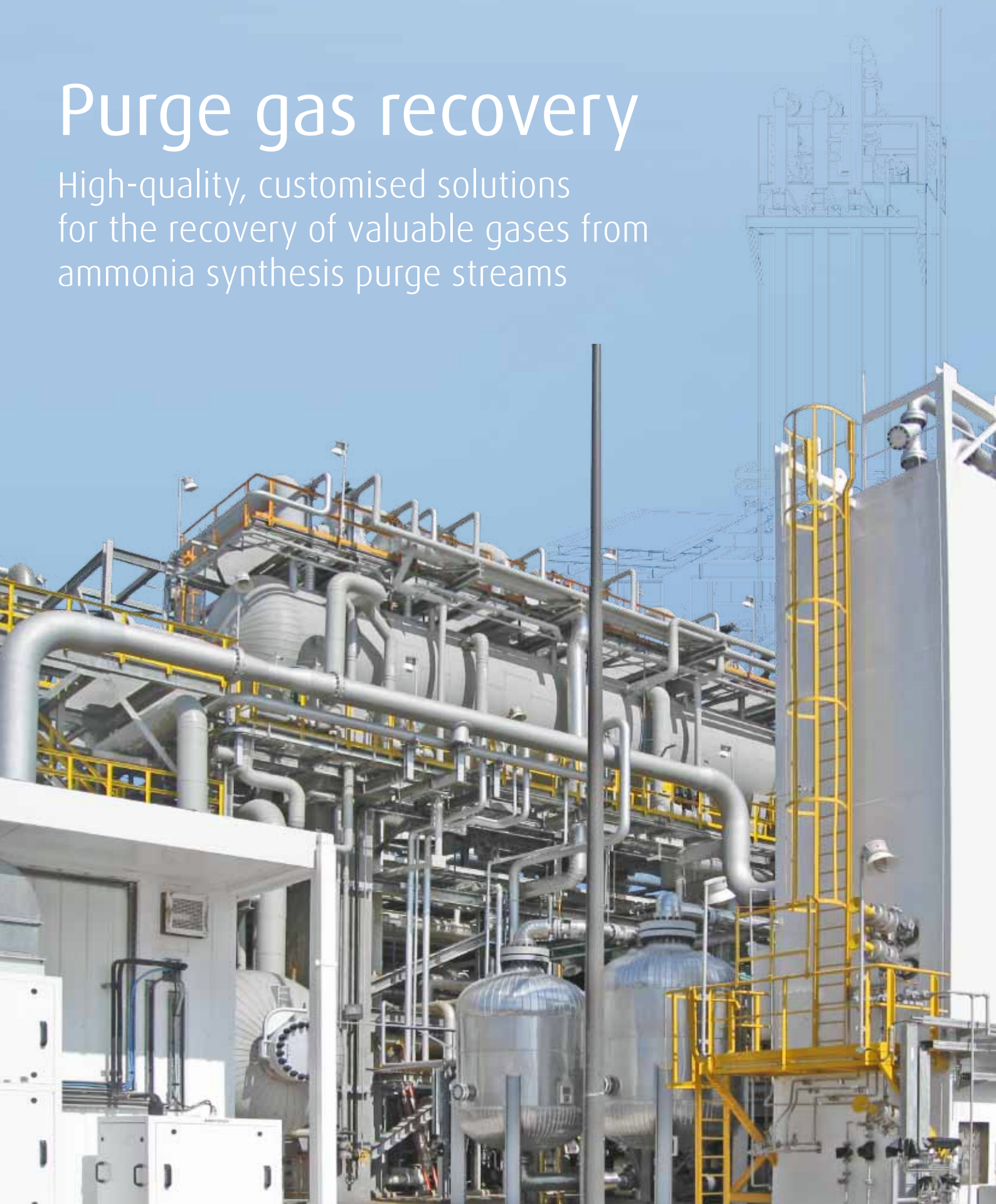


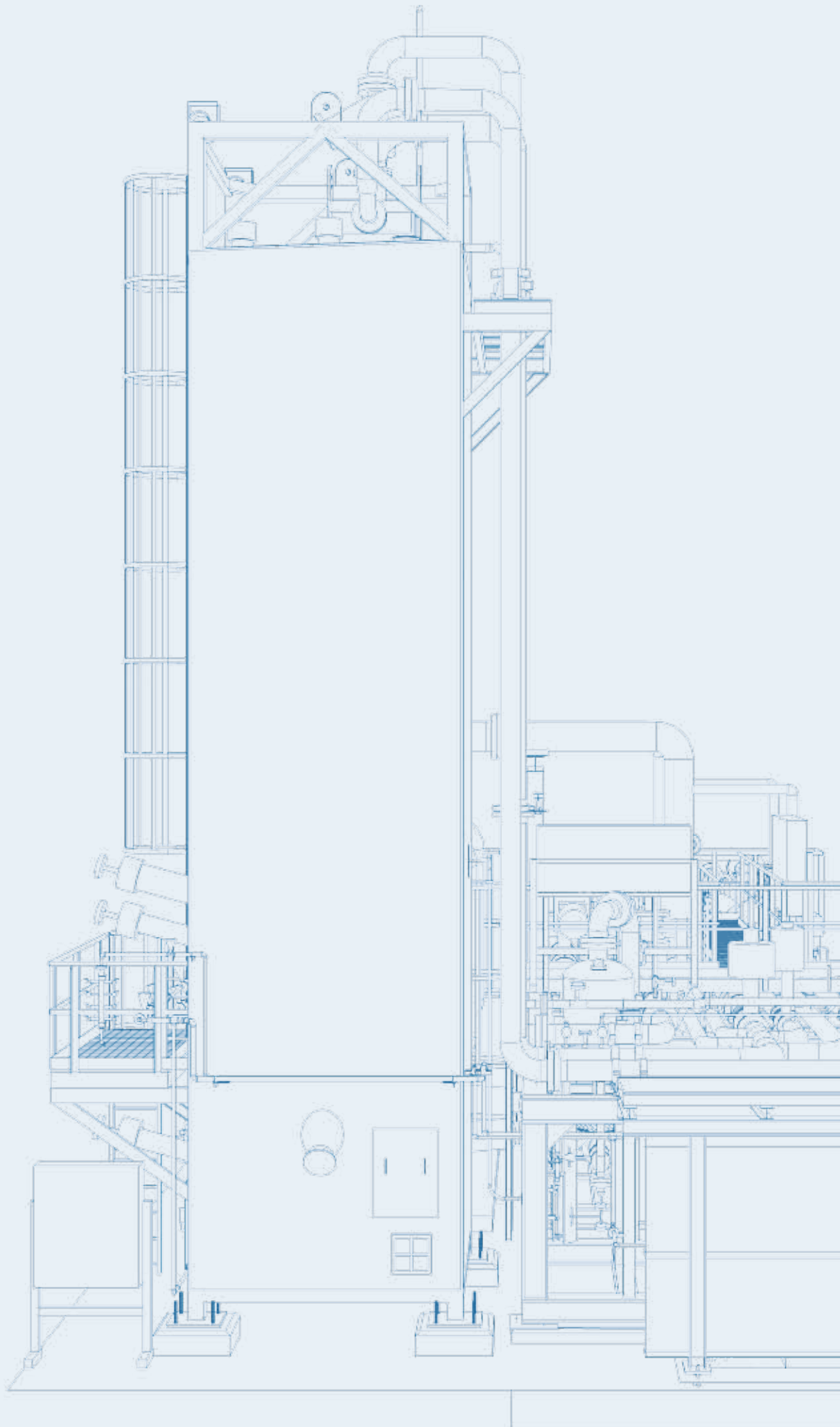
Making our world more productive



Purge gas recovery

High-quality, customised solutions for the recovery of valuable gases from ammonia synthesis purge streams





