

Making our world more productive



Liquefaction for highest density

# Hydrogen solutions



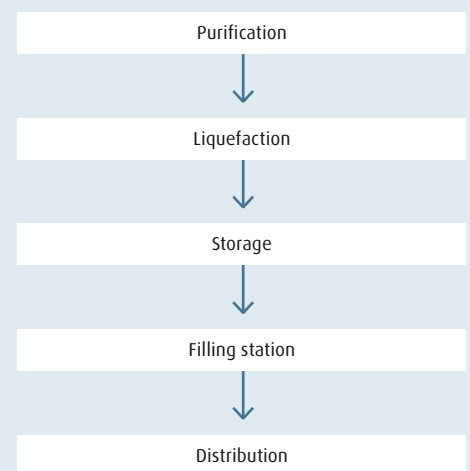


## Cleaner living through technology

**Hydrogen has been a key feedstock in the chemical industry for over 100 years. Mixtures of hydrogen and air are not only non-toxic, tasteless and odourless, they are also combustible – and the only combustion product is water vapour. Besides, unlike dwindling fossil fuels, hydrogen is available in virtually unlimited quantities. So there are good reasons why it is increasingly regarded as vital to the future of the energy economy.**

From a safety standpoint too, hydrogen has long been considered manageable. Intensive research has made Linde a standard-bearer in the development of innovative hydrogen technology and a leader in hydrogen plant engineering, production and distribution.

The core competency of Linde Kryotechnik is in the area of liquid hydrogen. Our efforts begin with purification and liquefaction and run all the way to distribution. All over the world we can point with pride to projects under construction and others successfully completed.





Linde hydrogen filling station in Unterschleissheim, Germany.



Hydrogen liquefaction plant in Leuna, Germany.



Coldbox and turbo expanders.



Purification and liquefaction of H<sub>2</sub>.

## Purification

Hydrogen is obtained from a variety of sources. It is a by-product of chemical processes and is obtained by electrolysis, but most of all it comes from the steam reforming of natural gas. It almost always needs one or more stages of purification before further processing. Pressure swing adsorption (PSA), for example, is a demanding process in which Linde is deemed an expert the world over, offering systems with capacities up to 400,000 Nm<sup>3</sup>/h and purities of over 99.999 vol. %.

## Liquefaction

To store hydrogen with the highest possible density and therefore the greatest efficiency, it must be cooled and liquefied. Linde Kryotechnik has more than forty years' experience in building hydrogen liquefaction plants. Industrial hydrogen liquefaction uses a variety of processes with helium, hydrogen or gas mixtures as

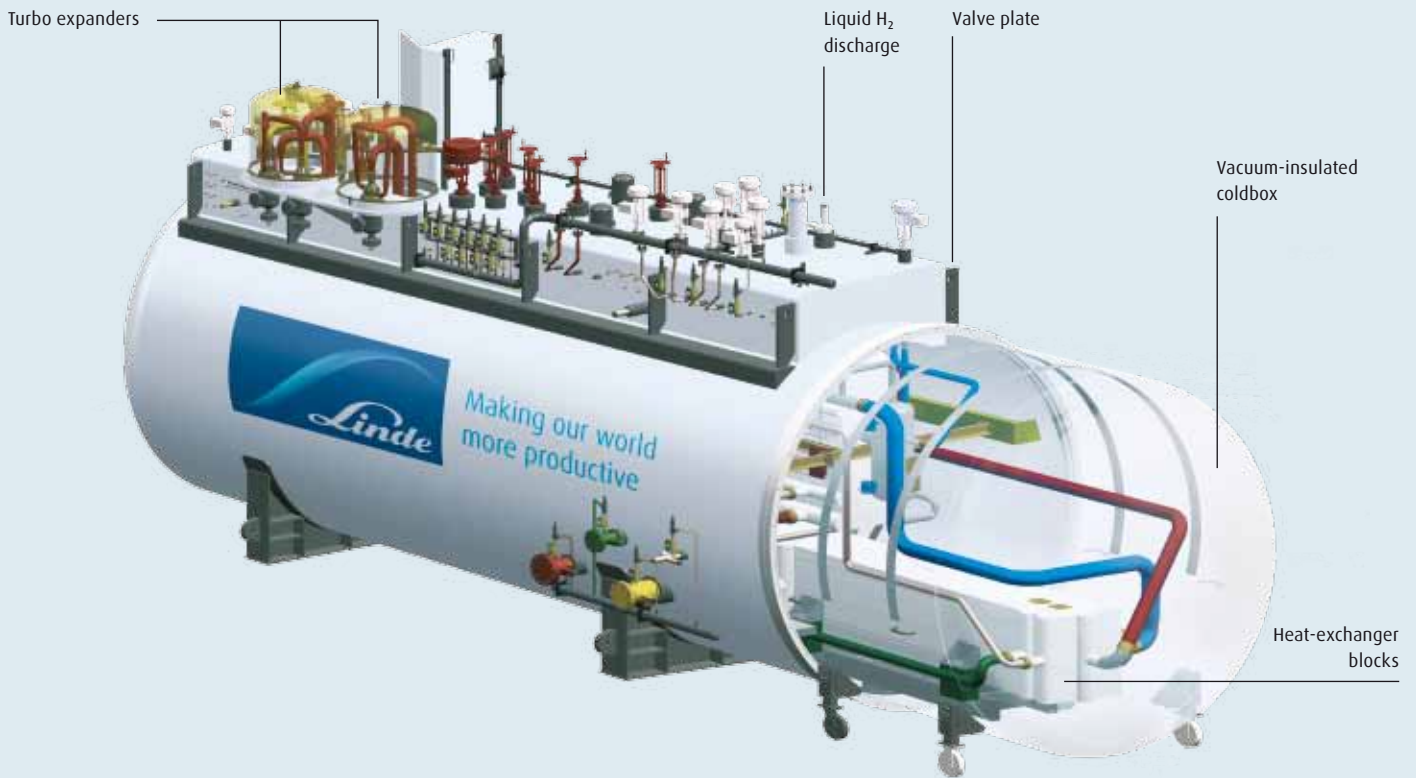
coolant. The hydrogen fed to the process is first cooled by liquid nitrogen, then further cooled in multi-stage heat exchangers, where the cooling power is provided by turbo expanders. Liquefaction is finally accomplished by throttling in a Joule-Thomson valve. The liquid hydrogen is stored in an insulated tank for further distribution.

