Ammonia's time to shine has come

Making the transition from versatile specialty gas to energy vector

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Ammonia is used for a myriad of industrial and specialty gases applications. It can be cracked to hydrogen and used for metals heat treatment to create a reducing atmosphere for annealing. Nitriding for metals heat treatment also requires ammonia. As a refrigerant gas, ammonia is deployed in most modern carbon dioxide (CO_2) liquefiers to cool gaseous feedstock to CO_2 in a cryogenic liquid form. The market for ammonia in these traditional industrial and specialty gases applications continues to grow steadily.

The energy transition is creating a step change in the growth potential for ammonia and paving the way for extremely high-volume applications. The supply chain for ammonia from production through to distribution and storage will expand dramatically.

Gas-fired power plant

And, since ammonia is of interest as a clean energy vector in support of decarbonisation, it must be produced in a low-carbon way using new technologies. Ammonia's time has come, and the industrial gases sector has the expertise to support the next wave of ammonia growth.

Bulk-breaking, blending and repackaging

Saudi Arabia is one of the largest bulk ammonia producers globally but at the same time, packaged ammonia is imported due to the limitation in local facilities. Localisation is a focus in the kingdom of Saudi Arabia (KSA) and Rawabi Holding Group and its subsidiary in Al Jubail, Rawabi Industrial Gas (RIG) has a clear vision to be active in the drive towards localisation.

Rami Nasser, General Manager at Rawabi Integrated Gas says that "we have invested in a world-class facility to serve increasing local demand for packaged aqueous and anhydrous ammonia. Our project aligns with the Saudi Vision 2030, which aims to support and develop local industries."

"Ammonia for our facility is produced by the Saudi Arabian Fertilizer Company, SAFCO," states Nasser. "We are also in negotiation with Maaden to secure an additional local supply of ammonia."

Commenting on RIG's approach, Nasser says that his "main aim is to supply ammonia with the highest quality standard and establish an international level of safety awareness through the value chain."

Using automised processing systems, RIG will be able to produce a stable aqueous ammonia solution. This is achieved using cooling during the exothermic mixing of ammonia with water. Cooling during blending is essential when operating in KSA where the ambient temperature is frequently above 35°C.

Nasser confirms that "RIG is ready to serve applications for anhydrous ammonia in industrial refrigeration, water treatment, rubber and leather processing." He adds that "packaged ammonia can be supplied in different purities such as 99.5% as an industrial grade and 99.99% as a refrigeration grade. The packaging is mainly in 50kg cylinders and 400kg drums."

The applications for aqueous ammonia differ from anhydrous ammonia gas. "With controlled blending and the option of stainless-steel storage tanks, RIG will have the capability to supply pharmaceutical, food and industrial applications," says Nasser. "Up to four different concentrations can be produced and stored at a time and will be supplied in road tankers, ISO tanks, IBC's, drums and jerricans."

Decarbonising ammonia production

Almost 100 years ago, in the 1930s ammonia was being produced from curtailed hydropower by the Hydro-Electric Power Commission of Ontario in Canada. At a similar time in Rjukan, Norway, 165 MW of electrolyser capacity across 150 modules produced 27,900 Nm^3 per hour of hydrogen to make ammonia through combination with nitrogen in the Haber-Bosch process. The ammonia was subsequently converted to ammonium nitrate fertiliser using the Otwsald Process which is often fed with oxygen from an air separation unit (ASU).

