Ammonia plants.
Flexible solutions for all feedstocks.
Meeting the challenges of a volatile marketplace.

With volatility in worldwide energy prices and markets, ammonia and fertilizer producers must be prepared to compete in a challenging global market. From light- to heavy hydrocarbon feedstocks, Linde Engineering’s solutions provide flexibility for recovery of valuable by-products, expansion and integration. Producers can get to market faster, earn higher margins and achieve earlier return on investment.

By combining optimized design with proven technologies and the highest quality standards, we offer our customers state-of-the-art solutions. You get inert-free ammonia synthesis gas in the right hydrogen (H₂)-to-nitrogen (N₂) ratio and adjustable carbon dioxide (CO₂) to NH₃ ratios.

It doesn’t have to be complicated.

The Linde Ammonia Concept (LAC™) minimizes the number of process steps to reduce investment and operating costs, shorten project completion time, and simplify plant start-up and operation.

Benefits:
- Less equipment and piping
- Fewer catalytic steps resulting in 50% less total catalyst volume
- Reduced number of control loops and instruments
- Smaller footprint, fewer foundation materials and less structural steel
- Start-up of the ammonia synthesis loop can proceed about two hours after feed is introduced to the reformer, unmatched by any other ammonia process

“Understanding our customers’ needs, offering a value-creating solution and executing are key capabilities at Linde Engineering.”

Jürgen Nowicki
Managing Director
Member of the Board of Directors

Meeting the challenges of a volatile marketplace.
A winning combination of proven technologies.

Hydrogen (H₂) reforming

Steam reforming is the most widely used process for generating hydrogen-rich synthesis gas from feed materials such as natural gas, liquid gas or naphtha. These hydrocarbon feedstocks are converted using steam from process heat or flue gas into synthesis gas in catalytic tube reactors. Linde is a leading supplier of steam reformer plants with more than 200 constructed units producing capacities of synthesis gas from 1,000 to over 120,000 Nm³/h of H₂.

Pressure swing adsorption (PSA) for hydrogen purification

Linde’s high performance PSA plants purify hydrogen from hydrogen-rich streams from reforming or pretreated feeds. These easily maintained plants deliver outstanding reliability and on-stream availability.

Nitrogen and oxygen air separation units (ASU)

For over 100 years, Linde has been a pioneer in air separation technologies. Depending on process needs, high purity nitrogen and/or oxygen are produced by low temperature separation in the air separation unit (ASU). Air is filtered, compressed and purified before being fed to the ASU cold box. Both our modularized and customized plants are scaled for the flow rates you need. High energy efficiency and low maintenance requirements lower operating costs.

Partial oxidation (POx)

Linde is one of the leading contractors for partial oxidation plants world-wide, and its process concept covers all types of hydrocarbon feedstocks and resulting products. Linde’s expertise is backed by more than 30 years of experience and we are the only company worldwide that not only engineers and installs POx plants but also operates them. One of the four POx plants operated by Linde is the world’s largest plant with natural gas feedstock (200,000 Nm³/h H2+CO).

Isothermal shift reactor (ISR)

Used in production from light hydrocarbons, the Linde isothermal shift reactor is a fixed bed unit with indirect heat exchange. This provides the benefits of a tube reactor while avoiding the heat tension problems of a straight tube reactor. The copper-based catalyst promotes CO conversion to CO₂ working at optimum temperatures, resulting in higher outputs, longer catalyst life, fewer by-products and efficient recovery of reaction heat with lower reaction costs.

RECTISOL® CO₂ removal for heavy feedstocks

With Linde’s RECTISOL unit, CO₂ and sulfur compounds are removed in separate fractions, resulting in a pure CO₂ product (for example for urea production) and an H₂S/COS enriched Claus gas fraction. The process can purify synthesis gas down to 0.1 ppmv total sulfur (including COS) and CO₂ in down to ppm range.

The main advantages of the process are low utility consumption figures, use of an inexpensive, easily available solvent and flexibility in process configuration.

