NX STAMI™ AMMONIA MEDIUM PRESSURE SYNLOOP FOR WORLD-SCALE GREEN AND BLUE AMMONIA PLANTS

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1 ABSTRACT

The NX STAMI™ Ammonia Medium Pressure process presents a scalable and efficient solution for green and blue ammonia production, addressing the growing demand for low-carbon hydrogen carriers and fertilizers. This technology integrates seamlessly with renewable hydrogen sources and advanced reforming systems, achieving near-complete hydrogen utilization and up to 99% carbon capture. The process design emphasizes energy efficiency, operational flexibility, and integration with downstream technologies such as urea and nitrate production. Key innovations include a high-efficiency ammonia converter and the use of standard equipment to reduce capital expenditure. The NX STAMI™ Ammonia MP synloop supports the transition to sustainable ammonia production through modular, integrated, and future-ready plant configurations.

2 INTRODUCTION

Ammonia has been produced at industrial scale for over 100 years, and many innovations have been introduced to the process over time to tune production to feedstock and market needs. It is predicted that the role of ammonia in the future will be significantly expanded, not only focusing on the traditional markets, mainly fertilizers and plastics, but also expanding into an energy vector and hydrogen vector in the transition towards a net-zero planet. The worldwide production capacity of ammonia is predicted to double or triple by 2050 due to these new uses. Just as the production of so called 'grey' ammonia over the last century required continuous improvements, to increase plant efficiency, stability and reliability, the shift towards no- or low-carbon ammonia plants requires reworking of the current concepts. The focus for the next-generation ammonia plants will be efficient feedstock usage, minimization of waste streams, including greenhouse gases such as CO_2, and an increase in overall plant efficiency aiming to compete with and even outperform the traditional 'grey' plants. Many of the next-generation ammonia plants will be greenfield standalone plants requiring a high level of integration between the hydrogen production plant and the ammonia plant, as no utilities can be shared with neighboring plants. Alternatively, integrated complexes can be used to make carbon-free fertilizers, based on ammonium nitrate; or integrated urea plants can be used as an economically attractive way to sequester carbon from neighboring carbon-intensive plants, such as cement producers or steel mills.

Stamicarbon, together with its Nextchem sister companies, has a market-ready process for efficient green (no carbon) or blue (low carbon) world-scale ammonia production. The technology is proven at commercial scale, with over 45 operating references. The process has been thoroughly optimized for green and blue feedstocks, allowing for reductions in both OPEX and CAPEX and near-100% hydrogen utilization. For green ammonia synthesis, the plant can be coupled with any available electrolyzer system. For blue ammonia synthesis, the NX STAMI™ Ammonia MP synloop can be coupled with the Adwin Hydrogen Auto Thermal Reforming (ATR)-based reforming plant, from Stamicarbon's sister company GasConTec, allowing for up to 99% carbon capture rate. Furthermore, the NX STAMI™ Ammonia MP plant can be coupled with any downstream Stamicarbon technology, including urea, nitric acid, or ammonium nitrate, for efficient, seamless integration.

3 NX STAMI™ Ammonia MP synloop

A block flow diagram of the NX STAMI™ Ammonia MP process is shown in Figure 1. Hydrogen and nitrogen are mixed at B.L. to the correct stoichiometric ratio (3:1), the mixed gas gets subsequently combined with the flash-gas recycle, which recovers valuable hydrogen and nitrogen released from the ammonia product upon depressurization. The combined stream is pressurized in the syngas compressor, the high-pressure recycle is added at an interstage and compressed together to the synthesis pressure (between 150-180 bar). The compressed make-up gas gets preheated against the converter effluent before entering the ammonia converter.