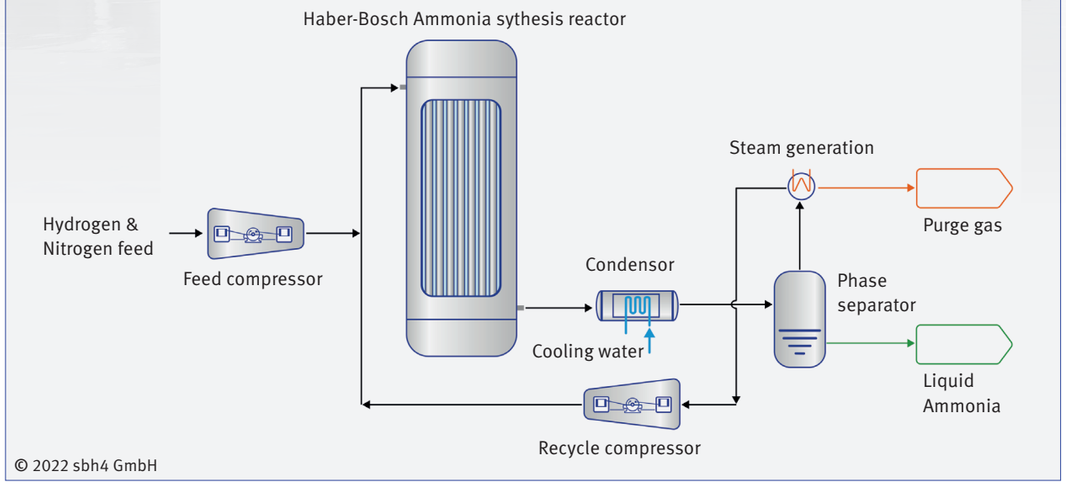
> "Ammonia's time has come, and the industrial gases sector has the expertise to support the next wave of ammonia growth"

In the 1960s and 1970s, green hydrogen was produced on MW-scale electrolyser schemes pulling renewable hydropower on the Aswan dam in Egypt. Green nitrogen-based fertilisers to develop local agriculture for food and cotton was the goal.

Green hydrogen and green ammonia projects in this decade have yet to catch up with the scale of operations from the past century. The first GW-scale green ammonia scheme to start up, in NEOM in the Kingdom of Saudi Arabia (KSA), has been pioneered by Air Products. Electrolysers will convert water to hydrogen, which will be reacted with nitrogen from ASUs supplied by Air Products to produce ammonia.

Hekinan coal-fired power plant, Japan

Figure 1. The Haber-Bosch Ammonia Synthesis Process



Green ammonia from this project is destined to be exported by ship to energy importers in Asia and Europe that are seeking to decarbonise power generation and heavy industry. Air Products will also be instrumental at the receiving end of the green ammonia supply chain. The company has announced its intention to partner with Oiltanking Deutschland (a subsidiary of Mabanaft) to construct an ammonia import terminal in Hamburg, Germany. Hamburg is the head office location of Mabanaft.

170 liquid anhydrous ammonia tankers sail the oceans each day, moving their ammonia cargoes between 120 port locations. Its high volumetric energy density makes it easy to store and distribute in this mode. Ultimately, ammonia has the potential to displace LNG as a fungible and internationally transportable energy vector.

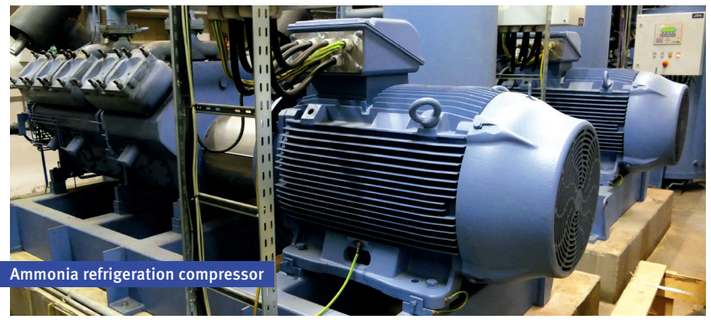
Clean power generation with ammonia

Ammonia co-firing on a coal-fired power plant in Japan is planned for 2027. JERA, Japan's largest power generator has proposed to co-fire 20% ammonia on one of the four 1GWe generation units at its coal fired Hekinan power station.

In 2022, JERA issued a tender for low-carbon ammonia supply where the expectation was that the CO_2 emissions from ammonia production would be at least 60% lower than conventionally produced ammonia. JERA awarded the supply to CF Industries Inc and Yara Clean Ammonia AS. Both are proposing to produce ammonia in the US Gulf coast.