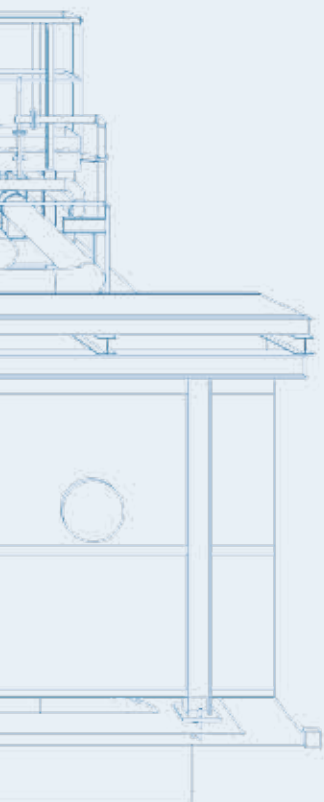
Introduction.

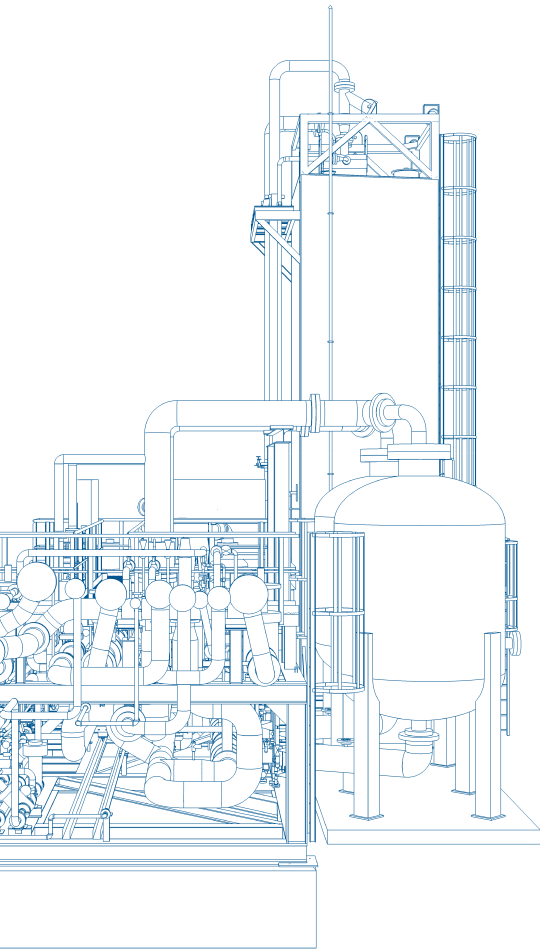
Faced with strong competitive pressures, operators of ammonia synthesis plants are often keen to increase cost efficiency. The recovery of valuable gases from the purge gas stream presents an attractive window of opportunity.

Ammonia synthesis uses syngas generated by steam reforming natural gas (as the feedstock). However, this reaction also produces a number of other gases that do not contribute to the ammonia reaction. These purge gases need to be continuously removed from the synthesis loop and are generally fed back to the reformer furnaces as fuel gas.

A typical purge gas contains about 60% hydrogen, 20% nitrogen, 5% argon, 10% methane and 4% ammonia in varying concentrations, depending on the process in place at the ammonia plant. Instead of burning purge gases, it makes good financial sense to recover valuable gases such as ammonia, hydrogen, nitrogen and argon.

Since 1958, we have been engineering, constructing, delivering and commissioning purge gas recovery plants for our customers. Building on our long-standing experience in the field, we have developed a wide portfolio of reliable, customisable solutions that allow operators to maximise the financial benefits of purge gas recovery.





Detailed view of the ammonia synthesis plant in Moron, Venezuela.

Benefits you can count on.

Customised to your needs

At Linde, we understand that performance needs, process requirements and investment constraints vary considerably from one plant to another. That is why we work with you to develop solutions that are customised 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.