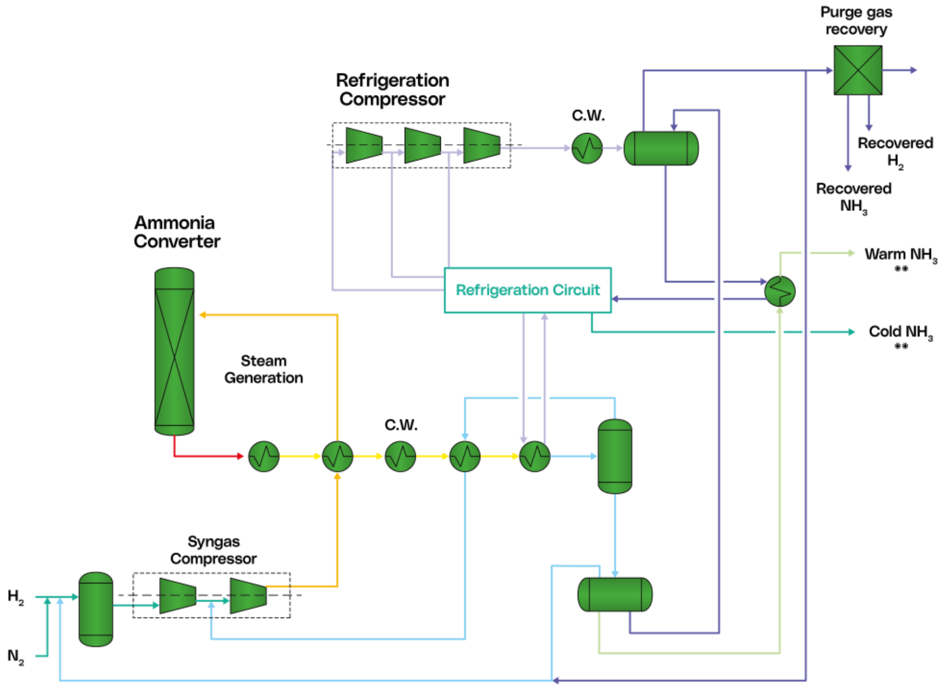

Figure 1: high-level block flow diagram of the NX Stami MP Ammonia concept

The ammonia converter is a three-bed radial-flow design, optimized to work with the industry standard multi-promoted iron-based catalyst. Internal heat exchange is optimized to maximize productivity, by staying close to the maximum rate curve, keeping temperature excesses below 500°C and maximizing converter outlet temperature for optimized steam production. A specialized submerged heat exchanger inside the catalyst bed is used to cool down reacting gases while ammonia production is ongoing, as is demonstrated in Figure 2, significantly enhancing productivity. The flow through the three internal heat exchangers can be optimized for all operating conditions, from start-up, start-off run through end of run operation as well as deep turndown. The configuration of heat exchangers for grassroot and revamp basket is fully optimized based on plant capacity, feedstock purity and any existing constraints like pressure shell size.

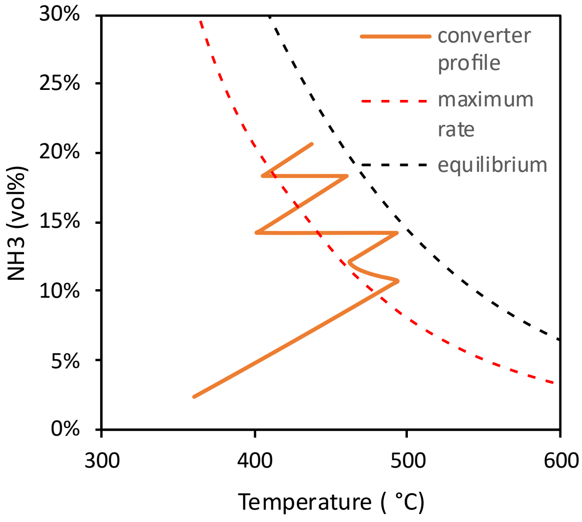

Figure 2: Typical temperature profile inside the NX Stami MP Ammonia converter

Firstly, the converter effluent passes the steam generation system, where, depending on the process needs, any grade of steam up to ca. 45 bar superheated steam can be produced. As a standard, HP steam at 44 bar and 390°C is produced, which can be used internally to drive the refrigeration compressor, leaving a sizeable amount for export.

The converter effluent subsequently passes the feed-gas interchanger as described above followed by a demi-water preheater (in case of a stand-alone green plant), a cooling-water-operated condenser, and a process-process heat exchanger that recovers cold from the recycle stream. The bulk of the product ammonia is condensed using refrigerant ammonia in a series of up to three chillers, the number depending on plant capacity.