Carbon monoxide (CO) shift conversion

At the outlet of steam reformers, partial oxidation reactors or coke oven gas units, the syngas contains hydrogen, carbon monoxide, carbon dioxide, methane, and water. Through CO (carbon monoxide) shift conversion an important portion of the remaining CO is used for additional hydrogen generation. There are three different versions of the CO shift conversion:

- High temperature: conversion around 570 to 840°F bringing carbon monoxide down to approximately 2.5%
- Medium temperature: conversion around 430 to 520°F bringing carbon monoxide down to approximately 0.5%
- Low temperature: conversion around 350 to 480°F bringing carbon monoxide down to approximately 0.2%, typically installed downstream of the high temperature shift to maximize hydrogen yield
Nitrogen wash

Trace components such as CO, argon (AR) and methane (CH₄) are removed from raw hydrogen via low-pressure condensed nitrogen and separated as fuel gas. To establish the desired H₂/N₂ ratio for ammonia synthesis, high pressure nitrogen is added to the process stream prior to the ammonia synthesis process. Linde manufactures and assembles the cryogenic components of the nitrogen wash unit as a transportable “cold box”.

Ammonia synthesis

Linde employs third-party licensed technology for ammonia synthesis, which has included an axial-radial flow converter in a three bed arrangement with a feed/product heat interchanger located in a single pressure shell. The hot gas leaving the ammonia converter is used to generate high pressure steam.

Most of the technologies in our ammonia plants have been developed by Linde

Read more:
www.leamericas.com/reforming
www.leamericas.com/airseparation
www.leamericas.com/ISR
www.leamericas.com/rectisol
www.leamericas.com/n2wash

Isothermal shift reactor  RECTISOL®  Nitrogen wash  Ammonia synthesis
LAC™ for light hydrocarbons.

A more direct route to ammonia than conventional processes.

Process overview
A LAC installation is primarily made up of a hydrogen plant, a standard nitrogen air separation plant, and high-efficiency ammonia synthesis loop. In the hydrogen plant, the synthesis gas (syngas) is purified by pressure swing adsorption (PSA) in a single process step. The high purity nitrogen delivered from the nitrogen plant is mixed with the syngas upstream of the synthesis gas (syngas) compressor and ammonia (NH3) synthesis unit.

Feed treatment
Natural gas (or other light hydrocarbon) feedstock is brought on site and preheated. Any non-reactive sulfur compounds are hydrogenated with a small amount of recycle hydrogen (H₂) from the syngas compressor. The feedstock is further heated in the waste heat recovery unit with hot reformer flue gas and sent to combined hydrogenation and desulfurization reactors to convert the sulfur components into hydrogen sulfide (H₂S), hydrogenating unsaturated hydrocarbons and simultaneously removing the formed H₂S through a guard bed of zinc oxide catalyst. The reactors are arranged in series to achieve a high loading of individual catalyst beds before they are replaced.

Steam reforming of hydrogen
Desulfurized feedstock is mixed with steam produced in the isothermal shift reactor (ISR) and supplemented by makeup from the steam drum and high pressure steam header, then preheated in the mixed feed preheater. In the reformer, the feed-steam mixture is reacted with steam over nickel-based catalyst in high alloy reformer tubes. Steam is added to the preheated and purified feedstocks to obtain the steam-to- feed ratio required for the reforming catalyst.

The feed hydrocarbon-steam mixture converts primarily into hydrogen and carbon monoxide.

To reduce residual methane content in the resulting gas while simultaneously improving hydrogen/carbon monoxide output and prevent carbon deposition on the catalyst, process steam is added to the feed gas in excess of the stoichiometric quantity.

Any required heat is supplied externally by top firing reformer burners, PSA burner purge gas, and supplemental natural gas fuel.

Flue gas from the radiant section of the reformer furnace preheats reformer feed, generates superheated high pressure steam, and preheats combustion air before being passed by an induced draft fan via a stack to the atmosphere.

Isothermal CO shift reactor
A copper-based catalyst promotes CO conversion into CO₂, which increases hydrogen yield and concentration in the product gas.