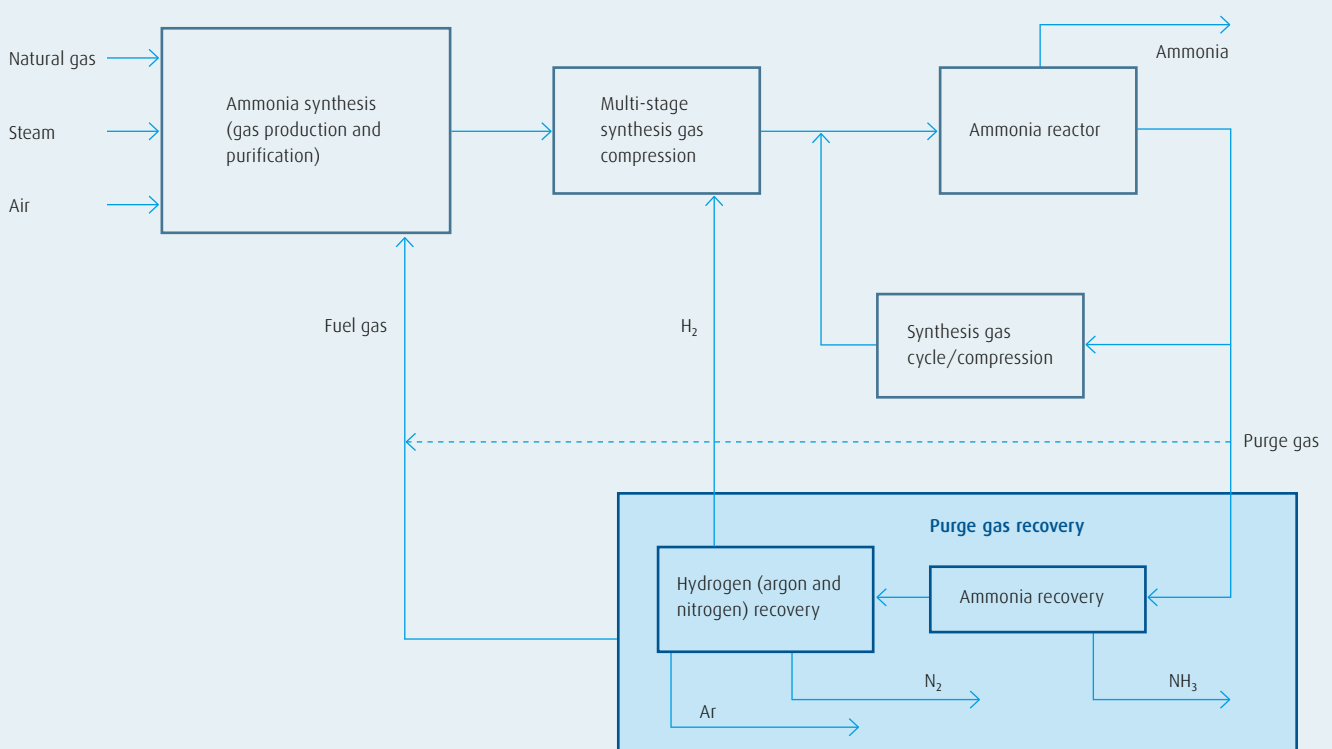
Highest quality standards

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 coldboxes.

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.

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



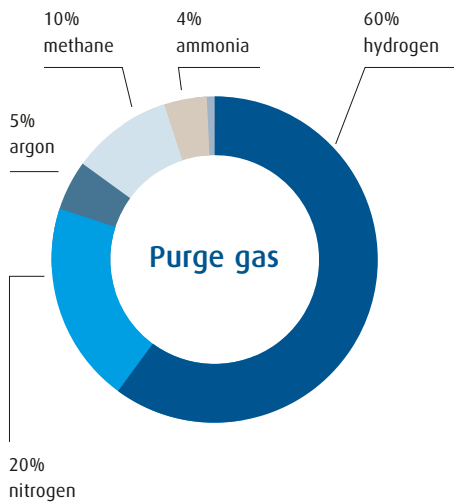


Skid-mounted solution for a purge gas recovery unit, ready for shipment.



Hydrogen recovery from the purge gas stream generated by an ammonia synthesis plant in Moron, Venezuela.

