodities, including urea. The Indian government owns a 90% stake in MMTC and STC, under the auspices of the Commerce Ministry. Both companies lost money in the 2016-17 financial year; around $6.5 million for MMTC and $3.5 million for STC.

KBR to revamp Trombay ammonia plant

KBR has been awarded an ammonia plant revamp contract by Rashtriya Chemicals & Fertilizers Ltd (RCF). Under the terms of the contract, KBR will provide a technology license and basic engineering design for the RCF ammonia plant at Trombay, Maharashtra, India. During this project, the existing Ammonia 5 plant will be revamped to provide energy savings to meet the new government requirements using KBR's proprietary *Purifier*™ technology.

"Partnering with a government fertilizer company such as RCF to help them meet their new energy requirements is an important milestone project for KBR in India," said John Derbyshire, president of KBR Technology & Consulting.

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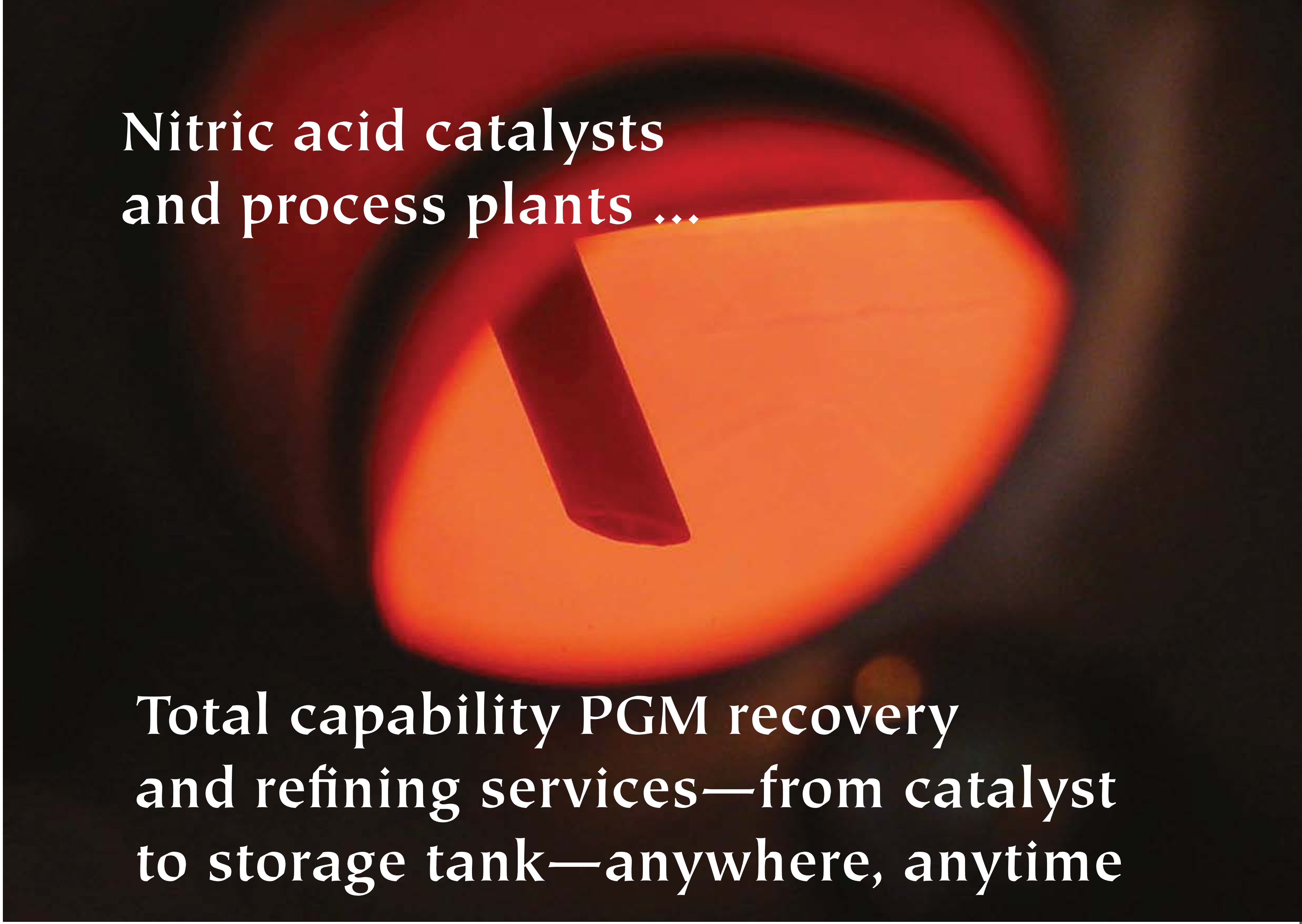

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GAIL issues contracts for new pipeline project

The state-run Gas Association of India Ltd (GAIL) has awarded contracts for work on the 2,655 km Pradhan Mantri Urja Ganga gas pipeline project, which will connect domestic, commercial and industrial users in eastern India. The estimated cost for the project is $7.92 billion. GAIL is fast-tracking the project and has awarded a contract for a 520 km pipeline section connecting Dobhi in Bihar state to Durgapur, West Bengal, passing through Uttar Pradesh, Bihar, Jharkhand, West Bengal and Odisha and supplying gas to fertiliser and steel plants, power plants and refineries along its route.

Phase one work is at an advanced stage and GAIL says that it hopes to complete it before the end of December 2018. Indian Prime Minister Narendra Modi launched the Urja Ganga pipeline project in October 2016 as part of a planned 15,000 km of gas pipeline installation to move India towards a gas-based economy.

UNITED STATES

Koch launches new inhibitor products

Koch Agronomic Services says that it expects to launch its new Centuro nitrification inhibitor and Anvol urease inhibitor in the US in 2018. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) registration for Centuro is pending, and the Environmantal Protection Agency's TSCA registration application is in progress with submission in 2018 for Anvol.

"US farmers and ranchers apply roughly 13 million tons of nitrogen fertilizer to their fields each year," said Justin Hoppas, executive vice president of Koch Agronomic Services, "yet due to many conditions, often outside their control, as much as half of it is lost through ammonia volatilisation, leaching and denitrification… by driving innovation through R&D, we are discovering new solutions that increase agricultural efficiency. Our goal is to deliver proven technologies that can make every ton of fertilizer more efficient and optimise our customers' crop nutrition investments."

Centuro is designed to work with anhydrous ammonia and provides a new nitrification inhibitor technology for both increased nitrogen protection and flexibility in handling. Despite its popularity, anhydrous applications require careful planning to guard against leaching and denitrification during the winter; even spring applications can be subject to loss.

PHOTO: POGDC

The Kermanshah Petrochemical Industries plant, Iran.

Sabin launches new website

Sabin Metal Corporation, North America's largest private precious metals refining organisation, has launched a redesigned website at http://www.sabinmetal.com/. The redesigned site presents a comprehensive view of the company's services, precious metals industry news, and describes the company's approach to precious metals refining.

Brad Cook, VP of Sales and Marketing, said: "Sabin focuses on the Company's vision: to be the world leader in responsible and innovative precious metals refining. This is accomplished through excellence in customer service, the ongoing development of our people, and a dedication to the highest ethical and environmental standards."

IRAN

KBR to license Kermanshah plant

KBR has agreed to license its ammonia technology for the expansion of the Kermanshah Petrochemcial Industries plant, according to the Iranian company. Kermanshah currently produces 400,000 t/a of ammonia and 660,000 t/a of urea, but is now in the progress of expanding production with the construction of a new 2,400 t/d (790,000 t/a) ammonia and 4,000 t/d (1.32 million t/a) urea plant. Stamicarbon has already agreed to license urea technology for the plant, which is according to the Iranians already 25% complete. Financing remains an issue for all Iranian projects, with international banking sanctions making financial transfers difficult. While most of the financing is coming from the Iranian government, around $475 million is expected to have to come from overseas loans.

Iran is expanding its petrochemical industry to monetise its oil and gas industries with downstream products, and the state-owned National Petrochemical Company hopes to lift its total capacity of all products to 120 million tons per annum by 2022, the end of Iran's Sixth Five-Year Economic Development Plan. Production is currently forecast to reach 60 million t/a by March 2018, from a total capacity of 72 million t/a, as ongoing projects are completed.

Iran offers management rights for Chabahar port

Iran has offered India management rights for Phase-1 of the new Chabahar Port development, the official opening ceremony for which was held in November after grain shipments began in late October. The Iranian proposal involves management rights for two years with the right to renew for a further 10. Japan is partnering India for the $235 million Phase II expansion of the Chabahar Port complex, which aims to boost India's connectivity with Iran and central Asia. Two Indian fertiliser firms are looking to establish a urea and ammonia plant in the Chabahar free trade zone.

CROATIA

Petrokemija completes NOX reduction project

Croatian fertiliser producer Petrokemija says that it has completed a project to reduce NOx emissions at its DUKI-2 nitric acid plant at Kutina. The project was completed by

Casale subsidiary Chemoprojekt, using a selective catalytic reduction (SCR) system, at a cost of $1.6 million. This, taken with a similar project at the DUKI-1 nitric acid plant, have allowed Petrokemija to meet its requirement to reduce N_2O emissions and comply with the EU's Decision on Integrated Environmental Protection Requirements and IPPC Implementation Plan of Directive 2008/1/EC by its deadline of December 31st 2017.

CANADA

Agrium and PotashCorp merge

Agrium and PotashCorp successfully completed their merger at the beginning of January.

Nutrien, the new company created by the merger, will be the world's largest fertilizer manufacturer and retailer. It will be a massive international player with nearly 20,000 employees and operations and investments in some 14 countries.

The proposed merger was originally unveiled in September 2016, with the unanimous blessing of the boards of both companies, and promised to create a new fertilizer sector giant valued at around $36 billion. The so-called "merger of equals" was subsequently subject to a drawn-out regulatory review and approval process in Brazil, Canada, China, India, Russia and the US. After 15 months, the merger finally received the all-clear and overcame its last hurdle with the regulatory approval of the US government in late December 2017.

Confirmation of the merger's success came from Chuck Magro, Nutrien's new president & CEO: "Today we are proud to launch Nutrien, a company that will forge a unique position within the agriculture industry. Our company will have an unmatched capability to respond to customer and market opportunities, focusing on innovation and growth across our retail and crop nutrient businesses. Importantly, we intend to draw upon the depth of our combined talent and best practices to build a new company that is stronger and better equipped to create value for all our stakeholders."

To gain regulatory approval, Potash Corp has agreed to divest itself of its stakes in rival potash producers SQM, Arab Potash (APC), and Israel Chemicals Limited (ICL). Agrium also divested its US nitric acid and phosphate production assets. Despite these sell-offs, Nutrien still emerges as the world's largest standalone fertilizer producer, selling over 25 million tonnes of potash, nitrogen and phosphate products annually – into worldwide agricultural, industrial and feed markets.

Nutrien will control almost 11 million t/a of tonnes of nitrogen production capacity, making it the third-largest nitrogen fertilizer producer globally. It has also come into possession, via Agrium, of the world's largest agricultural retail network, spread across some 1,500 locations in North America, Australia, and South America, capable of generating around $12 billion in annual sales. Nutrien also gains global distribution and market access for its potash output through its participation in Canpotex, Canada's highly successful potash export partnership.

Nutrien has committed itself to cutting its annual operating costs by $500 million by the end of 2019. This includes initial savings of $250 million this year. These will be delivered through distribution and retail integration, procurement savings and optimisation of production and SG&A.

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Syngas News

SWITZERLAND

Clariant-Huntsman merger called off

Clariant's planned $20 billion merger with Huntsman has been called off due to a move by activist investment company White Tale. White Tale is an investment vehicle backed by hedge fund manager Keith Meister and New York-based fund 40 North, and bought a 20% stake in Clariant ahead of the planned merger. White Tale felt that the merger undervalued Clariant, and argued that the company should sell its plastics and coatings business instead and reinvest the proceeds in higher-margin areas. White Tale subsequently met with the company board, calling for – amongst other things – a strategic review of the company's operations, as well as a call to put three of its own people onto the 9-member board. Clariant has offered one seat on the board, to be voted on at the company's annual general meeting in March 2018.

Clariant said in a November 24th press release that "the Board of Directors supports the Executive Committee's intention to build upon Clariant's existing strategy by defining further actions such as M&A activities, short-term portfolio management options, potential returns to shareholders, a thorough review of the cost base and the pursuit of additional growth opportunities. Clariant's recently announced investment in the *sunliquid*® technology is one example of the latter."

UNITED STATES

Sasol formally abandons GTL plans

Sasol says that it is cancelling all of its plans to build greenfield gas-to-liquids (GTL) plants, as well as planning to sell off its Canadian shale gas assets. The highest profile GTL plant was planned for Louisiana, and would have cost $13-15 billion. However, low oil and gas prices have eroded the commercial rationale for such a project. In a statement, Sasol said: "While our current GTL assets are generating good returns and cash flows, the value proposition for Sasol to build new GTL projects is uneconomic against a volatile external environment and a structural shift to a low oil price environment."

The company did however say that it still intended to complete plans to build an ethane cracker in Louisiana at a cost of $11 billion – this plant is already 80% completed, albeit $2 billion over budget.

Lawsuit aims to reverse permit decision

The Port of Kalama has filed a lawsuit asking the local Superior Court to reverse a state decision to deny key shorelines permits for a $1.8 billion methanol project being developed by Chinese investors Northeast Innovation Works (NWIW). The environmental permits were originally granted in February 2017, but in September the Shorelines Hearings Board found that the environmental impact statement for the project did not adequately assess climate change. The Port of Kalama says that the statement "fully disclosed potential GHG emissions from the project and properly concluded that those project emissions do not cause a significant adverse impact on the environment."

The NWIW plan is to make methanol in the US using cheap shale gas and then transport it to China to make olefins. Northwest Innovation Works says it would use new technology which would cut greenhouse emissions by 31% compared to traditional manufacturing methods, as well as reduce the impact of China using coal-based methanol.

Toyota to build hydrogen from waste plant

Toyota says that it intends to build a megawatt-scale hydrogen fuel and renewable electricity generation plant at the port of Long Beach, California, using agricultural waste to generate electricity, water and hydrogen. Dubbed the Tri-Gen facility, the plant will generate around 2.35 MW of electricity from a hydrogen fuel cell, sufficient to provide daily power for around 2,300 homes, as well as about 1.2 t/d of hydrogen, to operate a fleet of up to 1,500 hydrogen-powered cars. The plant is a scale-up of a technology developed by University of California, Irvine scientists, FuelCell Energy, and partners including the US Department of Energy, California Air Resources Board and Orange County Sanitation District, at a waste treatment facility in Fountain Valley, California. It uses methane from cow manure which is then catalytically broken down to produce hydrogen. The hydrogen is then used to generate water and electricity in a fuel cell, with excess hydrogen being stored for use in Toyota's fuel cell vehicles, such as the Mirai and Project Portal trucks. The fuel cells are being provided by partner FuelCell Energy.

Air Products buys Shell's coal gasification technology

Air Products has agreed to acquire Royal Dutch Shell plc's coal gasification technology business as well as Shell's patent portfolio for liquids (residue) gasification for an undisclosed sum. Air Products says that this will extend its supply model to use coal gasification to generate syngas for major projects, which it is already doing in projects such as Lu'An in Changzhi, Shanxi Province, China. Shell has been at a leader in gasification innovation over the past 50 years, developing technologies to take varied lower-value feedstocks and convert them into syngas, which Air Products can now provide to customers to make higher-value products.

Seifi Ghasemi, chairman, president and CEO of Air Products, said that the acquisition supports his company's focus on providing a full scope of industrial gases, and does not represent a shift into technology licensing. "The acquisition of Shell's technology, already in operation at more than 20 coal gasification plants, gives us access and opportunities to fully explore outsourcing options to produce and supply syngas for customers planning to use gasification," he said.

The two companies have also formed a strategic alliance in liquids gasification, to offer engineering procurement and construction (EPC) activities, plant operations, technology licensing and other services. Air Products will act as the operating partner for industrial gases supply, while Shell will provide the liquids gasification technology.

ESTONIA

"Bio-coal" gasification plant planned for Estonia

Baltania OÜ, a subsidiary of Dutch private equity investment firm Momentum Capital, says that it has made a conditional investment decision to commission an industrial-scale torrefaction “bio-coal” plant in Vägari, Estonia. The $53 million project would be carried out with the cooperation of Estonia’s ministry of the environment, funded by Momentum Capital and other venture capitalists and financial institutions, as well as a $30 million grant from the European Union. The plant is based on a torrefaction technology developed by Dutch company Clean Electricity Generation (CEG). It will convert 160,000 t/a of “woody biomass” sourced in Estonia into torrefied bio-coal pellets which can then be used to replace fossil coal in electrical power or heat generation. The torrefaction reactor also generates syngas which is then cleaned by wet scrubbing and used to power a gas turbine to generate electricity. The hot engine exhaust is also used to heat the torrefaction reactor and supplement the biomass material drying. Although the process is similar to charcoal production, “it takes place in a much lower temperature environment that requires less exotic and less expensive materials, which results in biofuels with more favorable combustion properties, better mechanical and storage properties, and higher energy density,” according to CEG.

INDIA

India may convert more petcoke to syngas

India’s petroleum minister Dharmendra Pradhan says that the government is working to curb India’s imports and use of petroleum coke. The plan is to only allow the use of pecoke in sectors which absorb the sulphur emissions in the manufacturing process, such as the cement industry and gasification plants, to reduce sulphur emissions to atmosphere. India’s imports of petcoke have soared from 3.3 million t/a in 2012-13 to 14.4 million t/a in 2016-17, and total national consumption reached 23.25 million t/a that year due to its use in power generation. Reliance Industries has also recently brought on-line a massive $4.6 billion petcoke gasification plant at its Jamnagar refinery complex, which will produce up to 2,000 t/d of sulphur extracted from the gasification process.

Other refiners are considering following suit; IOC is evaluating building a 2 million t/a petcoke gasifier costing $2.3-3.1 billion at its 300,000 bbl/d Paradip refinery in eastern India, able to draw on petcoke from new cokers at the company’s 11 refineries across India.

CHINA

Clariant opens new office in Shandong

Clariant has opened a new office for its Catalysts business in Qingdao, Shandong Province, which will focus on providing enhanced services for customers in central and northern China. The expansion follows the establishment of another office in Yinchuan city in July 2017, and, says the company, reinforces its commitment to supporting the Chinese refining and chemical industries and intensifying growth through strong local presence.

Thomas Wenger, Head of Business Unit Catalysts, Clariant China, said, “Proximity is crucial for our customers and our company. Therefore, we are actively expanding our businesses in China, and providing more autonomy in decision making at points closest to our customers. This allows us to clearly understand their opportunities and challenges, so that we can offer tailor-made support for China’s industrial transformation through our innovative and sustainable catalyst technologies.” ■

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

People

Amy Herbert

Amy Hebert joins Haldor Topsoe A/S on February 1st as deputy CEO and executive vice president (EVP) of the Chemicals division. Ms. Hebert has previously worked in senior positions at global industry players such as Albemarle Corporation and Celanese, and has wide experience in various board member positions of both associations and corporations within the chemical industry. She holds a BSc in Chemical Engineering from the Georgia Institute of Technology, Atlanta.

"I have known Topsoe throughout my career, both as a competitor and as a supplier. Topsoe is a company well-known for excellent quality and high credibility. I am very pleased to join and very much look forward to embarking on an exciting growth journey together with my management colleagues and my team," she said.

"I am pleased to welcome Amy Hebert to Topsoe. She is an international leader with a solid track record for business growth and a deep knowledge of the industries we operate in. Already today, Topsoe is market leader within many of our business areas, but we also have a clear ambition to expand our position and grow even more. I believe Amy is the right person to head that journey together with her talented and dedicated organization," said Bjerne Clausen, CEO, Haldor Topsoe A/S.

Per Bakkerud, the former EVP Chemicals, will now take up a position as board member of global strategic partners to Topsoe in Pakistan, Germany and Bangladesh. With today's announcement, the executive management of Topsoe now consists of: CEO Bjerne S. Clausen, deputy CEO & EVP Chemicals Amy Hebert, CFO Peter Rønnest Andersen, EVP Refinery Morten Schaldemose, and EVP Sustainables Kim G. Knudsen.

EuroChem has appointed **Dmitry Strashnov** as its new Chief Operating Officer (COO), a new role based at its corporate headquarters in Zug, Switzerland. Strashnov is tasked with the day-to-day running of EuroChem's global business and driving further expansion across the world. He will report to Group CEO, Dmitry Strezhnev.

Nutrien, the new company created by the Agrium-PotashCorp merger, has formed its board of directors. In keeping with this 'merger of equals', the board has equal representation from both companies. As expected **Chuck Magro**, who formerly headed Agrium, becomes Nutrien's president and CEO. **Jochen Tilk**, who previously led PotashCorp, will serve as the company's executive chair. Derek Pannell, who was the chair of Agrium, becomes independent lead director on Nutrien's Board. In other senior team appointments, **Wayne Brownlee** becomes executive vice president and chief financial officer, and **Steve Douglas** becomes executive vice president and chief integration officer. Filling other executive vice president roles at Nutrien are: **Harry Deans**, executive vice president and president, nitrogen; **Michael Frank**, executive vice president and president, retail; **Kevin Graham**, executive vice president and president, sales; **Susan Jones**, executive vice president and president, phosphate; **Lee Knafelc**, executive vice president & chief sustainability officer; **Leslie O'Donoghue**, executive vice president & chief strategy & corporate development officer; **Joe Podwika**, executive vice president & chief legal officer; **Brent Poohkay**, executive vice president & chief information officer; **Raef Sully**, executive vice president and president, potash; and **Mike Webb**, executive vice president & chief human resources officer. ■

Calendar 2018

FEBRUARY

26-MARCH 1

Nitrogen+Syngas 2018,
GOTHENBURG, Sweden
Contact: CRU Events,
Chancery House, 53-64 Chancery Lane,
London WC2A 1QS, UK.
Tel: +44 (0) 20 7903 2444
Fax: +44 (0) 20 7903 2172
Email: conferences@crugroup.com

MARCH

6-9

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

APRIL

9-12

IFA Global Technical Symposium,
MADRID, Spain
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

16-18

SynGas Association Meeting 2018,
TULSA, Oklahoma, USA
Contact: SynGas Association
Tel: +1 225 922 5000
Web: www.syngasassociation.com

JUNE

18-20

85th IFA Annual Conference,
BERLIN, Germany
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

SEPTEMBER

16-20

63rd AIChE Annual Safety in Ammonia
Plants and Related Facilities Symposium,
TORONTO, Canada
Contact: AIChE Customer Service
Tel: +1 800 242 4363/
+1 212 591 8100
Fax: +1 212 591 8888
Email: xpress@aiche.org

16-21

Ammonium Nitrate/Nitric Acid
Conference, CALGARY, Canada
Contact: Hans Reuvers, BASF
Karl Hohenwarter, Borealis
Email: johannes.reuvers@basf.com
karl.hohenwarter@borealisgroup.com
Web: www.an-na.org/2018-conference


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Plant Manager+

Problem No. 46 CO_2 cooler failure

CO_2 coolers in the inter stages of CO_2 compressors typically cool down the CO_2 stream by means of cooling water. It is preferable for the cooling water through the tubes to have a minimum velocity to avoid fouling and corrosion issues. This is not a problem after the first and second stage when CO_2 pressures are still relatively low. However, after the third stage the CO_2 pressure is about 80 bar, too high (meaning too expensive) to have the CO_2 on the shell side. Vendors specify coolers with the cooling water on the shell side and the CO_2 through the tubes. This however introduces several failure mechanisms: As cooling water velocities cannot be guaranteed to be above a minimum value in the complete shell, fouling can occur. Also, chlorides accumulate (even when chloride levels are relatively low) and cause chloride stress corrosion cracking in austenitic stainless-steel tubes. In this type of cooler choosing duplex as the material of construction for the tubes is the best choice for a reliable heat exchanger.

