Ammonia Technology Solutions

Reducing your capital and operating costs while maximizing productivity, safety and profitability
Providing a Cost-Effective, Flexible Ammonia Processing Solution

KBR’s Purifier Ammonia Process combines the following proprietary technologies to yield an extremely reliable, robust, low-energy plant:

- Mild reforming with excess air
- KBR Purifier
- Magnetite ammonia synthesis in a horizontal converter

With KBR’s cryogenic Purifier syngas technology, you receive a lower-cost, more robust processing route to high-purity synthesis gas in ammonia manufacturing plants. The proprietary, front-end process technology simultaneously removes impurities (i.e., methane, argon) from synthesis gas by washing it with excess nitrogen while adjusting the hydrogen to nitrogen (H2/N2) ratio to 3:1.

Benefits of Purifier™ Ammonia Process

Providing a clean, dry, make-up gas to the synthesis loop and simple and precise H2/N2 ratio control, Purifier technology offers benefits to the entire operation in several key areas:

**Low Energy Consumption**

- A clean, dry make-up gas reduces the load on the synloop compressor and refrigeration systems, providing operational cost savings
- Mild reforming temperatures are used as methane slip is unimportant, which reduces fuel consumption and increases tube life
- Higher loop conversion is achieved with low inerts
- Purifier plants operate at the lowest proven energy consumption; a recent plant achieved an energy consumption of 6.5 Gcal/MT(ISBL, LHV basis)
Reduced Capital Costs

• No separate purge gas recovery unit is needed because purge gas rejected from the synloop is passed through the Purifier unit
• Very clean make-up gas provided by KBR’s Purifier lowers synthesis pressure, catalyst volume and purge rate, which means that smaller synloop equipment can be used

Flexibility

• Achieves greater stability and flexibility of operation, since the reforming section does not need to be tightly controlled to produce a precise H2/N2 ratio
• Maintains production even in the event of catalyst deactivation upstream of the Purifier

Reliability

• Low reforming temperatures translate to lower stresses in and longer life of reformer tubes
• Numerous Purifier plants have run 3 - 4 years without a maintenance shutdown

Purifier – Simple design offers superior results

The Purifier system is a simple design consisting of three pieces of equipment: a feed/effluent exchanger, a column with a built-in condenser and an expander. All items and the connecting piping are welded and enclosed in a perlite-insulated cold box. Specific equipment design features include:

- Exchanger, which is a plate-fin design and constructed of aluminum
- Cryogenic column, which operates in the range of minus 170°C to minus 200°C
- Integral condenser, which is a shell-and-tube design
- Expander, which is a compact, low-speed unit that is typically coupled to a generator to recover power. A 2000 metric ton per day (MTPD) ammonia plant requires an expander with a capacity of about 200 kW.

KBR Purifier™ technology removes methane, argon and excess nitrogen from synthesis gas and allows use of air instead of oxygen in the reforming section of the ammonia plant, eliminating need for an expensive air separation unit.
Since the first installation in 1966, KBR has licensed the Purifier process for ammonia plants worldwide. Recent successes include a grassroots fertilizer plant for CNOOC Chemical Ltd. in China.

**Horizontal Synthesis Converter**

For conventional magnetite ammonia synthesis loops, KBR offers its horizontal ammonia synthesis converter. The converter contains two or three reaction stages, each with vertical downward flow in the magnetite catalyst beds. Intercoolers are provided between the catalyst beds for maximum conversion and heat recovery. The catalyst basket is easily removed from the converter shell for catalyst loading and unloading. The basket can be rolled out of the horizontal converter vessels on tracks, thus avoiding the need for scheduling and erecting a heavy and expensive crane for periodic maintenance.
Reduce Costs. Gain Flexibility. Save Energy.

With over 40 years of experience in designing and optimizing ammonia manufacturing facilities, KBR is a leading authority in ammonia technology. Since the first Purifier plant started up in 1966, KBR has licensed, designed, engineered and/or constructed 18 Purifier ammonia plants worldwide, achieving significant operating records and low energy costs. Let us put that experience to work for you.
Combining well-proven KBR technologies to improve reliability and lower costs in ammonia production

KBR's PURIFIERplus™ ammonia process combines proven and reliable technologies from our proprietary KRES™ (KBR Reforming Exchanger System), Purifier™ and horizontal ammonia synthesis converter to produce a synergistic, lower cost process that eliminates the need for an air separation plant and a primary reformer.

KRES™

KRES is a proprietary heat exchanger-based steam reforming technology consisting of a fired preheater, an autothermal reformer (ATR) and a reforming exchanger. KRES takes the place of a conventional primary reformer by feeding excess air, natural gas feed and steam to the ATR and feed and steam in parallel into the upper end of the robust, shell-and-tube reforming exchanger. The compact ATR and reforming exchanger in combination with the fired preheater take up much less plot space than a conventional fired steam methane reformer.