The reactor is maintained at a constant temperature of about 250°C by a spiral-wound cooling bundle. Inside the bundle tubes, process condensate is circulated, producing steam for the reforming process.

Further process gas cooling takes place with heat recovery from various streams, including process condensate. Separated process condensate is recycled to the ISR to generate process steam and maintain catalyst temperature. No process condensate treatment unit is required.

Hydrogen purification with pressure swing adsorption
Components in the raw process gas such as CO, CO₂ and methane are removed in a single process with four basic steps:

- Adsorption
- Depressurization
- Regeneration
- Repressurization

The process gas passes through some of the adsorber vessels and is purified up to 99.9999 mol% hydrogen. Meanwhile, the loaded adsorbers pass through a controlled sequence of depressurization and purging steps for regeneration. Tail gas produced in the PSA unit is used as fuel gas for the reformer furnace, accounting for about 75% for reformer fuel gas demand. Swings in tail gas composition and pressure are leveled out with a buffer drum, allowing a steady supply of fuel gas to the reformer furnace.

Nitrogen production
High purity nitrogen is produced by low temperature separation in the air separation unit (ASU). Air is filtered, compressed and purified before being fed to the ASU cold box. The nitrogen is further compressed prior to mixing with hydrogen for ammonia synthesis.
Ammonia synthesis
Hydrogen from the PSA unit and pre-compressed nitrogen from the ASU are mixed, and the combined gas is compressed in a steam turbine-driven centrifugal syngas compressor. The ratio of hydrogen to nitrogen fed to the compressor is controlled to achieve stable operation of the syngas compressor and ammonia synthesis loop.

Linde employs third-party licensed technology for ammonia synthesis, which has included an axial-radial flow converter in a three bed arrangement with a feed/product heat interchanger located in a single pressure shell. The hot gas leaving the ammonia converter is used to generate high pressure steam.

The benefits of this design include:

• No top cover on the catalyst beds, allowing some gas to enter axially
• Even radial gas flow distribution throughout the bed obtains maximum performance from the catalyst volume charged in the converter
• The three adiabatic bed design with intercooling provides for lower catalyst volume and high performance
• Modular construction of the converter provides easy maintenance and fast catalyst replacement.

Flexibility in plant design
• CO₂:
  • Removal process is eliminated for pure NH₃ production
  • If CO₂ as a by-product is needed, an additional CO₂ removal system can be included
  • CO₂ removal can be integrated into the plant at a later stage with no pre-investment
• Pure hydrogen and nitrogen are directly available from process streams. Other potential by-products such as oxygen, argon, carbon monoxide, CO₂ and methanol can be easily recovered for increased profitability.
• Steam produced from the ammonia synthesis process can be used in a valuable manner throughout the plant for driving rotating equipment or for other process requirements.
• Our sophisticated PSA gas purification technology is highly reliable, and can allow for NH₃ production without a water gas shift conversion if capital and operating savings are required.

Comparison of LAC.L1 and conventional ammonia process block diagrams
Modifications to the basic LAC design provide the opportunity to increase NH₃ to CO₂ ratio flexibility, overall plant energy efficiency, and to achieve higher plant capacities.

The following additions are made to the basic LAC.L1 design:

- Oxygen separation is added to the air separation unit
- Catalytic or non-catalytic oxidation of the feed gas using oxygen from the ASU
- CO₂ removal via acid gas removal technologies such as amine or RECTISOL
- Hydrogen purification via nitrogen wash technology

Through the production of a high concentration CO₂ stream, the production of downstream products such as urea is more easily facilitated. Additionally, the use of the oxidation process for reforming the feed gas enables the process to operate at larger single train capacities than the world’s largest H₂ steam reformers.
Hydrogen-rich feedstocks.

In cases where a hydrogen-rich feedstock is already available, the LAC can be designed to skip the reforming section and product high purity hydrogen from the purification of the feed gas via a PSA. The nitrogen stream is still produced in the ASU and blended with the hydrogen stream in the ammonia synthesis reactor. This is an economical and high value-added to any chemical or industrial facility which has an excess of hydrogen production in an off-gas.

