

Making our world more productive



# In-house expertise you can count on

Manufacture and delivery of key  
air separation components worldwide





Coldbox lifting in Sagunto, Spain.

*“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

## Trusted partner.

As one of the largest and most experienced suppliers of air separation plants and industrial gases worldwide, Linde has already delivered over 3,000 air separation plants around the globe. In addition, we operate more than 400 air separation units (ASUs) ourselves. Building on our long-standing experience in both plant engineering and operation, we have developed a portfolio of modular ASUs to meet today’s air separation challenges. For more complex, challenging projects, we design and deliver customised plants, which we assemble on site to meet individual needs. In fact, we have successfully engineered and executed most of the largest air separation complexes in the world today. This vast, hands-on experience makes us the partner of choice for today’s air separation projects. The quality of these plants – whether customised or modular – obviously hinges on the quality of their component parts.

# Engineering excellence – made in house.

To ensure the success and reliability of all our plants, we design and manufacture all key cryogenic components at our own fabrication workshops in Schalchen, Germany, and Dalian, China. The fact that the plant and process engineering team and as the manufacturing team are integral parts of one company ensures seamless project execution and premium quality every step of the way. All of which contributes to the lowest possible total cost of ownership (TCO) for our customers.

Key components for air separation plants manufactured in house include:

- Plate-fin heat exchangers (PFHEs)
- Rectification columns
- Packings, sieve trays, distributors, collectors
- Completely assembled and pressure-tested coldboxes

## Benefits of in-house manufacturing

Our in-house manufacturing expertise brings a range of benefits to our customers around the world. These include:

- Lowest total cost of ownership (TCO) thanks to proven, high-quality parts leveraging proprietary engineering
- Timely deliveries with fixed manufacturing slots and flexibility to prioritise projects and adjust manpower on demand
- Highly skilled, in-house fabrication specialists
- Flexibility to combine in-house manufacturing with on-site fabrication to deliver world-scale ASUs
- In-house development of new technologies for cryogenic equipment and manufacturing techniques
- Ongoing optimisation thanks to full lifecycle management
- Short project timelines due to common tools and globally standardised processes
- Price stability

## Key cryogenic components

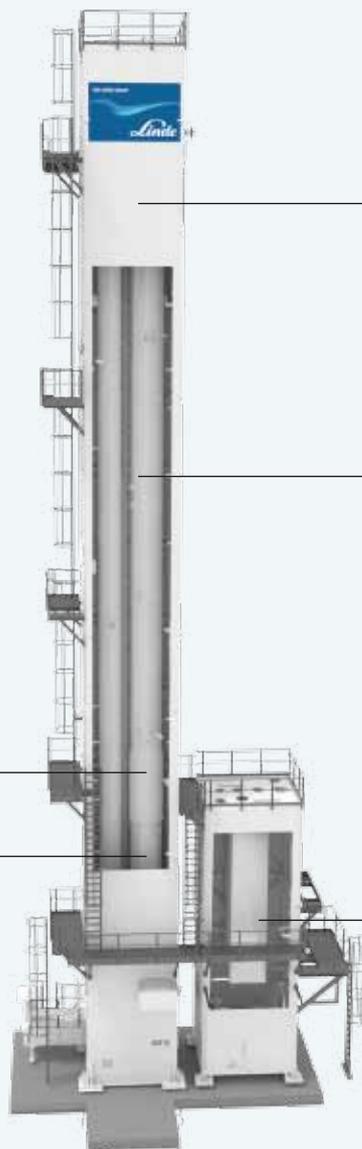
Main condenser



Pressure column with sieve trays



Coldbox shell



Low-pressure column with structured packings



Main heat exchanger



# Key components in focus: plate-fin heat exchangers.

PFHEs are key components in many process plants. They can be implemented across a wide range of applications, especially in low-temperature services. Due to their compactness, they offer both footprint and cost gains. In air separation plants, PFHEs are used to cool down the process air to near-liquefaction temperature. They offer a number of operational benefits:

- Very high specific heating area per volume
- Small temperature differences feasible
- Multiple streams possible
- Low pressure drops
- Fast response to flow and temperature duty changes