Purge gas recovery in detail: How recovery plants work.



Composition of a typical purge stream.

Hydrogen, argon, nitrogen and ammonia can be recovered from the purge gas stream. The recovery method depends on the feedstock in question and the gas(es) the customer wishes to recover. Ammonia is recovered in a water wash system; hydrogen in a cryogenic or membrane recovery system; and argon and nitrogen in a cryogenic recovery system.

Hydrogen recovery (cryogenic)

The pre-purified purge gas from the ammonia recovery plant is water saturated. As a first step, the purge gas is dried and freed from traces of ammonia in an adsorber station.

The hydrogen is separated in a coldbox. The drop in temperature necessary for a stable process is achieved with a throttle valve using the Joule-Thomson effect. The purge gas is cooled down in the coldbox heat exchanger using the cooling power of some of the cryogenic hydrogen separated in the coldbox.

Thus the gas is partly liquefied. The gas phase is separated in the hydrogen separator, warmed up, and the hydrogen is sent to the syngas compressor.

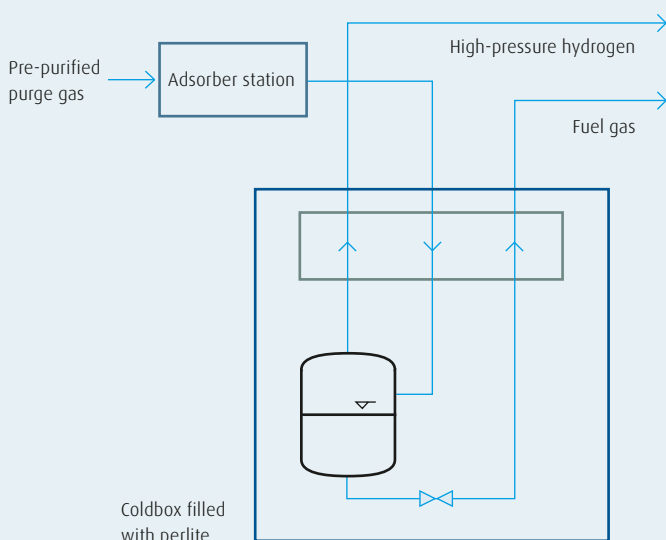
Hydrogen recovery (membrane)

The pre-purified purge gas is warmed up to increase the water saturation value of the purge gas before entering the membrane unit. The membrane unit is usually set up in two stages. One part of the hydrogen recovered is fed to the suction part of the syngas compressor and another part is fed back to an intermediate pressure stage of the compressor.

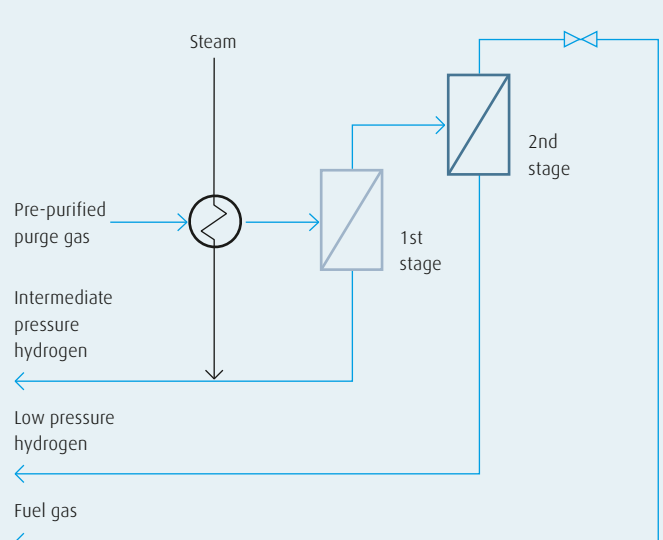
Hydrogen, argon and nitrogen recovery (cryogenic)

The separation of hydrogen, argon and nitrogen takes place in a coldbox. First the pre-purified purge gas from ammonia

Typical process flow for hydrogen recovery (cryogenic)



Typical process flow for hydrogen recovery (membrane)



recovery needs to be dried and freed from traces of ammonia in an adsorber station.

