Use of Process Analytics in ammonia (NH₃) production

Gas analyzers and chromatographs control production of fertilizer base material

Case Study · May 2011

Ammonia

Ammonia (NH₃) is an intermediate product in the manufacture of nitrogenous fertilizers. It is also used for direct application to the soil and in solutions of other nitrogenous fertilizers like ammonium nitrate and/or urea. Besides these, ammonia is used in many industries including explosives and refrigeration.

Ammonia is produced by a reaction between nitrogen (N₂) and hydrogen (H₂). Hundreds of ammonia plants are in operation globally, most of them using natural gas as feedstock and as fuel. Hence, the ammonia production industry is concentrated around areas where natural gas is available at low costs.

Fertilizer for plant growth

Plants need certain chemical elements as nutrients. Important are carbon, hydrogen and oxygen (all available from air and water), and nitrogen, phosphorus and potassium, which are applied through fertilizers. Nitrogen, phosphorus and potassium are crucial for the plants basic building blocks because every amino acid contains nitrogen, every cell’s membrane contains phosphorous and up to 2 percent of the weight of any plant is made up by potassium.

Fertilizer industry

The largest issue for global agriculture is to supply sufficient food to the increasing world population. Nitrogen is a vital component in fertilizer production. An estimate of 80 % of total nitrogen produced worldwide is consumed in fertilizer application. Natural gas and process air - as source of nitrogen - are the key components in production of fertilizers such as ammonia, ammonium nitrate, ammonium calcium nitrate and urea.

Process gas chromatographs and gas analyzers are part of the standard instrumentation of fertilizer plants. Their objective is to continuously monitor and control of processing variables such as composition of the process streams. Measuring results are essential to plant efficiency and product quality.

Siemens Sensors and Communication is well known worldwide for its excellent process analyzer technique, application know how and expertise in engineering and manufacturing turn-key solutions including those for ammonia production.
From starting materials to fertilizers

In common fertilizers, three primary nutrients are present in large quantities: nitrogen, phosphorus and potassium. Nitrogen accounts for over 60% of the total nutrients, phosphorus for 23% and potassium for less than 17%. In addition, secondary nutrients such as sulphur, magnesium and calcium are also required for optimum plant growth.

In fertilizer production routes (Fig. “Fertilizer production routes from starting elements to fertilizer products”), starting materials are air (providing nitrogen), natural gas (providing hydrogen), rocks and salts (providing phosphorus and potassium), and sulfur, magnesium and calcium.

Starting materials are first processed to various raw materials with ammonia as key component for nitrogen based fertilizers. Ammonia is formed by a reaction of natural gas with the nitrogen of the process air. Other raw materials are e.g. nitric and phosphoric acids as well as CaCO₃ and CO₂.

From the raw material, various sorts of fertilizers are produced using further processing routes (DAP/MAP: Di-/Mono-ammonium phosphate). Two major routes exist for syngas production: Steam Reforming of natural gas or other light hydrocarbons e.g Natural Gas liquids or Liquified Petroleum Gas, and Partial Oxidation of heavy fuel oil or vacuum residue with oxygen.

The design of ammonia plants varies depending on raw materials, plant size, product specification etc. Therefore, the process described here is a typical example but may differ from real processes.
Sampling points and measuring details, related to Fig. „Ammonia production process (Steam reforming route; typical example)” (TPA: Third Party Analyzer)

Steam Reforming route (Fig. “Ammonia production process (Steam reforming route; typical example)”)  
- The natural gas or light hydrocarbon feed stream is pre-heated and treated in a desulphurization reactor to remove sulfur and other components that would damage the catalysts of the subsequent reactors.  
- Process steam is then added and the stream is heated further and enters the primary reformer where the hydrocarbons partially react with water (from the steam) to form hydrogen and mixed carbon oxides over a catalyst. The heat for this highly endothermic reaction is supplied by burning gaseous fuels in the reactor. The flue gases of the reformer are major emission sources.  
- The stream then enters the secondary reformer to achieve further conversion at higher temperature. This is done by internal combustion of part of the gas with added process air.  
- The process air also supplies nitrogen to the stream that is required for the ammonia synthesis at the end of the route.  
- After passing through a cooler (not shown in Fig. “Ammonia production process (Steam reforming route; typical example)”) the process gas enters a combined high and low temperature CO shift converter where most of the CO reacts with water to CO₂ and H₂.  
- Before conversion to ammonia most of the CO₂ must be removed from the stream in an absorption (scrubbing) process. Typically aqueous amine solutions are used as solvents.  
- Residual amounts of CO and CO₂ in the syngas are poisonous to the ammonia synthesis catalyst and are, therefore, removed by conversion to CH₄ in the methanator.  
- The syngas is then dried, filtered and compressed and enters the synthesis reactor where a portion of the gas is converted to ammonia at high pressure. A recycle gas stream returns to the compressor for reprocessing. A purge gas stream is removed to control the build-up of inert gases and is used as fuel gas for e. g. the primary reformer.
The converter effluent is cooled to condense ammonia which is removed in the separator.