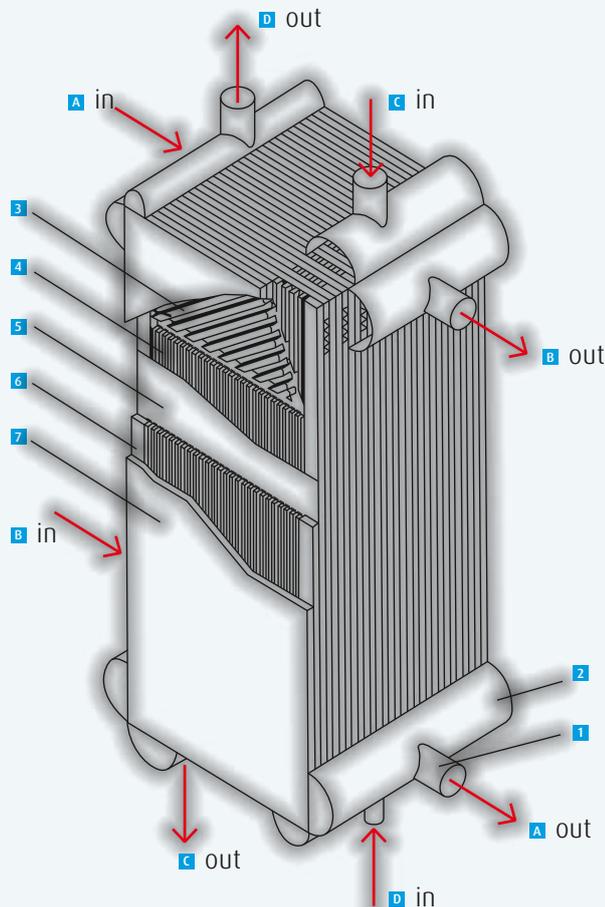
## Designed to last

Since 1981, our manufacturing workshops have built over 12,000 vacuum-brazed PFHEs at our sites in Germany and China. Around the world, these PFHEs enjoy a strong reputation for their market-leading quality and technical reliability across a wide variety of cryogenic applications. The fact that many of these PFHEs are still in operation after decades of service bears clear testimony to the enduring nature of our designs.

## The brazing advantage

Our PFHEs are manufactured at our global production facilities using vacuum brazing technology that does not require flux. This means that all cores are delivered completely free from corrosive residue. Brazing is one of our core areas of expertise. We advise our customers on the brazing furnace best suited to each application scenario and we operate several vacuum furnaces in Germany and China. This gives us the flexibility to meet demand for rapid turnarounds. Regardless of the complexity and size of the assembly, we can deliver sophisticated solutions designed to the highest quality standards – on time, on spec and on budget.

## Structure of PFHE



- A** Warm (condensing) fluid
- B** Cold (boiling) fluid
- C** Warm fluid
- D** Cold fluid

- 1** Nozzle
- 2** Header
- 3** Distributor fin
- 4** Heat transfer fin
- 5** Parting sheet
- 6** Side bar
- 7** Cover plate



Aluminium plate-fin heat exchanger fabrication.

### A closer look

A PFHE consists of alternating layers of fins separated by parting sheets that have been brazed together with side bars. Process streams flow along the passages created by the fins between the parting sheets to exchange heat.

PFHEs can treat many process streams in one single unit thanks to the flexibility of layer stacking and the overall heat exchanger dimensions. They can be used to vaporise and condense both single- and mixed-component liquid and gaseous streams, supporting counter-flow and cross-flow arrangements. The aluminium alloys we use to fabricate brazed PFHEs provide the best possible heat transfer performance, thus enabling low-temperature differences down to 1 K.

This drastically reduces equipment weight, the size of the heat exchanger and the size of support structures.

By selecting the fin type best suited to each customer's needs, we can optimise the thermal and hydraulic performance of the exchanger. We cover the full spectrum from plain through perforated to serrated fins, and from stand-alone PFHEs through manifold assemblies to block-in-shells and coldboxes. Our compact designs ensure the best surface to volume ratio – values of more than  $2,000 \text{ m}^2/\text{m}^3$  are possible. Up to 20 streams can be accommodated within one heat exchanger.

Over  
**12,000**  
plate-fin heat exchangers  
delivered since 1981.

Read more:  
[linde-engineering.com/plantcomponents](https://www.linde-engineering.com/plantcomponents)



Column packing.

Up to  
**1,200 m<sup>2</sup>/m<sup>3</sup>**  
 packing surface.