Of course, should CO₂ be available in the hydrogen feed gas stream, the plant can be designed to recover it as well for other process purposes. Purge gas from the PSA can be used as a heating media or fuel gas elsewhere in the facility.

Comparison of LAC block diagrams
LAC.M - modularized design.

For smaller capacity ammonia production that requires absolute lowest installed capital cost for profitability, Linde is well suited to design and fabricate a highly modularized ammonia facility which can be trucked or barged into challenging locations for increased constructibility. Based on our Hydro-Chem offerings for small scale hydrogen production, ammonia plants up to approximately 300 mtpd capacity can include a Hydro-Chem hydrogen plant, modularized ammonia synthesis loop and cooling train, and highly transportable nitrogen production facility.

The Hydro-Chem plant may consist of one or two can-type reformers or a conventional HYDROPRIME® box reformer followed by a PSA for hydrogen purification. In this design, the plant is designed strictly for lowest installed cost, without sacrificing significantly on efficiency.
**Process overview**

- High pressure gasification of heavy fuel oil with oxygen ($O_2$) to produce raw synthesis gas
- $N_2$ and $O_2$ supplied from ASU
- RECTISOL wash system for gas clean up and sour gas removal
- Liquid $N_2$ wash system for an inert-free syngas with optimum $H_2/N_2$ ratio
- Syngas from the plant can also be used to produce other products and chemicals such as methanol, carbon monoxide and carbon dioxide

**Gasification**

The chemical reaction of a hydrocarbon feedstock in a reduced oxygen environment will produce a synthesis gas that is comprised of hydrogen, carbon monoxide, carbon dioxide, water, nitrogen, ammonia and other by-products based on what was present in the feedstock itself. Many commercially available gasification technologies are available with well proven track records for conversion of challenging solid and liquid hydrocarbon feedstocks.

**Sour shift**

A catalytic reaction, sour shift, or water-gas shift, will convert carbon monoxide and water into hydrogen and carbon dioxide through an exothermic reaction across one to three shift reactors. The resulting syngas has converted most all CO into $CO_2$ and thereby maximizing the $H_2$ production for ammonia conversion.

**CO$_2$ and sulfur removal with RECTISOL**

With Linde’s RECTISOL unit, $CO_2$ and sulfur compounds are removed in separate fractions, resulting in a pure $CO_2$ product (which could be used for urea production or other processes) and an $H_2S/COS$ enriched tail gas stream designed for Claus conversion into $SO_2$. The process can purify synthesis gas down to 0.1 ppmv total sulfur (including COS) and $CO_2$ in down to ppm range.

The main advantages of the process are low operating costs, inexpensive and highly available solvent and flexibility in process configuration.
Our purge gas plants.

Faced with strong competition, ammonia producers are pressured to increase cost efficiency. The recovery of valuable gases from the purge gas stream lets you maximize the return on your plant operation.

Synthesis gas generated by steam reforming natural gas produces a number of other gases that do not contribute to the ammonia reaction. These purge gases must be continuously removed from the synthesis loop and are generally fed back to the reformer furnaces as fuel gas.

Instead of burning purge gases, it makes good financial sense to recover valuable gases such as ammonia, hydrogen, nitrogen and argon.

Building on our long-standing experience in the field, we have developed a wide portfolio of reliable, customizable solutions that allow operators to maximize the financial benefits of purge gas recovery.

Customized to your needs - for new and existing ammonia plants

At Linde, we understand that performance needs, process requirements and investment constraints vary considerably from one plant to another. We work with you to develop solutions that are customized to your individual business and application challenges.

Building on our extensive technology portfolio, our experts cover everything from ammonia recovery through cryogenic or membrane-based hydrogen recovery to cryogenic argon recovery. We bundle the technologies you need to create the perfect fit for your plant.

