THE LINDE GROUP

Linde

Looking Inside...

Plate-Fin versus Coil-Wound Heat Exchangers

Contents.

Introduction.

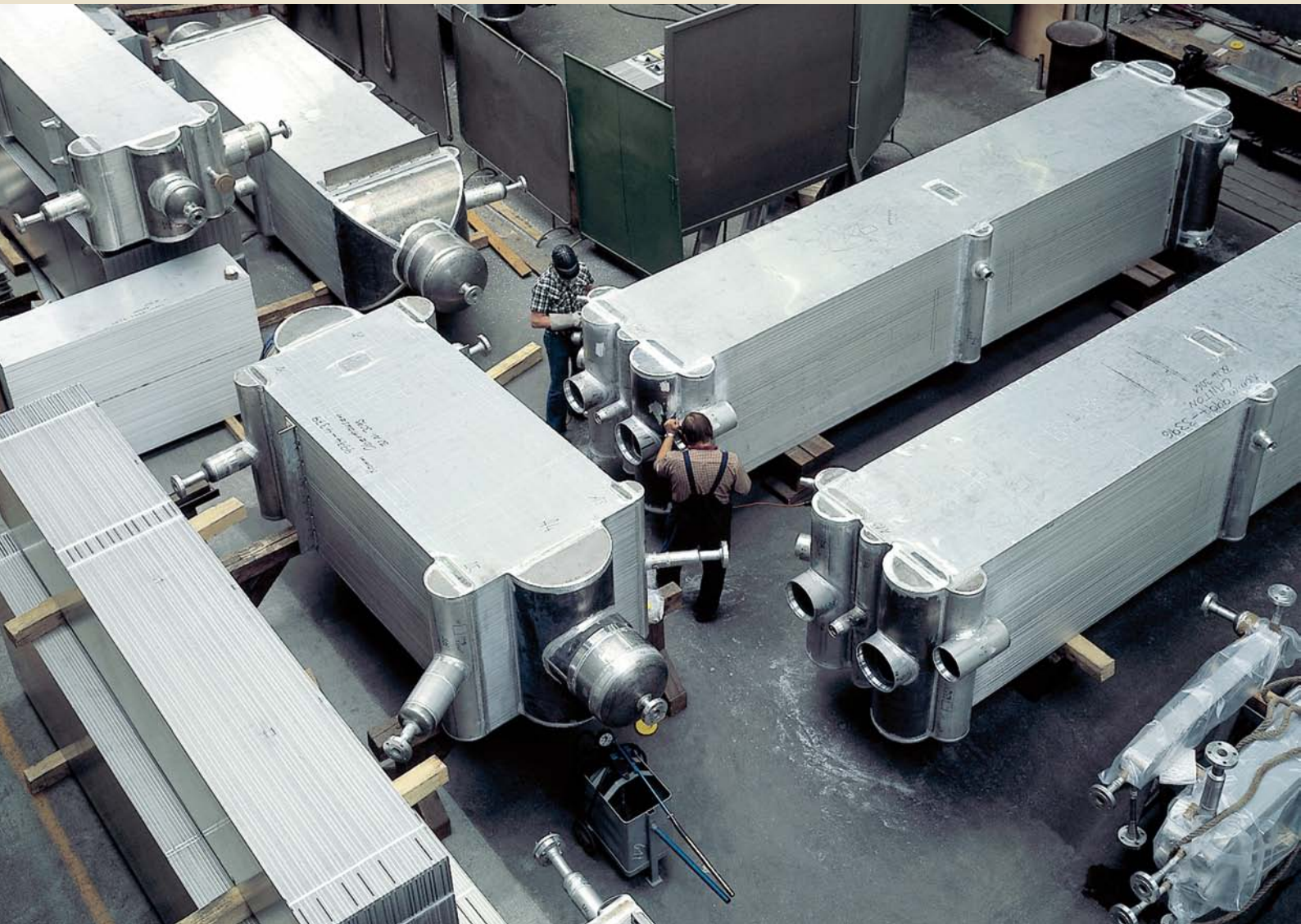
The fabrication facility of The Linde Group is the Engineering Division, a competent and well-known supplier of two special types of cryogenic heat exchangers with an emphasis on LNG production and cryogenic gas processing.