In a similar development, Linde has entered into an agreement to supply the ammonia producer OCI with nitrogen gas and blue hydrogen to produce low-carbon ammonia on the gulf coast. During blue ammonia production, the CO_2 emissions from steam methane reforming, autothermal reforming or partial oxidation of natural gas are captured and permanently sequestered.

Ammonia also has the potential to be fired on turbines for power generation, as natural gas is used today. Many leading turbine manufacturers such as GE and Toshiba are innovating in this area. One of the technical challenges is to avoid the generation of nitrous oxide emissions from the combustion. The use of ammonia as a fuel avoids CO_2 greenhouse gas emissions, but nitrous



Ammonia refrigeration compressor

Table 1. Ammonia, A Myriad of Traditional and Emerging Applications

Traditional applications	Purity grade	Supply scale
Refrigerant gas	Specialty gas	Cylinders or drum tanks
LED production	Semiconductor grade	Drum tanks
PV Solar cell production	Aqueous ammonia	IBCs or bulk liquid
DeNOx with SCR or SNCR	Aqueous ammonia	Bulk liquid
Heat treatment of metals	Oil-free	Cylinders or drum tanks
Latex storage and transportation	Technical-grade	Cylinders
Water treatment	Technical-grade	Cylinders or drum tanks
Direct application as fertiliser	Technical-grade	Bulk anhydrous liquid
Urea production	Technical-grade	Pipeline supply
Ammonium nitrate production	Technical-grade	Pipeline supply
Emerging applications		
Maritime fuel		Port terminals and bunkering
Land-based mobility		Bulk liquid
Aviation fuel		Airport terminals and bulk liquid
Power generation		Port terminals and pipelines

oxide is a significantly more potent greenhouse gas per kg emitted to the atmosphere, so the smallest traces of this pollutant in the flue gas must be avoided.

An alternative to firing green ammonia on a gas turbine is to crack the ammonia back to hydrogen and fire the hydrogen on a gas turbine, or use it in other applications. Rolls-Royce, Mitsubishi Power and other gas turbine manufacturers have developed pure hydrogen-fired turbines.

Ammonia cracking has rarely been performed at scale and is an energy intensive process. Therefore, the direct use of ammonia has been considered. With recognition of the hurdle that cracking currently represent to the energy transition, Aramco and Linde Engineering have signed an agreement to jointly develop ammonia cracking technology.

Ammonia as a carbon-free fuel

Ammonia is a cost-effective fuel for rail applications. German start-up Ammonigy, Fortesque Future Industries and the German national railway operator Deutsche Bahn have partnered to demonstrate ammonia partially cracked ammonia as a fuel for goods train locomotives. In this mobility application, the partially cracked ammonia is fired on a modified diesel internal combustion engine.

Aviation H_2 – a start-up based in Australia – plans to use a mixture of hydrogen and cracked ammonia as the fuel for their jet aircraft. The system leverages the high gravimetric energy density of ammonia as an aviation fuel. Reaction Engines in the UK has also innovated an ammonia cracker technology that can be used for use to prepare fuel for jet engines.

In a different approach, the US company Amogy is implementing full ammonia cracking to hydrogen which is then used on fuel cells in heavy-duty trucks for long-range transportation.

> “Ammonia cracking has rarely been performed at scale and is an energy intensive process”

In a maritime propulsion application, ammonia will be used directly as fuel for a solid oxide fuel cell developed by Prototech and Sunfire on Viking Energy. This offshore support vessel is operated by Eidesvik in service to Equinor’s operations in the North Sea.

“We believe that ammonia applications in the energy sector will have the highest growth but in KSA, but we think that this will be mainly controlled by the Saudi’s national oil company,” says Nasser. “Fuel cell power generation, industrial and specialty applications are sectors where RIG could play a role. Our agility will be of paramount importance when reacting to the urgent requirements of ammonia for mobility applications.” gw