The purge gas is cooled down in the coldbox heat exchanger. The hydrogen product is separated in the hydrogen separator and warmed up. Some of the hydrogen is then sent to the syngas compressor and some is used as a cooling medium in the coldbox.

The argon, nitrogen and fuel gas are separated in cryogenic rectification columns. Recovery is based on an open nitrogen cycle, which generates the refrigeration capacity required to liquefy the argon gas. If required, the customer can also recover liquid nitrogen.

With small modifications, this cryogenic recovery solution for hydrogen, argon and nitrogen can also be installed as a separate argon and nitrogen recovery solution downstream of an existing hydrogen recovery unit.

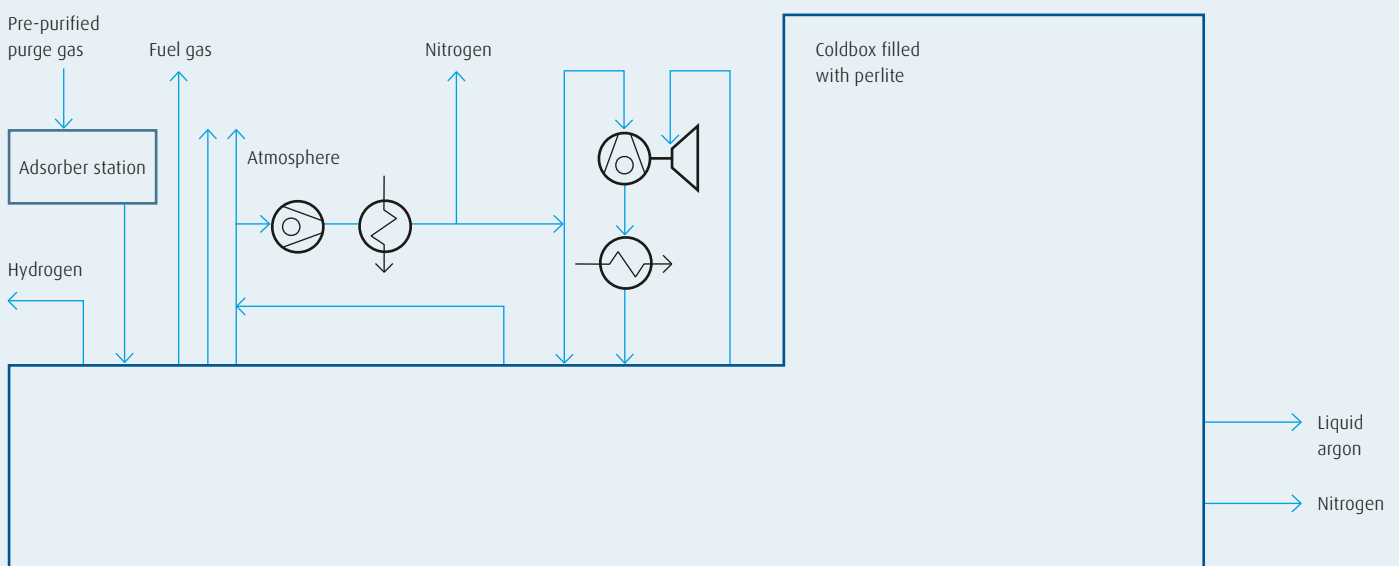


Hydrogen recovery from the purge gas stream generated by an ammonia synthesis plant in Palembang, Indonesia.



Plant for the recovery of liquid argon from ammonia synthesis purge gas in Hazira, India.

Typical process flow for hydrogen, argon and nitrogen recovery (cryogenic)



“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

- Indicates a positive trend (e.g. drop in costs, new business potential)
- Indicates no significant difference between the technologies
- Indicates a negative trend (e.g. slight/marked drop in performance, increase in costs)

Our recovery solutions at a glance. Tailored to your specific needs.