Any non-condensed gases are recycled back to the converter to maximize productivity. The product liquid ammonia is separated and depressurized, upon which the flashed gases are recycled to the syngas compressor.

The NX STAMI™ Ammonia MP synloop can produce any specification within the range from cold (-33°C, atmospheric pressure) to warm (25°C, 16 bar(a)). Although, if desired, the plant can be simplified to produce only warm or only cold ammonia product. The warm ammonia product flows from the flash-tank through a heat exchanger, which heats the product ammonia, while cooling the refrigerant ammonia, thus increasing the efficiency of the refrigeration circuit. All remaining ammonia product, including the fraction reserved for cold ammonia, flows into the refrigerant ammonia vessel.

The refrigerant ammonia vessel has the only continuous purge within the process, provided the feedstock is lean in inert gases (Ar, CH_4). The purge stream is cooled to -25°C in a reflux condenser, removing most of the ammonia while allowing the inert gases to escape. Liquid ammonia leaves the refrigerant ammonia vessel and is gradually depressurized as it flows through the chillers' shell sides. Any flashed or evaporated ammonia will be compressed by the refrigeration compressor, then condensed and returned to the refrigerant ammonia vessel. After the lowest pressure chiller, the remaining liquid ammonia will flow to the atmospheric ammonia receiver, from which it can be pumped to a downstream storage facility or chemical plant.

The continuous purge from the refrigerant ammonia vessel, as well as any discontinuous purge from the synthesis loop and flash tank, can be treated in the purge-gas recovery section. Here, depending on purge flow and plant requirements, ammonia and/or hydrogen can be fully recovered from the purge stream, to be reused in the plant. This leaves a stream of nitrogen enriched in inert gases (Ar, CH_4), which can be safely vented.

One of the key features of the NX STAMI™ Ammonia MP concept is the use of commonly available, non-proprietary equipment in the condensation section of the synthesis loop, which reduces initial investment cost, while increasing flexibility and ease of maintenance, without sacrificing efficiency.

4 Front-end integration

Green ammonia synthesis

Green ammonia synthesis is based on water electrolysis to produce hydrogen and a cryogenic nitrogen separation unit to produce nitrogen, with all equipment driven by renewable or low-carbon electricity, such as wind, solar or nuclear. There are three main types of water electrolysis: conventional alkaline electrolysis, based on the chloralkaline process; proton exchange membrane (PEM) electrolysis; and solid oxide electrolysis cell (SOEC). Alkaline electrolysis technology is the most mature and can be scaled to larger capacities. PEM electrolysis is more efficient but still requires proof at scale. SOEC can be the most efficient electrolysis method, as it uses steam as input for electrolysis, seamlessly integrating with the ammonia process, although this technology still requires some maturation before industrial implementation.

One of the waste-streams from electrolysis as well as nitrogen generation is pure oxygen. There is no direct use for oxygen within the ammonia synthesis loop, although downstream plants, such as NX STAMI™ nitric acid plants can use the oxygen to improve their overall plant efficiency. Alternatively, oxygen can be sold as an additional product.

Blue ammonia synthesis

As the nitrogen technology licensor of Nextchem, together with its sister companies GasConTec and KT Tech, Stamicarbon can offer a fully integrated blue solution for world-scale ammonia plants, by coupling the NX AdWinHydrogen® process to the NX STAMI™ Ammonia MP process as shown in Figure 3. In this case the air separation unit (ASU) will provide oxygen to the ATR burners and nitrogen to the ammonia plant. The ATR-based hydrogen plant and ammonia plants are fully integrated in terms of utilities and steam system, generating all internally required power to drive the compression duties inside the ATR, NH_3 and ASU plant, as well as leaving an excess for downstream plants, such as an NX STAMI™ Urea plant. The quantity of steam can be tuned for the required demand, lowering steam export, or even taking steam import, in case of a downstream NX STAMI™ Nitrates or nitric acid plant.