Irfan Rashid, working in Operations at FFBL in Pakistan starts the discussion with the following question: Does anyone have experience of CO_2 cooler failure where failure occurs after the third stage of the CO_2 compressor?

Mark Brouwer of UreaKnowHow.com in the Netherlands replies: Please share your experiences with us as I think it will trigger more discussions.

Irfan continues: We have a Dresser Rand design CO_2 compressor which takes CO_2 at 0.34 kg/cm²g and compresses it to 145 kg/cm²g in four steps. We have a CO_2 cooler after each compression stage. Recently we have been experiencing leakage problems in our CO_2 cooler after the third stage. It receives CO_2 at 76 kg/cm²g. Due to this problem, we replaced this exchanger but the new exchanger collapsed in a hydrotest, after just two years of service. I would like to know what types of problems can cause this type of failure.

Mark comes back with a question: Which materials of construction were applied?

Irfan replies: The tubes are stainless steel and the shell is carbon steel. In the old cooler the baffles were made of carbon steel but in the new cooler we specified stainless steel for the baffles to avoid any galvanic corrosion effect.

Ramchandra Nesari, a freelance consultant in India shares his valuable experiences: I have had experience of CO_2 cooler failures in three urea plants. We had frequent failure of the third stage cooler in one stream but in the other two the failures used to occur in second stage cooler.

You have provided some details about your CO_2 cooler in the third stage. You mentioned that the tubes are of SS 304 whereas the shell and baffles supporting the tubes were of CS initially. You then replaced the baffles with SS material to avoid galvanic corrosion effect. By doing this, you have removed one of the major causes of tube failures. We had similar observations in our CO_2 cooler failures. After replacing the baffle material with SS 304, we overcame the failures. So I would like to know whether you are still facing tube failures after replacing the baffle material. Please also provide details about the tube arrangement – whether it is a straight tube or U-tube bundle. Often, vibrations occur in U-tube bundles if the cooling water flow is above a certain limit. Normally in the third stage cooler a temperature control valve is provided at the discharge of cooling water flow to limit the CO_2 temperature above a critical temperature. So, if the failure is due to vibration problems, then the design of the baffle spacing needs to be looked into.

Koorosh Lieravizadeh from the process engineering department of Shiraz Petrochemical Complex in Iran shares his valuable experiences: We have also experienced some failures, not only of the tubes, but also on the shell of the third stage cooler of the CO_2 compressor. The cooler type is a fixed tube sheet.

Faraham Jafarvand of the Engineering department of NEWJCM Turbomachinery manufacturing co. in China provides his expert opinion: Everybody may have their own ideas about the reasons for failure, but I think the following information is necessary to investigate the root cause of failure:

- Type of heat exchanger (TEMA class).
- Location of failure in the tubes: it would be very useful if you could provide a photo of the failed tubes as the crack direction and other features may indicate the type of failure. If a photo is not available please describe the crack feature according to your own observations (direction of crack, location of the cracks in the tube with respect to tube sheet or baffles or U bend in case of a U-tube, uniformity of failure in different tubes, surface morphology of failed parts, buckling of tubes if any...)
- Type of temperature control you are using to control the CO_2 temperature: The CO_2 condition in third stage cooler outlet is near the critical point and there is a probability of formation of CO_2 condensate if the temperature falls below a certain level. So please provide some info about the temperature control method you are using.

Irfan provides further information: We carried out a detailed investigation of this failure and the probable cause is strain induced intergranular corrosion. Our exchanger is a U-tube type, and baffle design/spacing is not a problem.

Harun Idrees, Technical Services of Fatima Energy Limited in Pakistan shares his experiences: At our plant, we have a brand new third stage intercooler with duplex tubes and after in 1.25 years of operation we have not faced any problems.

THE CULTURE OF INNOVATION

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Gas market liberalisation

PHOTO: CROFT PRODUCTION SYSTEMS

The continuing liberalisation of global gas markets, now spreading into Eastern Europe, Mexico, Japan and even the Middle East continues to affect feedstock prices and plant siting decisions for nitrogen and syngas producers.

Above: Increased gas transport is leading to greater liberalisation.

The global market for natural gas is continuing to change, with progressive liberalisation of production and supply, third party access to pipeline networks, the development of gas trading and pricing hubs, and more transparent, market-based pricing. While gas market liberalisation began more than two decades in the 1990s in the UK and United States, and has taken a long time to reach its current stage, the pace of developments has begun to pick up in the last few years, and even previously highly regulated gas markets are now starting to see considerable loosening.

Some of the major recent developments around the world include:

Egypt

In August 2017 president Sisi signed into law a new regime for Egypt's natural gas sector. It sets up a natural gas regulatory authority charged with licensing and devising a plan within the subsequent six months to open Egypt's state-controlled gas market to private sector involvement and greater competition. The law would allow the private sector to directly ship, transport, store, market and trade natural gas using the pipeline and network infrastructure, with the aim of eventual imports of gas by private companies, hopefully ending supply shortages that have dogged the country and turning Egypt into a regional LNG hub. Egypt is undergoing a sweeping programme of IMF-backed reforms which have included floating the currency, cuts to various subsidies (electricity prices rose 40% in July 2017), and encouraging more foreign direct investment.

Egypt is now aiming to achieve energy self-sufficiency by 2019, with its largest field now producing 900 million cfd, and additional output coming from the West Nile Delta. The huge offshore Zohr gas field in the Mediterranean is also due to come on-stream soon. Egyptian fertilizer companies have welcomed the moves, hoping that the liberalisation of the gas market will open up other options for gas supply and lower prices.

Japan

Japan's $20 billion natural gas sector also finally opened up fully in April last year, in the wake of a wide-ranging shake-up of the country's energy sector following the Fukushima nuclear disaster, which has led to most of the country's nuclear power stations being shut down, and a huge boost

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to the country's LNG imports. Electricity markets were liberalised in 2016, and an electricity and gas market regulator was created in 2015. Japan's gas market has been progressively liberalised from 1995 onwards, with sales to medium to large scale users becoming contestable first, to 2007, before the current move to liberalise supplies to retail customers. Electricity companies have also moved in on the gas market as large scale buyers of LNG – Tepco, the Tokyo Electric Power Company that was the operator of Fukushima, is now a major gas supplier to the city of Tokyo. The move towards gas-based electricity generation means that electricity suppliers now account for around 70% of Japan's LNG imports.

Malaysia

Malaysia signed into law its Gas Supply (Amendment) Act in 2016, allowing for third party access to Petronas' network of pipelines and LNG regasification capacity from 2017. Petronas initially expects about 50% of its regasification capacity and 20-25% of pipeline capacity to be open to outside suppliers, subject to a transit fee. However, ongoing price subsidies to consumers continue to be a barrier to market entry for private gas marketers.

China

China's policy on natural gas is also evolving. In response to rapid economic growth, urbanisation and efforts to cut dangerous pollution levels, the government's energy policy envisages gas' share of the country's energy consumption to rise from 6% as it is at present to 15% by 2030. The 13th Five-Year Plan (2016-2020) allowed for partial privatisation of key energy companies and introduced limited market incentives. It is hoped that upstream exploration and development for gas as well as gas storage will no longer be the exclusive preserve of state-owned behemoth energy companies such as CNPC, Sinopec and CNOOC. Likewise there is talk of 'unbundling' and third party access to pipelines and some freedom of market pricing to boost domestic gas production and demand. Currently CNCP controls nearly 80% of the national gas pipeline network, and Sinopec much of the remainder. As China imports more and more LNG as well as pipeline gas from Turkmenistan, it will need more and more gas transport and storage capacity, and for that it probably needs foreign investment. At the moment the government has recognised these need but has not as yet committed to a firm timescale for implementing them, although it has progressively liberalised pricing over the past couple of years. However, this winter's gas shortages (see Nitrogen Industry News, p10), driven by rapidly increasing gas consumption, may help focus its mind.

Mexico

Mexico, in spite of currency fluctuations driven by its mercurial neighbour to the north, has continued to press ahead with the energy market reform programme that it began in 2013. Deep water exploration blocks were auctioned in 2016, and now the focus has turned to the downstream gas market. During 2017 the government offered third party access (TPA) to Sistransgas, the state-owned national gas pipeline network. State oil and gas monopoly PEMEX has also lost 70% of its gas supply contracts to independent suppliers, and gas price formulae have been relaxed.

> **"Liberalisation continues to creep through the European gas market.**

It is hoped that this may also give an imperative for the development of more gas storage in Mexico – currently the country only has three days' of gas storage capacity, but a gas market with swings in demand and supply would need to store gas in times of surplus or cheaper prices as a hedge against price peaks.

Russia

While Russia has made some changes to its domestic gas supply, with some competition to the Soviet-era behemoth that is Gazprom emerging from privatised oil companies and some new market entrants like Itera (now bought up by Rosneft), export of gas from Russia to foreign customers remains dominated by Gazprom, although there is increasing pressure for this monopoly to be broken by regulatory changes.

Gazprom itself is now 50% privately owned, and there are 'Chinese walls' between its upstream/production, transportation, distribution, sales and export divisions, although the Russian government continues to resist calls to break the company up into smaller units.

In the meantime, in 2018 domestic wholesale gas prices are expected to be fully liberalised, at the same time that a uniform transmission tariff for all users of Gazprom's pipeline network will be introduced. Russia has had a gas trading exchange – the St. Petersburg International Mercantile Exchange – since 2014, and liquidity is gradually increasing and with it its reliability as a price indicator, although Gazprom still represents over 60% of sales and purchases on the exchange.

Europe

Europe too continues to see a steady pace of gas liberalisation, under the auspices of the European Union (EU). Directive 2003/55/EC provided for the definitive opening of EU member states' gas markets to competition, and was superseded by Directive 2009/73/EC, which introduced new rules aimed at accomplishing a more effective unbundling of companies active in the transmission, storage and distribution of gas. The unbundling of companies involved in the energy sector is a key part of the Third Energy Package, a new set of regulations issued by EC bodies. As can be seen from the age of these directives, this has not been a rapid process. However, liberalisation continues to creep through the European gas market. In April 2017, the Latvian gas market was opened to competition, with a choice of several possible suppliers. The vertically integrated gas company JSC Latvijas Gaze was fully unbundled by end of 2017, separating it into retail gas provision and gas transmission companies. The start-up of the Klaipeda LNG terminal in 2015 has also helped reduce Latvia's dependence on Russian gas imports, and the Baltic states are continuing to invest in pipeline interconnections to try and reduce this dependence further. The connection of the Balticonnector pipeline between Finland and Estonia will also be the trigger for the opening up of Finland's gas market. Last year the government published its proposal for a new Natural Gas Market Act, opening gas wholesale and retail markets to competition in 2020 and abolishing special regulations concerning pricing. The act came into force on January 1st 2018.

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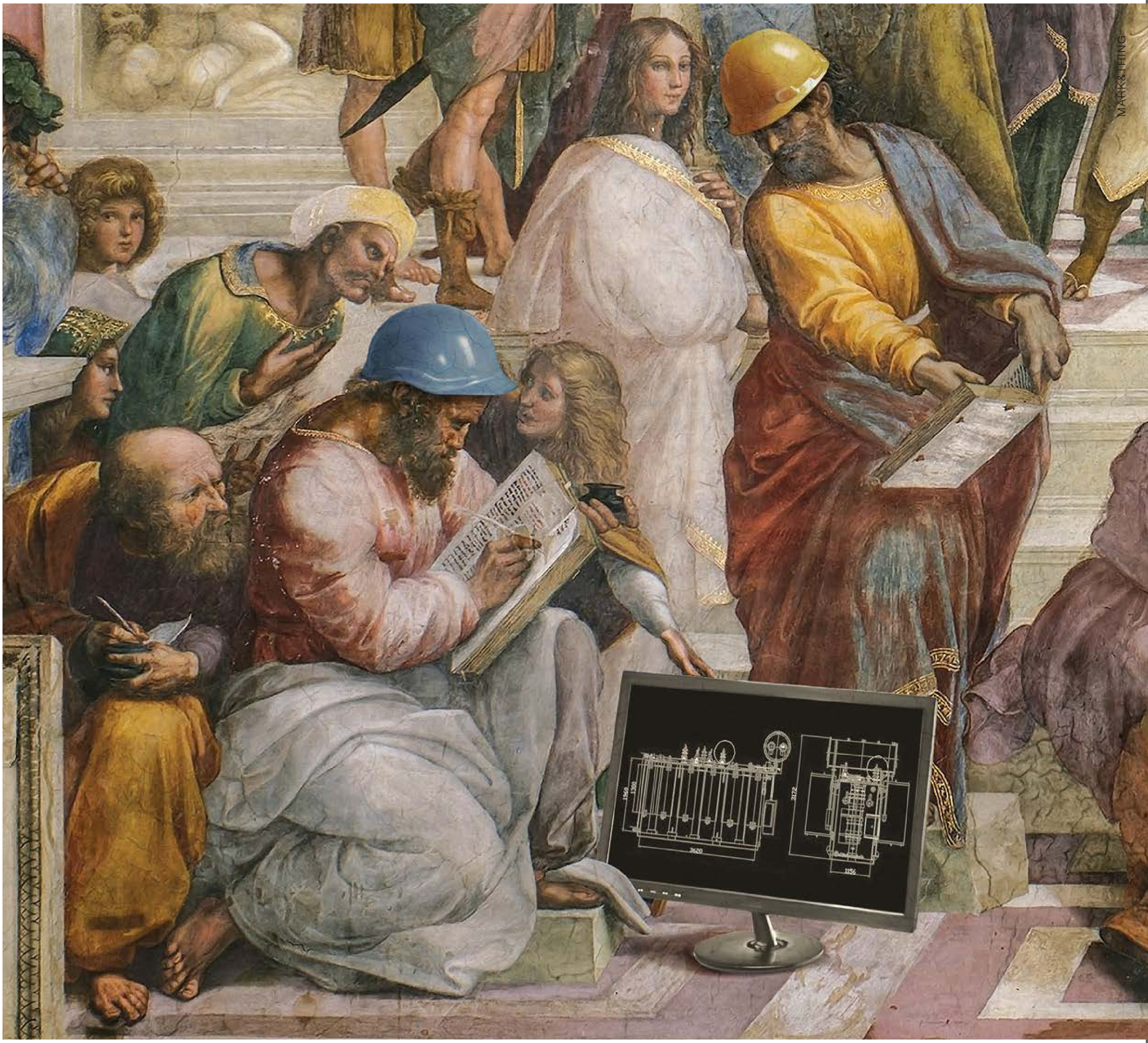

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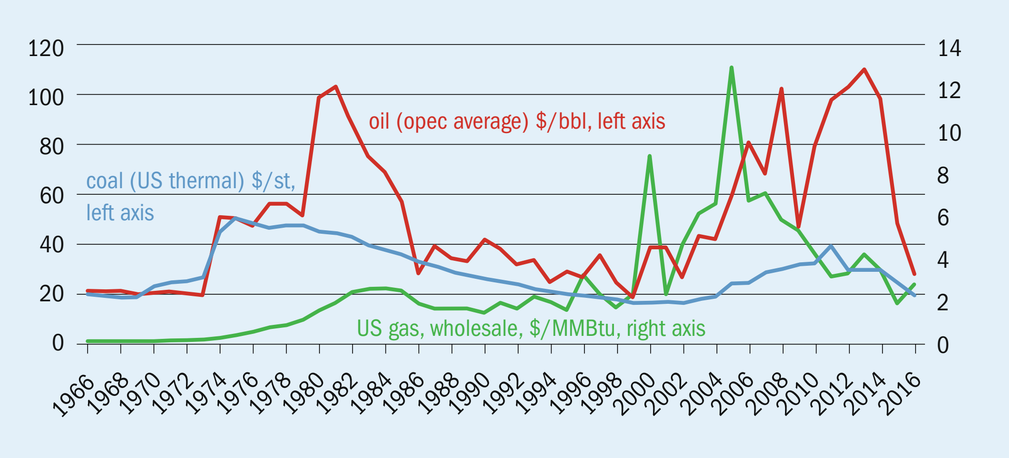
Fig. 1: **Historic feedstock costs (inflation adjusted)**



Finland will waive its right to derogate from some of the requirements of the EU's Internal Market in Natural Gas Directive, which will result in the unbundling of the Gasum-owned gas transmission network and gas sales.

Croatia has been slowly recovering from the deep recession it entered in the wake of the 2008 global financial crisis, leading to its government to postpone gas price liberalisation. However, this was finally achieved in 2017. The Italian retail gas and electricity market will be fully liberalised from 2019 under the framework of a market competition law passed by its parliament in 2017.

Increased interconnectivity has also led to a gradual erosion of price differentials across the continent. Natural gas prices in the Czech Republic have already converged with German gas hub prices and this trend is expected to continue with the development of interconnectors in other less connected nations in southeastern Europe. In 2014, for example, Czech wholesale gas prices were 28% higher than Dutch TTF trading hub prices, but in 2016 this differential was less than 1%.

Outside the UK, European gas prices used to be mainly set via oil price escalators, often tied to the Dutch gas tariff or Russian cross-border prices, but gas-on-gas (GoG) competition is spreading as the EU liberalises its internal gas markets. The International Gas Union calculated that in 2016, 60% of European gas was traded as GoG, with trading hubs like the UK National Balance Point (NBP) and Zeebrugge now setting prices across the continent. Oil price-linked contracts by contrast now account for only 30% of gas bought in Europe, with GoG steadily spreading from the more liberalised markets of northwest Europe into central and even eastern Europe. The main holdout for oil-linked contracts is now in Mediterranean countries.

LNG

One of the main drivers for gas market liberalisation has been the rapid growth of the international market for liquefied natural gas (LNG). The LNG market is expanding by 4-6% per year, compared to around 1-2% for overall gas consumption, and LNG now accounts 12% of all gas demand. However, over the past few years LNG production has outstripped demand. LNG demand finally began growing again in 2016, after four years of stagnant consumption which in turn had been due to high market prices from 2011-13. But more than 50 bcm/year of new supply came on-stream during 2016, leading to a large number of cargoes trying to find customers, and consequently a growth in the LNG spot market. Oversupply has begun to shut off the tap of new LNG projects, but the overhang of excess capacity is likely to last into at least 2019, according to most industry analysts.

Most (around three quarters) of LNG that is purchased worldwide is still traded on oil-indexed contracts, some of them very long term, but the period of high oil but relatively low natural gas prices from 2009-2016 (see Figure 1) encouraged LNG consumers to switch away from such contracts and purchase on the LNG spot market, where prices were often far cheaper than long-term oil indexed contracts.

Contracts and pricing

The most recent wholesale gas price survey by the International Gas Union (IGU) argued that there have been "significant changes in wholesale price formation mechanisms during a period of key developments and upheaval in the global gas market."

Figure 2 shows the percentage shares of each price mechanism according to the International Gas Union's 2017 wholesale gas price survey. Gas-on-gas competition has the largest share of total consumption, at 44%, representing around 1.6 trillion cubic metres of gas. This slice is dominated by North America (960 bcm), where GoG represents almost 100% of gas consumed. Europe adds another 340 bcm of GoG, representing over 60% of all gas consumed on the continent. Gas on gas competition can now be found in 52 countries worldwide in some form or another, and across all regions, although its percentage share of consumption in Africa and the Middle East remains very low. However, in terms of pipeline trade, the GoG share has been increasing significantly, with the IGU recording that contract changes in cross-border trade have seen the gas-on-gas share rise from 23% of pipeline trades in 2005 to 57% in 2016, all of this represented by the decline of oil-indexed pricing (by Gazprom) and rise of gas traded via hubs. The introduction of Norwegian gas to Europe has been a major factor in this development, as well as high oil prices at a time of low gas prices from 2009-2016 (see Figure 1) putting considerable pressure on Gazprom to start decoupling the prices it charges from an oil price escalator.

The next largest single slice in terms of pricing arrangements is represented by oil price escalator (OPE) contracts (20%, or around 725 bcm), predominantly in the Asian and Asia-Pacific regions. One of the reasons for this is the continuing dominance of OPE-based contracts in LNG trade. The IGU found that in 2016, 76% of all LNG trades were based on OPE contracts, with the remaining 24% based on spot gas purchases (GoG competition) – and accounting for much of the GoG competition to be found outside Europe and North America.