Capacities of Linde Kryotechnik hydrogen liquefiers range from 150 l/h to more than 20,000 l/h.

## Storage

There are two dominant methods for the efficient storage of hydrogen: in tanks under high pressure at ambient temperature, and in insulated vessels at low pressure and extremely low temperature (20 K).

Cryogenic liquefied hydrogen (LH<sub>2</sub>) has the advantages of a much greater energy content per unit volume and a smaller volume requirement for storage.



### Liquefier (coldbox)

The challenge for long-term storage of cryogenic hydrogen is to reduce the evaporation rate, which means insulating the storage vessel. The special cryotanks developed by Linde have advantages based on the design – double-walled metal vessels with a vacuum between the two containers – and the use of special insulation.

Linde Kryotechnik offers advanced, economical solutions for the storage of liquid hydrogen, from mobile tanks mounted in hydrogen-driven vehicles up to large, stationary insulated tanks (as much as 300 m<sup>3</sup> in capacity).

### Filling station

Bulk shipment of hydrogen to the dispensing station takes place in LH<sub>2</sub> container trucks with special tanks for cryogenic liquefied hydrogen. The truck container is filled from the fixed LH<sub>2</sub> tank at a filling station within the liquefaction plant.

While the cost of liquefaction does affect shipping costs, the energy density of hydrogen in liquid form is much greater.

Stations dispensing liquid hydrogen use a special LH<sub>2</sub> pump devised by Linde which ensures rapid delivery and is as user-friendly as the fuel pumps at a conventional filling station.

Linde has all the know-how for the design and safety engineering of liquid hydrogen filling stations, whether at the liquefaction plant or at the final filling station.

### Distribution

Despite persistent efforts with high-pressure gas, the efficiency in terms of shipping density does not even come close to the efficiency of the liquid hydrogen. This applies to both road and rail shipment. Linde Kryotechnik also supplies tanks and containers, with advanced insulation techniques.

# Deeds, not words

## References of hydrogen liquefaction plants

Linde Kryotechnik brings state-of-the-art components and systems to the global market. The table below lists projects from our reference list.

Small hydrogen liquefier 150–600 l/h	Medium hydrogen liquefier 600–3,000 l/h	Bulk hydrogen liquefier > 3,000 l/h
→ Beijing, China	→ Ingolstadt, Germany	→ Magog, Canada
→ Mahendragiri, India	→ Saggonda, India	→ Osaka, Japan
→ Kimitsu, Japan		→ Leuna, Germany
→ and elsewhere	→ and elsewhere	→ and elsewhere

Linde Kryotechnik strives to improve its position as the technology leader in hydrogen solutions through new products and innovative processes.

# Engineering excellence – every step of the way

Linde Kryotechnik AG and Linde Cryogenics are the world's leading cryogenic technology and engineering companies, bundling low-temperature know-how and cutting-edge technologies with value-add services for scientific research and industrial organisations around the globe. Highly skilled Linde teams partner with customers to develop and deliver innovative cryogenic solutions for liquefaction and refrigeration systems at temperatures below 80 K (-193°C).

Linde Engineering is a leading player in the international plant engineering business, covering every step in the design, project management and construction of turnkey industrial plants. Drawing on its extensive, proven process know-how, this division sets the standards for innovation, flexibility and reliability with ground-breaking concepts and a dedication to engineering excellence.

## Core competencies of Linde Kryotechnik AG and Linde Cryogenics:

- Helium liquefiers
- Helium refrigerators
- Helium recovery systems
- Hydrogen liquefiers
- Storage and distribution systems
- After sales services
- Special cryogenic plant engineering services

## Get in touch – find the best solution.

### Global contact

Linde Kryotechnik AG  
Daettlikonerstrasse 5  
8422 Pfungen, Switzerland  
Phone +41 52 304-0555  
sales@linde-kryotechnik.ch  
www.linde-kryotechnik.ch

### USA

Linde Cryogenics  
A Division of Linde Engineering  
North America Inc.  
6100 South Yale Avenue, Suite 1200  
Tulsa, Oklahoma 74136, USA  
Phone +1 918 477-1200  
Fax +1 918 477-1100  
www.leamericas.com

### Japan

Taiyo Nippon Sanso Corporation  
Plant Engineering Center  
Space & Cryogenic Equipment  
6-2 Kojima-Cho  
Kawasaki-Ku Kanagawa Pref.  
Kawasaki-City 210-0861, Japan  
scesales@tn-sanso.co.jp  
www.tn-sanso.co.jp

Koike Sanso Kogyo Co.  
Advanced Machinery Div.  
9-1-1, Ojima, Koto-ku  
Tokyo 136-0072, Japan  
Phone +81 35 8755045  
Fax +81 35 8755496  
sales@koikeox.co.jp  
www.koikeox.co.jp

Linde Kryotechnik AG  
Daettlikonerstrasse 5, 8422 Pfungen, Switzerland  
Phone +41 52 304-0555, info@linde-kryotechnik.ch, www.linde-kryotechnik.ch