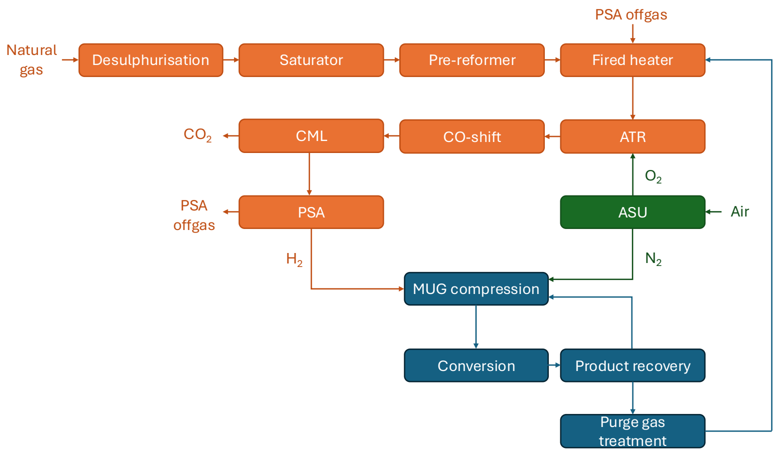

Figure 3: BFD of the Integrated NX STAMI™ Ammonia plant based on ATR hydrogen production and medium pressure ammonia synthesis

The unique feature of the NX AdWinHydrogen® process is its high operating pressure, up to 90 bar, which significantly reduces the syngas compressor duty within the ammonia plant. The refrigeration system within the ammonia plant can be used to aid in the cold-methanol loop used in the ATR plant to recover the CO_2 from the process gas.

5 Back-end integration

Urea fertilizer plants

The long history and intimate knowledge of the urea process position Stamicarbon uniquely to maximize and optimize integration between the ammonia and urea plants. In this context, two main concepts are identified: a urea plant linked to a green ammonia plant and a urea plant linked to a blue ammonia plant. In the former, the CO_2 source is generally a waste stream from local industry, such as power plants, bio-refineries, or heavy industry, such as steel or cement factories. As excess steam from the front-end hydrogen plant is not generated during electrolytic hydrogen production, the integration and optimization of the steam system between the ammonia and urea plants becomes crucial. By fully integrating waste heat between the two plants, Stamicarbon can maximize overall process efficiency in urea production. Note that in this case, rotating equipment for both plants will be run electrically. Further integration includes optimizing the pressure of the ammonia feed to the urea plant, as well as other process and utility connections.

For blue urea the combination of a NX AdWinHydrogen® plant with a NX STAMI™ Ammonia MP synloop makes a perfect front-end for an NX STAMI™ Urea plant. The front-end plants will produce all ammonia, carbon dioxide and steam required by the urea plant. The fact that an ATR plant has all CO_2 in the process stream means that there will never be a shortage of CO_2 for the urea plant, as opposed to some SMR based reformer plants, any remaining CO_2 will be pure enough for sequestration or commercialization. The pressure level of the CO_2 and NH_3 from the front-end plants can be optimized to minimize the required compression duties inside the urea plant, increasing overall process efficiency.

Nitrate fertilizer plants

A critical drawback of urea as fertilizer, considering decarbonizing the industry, is the inclusion of carbon in the molecule itself, which gets released into the atmosphere upon use. The most common carbon-free alternative to urea as fertilizer is nitrates, in the main form of ammonium nitrate. Ammonium nitrate is synthesized by neutralizing ammonia with nitric acid. Stamicarbon offers fully integrated green ammonium nitrate fertilizer plants. Firstly, ammonia will be synthesized via the NX STAMI™ Ammonia MP process, followed by the NX STAMI™ Nitrates dual-pressure nitric acid technology, in which roughly half of the ammonia is converted into nitric acid. Subsequently the nitric acid and remaining ammonia get blended with further additives to make calcium ammonium nitrate (CAN) and/or NPK fertilizers in close collaboration with external partners delivering a full scope from H_2, N_2 to CAN product. A green ammonium nitrate plant offers many possibilities for integration, for example the oxygen from the electrolyzer and nitrogen generation plant, which is normally a byproduct vented to atmosphere, can be used in the nitric acid plant.