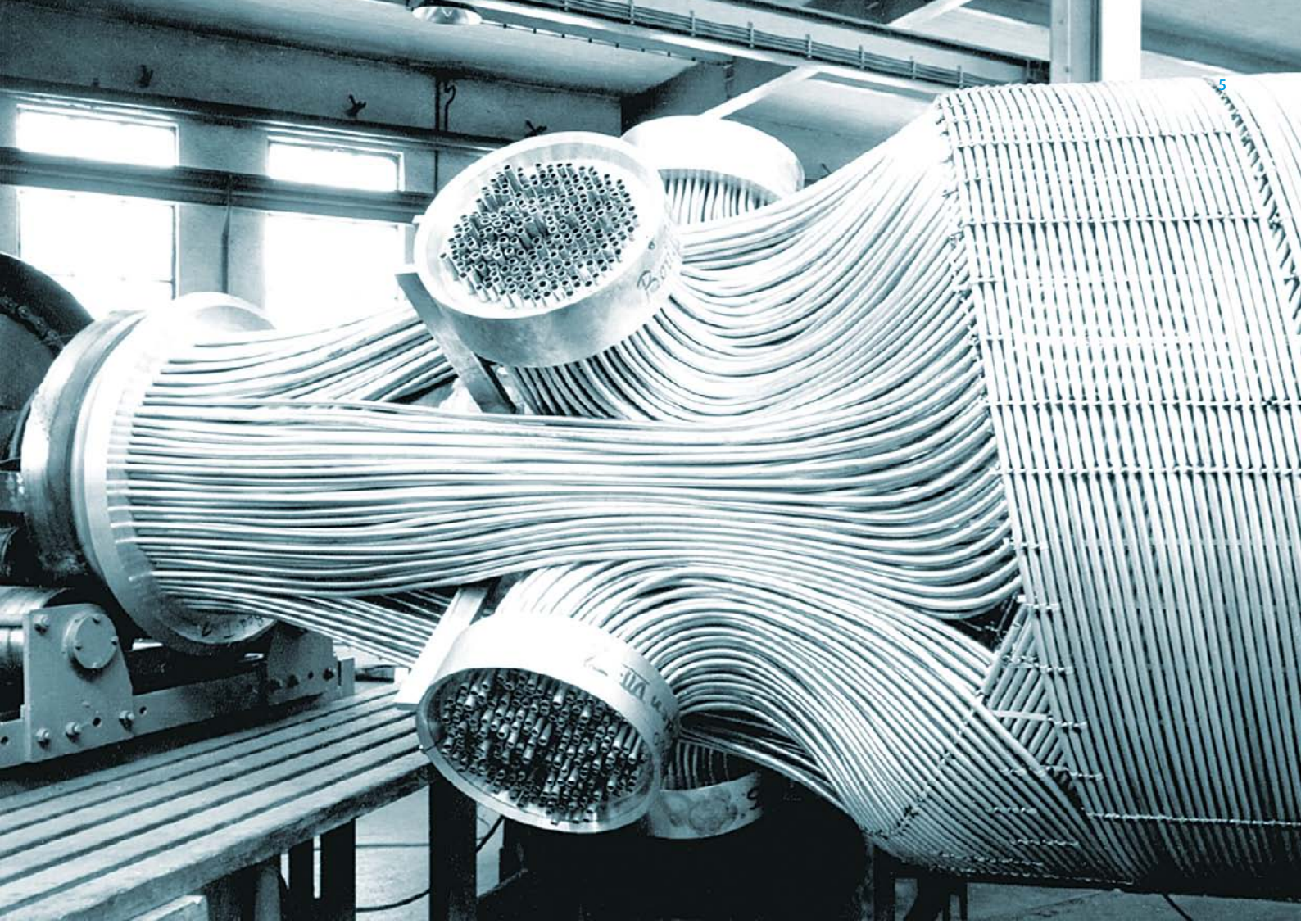
Plate-fin as well as coil-wound heat exchangers are fabricated at Linde´s facility in Schalchen. Here, in the south-east of Germany, some 700 highly qualified people are employed. Heat exchangers have been produced in various forms here for decades.

The specific technical features are outlined and a technical comparison of coil-wound and plate-fin heat exchanger is provided.

A brazed plate-fin heat exchanger is a stack of alternating flat and corrugated plates.

Plate-fin heat exchanger





Coil-wound heat exchanger

Overview.

Plate-fin and coil-wound heat exchangers are key components of cryogenic process plants worldwide. With more than one century of experience Linde is one of the major players in this business. Linde is the only company fabricating both types of heat exchangers in its own facilities.

As of today, approx. 5000 plate-fin heat exchanger blocks and some 1000 coil-wound heat exchangers have been fabricated by Linde for a wide range of applications.