The three regulated categories – regulated by cost of service (RCS), regulated for social and political reasons (15%) and regulated below cost price (RBC) or subsidised gas totalled around 31% or 1.1 tcm. China and the FSU are the main regions where gas is regulated by cost of service, along with Egypt and Nigeria, with regulated prices for social/political reasons dominating in the Middle East, especially

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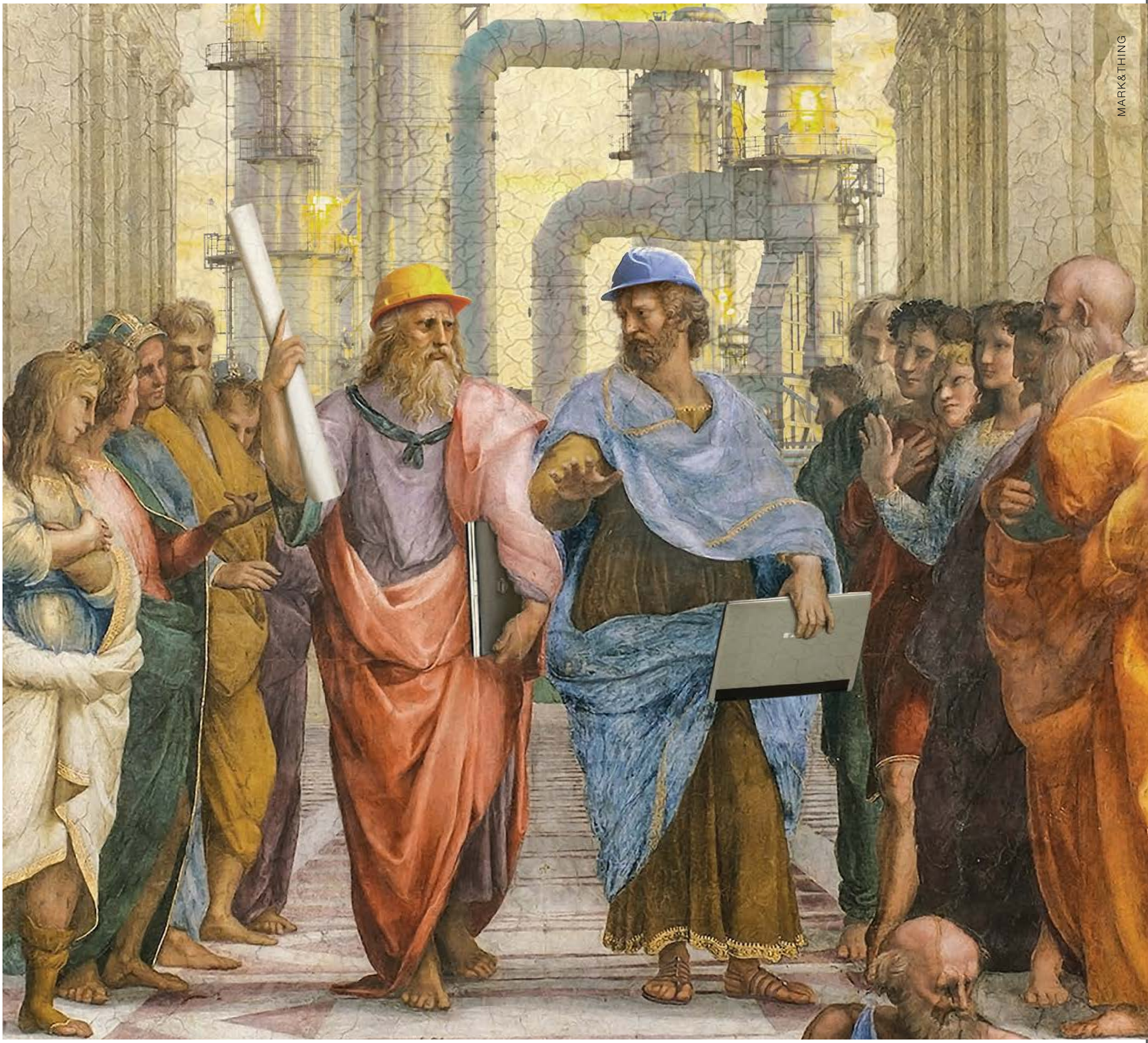

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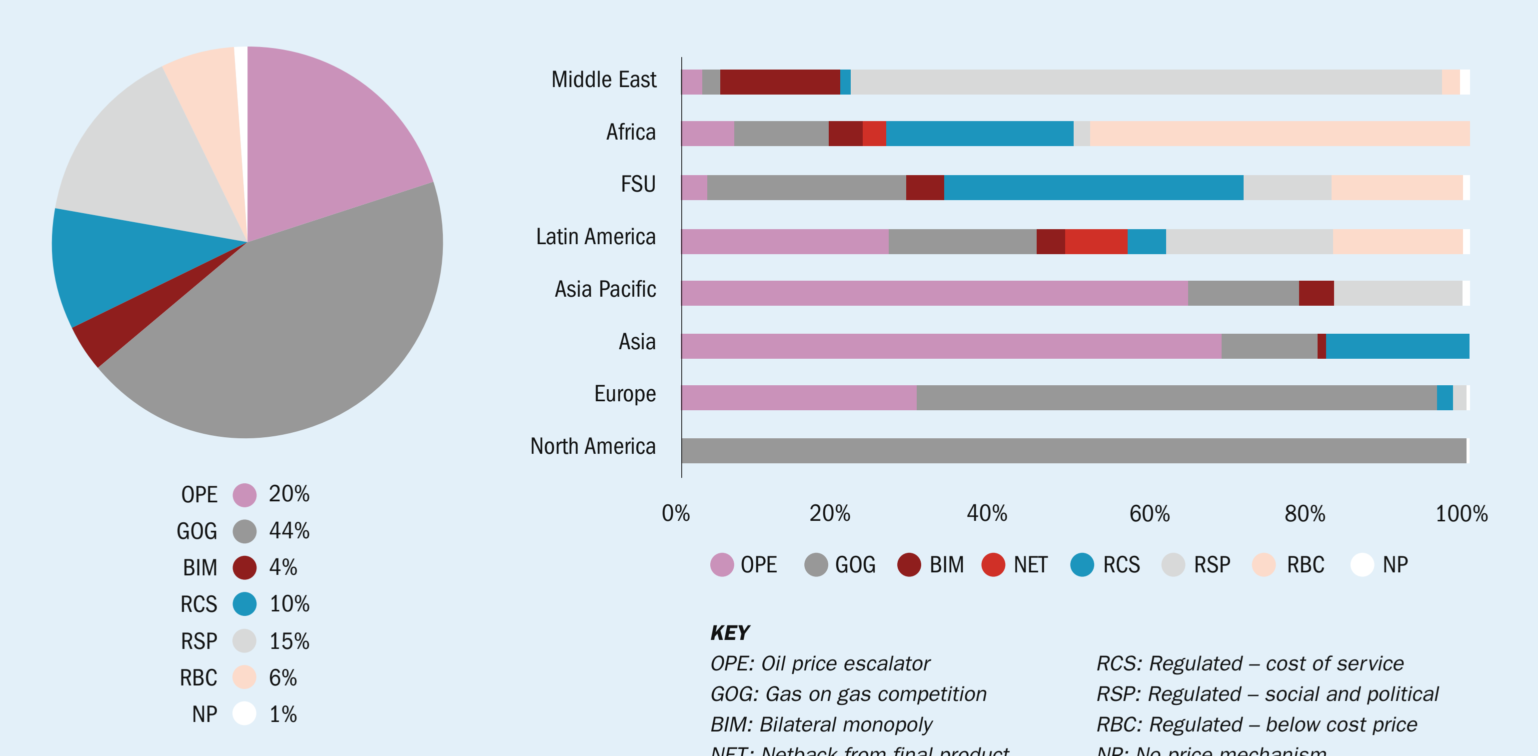
Fig. 2: **Gas markets by contract type**



Source: IGU

Iran, Saudi Arabia, the UAE and Oman, as well as countries like Indonesia and Malaysia, with some in Latin America – mainly Argentina. Finally, regulated prices below cost encompasses 14 countries, mainly the former Soviet states of Kazakhstan, Turkmenistan and Uzbekistan, as well as Egypt, Algeria and Venezuela. Bilateral monopolies are found mainly in Qatar, the UAE, Israel, Belarus, and Trinidad.

Convergence

Market-priced gas has become cheaper over the past couple of years as the slowdown in the Chinese economy, the continuing shale gas boom in the United States and a glut of LNG on world markets has brought prices down worldwide. Average wholesale prices worldwide were $3.35/MMBtu in 2016 according to the IGU, the lowest level recorded in a decade. At the same time, however, deregulation of previously regulated markets is causing prices to rise in most regulated markets such as the Middle East and parts of Asia. The result has been an interesting convergence between regulated and unregulated prices, and even LNG, which had traditionally traded at a premium. Figure 1 shows that the convergence has occurred not only within gas markets but also between different energy types – power producers in particular have been switching between coal, oil and gas far more than historically, seeking the cheapest feeds, and driving price convergence.

Effects on syngas producers

The bulk of operating costs for any ammonia or methanol producer remain the feedstock. Figure 1 shows the way that feedstock prices have changed over the past 50 years, and clearly illustrates why the syngas industry moved towards cheap, 'stranded' natural gas in the 1960s as the industry globalised and away from the coal-based feedstock which had dominated the industry in the first half of the 20th century. Where gas had no domestic use, in remote locations, or where it was available essentially free from oil production, and would otherwise be wastefully flared, it was available as a cheap feed for ammonia producers and encouraged the development of the industry in places like Southeast Asia, the Middle East and Trinidad.

However, greater use of gas as a fuel for electricity generation, especially in the developing world, and the growing spread of cross-border gas trade, initially by pipeline, and later by LNG, began to see gas prices move upwards towards electricity prices, while the 'dash for gas' of the 1980s saw coal use begin to rise less rapidly. By the 1990s, as gas markets began to liberalise, gas prices began to become more volatile, leading to the price spikes visible in Figure 1. The period from roughly 2000-2010 saw renewed interest in coal gasification as a feedstock for ammonia and methanol production, as gas prices soared and coal prices remained relatively low. The collapse in gas prices over the current decade has removed much of the economic incentive towards coal-based production, and instead it has been favoured mainly for self-sufficiency reasons, in countries like China, South Africa and Vietnam, and potentially India.

The convergence of global gas prices due to the spread of liberalisation and the increasing interconnectedness of the global gas market – 'stranded' gas is increasingly a rare phenomenon, perhaps really only a factor in parts of Africa these days – has eroded some of the rationale for building export-oriented plants in far-flung locations. Certainly the US shale gas boom has led to a large-scale move back 'onshore' by the nitrogen and methanol industries, while the threat of closure has eased from many European producers now that the gas price differential from foreign competitors is much lower, and given that they have far lower transport costs to their own domestic markets. Political, environmental and other factors are now starting to count far more highly in the minds of project developers.

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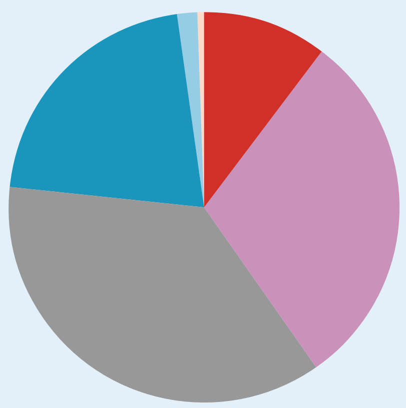
Ukraine looks towards coal gasification

Eugene Gerden reports on Ukraine's plans to reduce its dependence on Russian natural gas through the use of syngas derived from coal gasification.

Fig. 1: **Ukraine's energy mix, 2016**



Source: BP

The government of Ukraine is planning to significantly increase domestic syngas production in a move to reduce dependence on Russian natural gas and to strengthen national energy security, according to recent statements by the president and his government. The Ukranian government, together with some private investors, have recently announced plans to start building several facilities for the production of syngas in different parts of the country.

In recent years, a strict regime of conserving energy resources and the replacement of expensive natural gas by coal and other alternatives have become the main priorities of Ukranian energy policy. As part of these plans, Ukrainian thermal power plants have not been allowed to use natural gas, but rather have been actively converted to become coal burning. In addition, serious attempts have been made by the state to reduce the use of gas in metallurgy, which is its main consumer of gas in Ukraine. Now one of these initiatives will include the production of syngas in the country. According to a spokesman of Ukranian prime minister Vladimir Groysman, they will operate on coal. The volume of investment involved in the implementation of these plans is estimated at US$500 million, the majority of which is expected to be provided by the Ukranian government, while the remainder will be provided by private investors and Chinese banks in the form of loans.

A long history

Ukraine's involvement with coal gasification goes back to early underground coal gasification (UCG) experiments by the Soviet Union dating back to the 1920s and based on work conducted by the father of modern chemistry Dmitri Mendeleev in the 1880s and 90s. The USSR conducted extensive work on UCG and a test site at Lisichansk in Ukraine's Donetsk Basin was one of those selected. Here, the use of oxygen injection was pioneered, as relatively cheap oxygen was available as a byproduct of inert gas production at the site.

More recently, former Ukrainian president Viktor Yanukovych tried to tie up a $3.85 billion deal with the China Development Bank Corporation in 2013 to massively develop coal gasification as a solution to Ukraine's dependence on Russian gas. This was to have involved the development and use of a coal-water slurry, initially burned for heat production, but in a second phase new plants would be built to enable the gasification of brown and bituminous coal in three regions: Luhansk, Donetsk and Odessa, using Shell coal gasification technology.

However, the 2014 revolution that ousted Yanukovych and precipitated Ukraine's current struggle with Russian-backed separatists and the loss of the Crimea region also led to a series of economic crises in the country and the resulting suspension of the implementation of these plans. However, plans are now afoot to re-launch the project in Q1 of the current year and will involve participation of some foreign investors, and in particular China National Chemical Corporation and some leading Chinese banks. According to recent assessments made by the Ukrainian Ministry of Finance, the beginning of production of syngas in Ukraine would allow it to reduce imports of natural gas from Russia by about 2 billion cubic meters per year, and even achieve full independence from it in the years to come.

Current plans

At the initial stage, at least 7 facilities for the production of syngas will be constructed in Ukraine. An official spokesman of Oleksandr Danyliuk, Ukraine's finance minister, said that at this initial stage the project it will create more than 2,000 new jobs and provide a stable sale market for up to 14 million tonnes per year of domestic coal. In addition, successful implementation of the project would provide the opportunity to save up to US$1.5 billion on the purchases of Russian natural gas annually.

It is hoped that the China National Chemical Corporation will not be the only foreign investor that will participate in the project. The Ukranian government hopes to receive the required gasification technologies for the project through the use of Shell's technology – recently acquired by Air Products. However, in addition, the state hopes to attract Siemens and Lurgi as technology providers. At the same time the majority of equipment for the building of new facilities will be supplied from China.

To date, the Ukranian Ministry of Energy has already started preparations for the project. For this purpose, it has recently completed the establishment of Sintez-Gaz Ukrainy – a new company within the structure of Naftogaz of Ukraine, (the national oil and gas company of Ukraine, which is owned by the state), that will be directly responsible for the building of syngas facilities within the territory of Ukraine. In addition, it has already started preparations for certification of these gasification facilities in Ukraine.

It is planned that these facilities will be built in the Lviv-Volhynian basin and Dnieper brown coal mining basins, the most developed coal mining regions in the country after the Donets Basin, which is currently under the control of pro-Russian rebels.

The majority of syngas, that will be produced in Ukraine, will be supplied for the needs of the Ukranian chemical industry. Specialists from the Ukranian Institute of General Energy of the National Academy of Sciences have prepared several proposals for the production of synthesis gas in the Alexandria brown coal basin, which involves both reconstruction of the local Alexandria Thermal Power Plant and the construction of modular plants for the processing of coal into liquid fuel directly at the site of extraction.

The increase of syngas production will not only allow to reduce dependence on imported natural gas, but also to reduce carbon dioxide emissions.

Having joined the European energy community, Ukraine has committed to reduce emissions of harmful substances into the atmosphere by 2020, which means gasification of coal can become a good technical solution for the country.

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Nitrogen+Syngas index 2017

A complete listing of all articles and news items that appeared in *Nitrogen+Syngas* magazine during 2017.

Methanol as a shipping fuel, May/June 2017.

Increasing Plant Capacity or Absorption Efficiency of Nitric Acid Plants by Introduction of Oxygen

A new concept for a capacity increase or an improvement of absorption efficiency has been developed by Messer Group GmbH. Dosing oxygen to specific points in the liquid and/or gaseous phase in order to significantly decrease NOx emissions or increase capacity optionally.

Advantages at a glance:

- Considerable increases in capacity (up to 10%)
- Significant NOx reduction before and after existing DeNOx plants
- Longer life time of existing DeNOx catalysts, requiring less frequent investments
- Saves NH_3 or natural gas for DeNOx
- Low investment costs – short payback period
- Additional flexibility of production capacity

Messer produces industrial gases, medical gases and gas mixtures. In state-of-the-art competence centres, Messer develops application technologies for the use of gases in almost all branches of industry.

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EMEA
Heraeus Deutschland GmbH & Co. KG
Heraeusstr. 12-14
63450 Hanau, Germany
Phone: +49 6181 35-4463

AMERICAS
Heraeus Precious Metals North America LLC
15524 Carmenita Road
90670 Santa Fe Springs, CA, USA
Phone: +1 727 447-2084

APAC
Heraeus Materials Singapore Pte. Ltd.
Block 5002, Ang Mo Kio Avenue 5
Singapore 569871
Phone: +65 8121 8324

CHINA
Heraeus Materials Technology Shanghai Ltd.
No. 1 Guangzhong Road, Minhang District
201108 Shanghai, China
Phone: +86 21 3357-5512

Nitrogen+Syngas 2018

PHOTO: CLAES TORSTENSSON/ISTOCKPHOTO.COM

Gothenburg in winter.

CRU will be hosting the 31st Nitrogen+Syngas 2018 International Conference and Exhibition at Gothia Towers in Gothenburg, Sweden from 26 February to 1 March 2018. The content-rich programme has been carefully structured to provide a blend of market analysis, technology trends, operating experiences and networking opportunities.

The annual CRU Nitrogen+Syngas Conference and Exhibition regularly attracts over 700 attendees and is the premier event for the nitrogen and syngas industry. The 2018 conference with its comprehensive programme is geared to maximise professional development throughout the four day event. The large exhibition that runs alongside the conference includes more than 80 exhibitors covering the full nitrogen + syngas value chain, addressing a large range of technical concerns and offering solutions and operational expertise in the following areas: EPC services and process technologies, equipment and materials, emissions and environmental technologies, fertilizer finishing and packing, and reliability and maintenance services.

Preconference events include the regular UreaKnowHow.com Clinic and technical showcases.

The UreaKnowHow.com Clinic will focus this year on safety risks in urea plants and how operators manage and mitigate these risks within their organisation. Several critical safety and reliability risks will be discussed in detail, including leakages in the high-pressure synthesis section and hydrogen explosion risks in various urea plant sections. All urea melt and granulation licensors will be invited or present their latest insights related to safety and reliability.

Building on the success and popularity of the technical showcases first featured in the 2017 conference, this year's event will also include short presentations from technology providers and producers covering a wide range of topics relevant to the ammonia, urea, fertilizer, methanol and syngas industries.

On the first day of the conference the opening sessions will provide a big picture analysis of market trends including key CRU insights into nitrogen cost curves and the outlook for global capacity as investment slows. Other topics to be covered include: recent regulatory developments in the EU, a capital markets perspective on the nitrogen industry, methanol as a marine fuel, and outlooks for the AdBlue market and the fertilizer and syngas markets in Iran.

The technical programme features over 45 papers with this year's key topics being: new plant designs for large scale production, plant performance and capacity enhancements, ammonia operations and troubleshooting, CO_2 removal and energy efficiency, plant and project economics, emissions management and revamp options for ammonia and syngas plants, new urea technologies and concepts, plant safety, urea operations and troubleshooting, methanol production, syngas catalysts, nitric acid plant optimisation and fertilizer finishing.

Technical programme highlights

A selection of presentations from the technical programme are highlighted below.

Value added fertilizer production

In a competitive product environment, urea manufacturers see product differentiation as a way to maintain or increase market share and profitability. Producing enhanced efficiency fertilizers is a viable strategic business decision but the transition to installing and operating world-scale, value-added urea production facilities requires careful planning and assessment. Koch Agronomic Services will address the key factors to assess, starting with the areas of a typical urea granulation plant that must be considered, as well as flows and concentrations. Other topics include: protecting against chemical interactions and corrosion, product quality changes and contamination of recycled streams.

Digital solutions for the fertilizer industry

Toyo Engineering Corporation and Baker Hughes are in collaboration to explore digital solutions for the fertilizer and petrochemicals industry by utilising Predix, a unique cloud-based platform built exclusively for industrial applications. Toyo will present a set of digital solutions under development to improve the efficiency and performance of urea fertilizer plants. Several cloud-based services will be introduced which can be accessed from anywhere at any time, e.g. the monitoring of key performance indicators and the visualisation of operating data, operation optimisation and consultation service, maintenance assistant service and business management.

A new cost effective way to expanding urea production

NIIK will share its experience of expanding urea production by construction of a new urea solution and UAN plant based on existing standby facilities. The plant is designed to produce 72% urea solution which is converted to UAN, thereby eliminating the need for an evaporation section, granulation unit and wastewater treatment section. In addition, the low energy consumption and low air emissions and wastes makes the process environmentally friendly.

Optimising steam reformer operations

Optimising steam reformer performance in syngas plants is crucial for getting the most possible out of natural gas feedstock. Haldor Topsoe will expand on solutions that can ramp up the performance of the steam reformer, showing how significant value can be added throughout the whole steam reformer operating cycle. Real examples from the industry will be presented, illustrating how optimisation of the steam reformer performance has significantly contributed to increased plant profitability.

Cold wall add-on ammonia converter

Add-on ammonia converters are often considered for revamping existing ammonia plants to increase plant capacity and enhance process energy efficiency. Typically hot walled add-on converter designs have been used but there have been some reports of reliability issues. In this case study, KBR and Chambal Fertilizer & Chemicals (CFCL) will provide insight into the design of KBR's cold wall add-on converter which was installed in Ammonia Plant 2 in CFCL in April 2017, during a short turnaround. Its successful integration into the existing plant and key aspects of the project execution will be discussed. The plant has achieved the target performance including capacity and energy efficiency targets.

4,500 t/d single train ammonia plant

thyssenkrupp Industrial Solutions will present a study for a 4,500 t/d single train ammonia plant using proven technology. By using thyssenkrupp's dual-pressure ammonia process some critical equipment items can be built in a size that is smaller than one would require by scaling up a conventional plant, thus minimising scale-up risk. This proven concept is applied in this study and is combined with the design and operating experience of the largest ammonia plants in the world.

