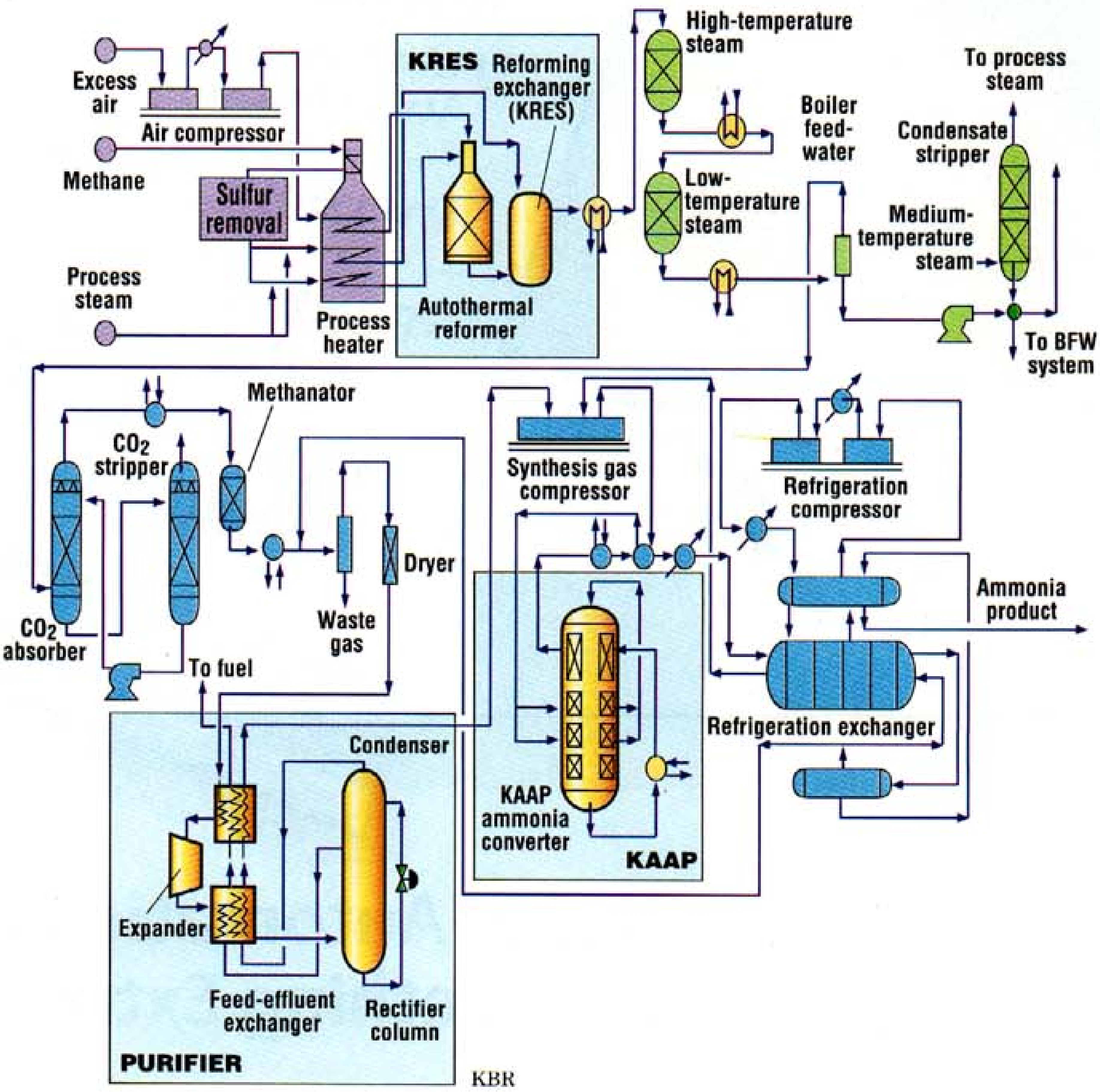
ALL ABOARD, AMMONIA

Doubling the size of a single-train plant has the potential to reduce the capital-related cost of production by about 20%



KBR

For ammonia synthesis using the KAAP process, a ruthenium catalyst (on a carbon support) is used in three of four beds. Reaction to be conducted at 90 bars instead of the normal pressure of about 200 bars for a standard magnetite catalyst

Sometime within the the next two months, Saudi Arabian Fertilizer Co. (SAFCO; Jubail), a subsidiary of Saudi Basic Industries (SABIC), will let a contract for what will be the world's largest single-train ammonia plant. Scheduled for startup in 2005, it will have a capacity of 3,000 m.t./d. This will be 50% bigger than the current largest plants, all of which have come online only during the past couple of years.