Fig. “Ammonia production process (Steam reforming route; typical example)” shows, as typical example, major sections of a steam reforming process route with measuring locations of process analyzers. The corresponding measuring tasks, measured components and suitable analyzers are shown in table “Sampling points and measuring details, related to Fig. “Ammonia production process (Steam reforming route; typical example)” (TPA: Third Party Analyzer). Real plant design may differ from this example.

Partial Oxidation route
The partial oxidation route is applied in case of using heavier hydrocarbon feedstocks such as naphtha or heavy oil, but also coal or plastic wastes. Partial oxidation gasification is a non-catalytic process at high pressure and temperature where the feedstock is cracked to shorter chain hydrocarbons. The cracked products are reformed. A supplementary air separation unit is necessary here to supply the required oxygen. Nitrogen is supplied via a liquid nitrogen wash solution to remove impurities from the synthesis gas. The subsequent process steps such as CO shift, CO₂ removal and ammonia synthesis are quite similar to those used in the steam reforming route.

Optimized processes
Although fundamental ammonia production technologies have not changed principally in recent years, numerous technological improvements have taken place, aiming for increased energy efficiency, higher process flexibility and lower plant operating costs. Most of these advantages are being achieved through development and implementation of better process conditions and more efficient equipment design including process analytical instrumentation.

The Linde Ammonia Concept (LAC)
The LAC is a process for the production of ammonia from natural gas or light hydrocarbons. An LAC plant primarily comprises a modern hydrogen plant, a standard nitrogen plant and a high-efficiency ammonia synthesis section.

The LAC process means a simplification of the classic process route and leads to savings in investment and operating costs, as well as simplified plant start-up and operation.

The Krupp Uhde GmbH process
This process is used to produce ammonia from natural gas, LNG, LPG or naphtha. Other hydrocarbons are possible feedstocks with an adapted front-end. The process uses conventional steam reforming synthesis gas generation and a medium-pressure ammonia synthesis loop. It is optimized with respect to low energy consumption and maximum reliability.

Ammonia technology licensors
In the last decade, improved and more efficient ammonia technologies have been commercialized worldwide by major licensors (table “Ammonia licensors”). These companies account for the majority of all ammonia plants being built worldwide.
Process Analytics in fertilizer plants

Process monitoring and control
As many other processes, ammonia production follows many stages from desulphurization and primary reformer up to the ammonia synthesis reactor. The process effluent runs from stage to stage and must be monitored at any stage with high accuracy.

Sudden variations in stream composition would affect all subsequent stages with severe impacts to process quality and efficiency. This is why Process Analytics is so important in ammonia plants.

Examples are:

- Energy savings through analysis of the feed BTU value for tight control of the steam to carbon ratio
- Increased efficiency through tight control of H₂/N₂ ratio or optimizing the purge gas to optimum conditions
- Increased production rate through minimizing plant downtimes

Other analytical applications
Fig. “Ammonia production process (Steam reforming route)” and table “Sampling points and measuring details” refers to the very common ammonia production process using the steam reforming route. In addition, other processes exist for different fertilizers with different analytical applications. An example is the DAP (Di-Ammonia Phosphate) route which is based on the reaction of ammonia with phosphoric acid. Here, the in-situ laser gas analyzer LDS 6 is used very successfully for the analysis of NH₃ and HF.

Emission monitoring
From ammonia plants (steam reforming route) the following emissions sources and components must be considered:

- Flue gas from the primary reformer: NOx, SO₂, H₂S and CO
- Vent gases from CO₂ removal: CO₂ and traces of synthesis gas
- Purge and flash gases from the synthesis section: These gases are typically treated and routed to the primary reformer fuel gas system, where they end up as part of the flue gas.

Siemens strength in ammonia process analytics
Siemens Process Analytics has proved its excellent competence and experiences in handling ammonia plant projects from the very beginning. Leading technology in gas analyzers and chromatographs, turnkey system engineering competence and outstanding application knowledge make Siemens a strong partner for delivery of process analytics to ammonia plants world wide. And with Totally Integrated Automation (TIA), Siemens Process Analytics is also able to provide efficient solutions that integrate process analysers into automation systems in the process industry. See a respective screenshot of a PCS 7 controlled ammonia plant displaying all measuring data received from an analyzer house (Fig. “Overview analyzer house; preconfigured visualization”).

