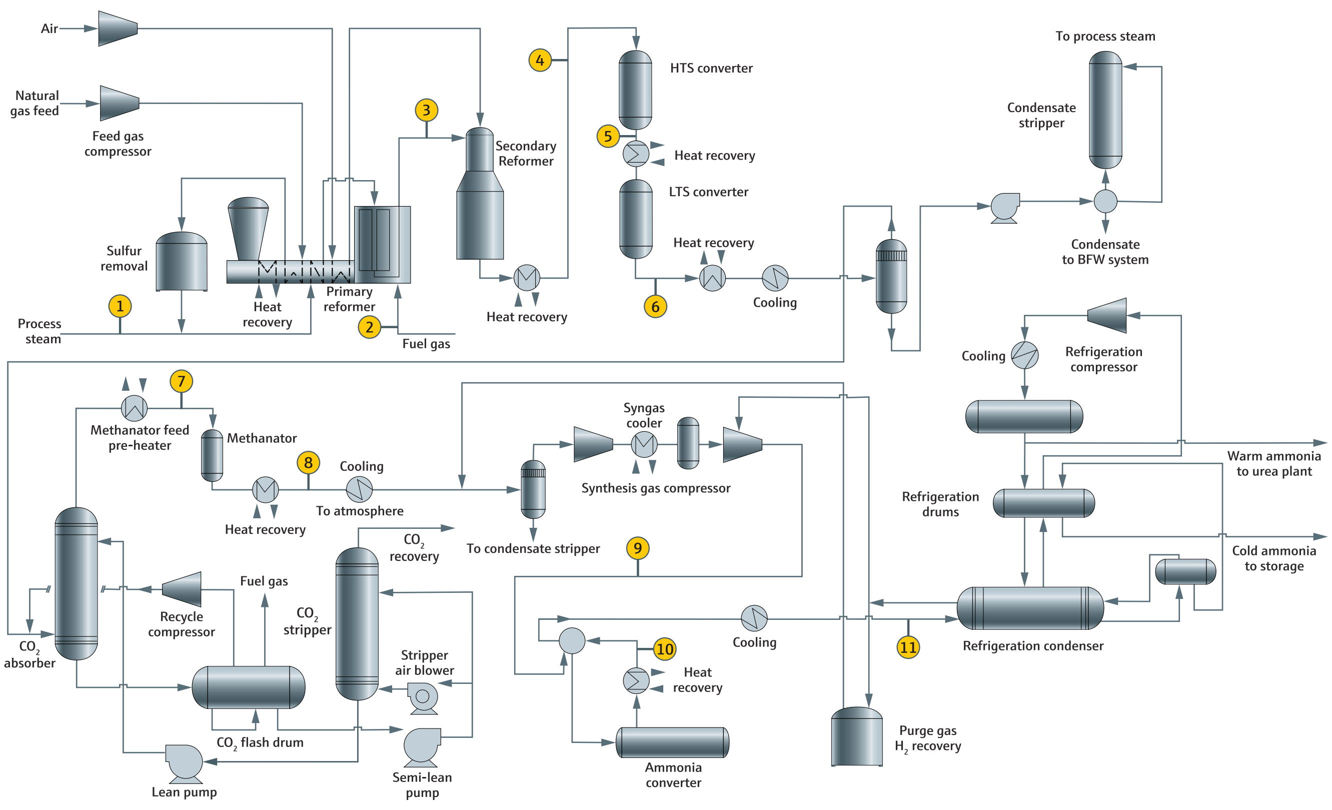
Ammonia: production analytics overview

Ammonia production and main uses

Ammonia is one of the most highly produced inorganic chemicals because of its many uses. There are numerous large-scale ammonia production plants worldwide, producing a total of 146 million tons of ammonia in 2015. [1] China produced 32.1% of the worldwide production, followed by India with 8.9%, Russia with 7.9%, and the United States with 6.3%. Fertilizing agricultural crops consumes over 80% of the ammonia produced. Other uses of ammonia include the production of plastics, fibers, explosives, and nitric acid. Ammonia is also used as an intermediate in the manufacturing of dyes and pharmaceuticals.