The tubes in the KBR reforming exchanger are open-ended and hang from a single tube sheet at the inlet cold end to minimize expansion problems. They are packed with a conventional reforming catalyst, which can be easily loaded through a removable top head. The tubes are accessible and removable as a bundle for maintenance. This simple, proprietary design has proven to be extremely reliable and maintenance-free in commercial operation since 1994.

Heat to drive the reforming reaction is supplied by the effluent gas from the ATR, which operates in parallel with the reforming exchanger. To ensure adequate heat to drive the reaction, the ATR receives excess process air, typically 50 percent more than what is required for nitrogen balance.

The hot ATR effluent enters the lower shell side of the reforming exchanger where it combines with reformed gas exiting the reforming tubes. This combined gas stream travels upward through the baffled shell side of the reforming exchanger providing heat needed for the endothermic reforming reaction occurring inside the catalyst-filled reforming tubes. In this way, heat energy that would otherwise be used to generate possibly unneeded steam in a waste heat boiler downstream of the reformer is used, instead, to replace fuel as the source of heat to drive the reforming reaction.

KBR reforming exchanger
**Purifier™**

Downstream of the KRES unit, KBR’s cryogenic Purifier technology simultaneously removes impurities and adjusts the hydrogen to nitrogen ratio to 3:1. The system accepts purge gas from upstream, thus eliminating the need for a separate purge gas recovery unit.

The Purifier system consists of:
- A feed/effluent exchanger, plate fin-type design and constructed from aluminum
- A column that operates in the range of minus 170°C to minus 200°C, with a built-in condenser of shell and tube design
- A compact, low-speed expander that is typically sized for cool down and is coupled to a generator brake

All items and the connecting piping are welded and enclosed in a perlite-insulated cold box.

KBR proprietary cryogenic purification technology removes methane, argon and excess nitrogen from synthesis gas and allows use of air instead of oxygen in the reforming section of the ammonia plant, eliminating the need for an expensive air separation unit.

KRES Autothermal Reformer (left) and KRES Exchanger (right) as installed at an ammonia plant in British Columbia, Canada
Horizontal Synthesis Converter
For conventional magnetite ammonia synthesis loops, KBR offers its horizontal ammonia synthesis converter. The converter contains two or three reaction stages, each with vertical downward flow in the magnetite catalyst beds. Intercoolers are provided between the catalyst beds for maximum conversion and heat recovery. The catalyst basket is easily removed from the converter shell for catalyst loading and unloading. The basket can be rolled out of the horizontal converter vessel on tracks, thus avoiding the need for a heavy, expensive crane.

Combined Technology Provides Synergistic Benefits
While KRES and Purifier provide significant cost savings and operational efficiencies separately, combining them in PURIFIERplus™ allows for further economic gains. These include:

- Reduced capital costs – Replacing the primary reformer unit with a KRES unit may provide up to 5 percent savings in up-front plant capital costs. Significant capital costs are also realized by eliminating air separation and purge gas recovery facilities.
- Reduced energy requirements – Fewer burners are necessary in the fired heater, resulting in lower process temperatures. Purifier provides higher loop conversion with low inerts.
- Reduced plot space – A 25-35% smaller footprint is required for the reforming section of the plant compared to conventional processes.
- Improved reliability and flexibility – The reforming exchanger is more reliable than a conventional reformer, and the simple and precise hydrogen to nitrogen ratio control stabilizes the entire plant operation. For locations subject to feed curtailments in winter months, KBR’s KRES reforming system handles feed rate changes with little operator intervention and allows more expensive natural gas feed to be converted into syngas rather than used for fuel gas or steam generation.
- Improved environmental compliance – The system reduces CO₂ and NOx emissions.
Reduce Costs. Gain Flexibility. Save Energy.

**Low Capital Cost** – 3 - 5% capital cost savings over designs using a primary reformer

**Low Operating Cost** – Reduced operations and maintenance requirements by eliminating primary reformer

**Operational Flexibility** – Simpler operations with greater capability to handle process changes

**Reduced Construction Cost** – The smaller plot space and shop fabrication of the KRES reforming exchanger result in lower field construction labor costs

**High Reliability** – Based on well-proven commercial designs of KRES and Purifier technologies with low downtime and greater than 97% availability

**Low Environmental Emissions** – Reduced NOx and CO₂ emissions by eliminating the primary reformer

With over 40 years of experience in designing and optimizing ammonia manufacturing facilities worldwide, KBR is a leading authority in ammonia technology. PURIFIERplus is just one example of how we can build custom-designed processes to drive synergies and positively impact your bottom line. Let us put that experience to work for you.
Offering Competitive Advantages in Cost and Operability