Highest quality standards

We manufacture all key cryogenic equipment in house to ensure the highest, predictable quality standards. A global leader in the field of plate-fin heat exchanger technology, we have supplied over 10,000 units since production started in 1981. Columns used as rectifiers are designed and fabricated according to our own hydraulic design blueprint. Drawing on 125 years of experience in the field of cryogenic process plant design, we deliver both assembled packaged units and cold boxes.

Reduced installation and assembly effort

To further reduce risk and assembly effort on site, we also offer skid-mounted solutions. These pre-assembled and pre-tested units ensure a high level of quality.
Hydrogen recovery from the purge gas stream generated by an ammonia synthesis plant in Moron, Venezuela.

**Typical process flow for purge gas recovery in an ammonia synthesis plant**

- Natural gas
- Steam
- Air

- Multi-stage synthesis gas
- Ammonia reactor
- Syngas recycle/compression

- Fuel gas
- \( \text{H}_2 \)
- Purge gas
- Hydrogen (argon and nitrogen) recovery
- Ammonia recovery

- \( \text{Ar} \)
- \( \text{N}_2 \)
- \( \text{NH}_3 \)
Full service spectrum.

We offer a broad range of engineering, installation and after sales services to support our customers from initial design throughout the lifetime of the plant.

Linde Engineering supports you to minimize the total cost of plant ownership. We help you select the best technology for your needs, and standardize and modularize major components where possible to reduce your initial investment.

The bulk of total cost of ownership is found in the operating phase. Energy costs, down time, maintenance work repairs and spare parts management all contribute to the bottom line.

You benefit from our engineering expertise across a full portfolio of technologies, in house manufacturing, and global procurement and construction teams. Linde combines the advantages of local proximity with global strengths.

Some of the services we provide:

- Feasibility studies for modifications and revamps
- Reformer and PSA re-life, upgrades and revamps to improve efficiency, capacity and safety
- Controls upgrades
- Fitness for service assessments
- Outage planning and optimization services
- Retrofits to existing installations for feed flexibility
- Restart of mothballed plants
- Addition of purge gas recovery units for improved financial return on valuable by-products
- Spare parts inventory audits and supply
- Full engineering, procurement and construction services

Linde supports you throughout the lifetime of your plant.
Linde manufactures and modularizes a number of major components and assemblies at its plant in Schalchen, Germany.
Collaborate. Innovate. Deliver.

Linde’s Engineering Division is a leading player in the international plant engineering business. Across the globe, we have delivered more than 4,000 plants and cover every step in the design, project management and construction of turnkey industrial facilities. Our proven process and technology know-how plays an indispensable role in the success of our customers across multiple industries – from crude oil, natural gas extraction and refining to chemical and metal processing.

At Linde, we value trusted, lasting business relationships with our customers. We listen carefully and collaborate closely with you to meet your needs. This connection inspires us to develop innovative process technologies and equipment at our high-tech R&D centers, labs and pilot plants – designed in close collaboration with our strategic partners and delivered with passion by our employees working in more than 100 countries worldwide.

From the desert to the Arctic, from small- to world-scale, from standardized to customized builds, our specialists develop plant solutions that operate reliably and cost-effectively under all conditions.

You can always rely on us to deliver the solutions and services that best fit your needs – anywhere in the world.

Discover how we can contribute to your success at www.leamericas.com

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Core competencies at a glance

**Plant engineering**
- Air separation plants
- LNG and natural gas processing plants
- Petrochemical plants
- Hydrogen and synthesis gas plants
- Chemical plants
- Adsorption plants
- Cryogenic plants
- Carbon capture and utilization plants
- Furnaces, fired heaters, incinerators

**Component manufacturing**
- Cold boxes and modules
- Coil-wound heat exchangers
- Plate-fin heat exchangers
- Cryogenic columns
- Cryogenic storage tanks
- Liquefied helium tanks and containers
- Air-heated vaporizers
- Water bath vaporizers
- Spiral-welded aluminium pipes

**Services**
- Revamps and plant modifications
- Plant relocations
- Spare parts
- Operational support, troubleshooting and immediate repairs
- Long-term service contracts
- Expert reviews for plants, operations and spare part inventory
- Operator training

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