## Key components in focus: rectification columns.

Since Carl von Linde pioneered industrial air separation in 1902, rectification columns have been at the heart of cryogenic separation units. They determine the recovery rate and the purity of the gases produced. Innovative column designs thus make a big contribution to the energy efficiency of a plant and the required capital investment.

Linde workshops both in Germany and China offer structured packings and sieve trays to optimise the process design regardless of the application. Linde's process design and manufacturing know-how in sieve trays and packings covers everything from primary and secondary structures through collectors to distributors for gas and liquid. Furthermore, Linde owns the intellectual property of many of the key features of this equipment.

### A closer look

Since the mid-1980s, packed columns have been used in the cryogenic rectification process of air separation plants. They offer a number of advantages over sieve trays:

- The specific pressure drop of one mass transfer unit made of structured packing is much lower than that of packed columns. This paved the way for the recovery of pure argon by means of rectification.
- The possible load range for the gas and liquid is higher, which makes the plant more flexible.
- The liquid inventory of a packed column is lower than that of a tray column. This allows the plant to respond to load changes more quickly.

Our portfolio of structured packings has evolved since the first designs in the 1980s. Moving beyond aluminium packings without secondary structure and with a foil thickness of 0.2 mm, we now apply aluminium or copper with 0.1 mm thickness and a very efficient secondary structure. This creates a larger free area for the gas flow while reducing diameters for the same or similar loads. Higher efficiencies enabled by the secondary structure reduce the column height. Both factors combine to reduce capital investment cost.

Although many plants use structured packings in their columns, we have good reasons for keeping sieve tray technology in our portfolio:

- Elevated pressure rectification is more efficient with sieve tray columns
- Short sections with a limited number of trays can be realised more easily with sieve trays

The spectrum of column designs covers all air separation technology needs for the most efficient solution – spanning diameters from 800 mm to 6,350 mm, and column sections from two theoretical trays up to 20 theoretical trays.

Our portfolio of structured packings made from aluminium alloy and copper with film thicknesses of 0.1 mm and 0.2 mm extends from specific surfaces of 350 m<sup>2</sup>/m<sup>3</sup> all the way up to 1,200 m<sup>2</sup>/m<sup>3</sup>.



Column fabrication.



Sieve tray fabrication work at the Schalchen plant.



Worker welding steel.



Coldbox erection for a SCALE 60 plant in Texas, USA.

## Package unit concepts.

Assembling cryogenic plant components in advance is often an economical alternative to installation on site, as it accelerates the erection and start-up process. PFHEs and columns can be assembled into a steel container known as a coldbox. Usually, PFHEs and columns are assembled in two separate boxes: the PFHE box and the rectification box. If the plant is also designed for argon recovery, the corresponding columns with piping are housed in a separate third box. These pre-packaged, pre-tested coldboxes are delivered ready to operate for fast erection and start-up. Very little welding and testing work is required as they already contain all the piping, valves and inline instruments needed.

We deliver road-transportable coldboxes with innovative structured packing supporting gaseous oxygen capacities up to 30,000 Nm<sup>3</sup>/h. Coldboxes for larger gaseous oxygen capacities of up to 160,000 Nm<sup>3</sup>/h are transported by sea. As our workshop in Dalian has direct sea access, it is perfectly suited to the delivery of large packaged unit coldboxes.

### Packaging options

We offer a variety of delivery modes to suit individual customer needs:

- At our workshop, the equipment is ready-piped and assembled in the coldbox and the complete coldbox is shipped to the customer site as a packaged unit, pre-tested and ready to operate.
- The equipment is pre-assembled with nozzles, sealed and filled with nitrogen – ready to be installed in the coldbox on site.
- The equipment is delivered in sections to the site and then the parts are installed in the coldbox, which is then welded and pressure-tested on site.
- Very large equipment is always assembled on site.



Largest pre-fabricated ASU coldbox.

More than  
**8,000**  
tonnes of aluminium  
processed per year.

## Linde Engineering Schalchen, Germany.

Our production facilities in Pullach near Munich, Germany, stretch over 52,000 m<sup>2</sup>. The shop floor accounts for 13,000 m<sup>2</sup> of this and 2,600 m<sup>2</sup> is office space. This location is dedicated to the brazing of PFHEs. We operate six brazing furnaces at this site.