The new Saudi plant is expected to be the forerunner of a number of plants of similar or larger capacity. Major suppliers of ammonia technology say they have been working with clients on preliminary designs for plants up to 4,000 m.t./d and they are confident of their ability to build such plants. "Once the SABIC plant goes ahead, others will follow," says Svend Nielsen, ammonia technology supervisor for Haldor Topsøe A/S (Lyngby, Denmark; haldortopsoe.com). Bids for the SAFCO plant, and an associated 3,250-m.t./d urea plant, were scheduled to be opened at the end of October.

At present, the world's largest single-train grassroots plant is a 2,050-m.t./d unit operated by Profertil S.A. (Buenos Aires, Argentina). It uses Haldor Topsøe technology, as does a 2,000-m.t./d plant owned by Kaltim Pasifik Amoniak (Bontang, Indonesia). Elsewhere, BASF is operating an upgraded plant in Antwerp, Belgium, at 2,060 m.t./d. Built by Uhde GmbH (Dortmund, Germany; thyssenkrupp.com/uhde), it had an original nameplate capacity of 1,800 m.t./d. KBR (Houston, Tex.; halliburton.com) has built three 1,850-m.t./d plants in Point Lisas, Trinidad, with a fourth under construction. The third plant, operated by Caribbean Nitrogen Co., has attained production of up to 2,000 m.t./d. since it was started up in July. All the plants use KBR's KAAP technology (KBR Advanced Ammonia Process) for ammonia synthesis.

As is the case with other technologies, the benefit of going to bigger plants is to realize economy of scale. Doubling the size of a single-train plant has the potential to reduce the capital-related cost of production by about 20%, says Richard Strait, director of KBR's ammonia team.

Scaling up by 100% presents some technical challenges, but industry spokesmen say the technology is available to do it, with some deviations from the single-train philosophy. "Up to 3,300 m.t./d, a true single-train concept is possible," says John Larsen, chief process engineer for Uhde Corp. of America (The Woodlands, Tex.). "Beyond that, the waste-heat boiler will be paralleled, and beyond 4,000 m.t./d some piping in the carbon dioxide wash will also be paralleled."

KBR has designed a 4,000-m.t./d plant in which all the equipment is single-train except for the primary reformer and the ammonia converter, each of which consists of two identical, parallel units. The design, dubbed KAAPplus, combines KAAP with

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AWASH IN AMMONIA?

The prospect of new, supersized ammonia plants going onstream in the future might be expected to exacerbate the serious overcapacity that has plagued the industry in recent years. At present, though, the reality is that plans have been announced for only one such plant — by SAFCO, in Saudi Arabia (see main story) — and that plant is not scheduled to go online until 2005. In the meantime, business conditions in the ammonia market are improving, and supply and demand are expected to be fairly well balanced over the next three or four years.

There will be a big surge in demand for nitrogen-based products over the next couple of years, with very little new capacity coming online, says Glen Buckley, chief economist and director of agri-business analysis with CF Industries, Inc. (Long Grove, Ill.; cfindustries.com), a leading fertilizer producer. After remaining fairly stagnant for several years, world demand for nitrogen (within its compounds) will jump about 5%, to 111.2 million m.t./yr in 2003, up from 106 million this year, says Buckley, who spoke on the state of the world's fertilizer markets at the annual ammonia symposium of the American Institute of Chemical Engineers (aiche.org), held in September in San Diego, Calif.

Fertilizers account for most of the nitrogen consumption, he notes, and the spurt in demand is due to increased crop plantings in the U.S. and elsewhere. Industrial use is expected to amount to 22.3 million m.t. this year and 23.2 million m.t. in 2003.

The current market situation presents a stark contrast with that of the past five years, in which world nitrogen capacity expanded by a record amount of nearly 14 million m.t. The construction of large, efficient ammonia plants in locations that have cheap natural gas, such as Trinidad and the Middle East, caused the closure of many older plants that have high feedstock costs, particularly in the U.S. and Europe. About 4 million m.t. of capacity has been shut down in the U.S. alone, says Buckley.