<table>
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<tr>
<th>Ammonia licensors</th>
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<tr>
<td>Ammonia Casale</td>
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<tr>
<td>Haldor Topsoe</td>
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<td>Jacobs Engineering</td>
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<td>Kellog Brown &amp; Root</td>
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<td>Texaco Development</td>
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Ammonia licensors
Siemens Process Analytics at a glance

Product overview

Siemens Process Analytics is a leading provider of process analyzers and process analysis systems. We offer our global customers the best solutions for their applications based on innovative analysis technologies, customized system engineering, sound knowledge of customer applications and professional support. And with Totally Integrated Automation (TIA). Siemens Process Analytics is your qualified partner for efficient solutions that integrate process analysers into automations systems in the process industry.

From demanding analysis tasks in the chemical, oil & gas and petrochemical industry to combustion control in power plants to emission monitoring at waste incineration plants, the highly accurate and reliable Siemens gas chromatographs and continuous analysers will always do the job.

Siemens process Analytics offers a wide and innovative portfolio designed to meet all user requirements for comprehensive products and solutions.

Our Products

The product line of Siemens Process Analytics comprises

- extractive and in-situ continuous gas analyzers
- process gas chromatographs
- sampling systems
- auxiliary equipment

Analyzers and chromatographs are available in different versions for rack or field mounting, explosion protection, corrosion resistant etc.

A flexible networking concept allows interfacing to DCS and maintenance stations via 4 to 20 mA, PROFIBUS, OPC, Modbus or industrial ethernet.
**Product scope**

**Siemens Continuous Gas Analyzers and Process Gas Chromatographs**

<table>
<thead>
<tr>
<th>Extractive Continuous Gas Analyzers (CGA)</th>
<th>In-situ Continuous Gas Analyzers (CGA)</th>
<th>Process Gas Chromatographs (Process GC)</th>
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<tr>
<td><strong>ULTRAMAT 23</strong></td>
<td><strong>LDS 6</strong></td>
<td><strong>MAXUM edition II</strong></td>
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<td>The ULTRAMAT 23 is a cost-effective multicomponent analyser for the measurement of up to 3 infrared sensitive gases (NDIR principle) plus oxygen (electrochemical cell). The ULTRAMAT 23 is suitable for a wide range of standard applications. Calibration using ambient air eliminates the need of expensive calibration gases.</td>
<td>LDS 6 is a high-performance in-situ process gas analyser. The measurement (through the sensor) occurs directly in the process stream, no extractive sample line is required. The central unit is separated from the sensor by using fiber optics. Measurements are carried out in realtime. This enables a pro-active control of dynamic processes and allows fast, cost-saving corrections.</td>
<td>MAXUM edition II is very well suited to be used in rough industrial environments and performs a wide range of duties in the chemical and petrochemical industries and refineries. MAXUM II features e.g. a flexible, energy saving single or dual oven concept, valveless sampling and column switching, and parallel chromatography using multiple single trains as well as a wide range of detectors such as TCD, FID, FPD, PDHID, PDECD and PDPID.</td>
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<tr>
<td><strong>CALOMAT 6/62</strong></td>
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<td><strong>MicroSAM</strong></td>
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<td>The CALOMAT 6 uses the thermal conductivity detection (TCD) method to measure the concentration of certain process gases, preferably hydrogen. The CALOMAT 62 applies the TCD method as well and is specially designed for use in application with corrosive gases such as chlorine.</td>
<td>MicroSAM is a very compact explosion-proof micro process chromatograph. Using silicon-based micromechanical components it combines miniaturization with increased performance at the same time. MicroSAM is easy to use and its rugged and small design allows mounting right at the sampling point. MicroSAM features drastically reduced cycle times, provides valveless sample injection and column switching and saves installation, maintenance, and service costs.</td>
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<td><strong>OXYMAT 6/61/64</strong></td>
<td><strong>SITRANS SL</strong></td>
<td><strong>SITRANS CV</strong></td>
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<td>The OXYMAT 6 uses the paramagnetic measuring method and can be used in applications for process control, emission monitoring and quality assurance. Due to its ultrafast response, the OXYMAT 6 is perfect for monitoring safety-relevant plants. The corrosion-proof design allows analysis in the presence of highly corrosive gases. The OXYMAT 61 is a low-cost oxygen analyser for standard applications. The OXYMAT 64 is a gas analyzer based on ZrO$_2$ technology to measure smallest oxygen concentrations in pure gas applications.</td>
<td>SITRANS SL is a compact transmitter-like designed gas analyzer for fast in-situ measurements of oxygen concentration in process gases. The measuring principle is based on the diode laser technology and almost free of cross-interferences. The analyzer consists of a transmitter and receiver unit which are mounted directly at the process.</td>
<td>SITRANS CV is a micro process gas chromatograph especially designed for reliable, exact and fast analysis of natural gas. The rugged and compact design makes SITRANS CV suitable for extreme areas of use, e.g. off-shore exploration or direct mounting on a pipeline. The special software “CV Control” meets the requirements of the natural gas market, e.g. custody transfer.</td>
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<td><strong>FIDAMAT 6</strong></td>
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<td>The FIDAMAT 6 measures the total hydrocarbon content in air or even in high-boiling gas mixtures. It covers nearly all requirements, from trace hydrocarbon detection in pure gases to measurement of high hydrocarbon concentrations, even in the presence of corrosive gases.</td>
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Analytical solutions are always driven by the customer’s requirements. We offer an integrated design covering all steps from sampling point and sample preparation up to complete analyser cabinets or for installation in analyser shelters (fig. “Analyzer house (shelter)”). This includes also signal processing and communications to the control room and process control system.