25 years of operating experience at NFCL

Nagarjuna Fertilizers and Chemicals Limited (NFCL) will share 25 years of operating experience of its Ammonia Plant 1 and will discuss the various modifications carried out to the plant, corrective actions in terms of plant operation philosophy, parameters monitoring and practices. Success stories and pitfalls over the years will be highlighted.

Ammonia plant revamping

ZoneFlow Reactor Technologies will be providing details of its innovative and proprietary structured catalyst design for steam reforming applications which overcomes the limitations typically attributable to conventional "pellet" steam reforming catalyst when revamping ammonia plants for increased capacity. The technology development, pilot test results and commercial demonstration will be discussed as well as various case analyses for illustrating advanced and attractive solutions for ammonia plant revamping.

Optimisation of CO_2 removal units

Carbon dioxide is an energy intensive step in the ammonia process and optimisation of the CO_2 removal unit can significantly improve the overall performance of the ammonia plant. Based on modelling methodology and techniques used to simulate case studies and by validating the simulation results by comparing them to actual operating performance data, The Dow Chemical Company will show that by converting ammonia plants from MEA to MDEA-based formulated solvents significant energy savings, reductions in solvent circulation rate and lower CO_2 specifications can be achieved.

Ammonia plant relocation

Relocation of a thoroughly investigated existing facility has some unique challenges. There is a significantly lower probability of using a known and proven process design and a cost and time savings versus a new facility. BD Energy Systems will provide an economic case for ammonia plant relocation. The presentation will focus on tasks, time-frames, approximate costs and lessons learned. The pros and cons for a relocated plant versus a new chemical plant will be summarised.

Safety to the fore

At last October's Ammonium Nitrate and Nitric Acid Producers' Meeting, ammonium nitrate safety and regulation and nitric acid emissions continued to be some of the dominant themes for the industry.

The Wolfdancer Golf Club at the Hyatt Regency Lost Pines Resort, Austin, Texas.

The Ammonium Nitrate/Nitric Acid Producers' Meeting (ANNA) convened last year at the Lost Pines resort near Austin, Texas. The meeting attracted nearly 400 delegates from producer and supplier companies and 70 exhibitors at the associated exhibition, with 33 countries represented at the five-day event.

Regulations

Noel Hsu of Orica discussed the US regulatory landscape for ammonium nitrate in the light of the April 2013 incident at West, Texas. The primary report into the incident is the one conducted by the US Chemical Safety Board (CSB), which was released in February 2016, and about which we reported last year (*Nitrogen+Syngas* 343, Sept/Oct 2016, pp32-35). It recommended that OSHA and the Environmental Protection Agency (EPA) update their programmes relating to AN safety; that state fire marshals must ensure that firefighters have the required training and hazard awareness of situations they might encounter; that product stewardship of AN be established throughout the supply chain; and noted that a lack of appropriate land use planning allowed the city of West to grow towards the facility, which had previously been a safe distance from residential buildings.

From this have flowed changes to the National Fire Prevention Association (NFPA) Code 400, which are due to take effect in 2019. Chapter 11 applies to the storage and handling of fertilizer which contains more than 60% AN (if solid) or 70% AN (if liquid), and requires all new AN storage sites to be of non-combustible material, including storage bins. AN must be separated from contaminants by a room of concrete block construction with a 1 hour fire barrier extending from floor to roof for bulk storage. Outdoor storage must be separated from combustibles by 30 feet instead of the previous 15 feet, and this includes storage in rail cares. Automated sprinklers must be fitted for all new combustible constructions, and fitted retroactively for combustible structures or those with combustible contents. There is also a 1 mile public notification area for such constructions, and an emergency incident plan must be agreed with the local Fire Department, including a 1 mile evacuation zone.

Other guides have been updated, including Transport Canada's Emergency Response Guidebook (Guide 140), which will now mandate a 1 mile evacuation zone instead of the previous half mile. The Institute of Makers of Explosives (IME) has also updated its Safe Handling of AN document in April 2017 to align its storage recommendations with NFPA Code 400, and it also includes a safety data sheet template for AN.

Wim Mak of Dutch research organisation TNO updated delegates on the new rationalised UN classification scheme for AN-based fertilizers. This has come from the International Group of Experts on Explosion Risks of Unstable Substances, or IGUS for short. The existing five entries for AN in class 5.1 have been reduced to one entry (UN2067), and the single entry for Class 9 AN has been retained (UN2071). In September 2017 these reformulations were adopted for the UN RID/ADR 'orange book' transport codes. A new Section 39 in the manual presents a flowchart of classification criteria depending on percentage AN and percentage of combustible substances as to whether it falls under the definition of 'explosive', UN2067 or UN2071. All of the documents can be found at: www.unece.org/trans/danger/danger.html

AN incidents

Several papers discussed AN incidents. PT Multi Nitrotama Kimia (MNK) in Indonesia reported on a September 1996 explosion at their 37,000 t/a MNK-1 ammonium nitrate plant at Kujang. The explosion happened in the wet section of the plant, and appeared to have begun in the evaporator seal tank system. Parts of the equipment were found 1km away. Fortunately there were no serious injuries, but one man had a very near miss from debris and some personnel were knocked unconscious by the shockwave. There had been no warning or visible signs prior to the explosion. The plant was out of commission for two years while repairs were made. Contributing factors appeared to be very low pH in the evaporator seal tank (around pH1.0), oil contaminants from a leak in the AN melt pump, and organic contaminants from the recycle stream, and finally a blockage of the AN melt line. This led to accelerating decomposition of high concentration AN solution in the evaporator seal tank.

OCI Nitrogen described the intense fire in the calcium ammonium nitrate (CAN) conveyor system at their Chemelot site at Geleen in the Netherlands in 2015. The fire stopped production not only at an AN, three nitric acid and three CAN plants, but also tripped two ammonia, two melamine, two caprolactam, a urea, an ammonium sulphate and a nitrate plant as the ammonia pipe rack was blocked. The fire began in the lining of a bucket elevator after a welding job had taken longer than normal, and 30 minutes later, after personnel had left the area, a manhole cover allowed air flow over the area that led to an extended fire in the lining of the bucket elevator. Follow-up investigations found a lack of cleaning and

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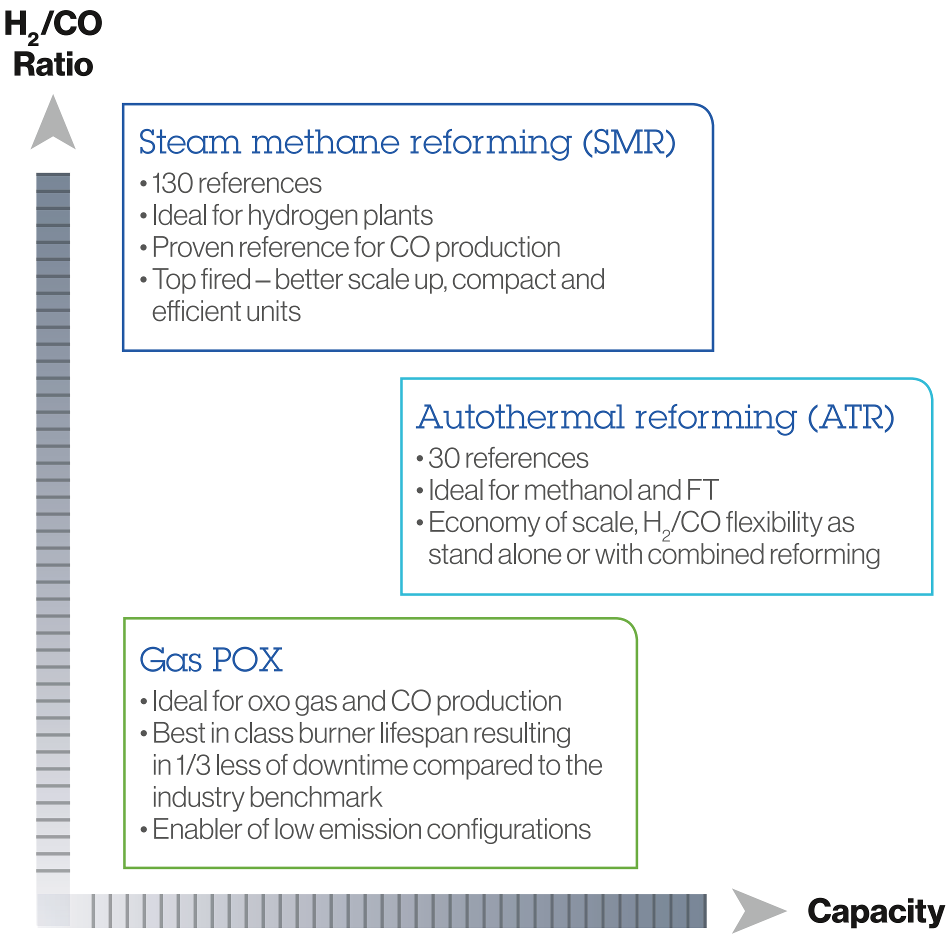

engineering-airliquide.com/syngas
syngas@airliquide.com

OCI's Chemelot site at Geleen, site of the intense CAN fire in 2015.

checking – procedures were not followed. Since then there have been major changes to working practices – no hot work is allowed on-site now when there is an alternative and the hot work permitting system is much tighter. All flammable materials have also been replaced by non-flammable or fire retardant alternatives. There is also a sprinkler system and camera surveillance (the elevator was enclosed and so the fire was not detected for many minutes). But more than that, there has been a change to safety training and awareness and an encouragement for workers to question when something does not seem right or procedures are not followed.

Yara described an ammonium nitrate solutions tank implosion at their Cartagena site in Colombia. The 1,000 tonne tank contained 400 tonnes of 83% AN solution at the time. While flushing a line with cold water into the tank, the low temperature led to steam condensation, causing a vacuum beyond the capability of the inlet air vent to compensate. An overflow line which should have acted as an additional vent had been sealed to avoid the release of NOx gases based on its previous operation as a nitric acid storage tank, and there had not been a proper management of change implementation. Calculations show that the tank design pressure was exceeded within 10 seconds. Fortunately, although there was major deformation to the tank, no leak occurred. Procedures were updated and the new venting capacity verified – a new vent was added. The tank was able to be repaired by pulling it back into shape and installing stiffening rings, although a full fitness for service evaluation was carried out. New dip pipes mean that water addition will be below the liquid level in future.

Transport incidents

Ron Peddie of Peddie Engineering discussed a serious incident in Australia relating to AN being carried by road. Five AN trucks have exploded over the past 40 years – at Taroom in Australia in 1972, in Brazil in 1997, in Spain in 2004 and also in Romania the same year – as well as a large number of incidents where a fire did not lead to an explosion. The most recent one occurred in Queensland in September 2014. The vehicle was a 52 tonne road train which came off the road near a bridge in a remote part of the state. A fire resulted from spilled diesel and burned for an hour before two fire trucks exploded. A small explosion caused all of those present to retreat, meaning they were further away when a second explosion occurred, injuring all seven, some seriously, although without fatality. The common factor of all of these accidents is that the fire burned for a long time – in each case more than 30 minutes. All were flatbed trucks, not containers, that way the heat is transferred, not confined. It needs a large mass to detonate, but the trucks were all carrying tens of tonnes. No detonators were present so the mechanism for the final initiation is unknown, but the AN presumably started to decompose due to the heat. A working party is active in Australia with recommendations due by the end of 2017.

Nigel Shields of Yara discussed the rupture of an ammonium sulphate truck during unloading at the Tertre site in Belgium in 2016. This was a full truck with 20 tonnes of AS on board. The unloading was split over two silos, and the accident occurred when the truck had moved to the second position and the driver was moving to the rear of the vehicle to hook up the discharge line. The front of the tank exploded, rupturing along half of its length – fortunately without any injury to the driver or other personnel. A root cause investigation found corrosion inside the trailer with low wall thickness around the broken nozzle valve (which was found 50m away). The explosion was caused by pressure from the compressor during unloading, even though this was only at 1.4 bar. AS is not an ADR product, so there was no requirement to inspect for corrosion even though it is known to be corrosive in the presence of water. Nigel said that this reiterates the need to be vigilant even with apparently 'benign' products.

Instrumentation

As well as AN safety, several papers touched on the subject of instrumentation. Rene Braun of Bruker Optik presented an infra-red imaging system which enables real-time monitoring of a chemical plant site for airborne pollutants such as ammonia to provide an early warning detection system and to be able to visually locate the source – particularly important for operators near urban concentrations.

Rodrigo Goncalves of Vale discussed the use of thermal imaging to identify problems in an ammonium nitrate neutraliser at Vale's Cubatao site in Brazil. Intermittent flow and vibration effects had constrained the plant to 40% capacity. The problem was isolated to the 2nd stage distributor, which was redesigned.

Manuel Quintas of Intertek looked at methods for measuring AN dust emissions to prove that a plant was in compliance with environmental legislation, and Ron Hastings of Apache Nitrogen showed how an infra-red fire detection system had helped to cope with a nitric acid plant expander failure in the high pressure air system.

Nitric acid

The nitric acid session included a look at the critical market for platinum group metals, presented by Tim Murray of Johnson

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

Matthey. South Africa remains the source of most precious metals, with 72% of platinum production in 2016. Other key producers are Russia and Zimbabwe, with the US and Canada trailing some way behind. The market has been in deficit for several years, but appears to have finally moved back into a modest surplus in 2017. However, over the past few years market prices appear to have moved away from these fundamentals due to exchange rate changes and increased recycling. Platinum also appears to have become a financial commodity similar to gold, which has also artificially inflated its price.

On the materials side, NSSC Japan presented its high silicon austenitic stainless steel. Developed by Sumitomo and Nippon Steel in the 1970s, it has been used extensively in nitric acid plants in Japan, but has only recently been offered for sale overseas. With low carbon, 17% chromium, 14% nickel and 4% silicon, it is suitable for strongly oxidising environments and high (ca 98%) concentrations of nitric acid below 60°C. Stamicarbon also launched its dual pressure nitric acid technology, which we described in *Nitrogen+Syngas* 349 (Sept/Oct 2017, pp43-45).

Emissions reduction

Nitric acid plant NOx emissions continue to be a headache for nitric acid producers, and four papers looked to this subject. Nitrous oxide emissions of course play into carbon markets and carbon credits due to its global warming potential, but Rico Stein of Muller-BBM showed how uncertainty levels in measurement can affect how data is treated by authorities and how uncertainty can be reduced by collaboration between testing companies, operators and instrument manufacturers.

Clariant showcased its advances in catalyst technology for secondary N_2O abatement via their *EnviCat N_2O-S* catalyst with high crush strength, which also increases NO generation and hence nitric acid yield. Lasse Nielandt of thyssenkrupp Industrial Solutions showed the typical NOx emission spikes encountered during nitric acid plant start-up, and how these can be reduced. Finally, IncitecPivot described their experiences with installing a selective catalytic reduction (SCR) system onto their 1965-vintage nitric acid plant, including measurement issues, lack of high pressure steam to pre-heat the catalyst, and handling problems with the catalyst cartridges. Nevertheless, the result was NO emissions below 30ppm and 'single digit' ammonia slip, with no N_2O detectable – roughly a 98% reduction even in the Australian summer.

On to Canada

The best paper awards went to "Use of Thermal Images to Identify Flow Problems in an AN Neutralizer" by Rodrigo Dias Goncalves of Vale Cubatão for the ammonium nitrate section, and jointly to "Installation of a new expansion turbine" by Nils D'Hoker of Yara and "LOMO SCR – installing abatement on a 1965 plant" by Don Hays of DynoNobel in the nitric acid session.

Next year's meeting will be held in Calgary, Alberta, Canada, hosted by Orica Carseland, from September 16th-21st, but will move back to Europe in 2019, in Vienna, Austria, hosted by Borealis. The organisation has now formed an ANNA-EU sub-committee to run future Europe-based meetings – so far the organisation has been working on a three-yearly cycle of running meetings in Europe, after a successful first trip across the Atlantic to Noordwijk in 2010.

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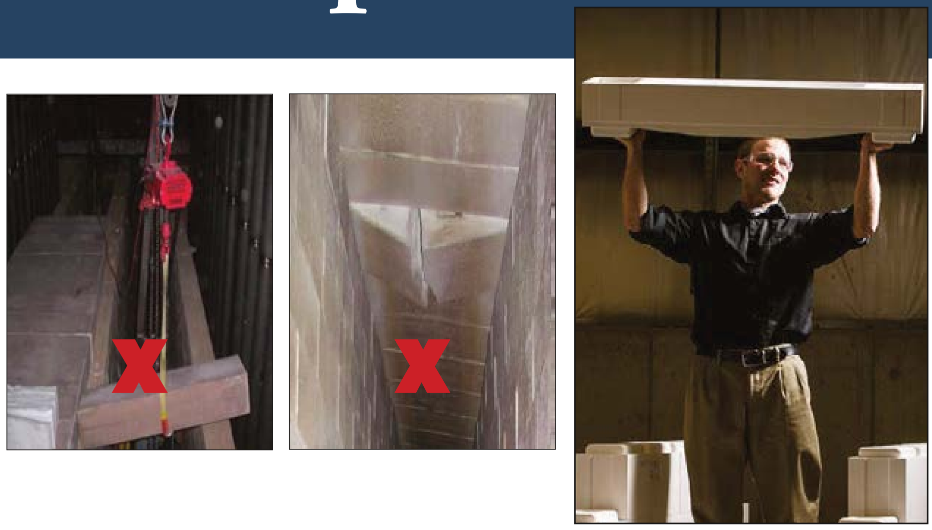

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Packed absorbers for deep CO_2 removal

When designing or revamping acid gas absorbers with structured or random packing, one must be very careful to ensure that the analysis correctly accounts for packing size and type on performance. In this article, **R. H. Weiland** and **N. A. Hatcher** of Optimized Gas Treating, Inc. demonstrate how the ProTreat® mass and heat transfer rate-based simulator can be used to show the effect of packing size and type on performance for two deep CO_2 removal applications, one in LNG production and the other in an ammonia syngas unit.

When an ideal stage calculation method is used to design or assess performance of an absorber in a CO_2 removal unit, the only way for packing size (and type) to be brought into play is through calculation of the stage count (or the number of transfer units) and then applying a stage efficiency or a value for the height equivalent to theoretical plate (HETP). Unfortunately, there is no way to compute such values unless one has direct experience in a nearly identical, or a very similar, column under the same operating conditions. In other words, to reliably design such a column and predict its performance, one must already know the answers. Such an approach can hardly be construed as prediction, and it is certainly not capable of allowing the effect of packing type and size on absorber performance to be assessed.

In contrast, this article demonstrates how packing size, even within the same packing series, directly affects overall absorber performance. To see this behaviour requires a modern simulation tool capable of modeling the mass transfer and heat transfer as rate-based processes. In this work, the ProTreat® (a registered trademark of Optimized Gas Treating, Inc.) mass and heat transfer rate-based simulator is used to show just how performance of packing varies in two deep CO_2 removal applications. Temperature profiles can be significantly impacted by changing packing size, even when all the operating conditions are kept the same. With the changing temperature profiles come changes in CO_2 removal performance and corrosion implications.

Normal temperature profiles in absorbers for deep CO_2 removal at high pressure typically exhibit a pronounced bulge or maximum somewhere within the column. Not only can the position of the temperature bulge be packing-size dependent, but so can the value of the bulge temperature. The bulge temperature itself can be higher when large packing sizes are used and how much it can vary depends on the particulars of the gas being treated and the solvent composition. For example, in the absorber of a syngas unit using MDEA lightly spiked with piperazine it is shown that the magnitude of the bulge does not vary greatly with packing size, although its width does. In an LNG plant, on the other hand, both the temperature at the bulge, and the shape of the temperature profile can depend greatly on packing size. Packing size dependence of the temperature bulge is somewhat counterintuitive, but it can be readily explained and understood by thinking about absorption as a mass transfer rate process.

There can be enormous variations in temperatures, flows and compositions within a column that are not manifested in the product stream temperatures and compositions, but that can have a huge effect on such critical parameters as solvent degradation, corrosion rates, and even on hydraulic performance measures. Locating where flooding is likely to initiate in a column requires accurate assessment of flows and properties of the phases throughout the tower. Such predictions are well suited to ProTreat® simulation but are challenging for an ideal stage simulator.

There are two different scenarios in which selecting the right packing size and being fully appreciative of the consequences of good and bad choices can be critical to success, namely: (a) design of a new column, and (b) revamp of an existing column. In the first scenario, one is free to choose the column diameter to achieve a specified flood condition. Large packings have lower pressure drop and flood later than small packings do; they have higher hydraulic capacity. In this case column diameter and the maximum vapour and liquid velocities through the column depend on packing size. At the same time, one might expect somewhat different separations performance because mass transfer coefficients depend on phase velocities and on the wetted area of the packing. In the revamp scenario, the column diameter is fixed regardless of packing size, so the vapour and liquid velocities are determined by the packing's hydraulic capacity, i.e., the packing's size, and it cannot be adjusted by specifying a larger or smaller column diameter. Choosing a large diameter packing to achieve higher capacity may be contraindicated by the inability of the limited surface area of large packing to achieve anything even close to the specified separation. This is one of the dangers in any tower revamp that focuses primarily on capacity. These situations are discussed in the context of two case studies, one in LNG production, where low CO_2 gases require low L/G ratios, and the other in an ammonia syngas unit, where high CO_2 gases need high L/G ratios.