Due to a dearth of available information about plate-fin and coil-wound heat exchangers, these items frequently have the status of black boxes in process plants. The objective of this paper is to open these black boxes and to have a look inside.

Furthermore this paper aims to provide a brief comparison of the two types of heat exchangers in order to familiarize plant owners with the typical features.

Plate-fin heat exchangers.

General arrangement

A brazed plate-fin heat exchanger is a stack of alternating flat and corrugated plates. The corrugations (fins) form the flow channels for the diverse process fluids. Each process stream occupies a certain number of passages within the stack. These are collected by half-pipe headers and nozzles to single point connections on the inlet and the outlet of the respective process stream. In this way, up to 10 process fluids can exchange heat in only one heat exchanger block. Fig.1 is a sketch of the various types of fins.

Materials and design temperature

Usually this type of heat exchanger is made of aluminium alloys 3003 (blocks) and 5083 (all attachments). It is important to know that with these standard materials the upper design temperature is limited to +65°C due to code requirements.

Fins

In order to meet the required performance, Linde can select the appropriate fin out of about 50 different fin types. In general a distinction is made between perforated fins and serrated fins.

Serrated fins have higher heat transfer coefficients than performated fins. However, serrated fins are more prone to fouling and result in higher pressure drop.

Fabrication

In order to bond the loose stack of plates and fins to a rigid block, vacuum brazing is used. This sophisticated process means spanning the loose stack together and heating it in a vacuum furnace up to a temperature of about 600°C. It should be understood that this temperature is very near the melting point of the aluminium base materials. The filler material is clad by rolling on both sides of each parting sheet. The fins however are pure aluminium alloy without any cladding. After the vacuum brazing the blocks are completed by welding all the attachments such as half-pipe headers, nozzles, support brackets and lifting trunnions to the block. Please refer to Attachment B on page 13).

Benefits

Vacuum brazed plate-fin heat exchangers made of aluminium offer a number of advantages: They are extremely compact due to the use of aluminium and highly efficient fins. The "heating surface density" can be greater than 1000 m^2/m^3. Thus this type of heat exchanger is perfectly suitable for installations which require compact design. The wide selection of heat transfer fins combines high heat transfer rates with low pressure drops (i.e. low energy consumption) in tailor made heat exchangers. The ability to combine up to 10 process streams in only one heat exchanger system can eliminate the need for multiple heat exchanger arrangements and the interconnecting piping. The use of high strength aluminium alloy results in light weight units thus reducing drastically the foundation and support requirements.

Knowing the limits

Knowing the technical advantages as well as the corresponding limits of a plate-fin heat exchanger helps to make correct procurement decisions and to avoid later disappointments and difficulties. Due to their arrangement as a large and rigid aluminium block, and considering the small gaps inside, this type of heat exchanger cannot be recommended for cases of operation such as :

- high temperature gradients (i.e. thermal shocks)
- high temperature differences between the cold and the warm process streams
- process streams containing particles or suseptible to severe fouling
- cyclic loads (pressure and temperature)
- service which is known to be corrosive to aluminium

Naturally Linde will advise a potential user whether a plate-fin heat exchanger is recommendable for a specified application or not.