The recovery technology best suited to your needs depends on a number of factors. These include the target product (i.e. the gas(es) you wish to recover), your performance requirements and your investment/operating budget. The following table gives a rough overview of recovery options with cryogenic and membrane technologies. It also shows how these technologies compare with each other – both in relation to key performance indicators (such as recovery rate, purity and pressure) and in relation to investment and operating costs. The final line in the table compares the business opportunities of each method.

	Hydrogen recovery (cryogenic)	Hydrogen recovery (membrane)	Hydrogen, argon and nitrogen recovery (cryogenic)
Targeted product(s)	H ₂	H ₂	H ₂ , Ar, N ₂
Hydrogen recovery rate	→	→	→
Hydrogen purity	→	→	→
Hydrogen pressure	→	↓	→
Hydrogen-specific investment cost savings	→	↗	→
Hydrogen-specific operating cost savings (incl. recompression costs to recycle hydrogen to the ammonia plant)	→	↓	→
Business opportunities (through recovery of argon and nitrogen)	→	↘	↗

Talk to our experts

Our experts would be delighted to evaluate your individual needs. To advise on the best set-up for your plant, we would need technical data about your upstream ammonia synthesis gas plant and the gas products you wish to recover downstream.

We have prepared a dedicated questionnaire on the following page outlining the technical data we require.



Linde engineers at work.

Our services for you.

At Linde Engineering, we do a lot more than deliver complete, customer-specific, turnkey solutions for hydrogen, ammonia, argon and nitrogen recovery from ammonia purge gases. At every stage of the project – from your very first query – our service-focused engineers are there to support you. You can rely on our team to deliver the project development services you need to make the best investment in purge gas recovery technology and maximise your return on that investment.

Our services include:

- Feasibility studies
- Market analyses
- Profitability analyses
- Technical design
- Front-end engineering
- Procurement of licences
- Permit management
- Complex logistics handling
- Financing solutions

In addition, you can rely on us for process gases (e.g. air and synthesis gases) in the supply mode that best suits your needs, whether that be bulk deliveries or pipeline supplies from an independent, over-the-fence facility.

“Our people, operational excellence and patented technologies empower us to deliver value to our customers.”

Dr Christian Bruch
Member of the Executive Board

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Linde Aktiengesellschaft
Engineering Division, Dr.-Carl-von-Linde-Strasse 6-14
82049 Pullach, Germany
Phone +49 89 7445-0, Fax +49 89 7445-4908
info@linde-le.com, www.linde-engineering.com

Your partner for the production and processing of gases

Delivering reliable process plants for maximum capital efficiency

Linde has been optimizing gas processing technologies for 140 years, successfully delivering more than 4,000 plant engineering projects around the globe. Favoring trusted, lasting business relationships, the company collaborates closely with customers to enhance plant lifecycle productivity and innovate process flows. The company's proven gas processing expertise plays an indispensable role in the success of customers across multiple industries – from natural gas and oil refining through petrochemicals and fertilizers to electronics and metal processing.

Operational excellence along the entire plant lifecycle

We work closely with our customers to gain an in-depth understanding of individual needs. Building on the unique synergies of Linde as an integrated plant operator and engineering company, Linde offers innovative process technologies and services to exceed our customers' reliability and profitability expectations. This commitment to innovation extends along the entire plant lifecycle. The LINDE PLANTSERV® service team supports customers every step of the way – from maintenance and repairs to full revamps. Leveraging the latest digital technologies to offer on-site and remote operational and support services, we consistently take asset performance to the next level.

Making the impossible possible

From the desert to the Arctic, from small- to world-scale, from standardized to customized designs, Linde's engineering specialists develop solutions that operate under all conditions. The company covers every step in the design, project management and construction of gas processing plants and components. Customers can always rely on Linde to deliver the plants, components and services that fit their needs best – anywhere in the world.

Discover how we can contribute to your success at www.linde-engineering.com

Get in touch with our hydrogen and synthesis gas plant team:
Phone +49 351 250-3760, inquiry: www.linde-engineering.com/contact

Core competencies at a glance

Plant engineering

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

Component manufacturing

- Coldboxes 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 aluminum 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