The packing series selected for the

Fig. 1: **Revamped absorber temperature profiles and packing size dependence – LNG**

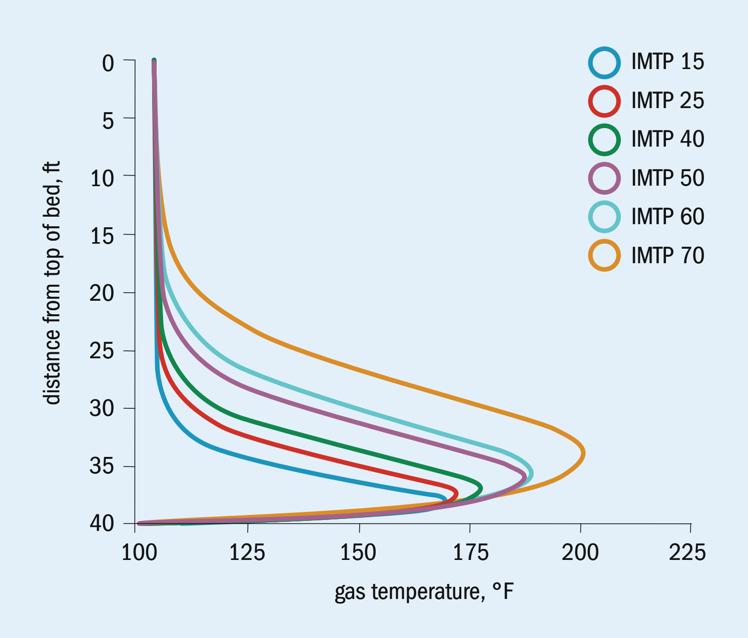
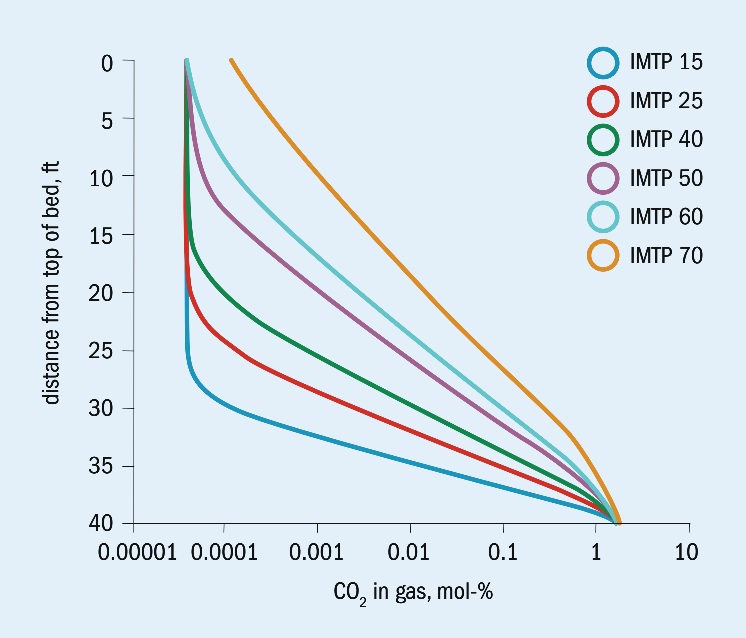


Fig. 2: **Revamped absorber CO_2 concentration profiles and packing size dependence – LNG**



study is Intalox Metal Tower Packing (IMTP®) because it is available in six commercial sizes from #15 to #70. This makes it easier to discern and discuss the effect of packing size without confusing the issue by bringing into play the effect of different packing types.

Case 1: LNG from pipeline gas

Revamp scenario

To isolate the effect of packing size from all other parameters, it is simplest to start with the revamp case. The tower to be revamped with new packing is 10 ft (3 m) diameter with sufficient height to hold a 40 ft (12 m) deep bed of random packing. Solvent and gas flow rates are constant at 1,000 US gpm (227 m³/h) and 250 MMSCFD (280,000 Nm³/h), respectively. Inlet gas is at 850 psig (59 barg) containing 2% CO_2. The solvent is 32 wt-% MDEA promoted with 8 wt-% piperazine. This pressure and solvent composition might be typical of an LNG absorber where very low residual levels of CO_2 in the treated gas are necessary. The optimal composition depends of course on the CO_2 content of the raw gas, the gas pressure, and sundry other factors. Diglycolamine (DGA®) and ADEG® are also used commercially in LNG applications. Which type of solvent is actually selected depends as much on licensing terms and the availability of process guarantees as on purely technical considerations.

Fig. 1 shows temperature profiles for these packings as predicted by ProTreat® simulation. There are two striking observations:

- Small packings have a small, sharp temperature bulge very close to the bottom of the absorber, and the bulge becomes ever broader as larger packings are used, and
- Much higher bulge temperatures are predicted to occur with large packings – the larger the packing, the higher the temperature.

Table 1: **Dry area, flood, and absorption performance vs. packing size**

Size designation	Specific area* (m^2/m^3)	% Flood	Temperature peak (°F)	Treated gas CO_2 (ppmv)
#15	290	94.6	170	0.40
#25	230	71.5	172	0.40
#40	155	65.3	178	0.40
#50	100	52.4	187	0.41
#60	85	49.7	189	0.43
#70	60	47.4	201	1.14

**Specific area is the surface area of the dry packing per unit of packed bed volume.*

Why do the profiles broaden, and why is the bulge temperature so much hotter with very large packings when there is almost complete absorption of CO_2 (>99.9%) and the total heat of absorption that is released is virtually identical in all cases?

Apart from the effect of temperature, the individual-phase mass-transfer coefficients do not vary widely from one packing to another. However, as Table 1 shows, the interfacial area varies markedly and, of course, at the identical gas and liquid flow rates, flooding is further advanced with small packings. Under the conditions of the present case study, treating to <50 ppmv CO_2 is achieved regardless of the packing size, although IMTP #70 barely meets this specification compared with the other packing sizes. Note: values of the area in the table have been rounded, and it might be noted that the designated number sizes correspond roughly to packing diameter in millimetres. It is simplest to address the breadth and position of the bulge first.

The #15 packing has nearly five times the area of #70 packing. One should expect, therefore, that the CO_2 might be almost completely absorbed in a much shorter packed depth. Indeed, the CO_2 composition profiles in Fig. 2 show this is exactly what happens. The treating level of 0.40 ppmv CO_2 is set by the lean loading of

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Fig. 3: **Temperature profiles in new absorber designed for 70% flood – LNG**

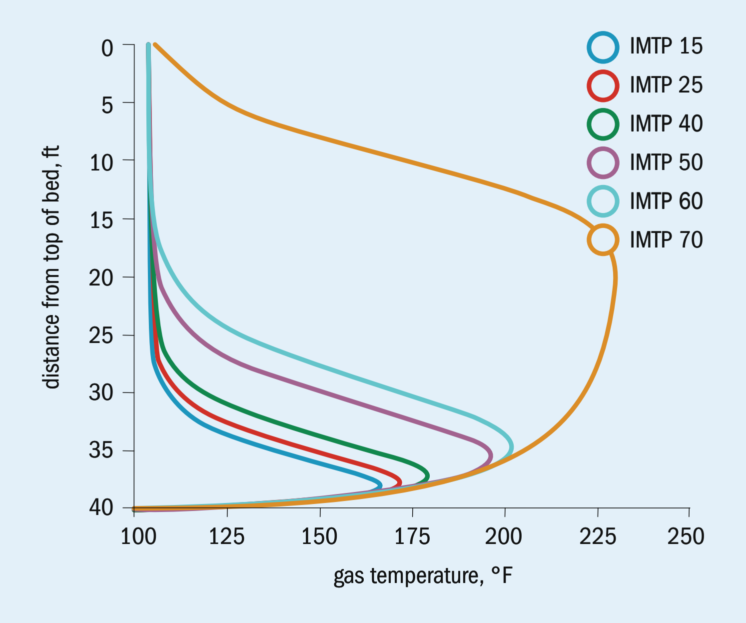
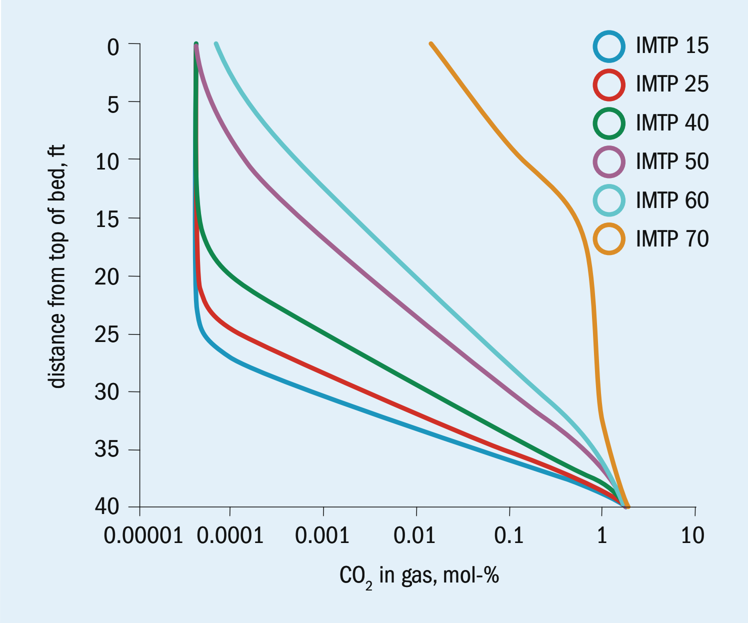


Fig. 4: **New absorber CO_2 concentration profiles and packing size dependence – LNG**



the solvent which, in this case, was 0.0225 moles of CO_2 per mole of total amine (set by the regenerator). Virtually complete absorption is achieved by all but the #70 packing. However, the #15 packing reaches this level of treating after the gas flows through less than the bottom 15 feet of packing. With #60 packing most of the bed is used, and with #70 packing, even using the entire bed depth leaves an unabsorbed residual CO_2 level in the treated gas greater than the lowest achievable level. The width of the temperature bulge shows a rough correspondence with the most actively absorbing region of the bed.

The lesson is that because larger packings have smaller surface areas, they need a greater proportion of the packed bed to reach the target level of absorption, and the temperature bulge is therefore broader. Of course, at the extreme ends of the absorber, phase temperatures return closer to the temperatures of the entering liquid and gas streams. The temperatures of the entering streams drive the temperatures of the hot exiting streams down at the ends of the beds. The remaining question is why larger packings produce hotter bulge temperatures.

Packings with small dry area necessarily have smaller wetted area, and they also have smaller total liquid holdup volume. In the case considered here, there is the same total extent of absorption regardless of the packing size. Thus, there is the same heat released, but now into a smaller liquid volume rather than into a large one. Consequently, the smaller liquid volume associated with a larger packing must become hotter simply in order to absorb the heat released.

Interestingly, this effect is not discernable in the outlet gas and liquid streams. The relative coldness of the feed gas and feed liquid streams dominate the top and bottom temperatures and confine the high temperatures to the column interior, away from the ends. However, keeping tower interior temperatures below a critical value can be paramount in controlling what could become runaway corrosion. If one is unaware of how hot the temperature bulge can really become, it is impossible to account for it in the revamp, so the final revamp recommendations could easily result in a tower that experiences both unexpected and excessive corrosion in actual operation. Ideal stage simulators, even with efficiencies and other embellishments are incapable of predicting this aspect of packing behaviour, however, the ProTreat® simulator's mass transfer rate basis does allow accurate assessment.

New design

New column design for a specified flood rating can present an even greater sensitivity to packing size. Figs 3 and 4 show temperature and composition profiles for a design case using identical gas and liquid flows, compositions and inlet temperatures to the revamp case. Again, the absorber contains 40 ft of packing, but its diameter is now adjusted from one size packing to another so as to achieve 70% flood in all cases.

Now there are very high, broad temperature bulges with large diameter packings, and absorption of CO_2 to design requirements needs more packed bed depth than is necessary when the packings are of smaller size. Large packing can accommodate higher liquid flow rates before flooding. Thus, when design is to a specified percentage flood, the same degree of flooding is reached in a smaller diameter tower when it contains large packing. In other words, the hydraulic load at a given percentage of flood is higher with large packings. Note: Hydraulic load is measured in terms of mass or volume flow rate per unit of tower cross-section and small diameter towers have higher hydraulic load, all other conditions remaining the same.

A new tower with fixed height but operating at the same percent of flood with large packing necessarily contains a lower total packing surface area. The absorption rate is slower which spreads the bulge over more of the column. However, the value of temperature at the bulge is higher in the new-design, large-packing case because the entire tower now has less total holdup volume to contain the released heat of absorption. Note: liquid holdup volume is fairly sensitive to the liquid and vapour loads (per unit tower cross-section). Perhaps the effect of hydraulic load might be more easily understood if hydraulic load were measured on the basis of the unit wetted area of packing as a more fundamentally meaningful parameter rather than on the tower cross-sectional area which pertains to gross hydraulics. In any event,


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Fig. 5: Revamped absorber temperature profiles and packing size dependence

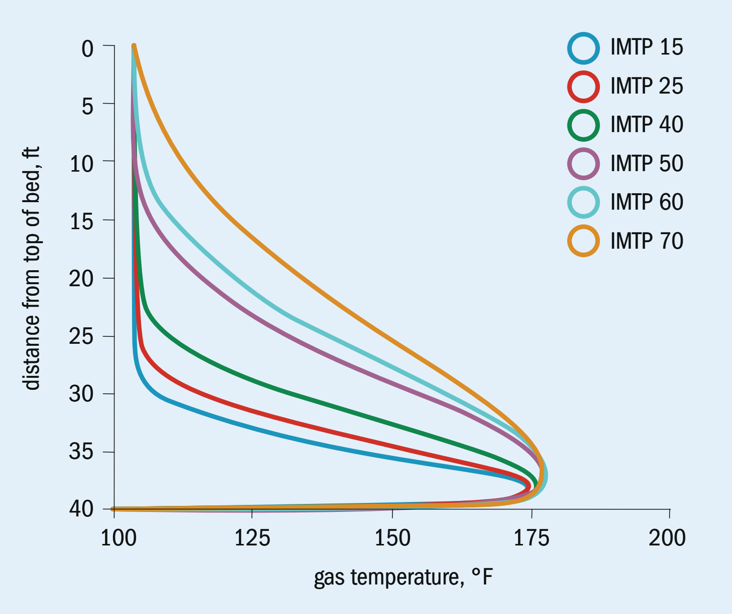
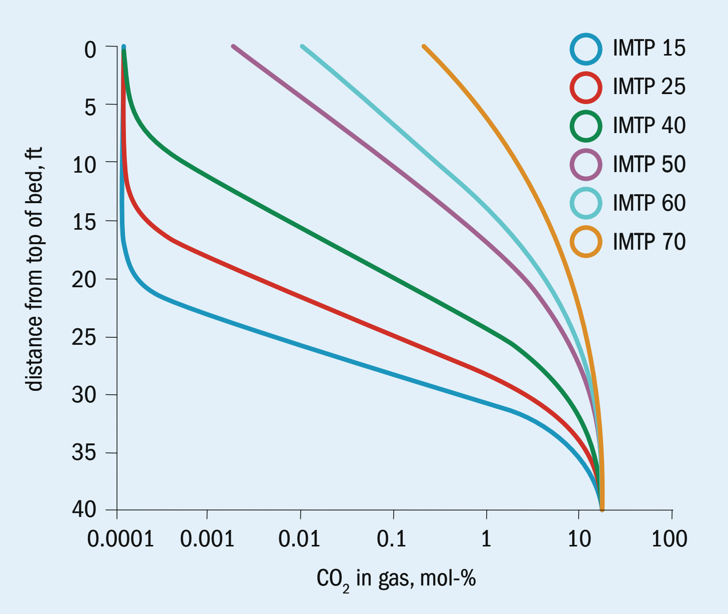


Fig. 6: Revamped absorber CO_2 concentration profiles and packing size dependence



the interaction amongst operating parameters in the design case is somewhat more complex because, unlike in the revamp case, now gross hydraulics is a function of packing size, too.

Case 2: Absorber in ammonia syngas treating

Revamp

The tower to be revamped from trays to packing is 15 ft (4.6 m) diameter with sufficient height to hold a 40 ft (12 m) deep bed of random packing. Solvent and gas flow rates are constant at 4,500 US gpm (1,022 m^3/h) and 250 MMSCFD (280,000 Nm^3/h), respectively. The crude syngas is at 350 psig (24.3 barg) containing 18% CO_2. The solvent is 40 wt-% MDEA promoted with 3 wt-% piperazine. MDEA promoted with moderate levels of piperazine is commonly used in syngas purification because extremely low CO_2 levels are not required in the treated gas. The tower pressures here tend to be lower than in LNG plants and the CO_2 level in the feed gas is usually quite high, 18 mol-% being common. Primary amines such as MEA and amine-promoted hot potassium carbonate are also used commercially in ammonia applications. Again, there are often many non-technical factors that determine solvent selection.

Fig. 5 shows temperature profiles for these packings as predicted by ProTreat® simulation. There are two striking observations that contrast with Case 1:

- Small packings now have only a slightly lower albeit sharp temperature bulge very close to the bottom of the absorber, and the bulge becomes only moderately broader as larger packings are used, and
- Only slightly higher bulge temperatures are predicted to occur with large packings versus the much higher bulge temperatures seen in Case 1.

The reason for the broadening of the temperature bulge in this case is identical with Case 1 – larger packings lack the surface area of small sizes and this slows down absorption rates and spreads absorption across much more of the tower.

Obviously in a column of fixed dimensions, flooding is further advanced with small packings. As Fig. 6 shows, under the conditions of the present case study, treating to below 1,000 ppmv CO_2 is achieved regardless of the packing size, except for IMTP #70 which fails to meet this specification.

The reason for the broadening of the temperature bulge in this case is the same as in Case 1 – larger packings lack the surface area of small sizes. This slows down absorption rates, spreading absorption across more of the tower. Thus, with small size packing, the CO_2 is almost completely absorbed in a much shorter packed depth, and the composition profiles in Fig. 6 show this is exactly what happens. The treating level of 1.26 ppmv CO_2 is set by the lean loading of the solvent which, in this case, was 0.0125 moles of CO_2 per mole of total amine (set by the regenerator). Satisfactory absorption is achieved by all but the #70 packing. However, the #15 packing reaches equilibrium absorption after the gas passes through not much more than the bottom 10 feet (3 m) of packing. With #70 packing, even using the entire bed depth leaves an unabsorbed residual CO_2 level in the treated gas greater than the specification. The width of the temperature bulge shows a rough correspondence with the most actively absorbing region of the bed. But there is a notable difference from the LNG case, now the magnitude of the temperature bulge is almost independent from packing size.

In the LNG example the relatively small CO_2 concentration in a large gas flow needs only a small solvent flow to make on-specification gas. However, crude ammonia syngas has nine times the CO_2 content. Even at the same total gas rate, this requires many times the solvent flow.

The magnitude (and position) of the temperature bulge depends on how strongly the solvent flow can drive the heat of absorption down the tower or, equivalently, how readily the gas flow is permitted to drive it upwards. As shown elsewhere[1], the Heat Transport Capacity Ratio,

$$HTCR = c_p^{(L)}\, L \,/\, c_p^{(V)}\, V$$

measures the relative ability of the two phases to convey heat through the column (c_p is heat capacity and L and V are mass flow rates of the liquid and vapour phases, respectively). The value of the HTCR relative to unity is the major factor determining the position of the temperature bulge.

Fig. 7: **CO_2 concentration profiles and packing size dependence for new absorber in syngas case**

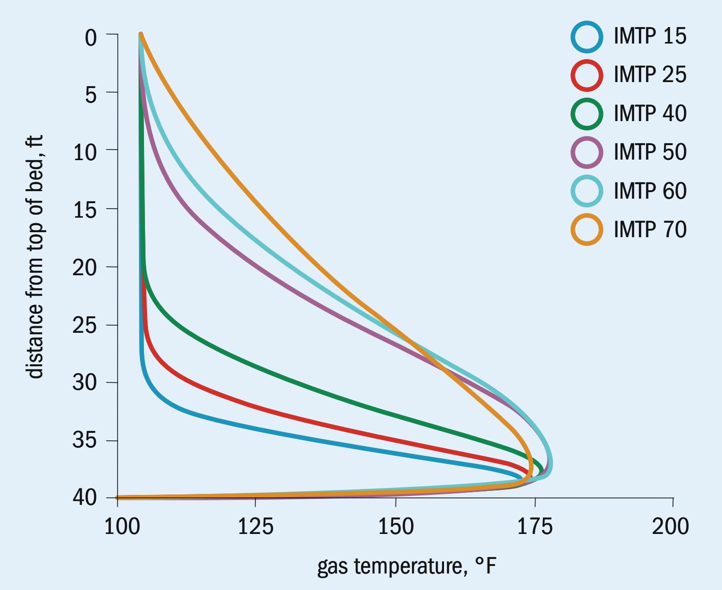
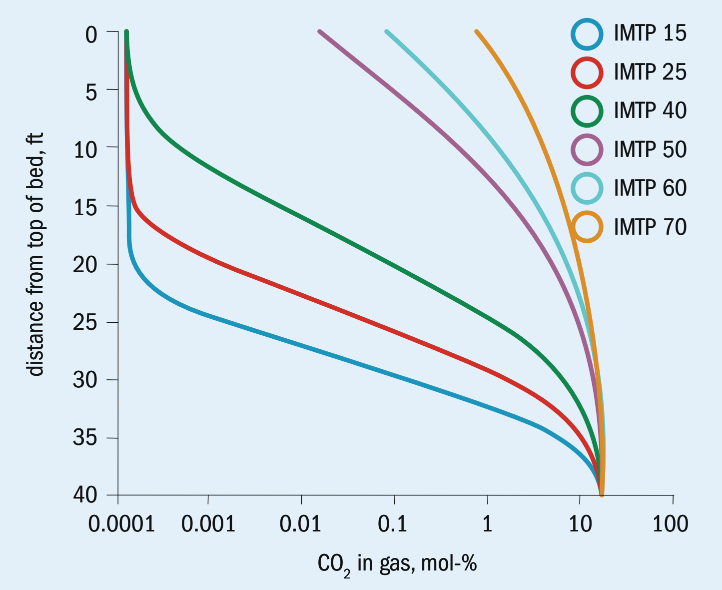


Fig. 8: **CO_2 concentration profiles in syngas absorber designed for 70% flood**



In the LNG example, the HTCR is about 1.4 while in the syngas case it is 12. The much larger heat carrying capacity of the solvent in the syngas case drives most of the released heat out the bottom of the column. In the LNG case, neither phase is dominant, and this allows the temperature bulge to spread more responsively to packing size and to develop a higher bulge temperature.

Design: New syngas absorber

The same reasoning as in the revamp case explains why, for a new design, temperature profiles (Fig. 7) remain fairly close to the revamp case (Fig. 5) and why they do not show the extreme broadening of Case 1. But in the syngas case, #70 IMTP fails to meet the 1,000 ppmv treating goal but quite a bit wider margin (Fig. 8) than in the revamp case. The reason is simple, the design case needs a smaller diameter column than was already available for revamp so the total quantity of #70 packing is smaller and the surface area for absorption is correspondingly lower. There is even less CO_2 absorption possible.

