Ammonia Process Gas Analysis

Hamilton Sundstrand
A United Technologies Company

Applied Instrument Technologies

The MGA™ Process Mass Spectrometers are offered by Hamilton Sundstrand for the precise and accurate on-line determination of stream composition for ammonia synthesis operations throughout the plant. Configured for this application, the MGA can monitor the percent concentration of the following typical gases:

Typical Gases Monitored

Hydrogen (H_2)	0–100%
Nitrogen (N_2)	0–100%
Methane (CH_4)	0–10%
Ammonia (NH_3)	0–20%
Water (H_2O)	0–20%
Carbon Monoxide (CO)	0–100%
Argon (Ar)	0–10%
Carbon Dioxide (CO_2)	0–100%

Note: Other gas configurations and/or full-scale percentages are available.

The MGA has a worldwide reputation for exceptional stability and reliability under the most adverse of installation conditions, making it an ideal tool for increasing ammonia operation efficiency.

Ammonia Converter Efficiency

For efficient and profitable ammonia plant operations, the chemical composition of several process streams must be delicately balanced. As a result of the precise analysis and control of these compositions, a plant can achieve greater economies in ammonia yield, and material and energy savings from fire reformers, drive compressors, and purge inerts that build up in the synthesis loop.

The MGA gas analyzer provides the rapid speed of analysis required to enable plant operators to maintain a tight control of critical processes. A key application is the precise determination of the H_2/N_2 ratio of the converter feed. The ammonia content of the converter effluent can also be monitored continuously to optimize conversion efficiency.

With a four-stream application, a complete analysis of all process gases of interest can be accomplished in 40 s with an MGA. This approximate analysis provides an extremely fast payback time on the MGA (see Figure 1).

Ammonia Plant Pilot Test Summary

The following summarizes the results from an MGA pilot installation in an ammonia operating plant closely paralleling the industry standard.

Most ammonia plants in the U.S. use natural gas and air as starting materials. Plants abroad tend to use naphtha, similar hydrocarbon liquids, or coal. Despite these differences in the composition of the raw materials, these plants all produce synthesis gas of approximately the same composition.

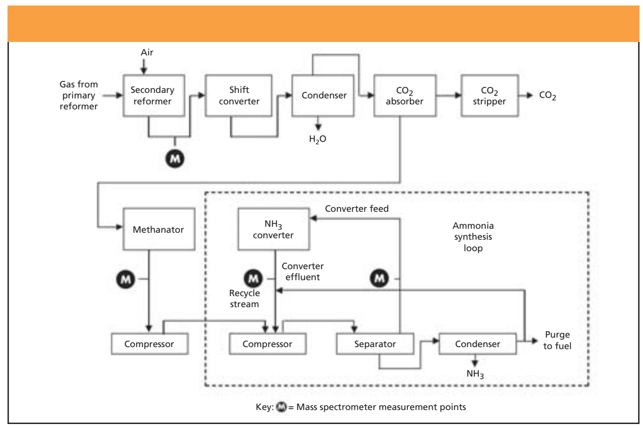

Figure 1: The typical ammonia plant process flow diagram is shown here with possible MGA monitoring points. A single MGA monitors the four points shown below.

Raw gases are usually produced in a primary-secondary stream reformed process according to the reaction:

$CH_4 + H_2O \rightarrow CO + 3H_2$

$CO + H_2O \rightarrow CO_2 + H_2$

Air is admitted in the Secondary Reformer step to give an exit gas with a three-to-one hydrogen–nitrogen ratio. On the pilot tests, this stream was monitored by the MGA, not only to control the ratio, but also to measure methane, which along with argon from the air, enters the synthesis loop as an inert gas. The gas then goes to a two-stage catalytic Shift Converter, where the carbon monoxide is converted to carbon dioxide to produce more hydrogen according to the reaction:

$CO + H_2O \rightarrow CO_2 + H_2$

In the next stage, the carbon dioxide is removed in the Absorber Section to prevent poisoning the ammonia synthesis catalyst. The absorbent is generally an ethanolamine or hot carbonate. From the Carbon Dioxide Absorber, the partially purified synthesis gas then goes to a Methanator, where the residual carbon dioxide, not removed during the absorber stage, is converted to methane by:

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

From the Methanator, small amounts of methane and water enter the synthesis loop as inert gases, but at this stage of the process they are not poisonous to the catalyst. However, it should be noted that the water is removed from the process stream before the gas enters the conversion stage. This exit gas from the Methanator is now the "make-up" gas for the synthesis loop, and the composition of the gas is critical at this stage of the process. During the pilot tests, the process stream was monitored by the MGA at the Methanator exit stream.

From the Methanator, the "make-up" gas goes into the conversion-separation loop where it is mixed with recycle gas from the Ammonia Converter, compressed, fed to the Separator to extract the processed ammonia, then finally fed to the Ammonia Converter. The composition of the gas after the ammonia has been removed at the Ammonia Converter inlet stream was monitored at the Converter feed stream.

At the outlet of the Ammonia Converter, the effluent containing ammonia is analyzed, and the ammonia content is maximized by "trimming" the hydrogen-nitrogen ratio. Depending on the compressor loads, this can be achieved by either varying the gas or air at the reformers.

Thus, while this example is a vast simplification of the overall flow, and many of the finer details of plant operation have been omitted, a single MGA can monitor the four critical stages of the ammonia synthesis process once every 10 s, and repeat the entire cycle for all four processes once every 40 s.

In summary, it can be concluded that in addition to increased ammonia production, the MGA permits increased efficiency in the operation of the Ammonia Converter, thus decreasing the recycle compressor loading, and yielding a significant savings in energy. This is due primarily to the fact that in the ammonia synthesis process, the conversion per pass is relatively low, and the recycle rates are relatively high; thus, efficient operation of the compressors is of paramount importance to the unit.

Analyzer Selection

Hamilton Sundstrand offers three different process mass spectrometers to meet our customers' varied needs. With each instrument type, the detection limit is application dependent.

The MGA 1200EC is the only process mass spectrometer that can provide simultaneous outputs for up to 10 compounds. Compounds can be monitored over the range of 300 ppm to 100%.

The MGA 1600ES can provide analytical results for up to 16 compounds. Compounds can be monitored over the range of 300 ppm to 100%.

The MGA iSCAN is the only double-focusing, magnetically scanned process mass spectrometer. Up to 40 compounds can be monitored over the concentration range of 20 ppb to 100%.

Applied Instrument Technologies
2771 North Garey Avenue
Pomona, CA 91767
Tel. (909) 593-3581, Fax (909) 392-3207
www.hs-ait.com