World nitrogen capacity is now 132.7 million m.t./yr (ammonia capacity is 160 million m.t.), which translates to an average plant operating rate of about 80%. While this is well below the effective operating rate of 85–86%, it is an improvement over the 78% of 2001 and is expected to increase to about 83% next year, says Buckley. "By 2005–2006, the market should be closer to a balance," he adds.

Ammonia projects whose capacity totals about 6.5 million m.t./yr are in the planning stage for a 2005 startup, but Buckley predicts that no more than 2.8 million m.t. will be built because of market uncertainty. Most of that will be in the Middle East, including SAFCO's 3,000-m.t./d ammonia plant (about 1 million m.t./yr). However, Buckley points out, that if more than the expected capacity is built, it could throw the market back into a surplus position. ❐

other KBR technologies: KBR Reforming Exchanger System (KRES), and the Purifier, which uses cryogenic distillation with nitrogen to strip methane and inerts from the synthesis gas prior to ammonia conversion (see flowsheet).

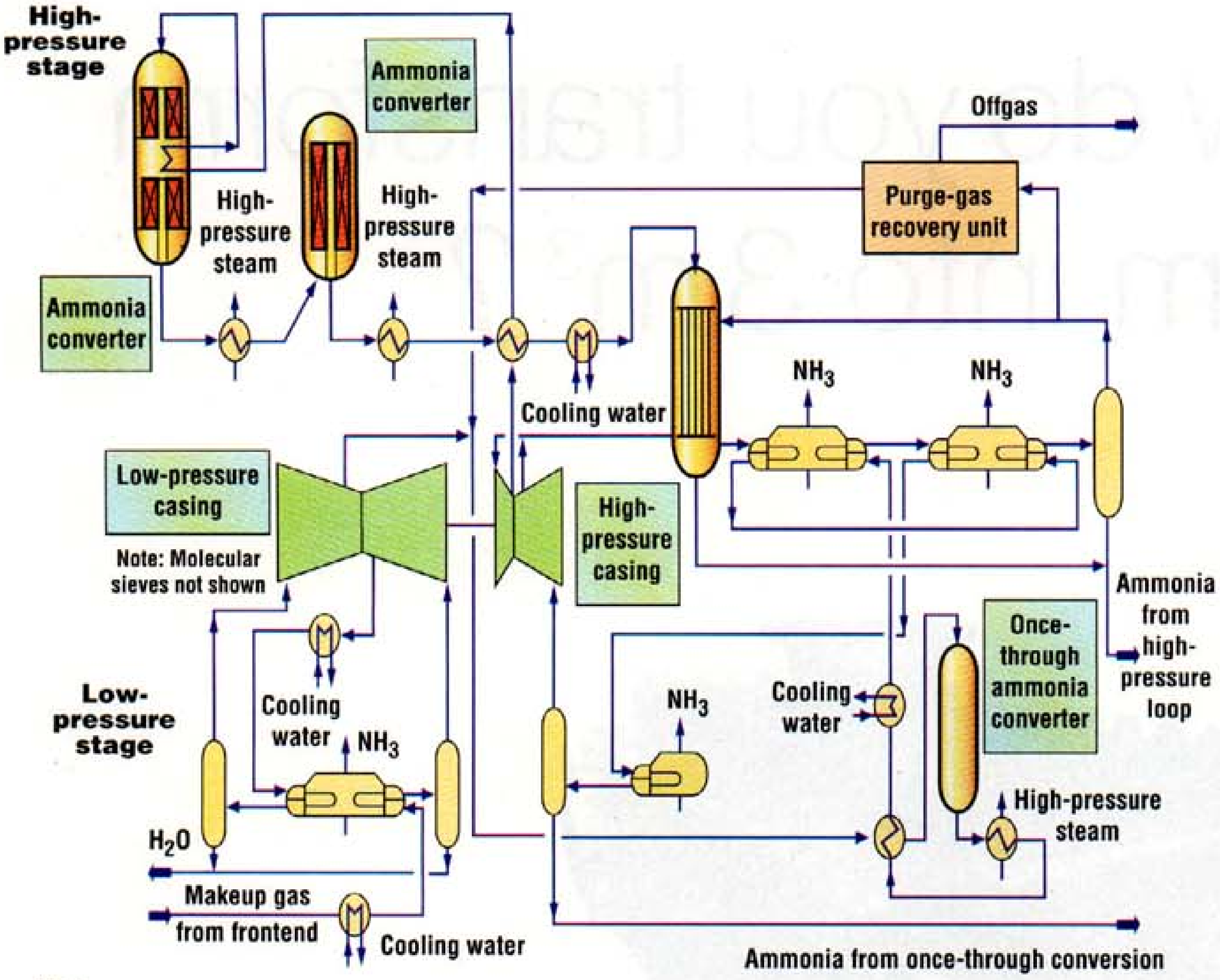
KRES uses a shell-and-tube heat exchanger in place of a fired primary reformer, thereby saving capital, energy and maintenance costs, says Strait. The heat comes from the secondary, autothermal reformer, which is run in parallel with the primary vessel in KBR's setup. To provide the necessary heat, the secondary reformer must use either oxygen-enriched air or excess process air. The KAAPplus plant design permits the use of about 50% excess air (thus saving the cost of an oxygen plant), because excess nitrogen and inerts are removed by the purifier. Earlier designs, without the purifier, required excess air to obtain adequate heat from the autothermal reformer. The heat for reforming in the KRES is generated from the reaction of the O_2 in the air.