The lesson here is that because larger packings have smaller surface areas, they need a greater proportion of the packed bed to reach the target level of absorption, and the temperature bulge is therefore broader. Of course, at the extreme ends of the absorber, phase temperatures return closer to the temperatures of the entering liquid and gas streams. The temperatures of the entering streams drive the temperatures of the hot exiting streams down at the ends of the beds. It is noteworthy that even the existence, let alone the size of quite a high temperature bulge cannot be detected just by measuring the outlet gas and liquid streams. The same corrosion implications apply to this scenario as for the revamp scenario, if not worse.

Summary

The inability to predict the mass transfer behaviour of packing in gas treating applications can result in less-than-robust designs and failed revamps. Furthermore, high temperature bulges in the wrong place can wreak havoc on the ability of tower shells and packing to resist corrosion. The ProTreat® simulator's fundamentals-based mass transfer rate model validated with extensive operating data is capable of reliably predicting out of the box the location and magnitude of critically important temperature bulges in packed columns, whether in revamp, troubleshooting, or design. This allows engineers to pinpoint accurately the part of the tower most prone to hydraulic flood, the location where corrosion may first become an issue because of a combination of high temperature and high acid gas loading, and where these same factors are most likely to cause the fastest amine degradation. Armed with this information, the engineer is in a position to recommend changes to operating conditions and the best lowest-cost packing size (and type) to mitigate these effects. Without such information any new design, and especially any revamp, is at risk not just of failure to meet treating goals, but also of massive corrosion in the absorber and rapid solvent degradation from the extremely high temperatures possible that are not easily visible just by monitoring treated gas and rich solvent temperatures. ■

Reference

1. https://www.protreat.com/files/publications/176/Contactor%20Vol_10%20No_7%20(Sensible%20Temperature%20Profiles).pdf

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SynCOR™: Modern technology for large chemical complexes

Topsoe's SynCOR™ technologies offer a smart and safe way to utilise the world's natural resources and diversify product slate, while ensuring minimal environmental impact and an attractive return on investment.

As the standard of living continues to rise for a growing world population, more and more people, companies, and nations acknowledge the growing threat of climate change and depleting essential natural resources. This realisation has led to an intensified drive for smart industrial solutions that utilise natural resources in an optimal way, while reducing the environmental impact. The chemical industry is no exception. In the years to come, we will need to optimise return of investment and lower the environmental impact of our operations.

For areas with abundant natural gas, there are already solutions available that support these goals. The Topsoe SynCOR™ portfolio of technologies makes it possible to design large chemical complexes that not only provide the highest level of efficiency and minimum environmental impact, but also low cost of ownership and high safety standards. SynCOR™ produces syngas which can be further processed into methanol, ammonia, diesel, jet fuel, and a wide range of other chemicals.

The combined industrial operation of SynCOR™ units exceeds 70 years. The technology has demonstrated availability factors greater than 99% as an average over operating periods longer than five years. SynCOR™ is continuously developed and improved in very close collaboration with customers, and industries regard the SynCOR™ technology as highly successful.

Fig. 1: Products produced directly or downstream from Topsoe SynCOR™ portfolio

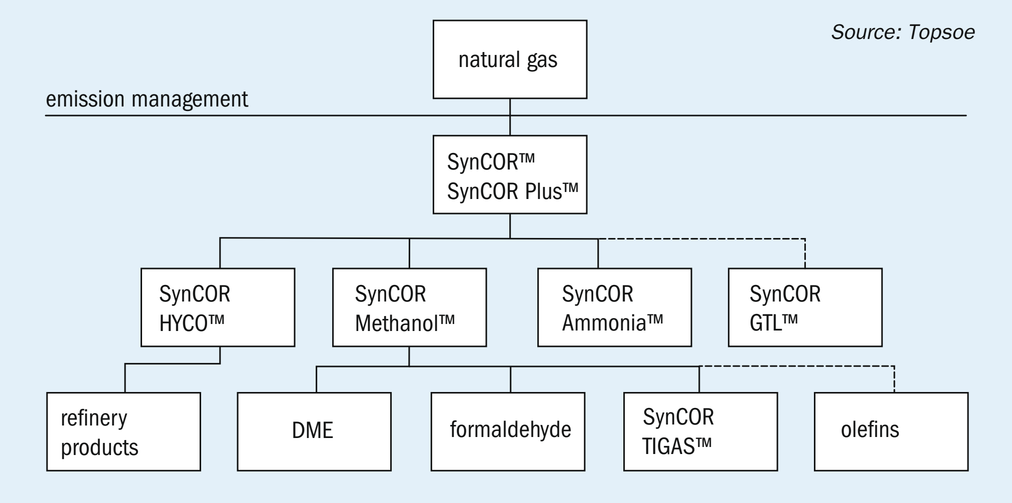

Table 1: Single-line capacities for selected SynCOR™ applications

SynCOR GTL™	SynCOR Methanol™	SynCOR Ammonia™
>19,000 bbl/d	> 8,000 t/d	> 6,000 t/d

Source: Topsoe

End-product flexibility

The variety of products that can be produced directly or downstream from the Topsoe SynCOR™ technology portfolio is presented in Fig. 1. The SynCOR™ portfolio provides economies of scale in large scale production with high end-product flexibility.

The core process step is the production of synthesis gas by autothermal reforming of natural gas. The syngas can then be further processed for the production of:

- methanol and downstream products: DME, formaldehyde, olefins, and gasoline;
- ammonia and downstream urea and other products;
- syngas to diesel and jet fuel by Fischer-Tropsch synthesis;
- syngas for a wide range of other chemicals.

For optimal utilisation of natural gas, SynCOR™ can function as a hub that provides syngas for several downstream synthesis units. This application named SynCOR Plus™ delivers optimal process integration and energy optimisation along with the opportunity to benefit from great product flexibility in times of volatile spot market prices.

Even though emissions with SynCOR™ are low, these large facilities may require emission management to comply with local regulations. Topsoe offers the necessary technologies for cleaning of flue gases.


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Increased safety
Proven technologies
Reducing total cost of ownership and securing a high return on investment over the plant's life cycle.
Scan the code or go to www.topsoe.com/syncor
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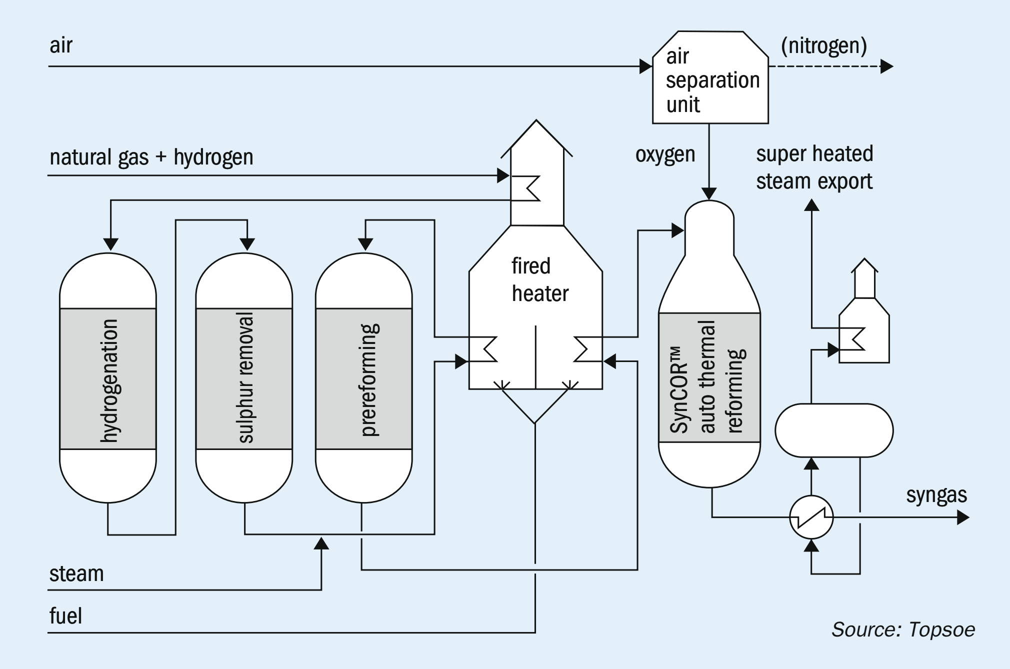
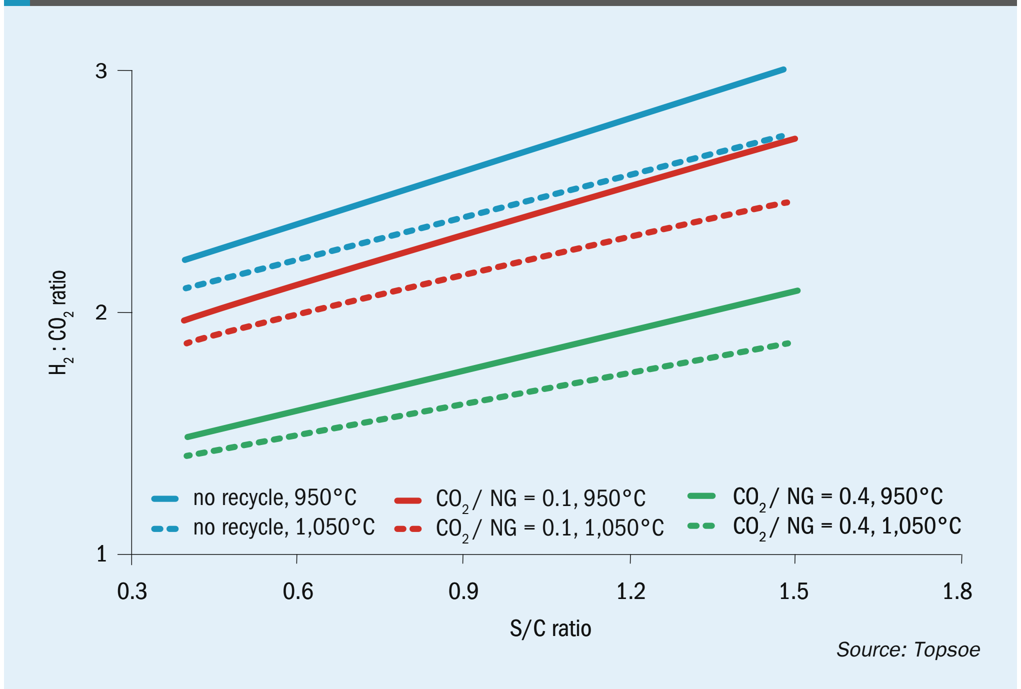
Fig. 2: **Topsoe SynCOR™ simplified layout**



Source: Topsoe

Fig. 3: **Relationship between operating parameters for SynCOR™**



Source: Topsoe

SynCOR™ saves water and energy

In the SynCOR™ process, pre-reformed natural gas is sent directly to an autothermal reformer, where hydrocarbons undergo combustion in the presence of oxygen (Fig. 2). SynCOR™ operates at a steam-to-carbon (S/C) ratio of just 0.6, which reduces water consumption significantly and boosts energy efficiency.

A major feature of the SynCOR™ technology is the ability to directly produce syngas with an H_2/CO ratio of approximately 2.0. This syngas is well suited for the production of both methanol and synthetic diesel via Fischer-Tropsch (FT) synthesis.

For methanol plants, the benefits include higher methanol reaction rates as a result of the high CO/CO_2 ratios in the syngas, low steam requirements that leads to lower capex and opex, and larger single-line capacity because of the low steam throughput.

For ammonia plants, the SynCOR™ front end provides an attractive scaling factor for single trains, 80% reduced steam throughput, and an inert-free ammonia synthesis loop[1].

In the gas-to-liquids (GTL) industry, SynCOR™ is established as the preferred technology for syngas production. The technology's ability to directly produce syngas with a H_2/CO ratio of 2.0 is an unrivalled asset when producing diesel via Fischer-Tropsch (FT) synthesis[2]. In fact, many of the advances made in the SynCOR™ technology are the result of renewed interest in GTL processes, which led to the successful start-up of the world's first large-scale GTL plant by Oryx GTL in Qatar in 2006[3].

Topsoe pioneered advanced autothermal reforming throughout the 1990s and commercialised the low steam-to-carbon ATR technology in 2002.

Carbon capture applied

The industry is looking for solutions for not only capturing but also utilising CO_2 in the production of chemicals and fuels. SynCOR™ makes it possible to recycle CO_2 to the natural gas feed to the unit in order to reach a desired H_2/CO ratio.

Obviously, a feed rich in CO_2 is most beneficial for GTL and methanol production. Depending on the composition of the CO_2-rich stream, it will be necessary to evaluate on a case-to-case basis whether the stream should be put to optimal use in the frontend or the synthesis loop.

The syngas composition outlet the SynCOR™ unit depends on some main operating conditions: pressure, temperature, S/C ratio, O/C ratio and CO_2/NG ratio. Fig. 3 shows the relationship between these parameters when optimised for a GTL and/or syngas (H_2 + CO) application. It is clear that the CO content of the syngas is favoured by low S/C, high temperature, and added CO_2.

The SynCOR™ reactor

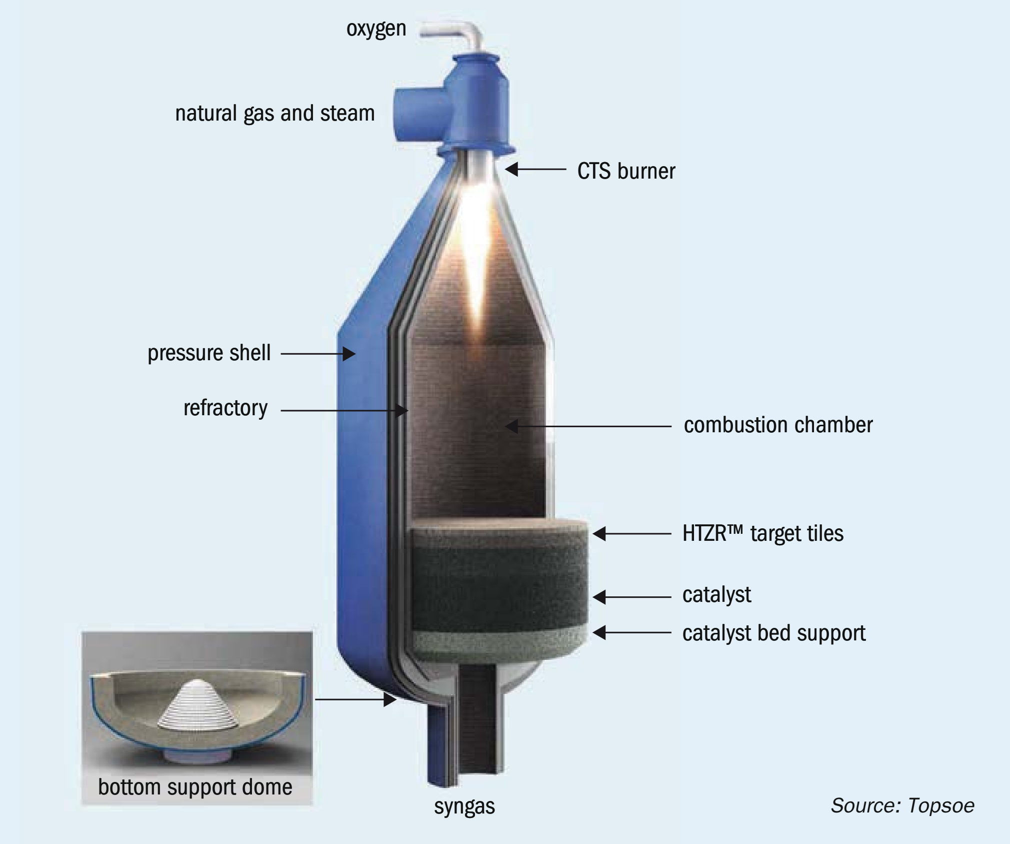
The operating conditions in the SynCOR™ reactor are even more challenging than in oxygen-blown secondary reformers, and the low S/C ratio of 0.6 results in very high combustion intensity and flame temperature. This is why the SynCOR™ process equipment has been specially developed.

The SynCOR™ reactor design consists of a burner, a combustion chamber, target tiles, a fixed catalyst bed, a catalyst bed support, a refractory lining, and a reactor pressure shell as illustrated in Fig. 4.

Flexible production lowers risk

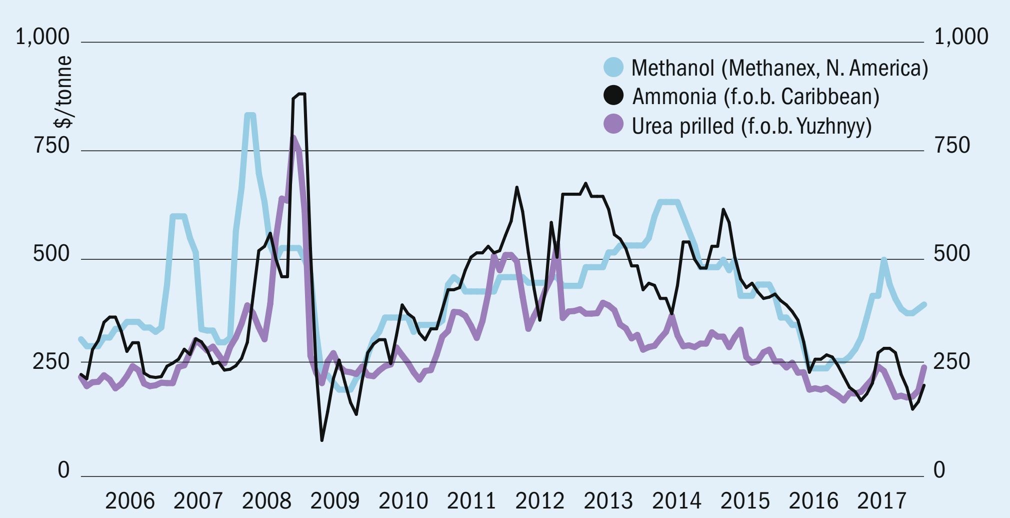
Fluctuating product prices as seen in Fig. 5 for methanol, ammonia, and urea complicates the decision on what products to produce in new chemical production plants.

Fig. 4: **SynCOR™ reactor**



Source: Topsoe

Fig. 5: **Product prices over time**



Source: BCInsight

SynCOR Plus™ provides high efficiency and a low scaling factor and allows the synthesis unit to produce syngas for several downstream synthesis units. This flexibility enables producers to optimally exploit resources, reduce risk, and secure the lowest possible cost of ownership through a broad product slate.

As an example, let's look at combining a 5,000 t/d methanol plant and a 2,000 t/d ammonia plant. These are today's most conventional capacities. Larger ammonia plants exist, but if urea is the desired end-product of the ammonia line, and we envision that the plant is to be built as single line through the entire production line, 2,000 t/d ammonia is reasonable.

A simplified flowsheet for such a plant can be seen in Fig. 6. The benefits of integrating the two plants are immediately obvious – there will be significant savings from only investing in one syngas generation unit, i.e. only one front end, one syngas production line.

SynCOR™ produces syngas with an optimal composition for methanol production at a S/C ratio of just 0.6, which leads to smaller equipment sizes compared to traditional plants and saves capex.

The SynCOR Plus™ process design secures an inert-free ammonia loop – a nitrogen wash upstream from the ammonia synthesis compressor ensures that only hydrogen and nitrogen enters the synthesis loop. The ASU that produces oxygen for the SynCOR™ unit also supplies nitrogen for the nitrogen wash. The absence of nitrogen in the front end sets SynCOR Plus™ apart from large scale conventional ammonia plants and ensures efficient process and minimal size of equipment

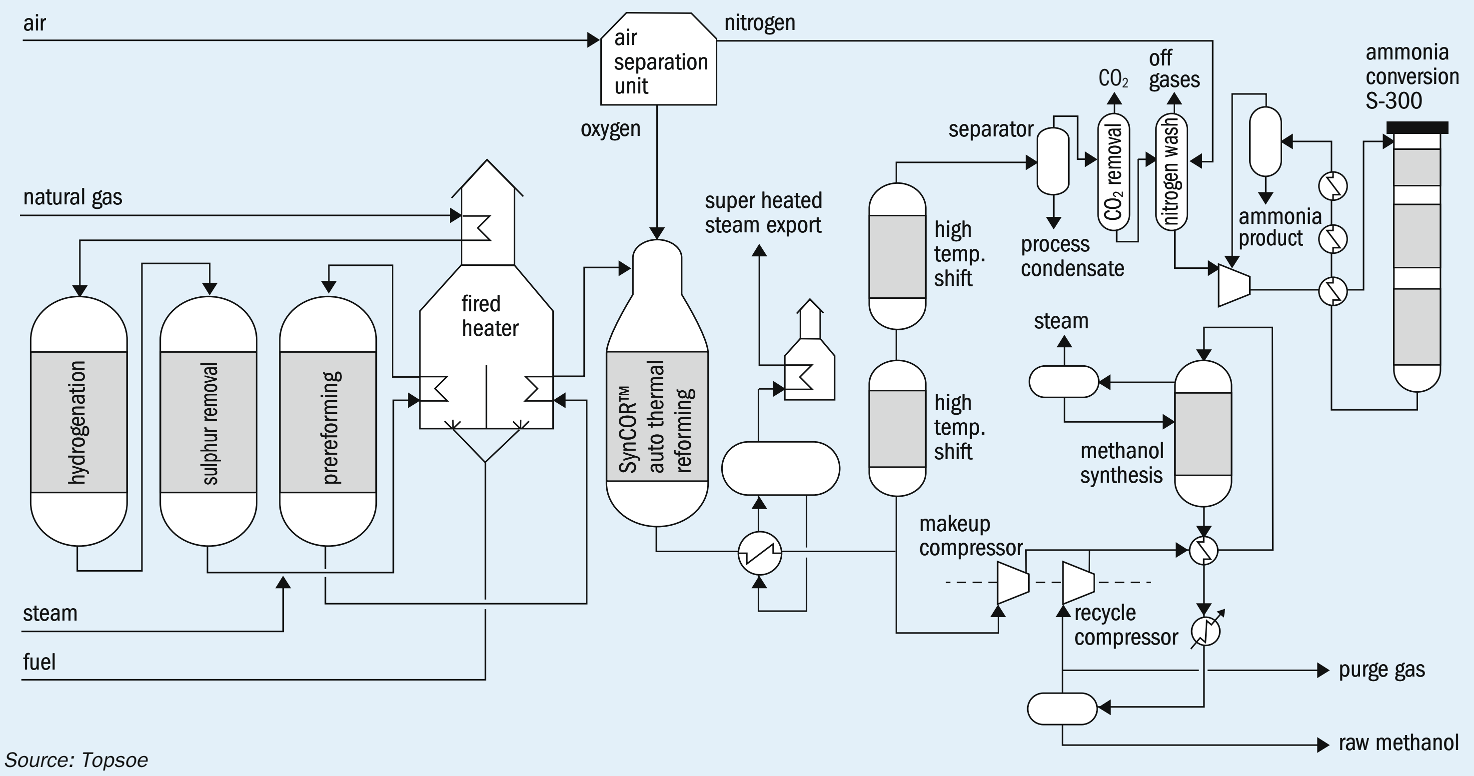
Table 2 shows equipment sizes with SynCOR Plus™ compared to conventional methanol and ammonia plants based on

Table 2: **Comparison of equipment sizes for SynCOR Plus™ with traditional state-of-the-art plants for production of 5,000 t/d methanol and 2,000 t/d ammonia**

	2,000 t/d ammonia	5,000 t/d methanol	SynCOR Plus™ ammonia + methanol
Layout	conventional layout (primary and secondary reforming)	conventional layout (2-step reforming) + ASU (oxygen) plant	SynCOR™ based common front end + inert free ammonia synthesis section + compact methanol synthesis section + ASU (oxygen and nitrogen) plant
Reforming units	primary and secondary	primary and ATR	1 SynCOR™
Compressor size	conventional	conventional	less than conventional
Synthesis reactor size	conventional	conventional	70-75%
Capex (ISBL)	base	base	90%

Source: Topsoe

Fig. 6: **Simplified flowsheet of SynCOR Plus™ with 5,000 t/d methanol and 2,000 t/d ammonia synthesis**



Source: Topsoe

standard SMR and oxygen/secondary reforming, respectively. An important take-away is that even though there is only one synthesis section, the reforming section is not extraordinarily large – as there will only be one SynCOR™ unit compared to conventional lay-out. Due to the low S/C ratio of 0.6, the downstream equipment is also smaller than in conventional plant designs. This all leads to significant capex savings.