For over 40 years, KBR has advanced ammonia technology with your key operational aims in mind: improved safety, lower capital costs and energy consumption, improved reliability and operability, and environmentally-sound operations. We offer expertise and processing solutions in conventional processing technology as well as many proprietary technologies for both syngas preparation and ammonia synthesis, including:

**SMR**

For conventional reforming operations, KBR's top-fired steam-methane改革器（SMR）design circumvents many of the mechanical design problems in competing primary reformer designs. The reformer tubes are efficiently heated from both sides, with firing occurring downwards from the top of the firebox, providing a relatively even load along the tubes. The convection section provides heat recovery from the flue gas for optimum furnace efficiency. Additionally, KBR's fired reformer can also be coupled with a gas turbine that drives an air compressor. This design allows the gas turbine exhaust to be used as preheated combustion air for the reformer radiant section, which reduces overall plant energy consumption.

**KRES™**

KBR Reforming Exchanger System (KRES) replaces a primary reformer with a fired preheater, autothermal reformer (ATR) and reforming exchanger. The system's proprietary design avoids direct firing on the exchanger tubes, which eliminates hot spots and keeps process temperatures lower. The system also provides decreased capital and operating costs, greatly-reduced plot space requirements and lower emissions compared to conventional reforming systems.

**Purifier™**

Following a mild primary reforming step and secondary reforming with excess air, KBR's proprietary cryogenic Purifier process removes excess nitrogen and impurities, resulting in nearly inert-free syngas. KBR's Purifier lowers capital and operating costs by allowing the reforming section to be operated with excess air and higher methane slip, reducing reforming catalyst volume and synthesis loop purge rates while eliminating the need for a separate purge gas recovery unit.

**Waste Heat Boiler**

Heat is recovered from the secondary reformer (or KRES) effluent in a waste heat boiler (WHB), often in combination with a steam superheater. KBR's proprietary design provides a vertical, natural-circulation, water-tube, floating-head design with refractory lining. Plant operators using our waste heat boiler design report lower initial costs, higher reliability and less maintenance. Another advantage with our design is the WHB tube bundle is removable, unlike bundles in a fired-tube boiler design.

**Ammonia Synthesis Solutions**

Chemical operators use KBR process technology in over 200 ammonia plants operating worldwide, which have earned a reputation for their high energy efficiency, operating reliability, and quality of construction. These plants employ a variety of proprietary process configurations and equipment items that KBR carefully selects to meet each client's specific needs and project requirements.
**Conventional Ammonia Synthesis**
KBR offers conventional ammonia process technology in which our well-known, top-fired primary reforming technology is combined with ammonia synthesis in a horizontal ammonia converter over a promoted iron magnetite catalyst at pressures of 140 to 170 bar. Having a long history of successfully optimizing energy consumption of this established process is what separates KBR from our competitors.

**Horizontal Synthesis Converter**
For conventional magnetite ammonia synthesis loops, KBR offers its horizontal ammonia synthesis converter. The converter contains two or three reaction stages, each with vertical downward flow in the magnetite catalyst beds. Intercoolers are provided between the catalyst beds for maximum conversion and heat recovery.

**KAAP™ (KBR Advanced Ammonia Process) Loop**
KAAP features ammonia synthesis over a proprietary promoted ruthenium on graphite catalyst that has an intrinsic activity ten to twenty times higher than conventional magnetite catalyst. This well-proven catalyst allows efficient ammonia synthesis at only 90 bar synloop pressure, which is two-thirds to one-half the operating pressure required for conventional ammonia synthesis. As a result of this lower pressure, only a single-case synthesis gas compressor is needed and vessel and pipe wall thicknesses are reduced throughout the synthesis loop, which reduces design complexity and equipment costs.

**Unitized Chiller**
The unitized chiller is a specially designed, multi-stream heat exchanger that cools the effluent from the ammonia synthesis converter with recycled gas and boiling ammonia refrigerant at several temperature levels. In doing so, the unitized chiller combines several heat exchangers, compressor knockout drums and interconnecting piping into one piece of equipment. This design saves pressure drop in the synthesis loop and reduces capital cost.

**Synergistic Process Combinations**
At KBR, our experts can combine our technologies in optimized configurations, resulting in further flexibility, process efficiency improvements and lower capital cost than conventional ammonia synthesis process schemes.

**Lower Costs. Increase Energy Efficiency. Boost Reliability.**
With over 50 years experience in designing and optimizing ammonia manufacturing facilities, KBR is a leading authority in ammonia and syngas solutions, and we have the technology and expertise to drive further process efficiencies in any plant, regardless of design. Let us put that experience to work for you.
# Recent KBR Ammonia Experience

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To learn more, visit ammonia.kbr.com or email ammonia@kbr.com
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