We rely on many years of world-wide experience in process automation and engineering and a collection of specialized knowledge in key industries and industrial sectors. We provide Siemens quality from a single source with a function warranty for the entire system.

Read more in chapter “Our services”.

Engineering and manufacturing of process analytical solutions increasingly comprises “networking”. It is getting a standard requirement in the process industry to connect analyzers and analyzer systems to a communication network to provide for continuous and direct data transfer from and to the analysers. The two objectives are (fig. “Networking for DCS integration and maintenance support”)

- To integrate the analyzer and analyzer systems seamless into the PCS/DCS system of the plant and
- To allow direct access to the analyzers or systems from a maintenance station to ensure correct and reliable operation including preventive or predictive maintenance (fig. “Communication technologies”).

Siemens Process Analytics provides networking solutions to meet the demands of both objectives.
Siemens Process Analytics is your competent and reliable partner worldwide for Service, Support and Consulting. Our resources for that are:

- **Expertise**
  As a manufacturer of a broad variety of analyzers, we are very much experienced in engineering and manufacturing of analytical systems and analyzer houses. We are familiar with communication networks, well trained in service and maintenance and familiar with many industrial processes and industries. Thus, Siemens Process Analytics owns a unique blend of overall analytical expertise and experience.

- **Global presence**
  With our strategically located centers of competence in Germany, USA, Singapore and Dubai, we are globally present and acquainted with all respective local and regional requirements, codes and standards. All centers are networked together.

**Service portfolio**

Our wide portfolio of services is segmented into Consulting, Support and Service. It comprises really all measures, actions and advises that may be required by our clients throughout the entire lifecycle of their plant:

- Site survey
- Installation check
- Functionality tests
- Site acceptance test
- Instruction of plant personnel on site
- Preventive maintenance
- On site repair
- Remote fault clearance
- Spare part stock evaluation
- Spare part management
- Professional training center
- Process optimisation
- Internet-based hotline
- FEED for Process Analytics
- Technical consulting

**FEED for Process Analytics**

Front End Engineering and Design (FEED for PA) is part of the planning and engineering phase of a plant construction or modification project and is done after conceptual business planning and prior to detail design. During the FEED phase, best opportunities exist for costs and time savings for the project, as during this phase most of the entire costs are defined and changes have least impact to the project. Siemens Process Analytics holds a unique blend of expertise in analytical technologies, applications and in providing complete analytical solutions to many industries.

Based on its expertise in analytical technology, application and engineering, Siemens Process Analytics offer a wide scope of FEED services focused on analysing principles, sampling technologies, application solutions as well as communication system and given standards (all related to analytics) to support our clients in maximizing performance and efficiency of their projects.

Whether you are plant operators or belong to an EPC Contractor you will benefit in various ways from FEED for Process Analytics by Siemens:

- Analytics and industry know how available, right from the beginning of the project
- Superior analyzer system performance with high availability
- Established studies, that lead to realistic investment decisions
- Fast and clear design of the analyzer system specifications, drawings and documentation
- Little project management and coordination effort, due to one responsible contact person and less time involvement
- Additional expertise on demand, without having the costs, the effort and the risks of building up the capacities
- Lowest possible Total Costs of Ownership (TCO) along the life-cycle regarding investment costs, consumptions, utilities supply and maintenance.
Additional information:

For additional information please contact:
E-Mail: processanalytics.automation@siemens.com

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