Environmental benefits

Besides capex, operational expenses and environmental impact must be minimised when establishing large chemical complexes.

When large volumes of natural gas are available, it is possible to make use of the synergies present in integrated larger complexes and achieve economies of scale. SynCOR Plus™ allows ideal energy optimisation across process units and lowers natural gas consumption by 5% compared to the most modern stand-alone units of the same size. For the example here, this adds up to a cost saving on natural gas alone of almost $10 million/year ($2.85/GJ).

Another benefit is that SynCOR Plus™ slashes water consumption by 60%. This has a huge impact on the environment. In many parts of the world, fresh water is a scarce resource, and this is very often the case in areas with abundant natural gas. In addition, cleaning/conditioning of water in order to make it applicable for chemical processes is both expensive and generates waste. The effluents from SynCOR Plus™ is minimal – 99% of effluents are handled within ISBL.

Due to improved energy optimisation CO_2 emissions can be lowered by as much as 25%. However, by combining Topsoe remaining technology portfolio with SynCOR™ it is possible to replace a large part of the energy consumption with sustainable energy and achieve up to a 40% reduction of the CO_2 footprint. Table 3 provides a direct comparison of consumption figures for SynCOR Plus™ versus traditional state-of-the-art plants for production of 5,000 t/d methanol and 2,000 t/d ammonia.

The example above is fairly simple; the prospect of ROI optimisation is

Table 3: **Comparison of consumption figures for SynCOR Plus™ with traditional state-of-the-art plants for production of 5,000 t/d methanol and 2,000 t/d ammonia**

	2,000 t/d ammonia	**5,000 t/d methanol**	**SynCOR Plus™ ammonia + methanol**
Layout	conventional layout (primary and secondary reforming	conventional layout (2-step reforming) + ASU (oxygen) plant	SynCOR™ based common front end + inert free ammonia synthesis section + compact methanol synthesis section + ASU (oxygen and nitrogen) plant
Natural gas consumption	base	base	95%
CO_2 emission	base	base	75%*
Make up water consumption	base	base	40%
Cooling water consumption	base	base	95%

**assumed full conversion of ammonia to urea*

Source: Topsoe

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SynCOR Ammonia™

Not all regions of the world are ready for very large chemical complexes. However, they can still benefit from the best technologies available.

Today's large-scale ammonia plants all apply some sort of tubular steam reforming. This very mature technology has significant drawbacks. The scaling exponent is very close to one, resulting in almost no economies of scale from increasing capacity. And although it is possible to build large tubular steam reformers, they become increasingly difficult to operate in terms of control, safety, and maintenance regardless of type.

In comparison, SynCOR Ammonia™ scales with a lower exponent and delivers significant economies of scale. Fig. 7 illustrates the difference in scaling between conventional tubular steam reforming and SynCOR Ammonia™.

The SynCOR Ammonia™ solution is referenced within the full capacity range to above 6,000 t/d. Above 3,500 t/d ammonia indicated by the dotted line, SMR technology is beyond reference. As SMR is a very mature technology further significant cost reduction is unlikely, while the SynCOR™ technology and catalyst is continuously improved.

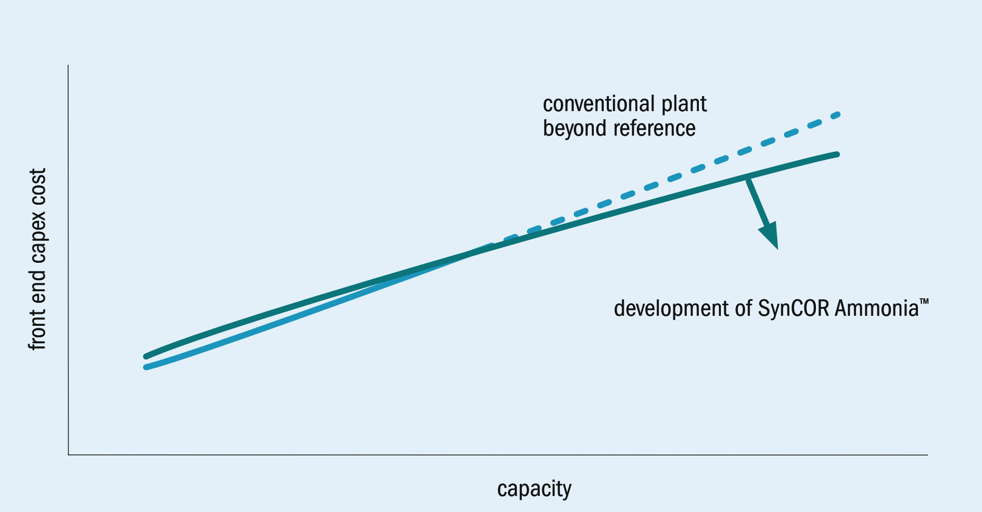
From a capex perspective, both conventional and SynCOR™ plants can be considered for lower capacities. SynCOR Ammonia™ is competitive from well below conventional SMR max capacities and becomes the preferred choice at larger capacities because of its referenced single line capacity above 3,500 t/d with significant economies of scale and lower capex. Where oxygen is available over the fence, capex of the SynCOR Ammonia™ solution is even more attractive.

Detailed studies show additional significant advantages of the SynCOR Ammonia™ plant:

- more than 3% lower opex;
- up to 60% less make-up water consumption;
- improved plant safety with the SynCOR™ reforming unit

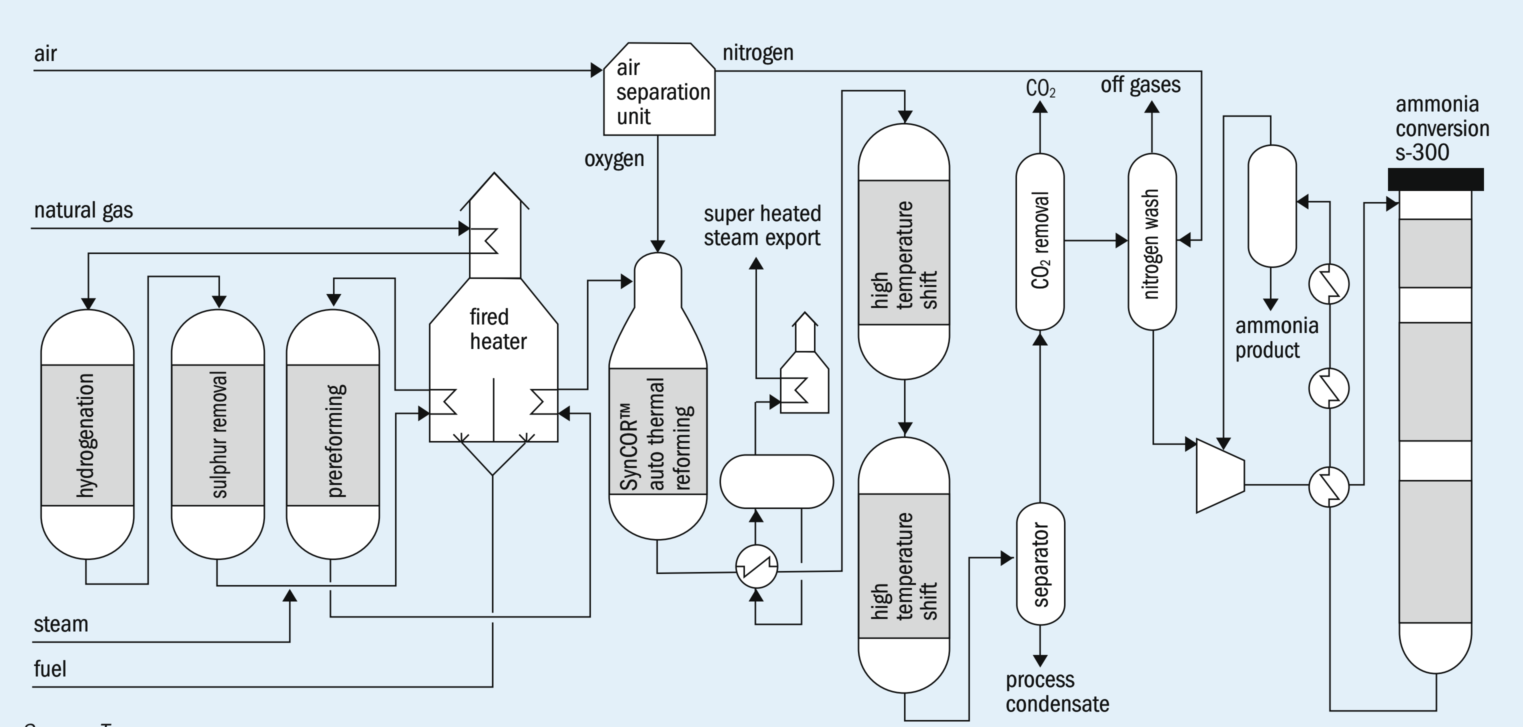
The most significant difference between conventional SMR-based plants and SynCOR Ammonia™ is the S/C Ratios. Conventional SMR-based plants operate at S/C ratios around 3, while a SynCOR Ammonia™ plant operates at an S/C ratio of about 0.6. As a consequence, the steam throughput is reduced by 80%.

Fig. 7: **Front end capex cost conventional vs SynCOR Ammonia™**



Source: Topsoe

Fig. 8: **SynCOR Ammonia™ simplified flowsheet**



Source: Topsoe

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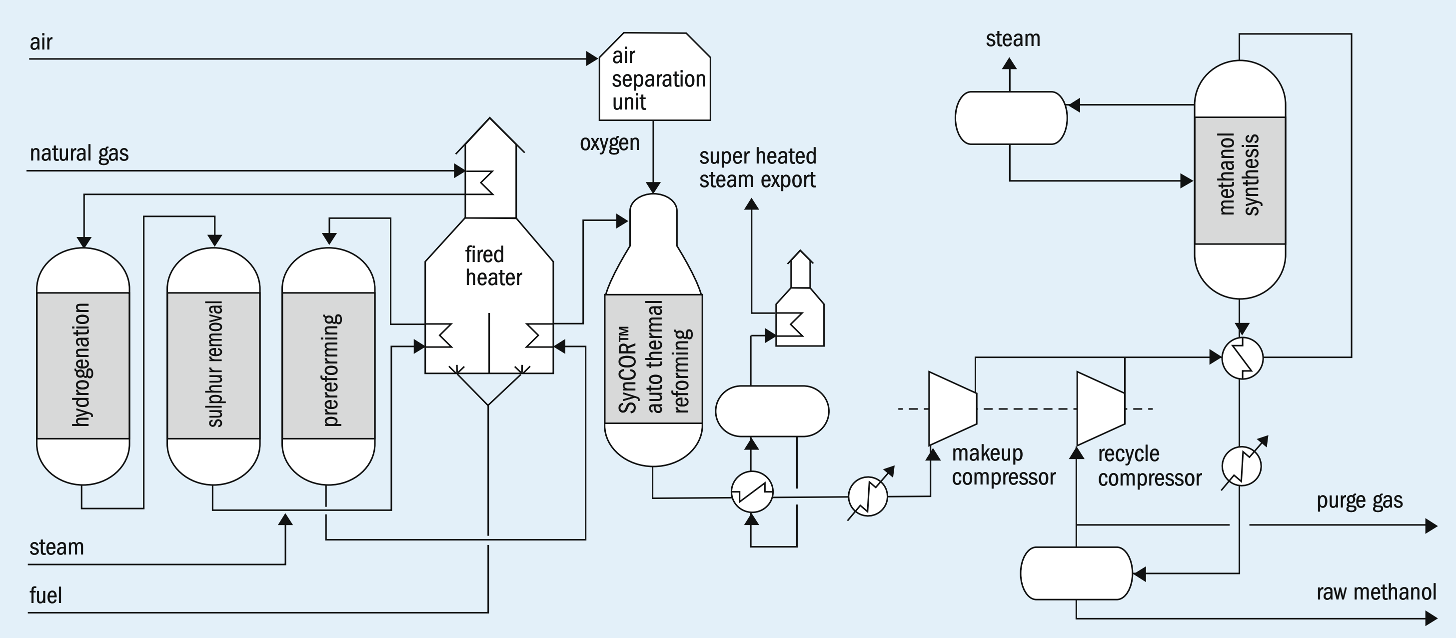
Fig. 9: **SynCOR Methanol™ simplified flowsheet**



Source: Topsoe

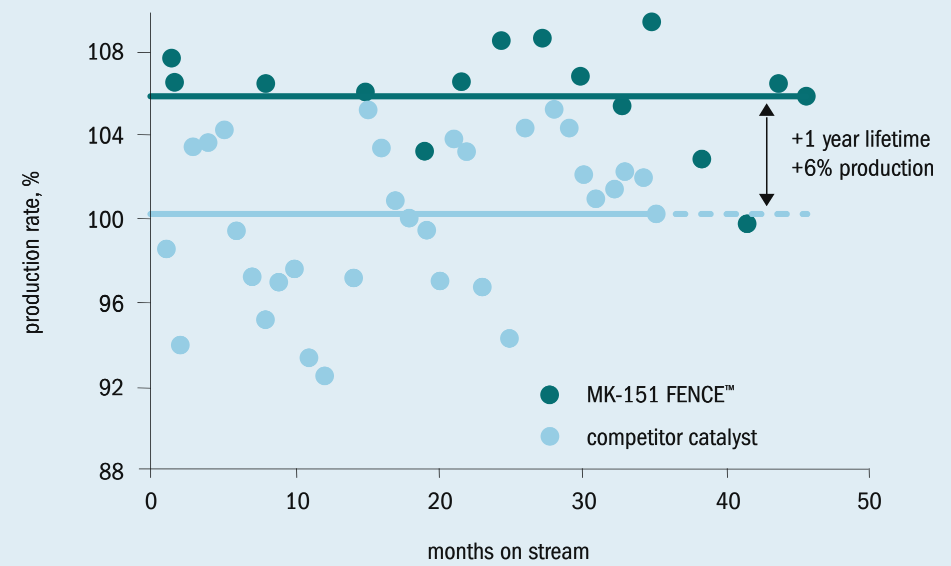
The trick to making this work is the SK-501 Flex™ catalyst. This shift catalyst is based on a promoted zinc aluminum spinel, which can operate at very low S/C ratios at otherwise typical high temperature shift conditions, but without risk to the mechanical integrity or by-products associated with a Fe/Cr catalyst. This catalyst enables a shift section that perfectly matches the S/C ratio of 0.6 in the SynCOR Ammonia™ design.

In conventional plants, the Fe/Cr high-temperature shift catalyst defines the minimal S/C ratio for the shift section. When the S/C ratio is lowered to 0.6, three factors limit the shift section, i.e. the required water content to perform the shift reaction, the acceptable CO slip, and the formation of by-products. An efficient solution to these limitations is the introduction of a second shift operated at medium to high temperature in combination with recirculation of steam from the process condensate stripper.

The process concept based on two shift reactors in series, a nitrogen wash to remove the CO, and recycling of shift by-products, has solved all the challenges in designing a workable shift section of a SynCOR™ based ammonia plant. The involved solutions are cost-efficient and the process technology well proven.

SynCOR Ammonia™ plants also benefit from an inert-free ammonia synthesis with the required nitrogen admitted just upstream of the ammonia synthesis section. Conventional plants introduce nitrogen in the reforming section, Fig. 8 shows a simplified flowsheet of SynCOR Ammonia™.

Fig. 10: **Production rates of Topsoe MK-151 FENCE™ versus competitor catalyst in same plant**



Source: Topsoe

Lower steam throughput and nitrogen-free frontend enable significantly reduced piping and equipment sizes with SynCOR™. This applies not only to the front end, but also the synthesis section, including a smaller synthesis gas compressor/recirculator, ammonia converter, and high-pressure heat exchangers. A further advantage of the inert-free synthesis gas is that a purge gas ammonia wash and hydrogen recovery unit is not required.

The most noteworthy benefit is that SynCOR Ammonia™ uses a single S-300 ammonia converter in a standard, well-proven Topsoe ammonia synthesis loop with single pressure level. Other large-scale designs require multiple pressure levels and multiple reactors in the ammonia synthesis section. The SynCOR™ ammonia converter is already well referenced with catalyst volumes above 150 m³. An inert-free 4,000 t/d ammonia synthesis loop in a SynCOR Ammonia™ plant requires only 105 m³ of catalyst.

SynCOR Methanol™

Methanol plants have increased significantly in capacity in recent years. SynCOR Methanol™ has been on the market for three years and the first plant is currently close to commissioning.

Leading contractors in the industry have evaluated different technical lay-outs to ensure the lowest possible cost of ownership and are now promoting SynCOR Methanol™ as the best solution for large-scale methanol plants.

There are several reasons why this technology utilises natural gas and CO_2 better than conventional solutions. Importantly, SynCOR Methanol™ produces syngas with high CO/CO_2 ratios, which results in higher methanol reaction rates. The technology's low steam requirements lead to lower capex and opex in large methanol plants, and the low steam throughput enables larger single-line capacity. Finally, the process applies the most active synthesis catalyst that secures lower capex and opex. A simplified flowsheet of the process is shown in Fig. 9.

A catalyst is used in order to make chemical reactions occur faster, more efficient and in a controlled manner. Hence, it is of utmost importance that the catalysts used in chemical production plants are of high quality and have been specially developed for the purpose. Topsoe MK-151 FENCE™ is currently the most active and stable catalyst for methanol synthesis. Fig. 10 shows how a methanol plant using MK-151 FENCE™ has been able to operate at a constant rate above design for more than 40 consecutive months.

To continuously improve efficiency and reliability of plants technology must be optimised, but plant owners must also ensure that they use the best available catalysts – otherwise efficiency and reliability, and investor returns, are jeopardised.

Safety

Safety is the most important parameter when designing and operating a chemical plant, both in terms of personal safety, environmental impact, and process reliability. Any accident, environmental slip, or plant upset will have a detrimental effect on return on investment, as production will cease for some duration.

SynCOR™ significantly improves safety on all three parameters. It is inherently safer than conventional plants and has the potential to significantly reduce the number of days with lost production.

The main difference between conventional and SynCOR™ technology is the reforming section. It is well known that tubular reforming involves a great deal of manual operation in the field, and that it can be difficult to implement and maintain a comprehensive Safety Integrated System (SIS) for this technology for the same reason. A large part of the manual fieldwork related to tubular reforming is required to avoid unplanned shutdowns, tube ruptures and to secure continuous performance. SynCOR™ incorporates a complete integrated SIS, which is in place during startup, normal operation and shut down.

The autothermal reactor itself requires no fieldwork during operation. Typically, a simple plant walk-through in every work shift is all that is needed to perform surface monitoring or alternatively camera surveillance can be used. Large-scale tubular reforming can demand as many as two to three more people than SynCOR™ for fieldwork alone. This means that SynCOR™ reduces the number of Lost Time Incidents, simply because less people are exposed to risk. Fieldwork is turned into control room work with more time spent proactively to optimise performance.

Process reliability

A higher degree of automation has a very positive impact on safety and reliability. Automation reduces the risk of human error considerably, simply because fewer operator interactions are required, and by applying strict permissives when interactions occur. This is a win-win situation since fewer human errors result in less lost time accidents, increases the availability of the plant, and thereby reduces the environmental impact by reducing flaring caused by erroneous upset situations.

Automation of the SynCOR™ plant operation also enables remote operation, which can provide the benefit of fewer errors and more efficient operation. The net result is a higher general safety level and a better bottom line. ■

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A new flowsheet for methanol production

The DAVY™ advanced series loop (ASL) developed by Johnson Matthey is a new multi-reactor flowsheet for methanol. In this article, **C Yiu** of Johnson Matthey looks at how the DAVY ASL combines the advantages of both a high recycle ratio and low recycle ratio loop using existing reactor designs. The article also compares the expected performance against some well-known methanol flowsheets.

An axial steam raising converter (ASRC) has high heat transfer area per unit volume of catalyst (100 m²/m³), so it can handle high reaction rates. Due to its catalyst-in-tube design with a restricted flow area, it has high pressure drop if the flow is high. The ASRC is suitable for low recycle ratio operation and high carbon oxide concentration.

A radial steam raising converter (RSRC) has an ultra-low pressure drop design where it has little penalty even at very high recycle ratio. The RSRC has a medium heat transfer area per unit of catalyst (25 m²/m³) but it can hold more catalyst per unit volume of reactor. The RSRC is suitable for high recycle ratio and low carbon oxides concentration.