The 4,000-m.t./d plant was designed to use two parallel KRES systems, each of 2,000 m.t./d, to avoid possible scaleup problems. Strait notes that the one KRES unit that is in commercial operation has a capacity of only 350 m.t./d. A second unit, of 1,100 m.t./d, is scheduled for startup in China next year.

High-activity catalysts

KBR's KAAP ammonia synthesis process differs from conventional technology in that three of its four beds use a ruthenium catalyst (on a carbon support), which is much more active than a standard magnetite catalyst. The higher activity allows the reaction to





Uhde

be conducted at 90 bars instead of the normal pressure of around 200 bars, thereby lowering capital and energy costs. Magnetite is used in the first bed of the synthesis loop, when the ammonia concentration is below 2% of the feed, then ruthenium is used in the next three beds to bring the ammonia level up to 18% or more.

The ammonia-synthesis section has two parallel ammonia converters for the 4,000-m.t./d-plant design to avoid pressure-drop problems. Strait points out that pressure drop increases as the square of the flow, so doubling the flowrate from the 2,000 m.t./d of the Trinidad plants would increase the pressure drop from 50 psi to 233 psi,

Uhde's dual-pressure process performs ammonia synthesis in two steps, at different pressures. Makeup gas is compressed and then converted to ammonia. The ammonia is separated from the gas, which is compressed again for second-stage ammonia synthesis

given the same hydraulic circuits. He adds that this pressure drop can be accommodated throughout most of the plant by redesigning and increasing the diameters of vessels and pipes.

A ruthenium catalyst that can perform ammonia synthesis at 200 bars is being developed by Haldor Topsøe. Although the catalyst is not yet ready for market, the combination of high activity with high pressure is very well suited for the design of large-capacity plants (larger than 4,000 m.t./d), since high pressure is required to keep equipment and piping at reasonable sizes, even at very large plant capacities, says Nielsen. He explains that the catalyst is able to handle higher pressures because it is on a boron nitride carrier. In the meantime, he says, the company's present technology, using a magnetite catalyst, is adequate for plants up to 4,000–4,500 m.t./d. Such a plant could be built in a single train, with no parallel pieces of equipment.

Dual-pressure conversion

Uhde's solution to the challenge of building larger plants is a dual-pressure process. Developed in collaboration with Synetix (Cleveland, England; synetix.com), which supplies the catalyst, it performs NH_3 synthesis in two steps, at different pressures. In the first step, makeup gas is compressed to about 110 bars in a two-stage intercooled compressor, then converted to ammonia in a three-bed, intercooled, once-through converter. Roughly one-third of the total ammonia is produced at this stage. About 85% of the ammonia product is separated from the gas, which is then compressed to the standard pressure of up to 210 bars for the second-stage ammonia synthesis loop.

The main benefit of the process, says Uhde's Larsen, is that the removal of ammonia after the first stage reduces the volume of the gas that has to be recompressed by about one-third, effectively increasing the capacity of the synthesis loop. Consequently, he says, the dual-pressure process reduces the risks of scaleup considerably, since it can be built with all proven, high-pressure equipment. ■

Gerald Parkinson