The overall ammonia process

In a typical ammonia producing plant using natural gas feedstock, a steam methane reformer (SMR) is used to convert the natural gas to syngas, which is a mixture of mostly H_2 and CO. The CO is then converted into additional H_2 and CO_2 using water shift (WS) reactors. Subsequent syngas processing purifies the syngas by removing the CO_2 via a CO_2 absorber followed by the methanation of any remaining CO_2 (which is a poison for the catalyst used to synthesize NH_3). The N_2 from an air separation unit is combined with the H_2 and reacted via the Haber-Bosch process in an ammonia conversion reactor. Because the $H_2 + N_2 \leftrightarrow NH_3$ process is reversible, the equilibrium is driven towards the NH_3 product side by continuously liquefying and removing some of the NH_3. This continuous synthesis loop results in the build-up of the original impurities in the purified syngas used as feed to the ammonia reactor, and needs to be purged on a regular basis.



A simplified process diagram showing the main process units in a modern ammonia plant using natural gas as the primary feedstock.

1. U.S. Geological Survey, 2016, Mineral Commodity Summaries 2016: U.S. Geological Survey, pp 118-119.

Process analytical challenges

There are several streams that are typically analyzed during the ammonia manufacturing process, and the analysis results form the basis for controlling and optimizing the main process units. Although most of the streams are relatively easy to analyze using traditional on-line analyzer techniques, such as GC, MS, and photometry, in several cases steam content and process conditions are severe enough to require special sample conditioning techniques. The use of the Raman Rxn5 analyzer, combined with the dynamic reflux sampling (DRS) interface, is a unique and robust solution for these challenging streams.

The solution: Raman Rxn5 analyzer

The Raman Rxn5 analyzer provides the unique spectroscopic ability to analyze the homonuclear diatomic gases H_2 and N_2, which allows measurement of all the streams shown in the typical "Stream services" list below. Speciation is achieved without any columns, valves, stream switching or the need for carrier gas. The Rxn5 analyzer uses fiber optic cables of up to 150 meters in length to connect an Rxn-30 gas probe to the analyzer. The user of fiber optic cables allows the gas probe to be interfaced with a sample conditioning system near a sample tap point, such that no gas needs to be transported to the analyzer via expensive and high-maintenance heated gas transfer lines, and eliminating lag time typical for GC and MS systems. No potentially toxic or explosive gas mixtures are brought near or into the analyzer, enhancing operator safety during maintenance activities. With a properly designed sample conditioning system, gas composition measurements can be made at temperatures up to 150 °C and pressures of up to 1000 psia. The ability of the Rxn-30 probe to measure under these conditions simplifies the sample conditioning required and often allows the sample to be returned to the process after non-destructive Raman measurement, eliminating costly flaring.

	Stream service	Key measurement parameter	Pressure* (barg)	Temp* (°C)
1	Ammonia: natural gas feed to primary reformer	Carbon number	26	25
2	Ammonia: fuel gas to reformer furnaces	Btu	6	40
3	Ammonia: raw syngas - primary reformer outlet	Composition/CH_4	36	800
4	Ammonia: raw syngas - secondary reformer outlet	Composition/CO	35	370
5	Ammonia: high temperature shift converter outlet	Composition/CO	34	445
6	Ammonia: low temperature shift converter outlet	Composition/CO_2	32	220
7	Ammonia: CO_2 absorber outlet - methanator inlet	Composition/CO_2	31	25
8	Ammonia: methanator outlet - purified syngas	Composition/H_2/N_2	30	330
9	Ammonia: converter feed stream	H_2/N_2 ratio	57	400
10	Ammonia: converter exit stream	Composition/impurities	220	440
11	Ammonia: synthesis loop purge gas	CH_4 impurities	150	25

* Pressure and temperature values listed are for typical process unit stream conditions