Recycle ratio is a well-known term in methanol loop design and it is a term clients like to discuss in technical meetings.

Low recycle ratio means a high concentration of carbon oxides into the reactor which means a high concentration of methanol at the outlet. Methanol synthesis is an equilibrium reaction and a high concentration of methanol also requires a relatively high concentration of carbon oxides at the exit of the converter, and therefore relatively high quantities of carbon oxides are lost in the loop purge.

High recycle ratio means a low concentration of carbon oxides into the reactor which means a low concentration of methanol at the outlet. This leads to a relatively low concentration of carbon oxides at the exit of the converter, and therefore relatively low quantities of carbon oxides are lost in the loop purge.

Some characteristics of high and low recycle ratio loops are summarised in Table 2. A better way to think about recycle ratio is that it is the amount of recycle gas you need to dilute the carbon oxides concentration of the feed make-up gas so that the gas is suitable for the reactor of choice. Each reactor has a specific optimum operating range. So instead of thinking about recycle ratio, let's think about carbon oxides concentration and use the term dilution requirement.

The new loop

All make-up gas, whether it is from natural gas or coal gas, has a higher carbon oxides concentration than the gas in the loop. The concentration in the gas to the reactors depends on the recycle ratio (or the amount of dilution flow).

So why not do some of the reaction at high carbon oxides concentration? That way, the reaction in the first reactor will naturally drive down the concentration for the second reactor. Then we can drive down the concentration further with recycle flow.

Fig. 1 shows how the system can be divided into a high-carbon loop (high-carbon oxides concentration) and a high-hydrogen loop (low-carbon oxides concentration).

Since the purge is not taken from the high-carbon loop, any unreacted gas can be further processed by the high-hydrogen loop, maintaining overall feed conversion efficiency similar to what is achieved in a high recycle ratio loop.

The DAVY ASL arrangement

The ASRC has a low cross-sectional area for flow, so the lower the flow that can be fed to it, the more beneficial (in terms of pressure drop). We want to dilute the make-up gas concentration down to the optimum range, so the dilution flow will be minimised if the dilution flow has the lowest concentration of carbon oxides (i.e. take the dilution flow from the high-hydrogen loop). Because the pressure drop is minimised, the ASRC tubes can be longer, giving a smaller reactor diameter for the same catalyst volume.

One minor adjustment is when, due to project-specific transportation limits, the

Table 1: **Characteristics of ASRC and RSRC**

Reactor type	ASRC	RSRC
Heat transfer	100 m²/m³	25 m²/m³
Pressure drop	high	low
Limitation	pressure drop	heat transfer
Suitability	low recycle ratio	high recycle ratio

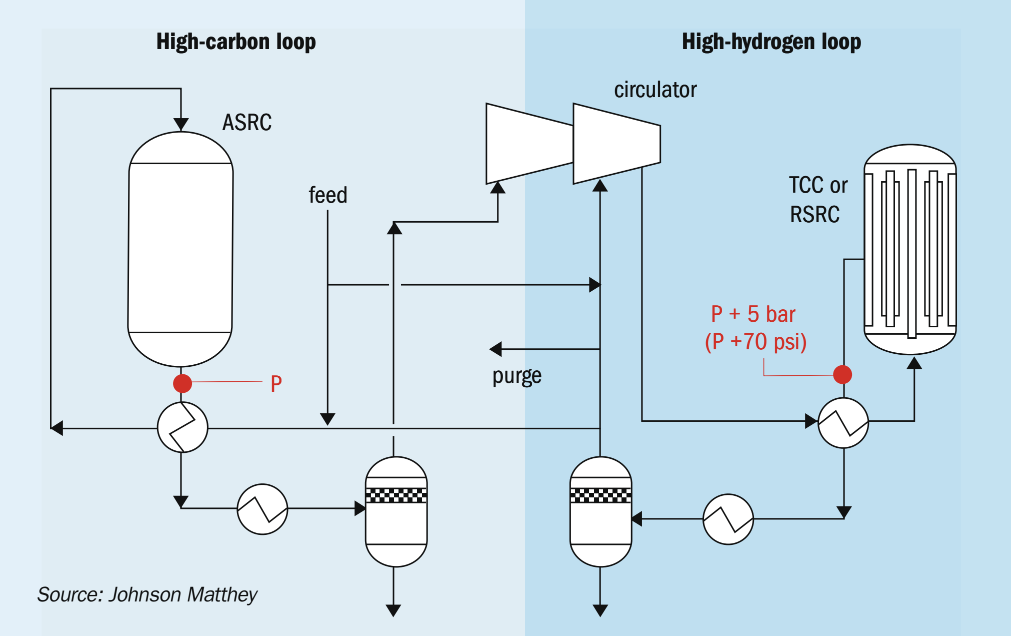
Source: Johnson Matthey

Table 2: **Characteristics of high and low recycle ratio loops**

Loop type	Low recycle ratio	High recycle ratio
Purge rate	high	low
Purge inert conc.	low	high
Feed efficiency*	90-95%	95-99%
Circulator flow*	low	high

**At fixed catalyst volume and operating pressure* *Source: Johnson Matthey*

Fig. 1: **The DAVY ASL flow scheme**



Source: Johnson Matthey

ASRC is not able to handle all the make-up gas feed. Rather than add a second ASRC, a proportion of the make-up gas feed can be sent directly to the high-hydrogen loop.

The high-hydrogen loop is at slightly higher pressure than the high-carbon loop. This arrangement means that only a part of the make-up gas needs to be compressed to the higher pressure, reducing the syngas compressor power.

The purge is taken from the gas stream leaving the high-hydrogen loop separator because this stream has the lowest carbon oxides and highest inert concentration, minimising the purge flow rate and associated loss of reactants.

The DAVY ASL vs other multi-reactor type flowsheets

There are already operating examples where multiple reactor types are used in a methanol loop flowsheet. In the flowsheets detailed in Figs 2 and 3 there are two reactors of different type, connected in series with a single circulator. The recycle ratio (the dilution requirement) is set by the first reactor, and in these cases both are ASRC. That means they are both low recycle ratio loops.

These flowsheets rely on the first reactor (ASRC) to perform its design duty in order to bring the reactivity of the gas down to suitable level for the second reactor. If the first reactor is prematurely deactivated (e.g. due to poisoning), then the gas that enters the second reactor would have a higher carbon oxides content and become too reactive for the second reactor, leading to overheating and non-optimum operation in this reactor. In order to avoid any unsafe conditions, plant throughput would have to be reduced even though the catalyst in the second reactor is still very active.

The new DAVY ASL is less prone to this issue because it has the flexibility for each reactor to achieve its correct dilution requirement, therefore even if the first reactor suffers premature deactivation, the second reactor will continue to operate safely while the catalyst is active.

The dilution requirement for the first reactor is controlled by adjusting the flow from the separator of the in high-hydrogen loop (using a simple ratio controller). The dilution requirement of the second reactor will be automatically controlled by a pressure controller adjusting the circulator speed. As the catalyst slowly deactivates, the unreacted gas exit the first reactor will increase, causing a small rise in the pressure at the suction of the circulator. The control action will speed up the circulator and consequently the circulation of the high-hydrogen loop will increase, reducing the $CO + CO_2$ concentration inlet the second reactor and thus provide the correct dilution requirement.

The original DAVY series loop from Johnson Matthey[3] does not have an equivalent issue because all of the operating examples use a single design for both first and second reactor.

The DAVY ASL vs the original DAVY series loop

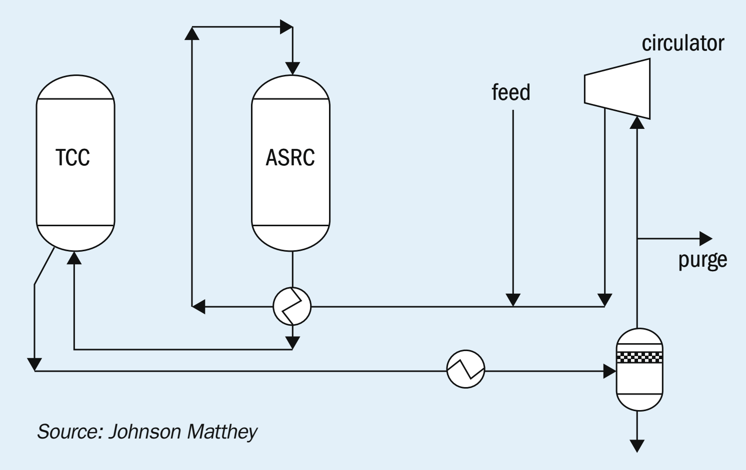
From a process flow diagram point of view, the changes seem small: one of the RSRC has been replaced by an ASRC and the circulator has two suction stages, receiving gas from both separators (see Fig. 4).

From an equipment point of view, the loop equipment and piping for half of the loop is smaller (in the high-carbon loop).

From the flowsheet point of view, the differences are:

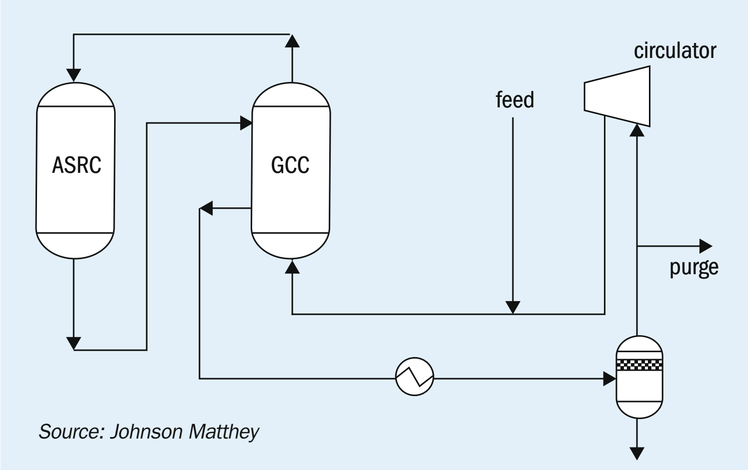
- in the DAVY ASL all the make-up gas feed goes to the first reactor;
- the DAVY ASL uses less energy;
- the DAVY ASL uses less catalyst.

Fig. 2: **The DAVY combi loop**[1]



Source: Johnson Matthey

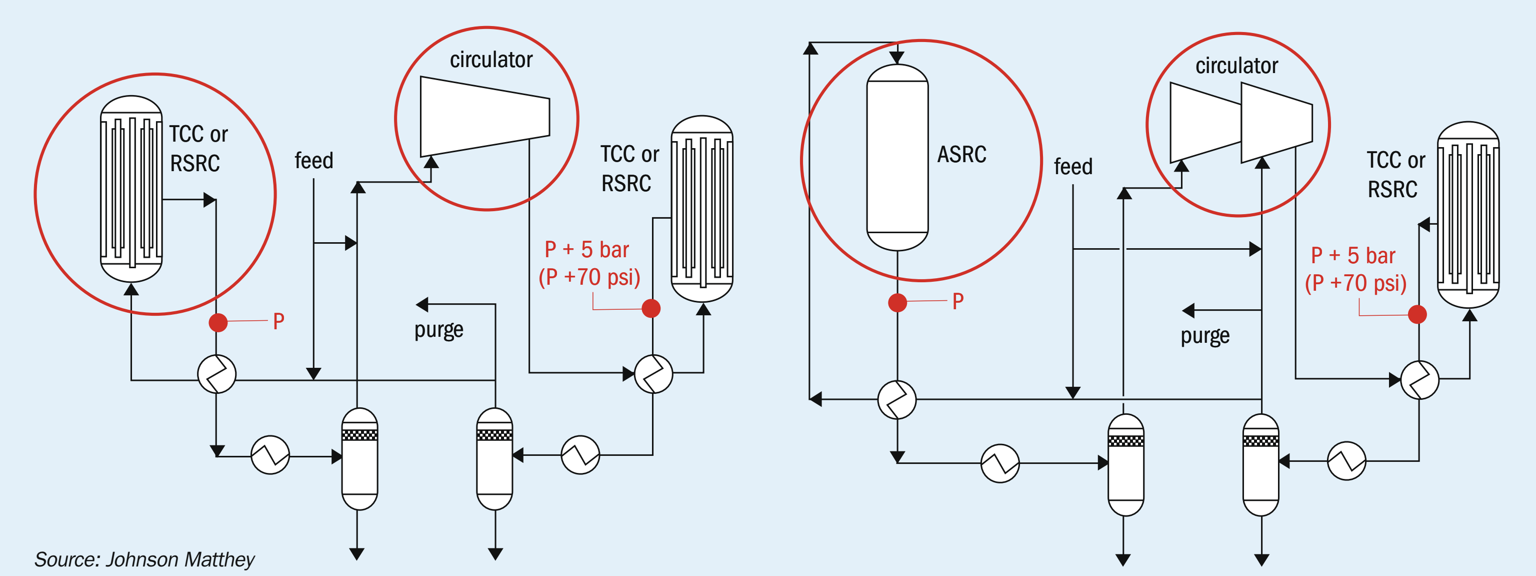
Fig. 3: **Lurgi megamethanol**[2]



Source: Johnson Matthey

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

Fig. 4a: **The DAVY original series loop**[3] Fig. 4b: **The new DAVY ASL**



Source: Johnson Matthey

Table 3: **The DAVY ASL vs the DAVY original series loop**

Fixed feed/same pressure	**ASL is...**
Total catalyst, m^3	better by 13%
Syngas comp power, MW	same
Total circulator power, MW	better by 44%
Total machine power, MW	better by 23%
Converter steam, t/h	better by 13%
MeOH in crude, t/d	worse by 0.7%
Interchanger 1 area, m^2	better by 62%
Interchanger 2 area, m^2	better by 35%
Basis: 5,500 t/d (6,060 short t/d) plant, fixed feed rate, same syngas discharge pressure	
Value ($/t MeOH)	**ASL is...**
Methanol product	same
Converter steam export	better by $3
Total value	**better by $3**
Cost ($/t MeOH)	**ASL is...**
Syngas consumption	worse by $1.84
MP steam cost	better by $2.29
Catalyst cost	better by $0.10
LP steam cost	same
Cooling water cost	better by $2.85
Total cost	**better by $3.4**
Value: cost	**better by $6.4**

Basis: Client cost model used during proposal
Source: Johnson Matthey

Table 4: **The DAVY ASL vs the DAVY combi loop**

Fixed feed basis	**ASL is...**
Pressure, bar (psi)	lower by 12 (175)
Total catalyst, m^3	same
Syngas comp power, MW	better by 33%
Total circulator power, MW	worse by 47%
Total machine power, MW	better by 15%
MeOH in crude, t/d	better by 3.3%
MP steam for turbine, t/h	better by 15%
Converter steam, t/h	worse by 16%
Basis: 2,000 t/d (2,205 short t/d) plant, fixed feed rate, same catalyst volume	
Value ($/t MeOH)	**ASL is...**
Methanol product	same
Converter steam export	worse by $4.12
Total value	**worse by $4.12**
Cost ($/t MeOH)	**ASL is...**
Syngas cost	better by $9.80
MP steam cost	better by $1.84
Catalyst cost	same
Total cost	**better by $11.64**
Value: cost	**better by $7.52**

Basis: Client cost model used during proposal
Source: Johnson Matthey

In Table 3 it can be seen that the DAVY ASL wins on almost all counts, with lower catalyst volume and lower equipment size.

It also shows that the DAVY ASL creates higher value, due to the increase in steam export, and lower cost – and therefore more profit per tonne of methanol.

The DAVY ASL vs the DAVY combi loop

The DAVY combi loop, as with all previous low recycle loops, uses a higher operating pressure to achieve a competitive loop carbon efficiency. The DAVY ASL achieves a better feed and energy efficiency for the same catalyst volume, but operating at lower pressure. Table 4 compares the two loop arrangements.

From Table 4 we see that there are some things that are better, some that are worse, so we need to look at the economic comparison for a better picture.

While the DAVY ASL has lower value due to the decrease in steam export, this is more than offset by a bigger saving in the costs – and therefore overall more profit per tonne of methanol.

Conclusion

This article gives an insight to the benefits of the new DAVY ASL. This optimised flowsheet delivers higher efficiency as well as capital cost saving in terms of loop piping and equipment. ■

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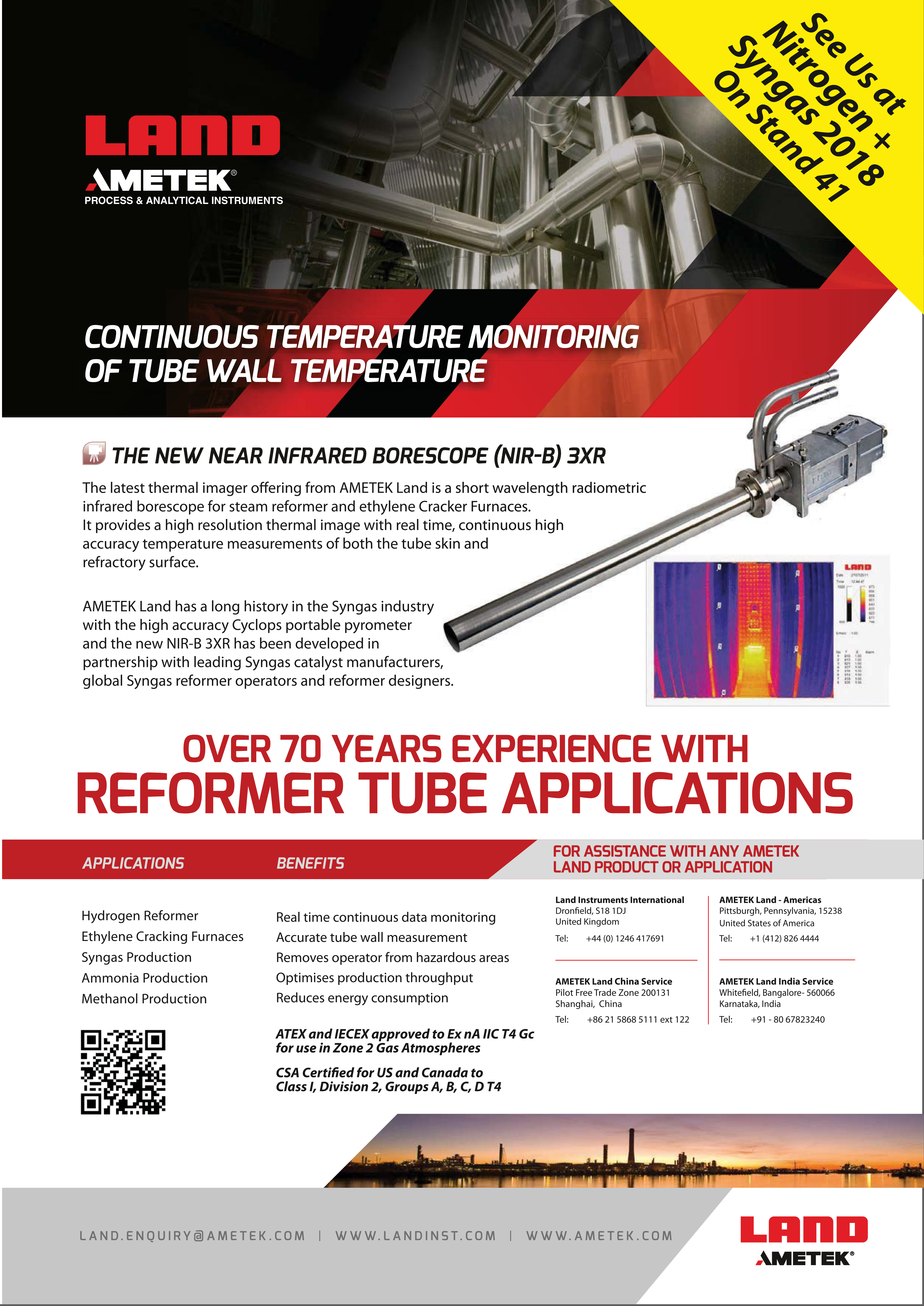
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Editor: RICHARD HANDS
richard.hands@bcinsight.com

Technical Editor: LISA CONNOCK
lisa.connock@bcinsight.com

Contributors:
LAURA CROSS
laura.cross@integer-research.com

MIKE NASH
mike.nash@ihs.com

Publishing Director: TINA FIRMAN
tina.firman@bcinsight.com

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Southbank House, Black Prince Road
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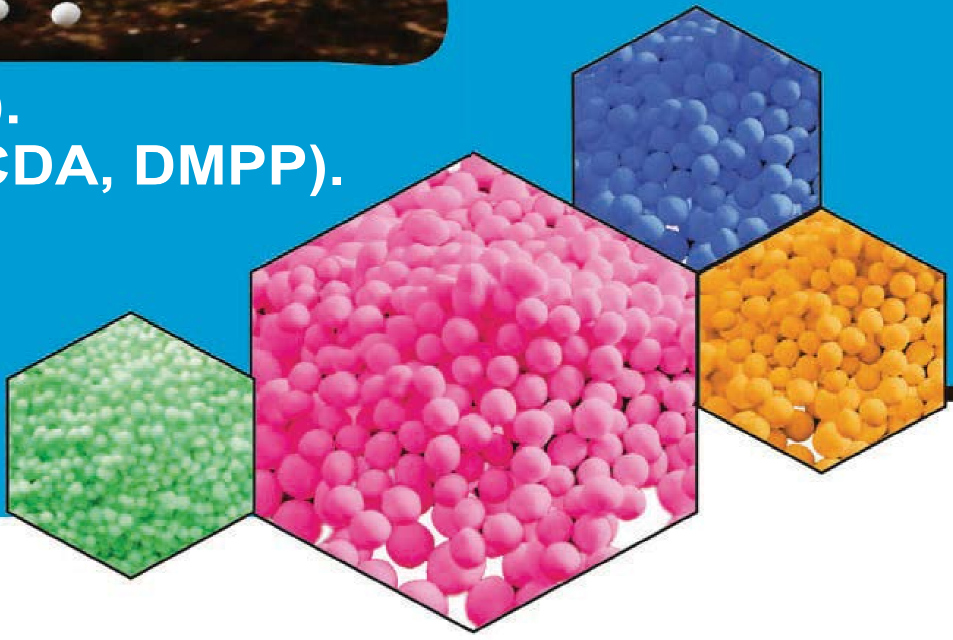

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