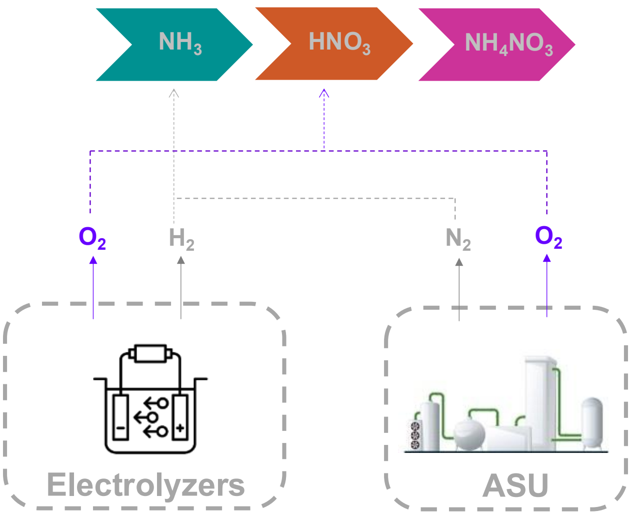

Figure 6: Green ammonium nitrate plant integration possibilities

Introducing oxygen into the nitric acid plant offers several advantages. The conventional nitric acid production process relies on oxygen from air, but this oxygen can be replaced by oxygen produced as a by-product from electrolyzers or nitrogen generation units. To supply nitrogen, also needed in the process, the tail gas conventionally exiting the nitric acid plant (containing more than 95%vol N_2) can be internally recycled within the plant. This approach will increase overall plant efficiency, boosting steam production, and minimizing NO_x and N_2O emissions. This integrated concept, known as Nitric Acid Total Recycle™ also provides significant CAPEX benefits. By eliminating the need for a compressor train and downsizing or even removing equipment such as the absorption column, tail gas heaters and abatement system the nitric acid plant achieves both operational and economic efficiency.

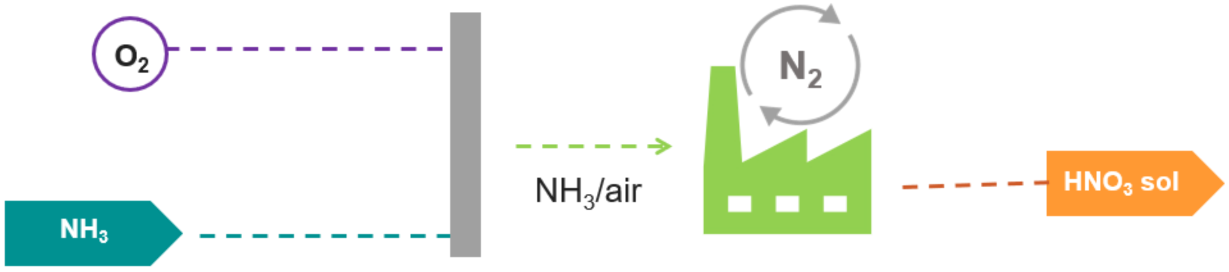

Figure 7: Further integration of process and utility streams will optimize the synergy between plants

Fully integrated UAN fertilizer plants

Combining the core available Stamicarbon technologies results in a urea ammonium nitrate fertilizer plant. Integrations, as mentioned before, can be combined to generate an overall integrated fertilizer complex. Similarly, part of the ammonia can be used for solid urea product, while another fraction is used to make nitrate base fertilizers, in which case the excess steam from the nitrate plant can be used to alleviate some of the load from the front-end plant, thus allowing for an overall more efficient process.

6 Conclusions

The NX STAMI™ Ammonia MP synloop offers a scalable, efficient, and flexible solution for green and blue ammonia production. Integrated with reformer technologies like NX AdWinHydrogen® for up to 99% carbon capture, and compatible with electrolyzer systems for green ammonia synthesis, it supports a wide range of decarbonization strategies, and the use of standard equipment reduces CAPEX while maintaining high efficiency.

Seamless integration with downstream technologies such as NX STAMI™ Urea, NX STAMI™ Nitric Acid, and NX STAMI™ Nitrates enables the creation of fully decarbonized fertilizer complexes. These synergies enhance energy efficiency and process optimization, making the NX STAMI™ Ammonia MP synloop process a key enabler in the transition to a net-zero ammonia and fertilizer industry.

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