Our Schalchen yard, located approx. 100 km east of Munich, is larger with a total footprint of 200,000 m<sup>2</sup>. It includes 22 production shops and 66,000 m<sup>2</sup> of shop floor, 7,000 m<sup>2</sup> of office space and 23 production shops for the fabrication of cryogenic equipment. It is our main fabrication point for plant components: over 100 coldboxes and more than 100 columns per year are manufactured at Schalchen's production facilities.

Further production capacity is available at our module yards in Bremen, Germany, and Tarragona, Spain.

These production sites specialise in the engineering, production and sale of:

- Plate-fin heat exchangers
- Cryogenic columns
- Packaged unit coldboxes
- Spiral-welded aluminium pipes
- Cryogenic tanks
- Water bath vaporisers
- Air-heated vaporisers
- Coil-wound heat exchangers





Manufacturing site at Schalchen, Germany.

## Linde Engineering Dalian, China.

More than  
**60**  
columns per year.

Established in 2005, Linde Engineering (Dalian) Co. Ltd. has a 37,000 m<sup>2</sup> workshop and 4,000 m<sup>2</sup> of office space. Direct sea access to the port makes this location highly advantageous for the transportation of large coldboxes. Over 30 coldboxes and more than 60 columns are manufactured at our Dalian site every year.

This production site specialises in the engineering, production and sale of:

- Plate-fin heat exchangers
- Columns
- Packaged unit coldboxes
- Pressure vessels
- Molsieve adsorbers
- Coil-wound heat exchangers
- Air-heated vaporisers
- Water bath vaporisers



Aerial view of manufacturing site at Dalian, China.



Office building in Dalian, China.

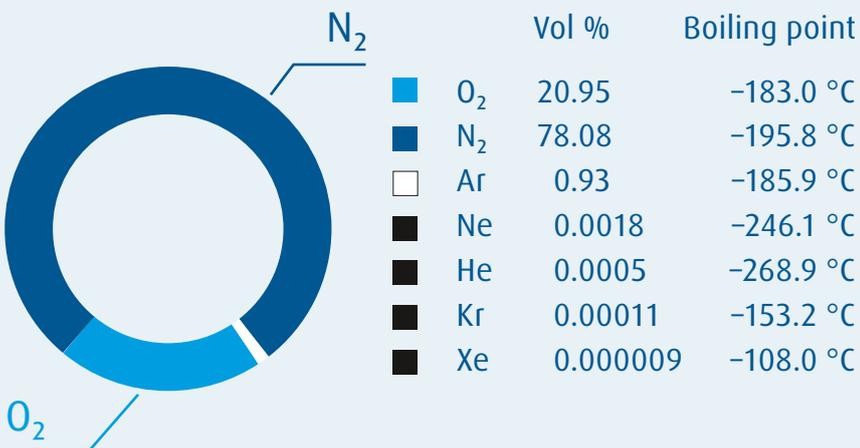


Linde Engineering.

# Facts and figures.

Our air separation business.

Composition of air



Number of patents

**150**

new air  
separation  
patents in last  
5 years

**3,000+**

air separation  
plants have  
been built  
by Linde

**400**

air separation  
units owned and  
operated by The  
Linde Group

World's largest single train  
air separation unit built by

**5,250 tpd**  
oxygen

**1902**

... World's first air separation  
unit for oxygen production

**1990**

... Linde introduced argon  
production by rectification.

**19%**  
**TCO**  
 (Total Cost of  
 Ownership)  
 savings in past  
**10**  
**YEARS**

Heat exchanger

**1,700 m<sup>2</sup>/m<sup>3</sup>**  
 max. surface

**-15%**

average power consumption  
 of our ASUs over the last  
 10 years

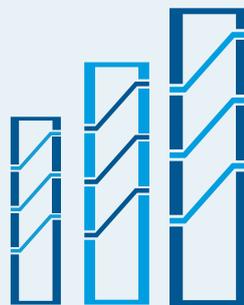
Read more:

[linde-engineering.com/air\\_separation\\_plants](http://linde-engineering.com/air_separation_plants)



Linde air separation units  
 built in more than

**90**  
 countries



Biggest  
 prefabricated coldbox:

**Height 70 m**  
**Weight 800 t**

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# 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](http://www.linde-engineering.com)

Get in touch with our air separation plant team:

Phone +49 89 7445-3526, inquiry: [www.linde-engineering.com/contact](http://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