Fig.1

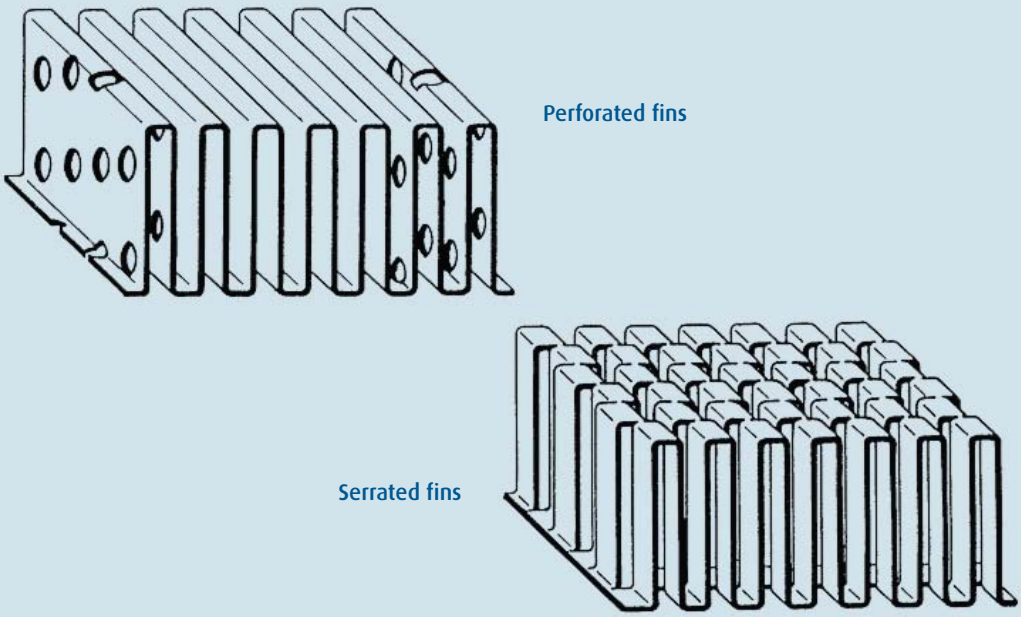


Plate-fin and coil-wound heat exchangers are key components of cryogenic process plants worldwide.

Tube bundle before insertion into the pressure vessel shell

Coil-wound heat exchangers.

History

Coil-wound heat exchangers have been manufactured by Linde since the early days, when Carl von Linde liquefied air on an industrial scale for the first time in Munich, Germany in May 1885. Improvements in aluminium welding technology in the late 1950s made it possible to change from rather expensive and heavy copper to the cheaper and lighter all-aluminium-designs. More than one thousand coil-wound heat exchangers for various application and in diverse materials such as stainless steel, special alloys, copper and aluminium, with heating surfaces of up to 20,000 m² and unit weights of up to 170 metric tons have been fabricated since.

General arrangement

A coil-wound heat exchanger is, in general, a tubular heat exchanger; however, the bundle does not consist of not using a straight tubes. Tubes of relatively long length and small diameter are wound in alternating directions around a centre pipe (the so called mandrel). In parallel a pressure vessel shell is prepared and the complete tube bundle is inserted. All single tubes start and terminate in tubesheets which are integral parts of the pressure vessel shell.

Features of Linde's coil-wound heat exchangers in LNG baseload plants

Flexible tube bundle

Due to the flexible tube bundle arrangement these heat exchangers can bear temperature gradients and differences clearly exceeding the limits of other heat exchanger types (e.g. plate-fin heat exchangers).

No bundle sagging

Over the specified design life no considerable bundle sagging is to be expected. This is due to Linde´s sophisticated bundle support system.

Best liquid distribution
Optimal liquid distribution of the shell side 2-phase stream over the whole cross section of the bundle is achieved by internal phase separation and special liquid distribution systems. The latest liquid distributor design minimises the liquid hold-up on top of the bundles, thus reducing negative thermal effects during trip cases.

Tube arrangement
The tube bundles are designed and fabricated to be vibration-proof and self-draining.

Tailor made materials
The pressure vessel shell is typically made of aluminium alloy 5083. For the tubes, special aluminium alloy and a non-standard (but approved) fabrication procedure is used for tube manufacturing.

Supporting the tube bundle
Each tube bundle is freely suspended from a special support system on top of each bundle. Thus shrinkage and expansion of the tube bundles due to rapid temperature changes during start-up or shut-down occur with minimum stresses between the tube bundle and the shell. The support system is designed to carry the weight of the tube bundles, the fluids and the pressure drops.

Eliminating by-pass streams
Each tube bundle is wrapped into a “shroud“ which is seal welded on the upper side of the shell to avoid any refrigerant passing between the tube bundle and the shell.

In case of tube failure the leaking tube can be easily repaired by plugging the concerned tube. In order to facilitate such repairs and to minimize the shut-down time the installation of suitable access holes is foreseen.

The tube bundles are designed and fabricated to be vibration-proof and self-draining.

Complete coil-wound heat exchangers during installation on site

Linde cold boxes in a LNG peak shaving plant

Plate-fin versus coil-wound heat exchangers.

Attachment C (page 14) provides an overview of the major differences between plate-fin and coil-wound heat exchangers. The most important feature of the plate-fin heat exchanger is the compact design. The coil-wound heat exchanger's defining characteristic is its intrinsic robustness.

The extreme compactness of the plate-fin heat exchangers becomes obvious when one knows that both of the cold boxes[1)] shown in this picture are designed for the same performance. These two cold boxes are installed in an LNG peak shaving plant in South Africa. The small coldbox on the left side contains a plate-fin heat exchanger. The much taller cold box on the right side contains a coil-wound heat exchanger.

Presently this peak shaving plant is operated using the coil wound heat exchanger with outstanding results regarding reliability and turn-down behaviour.

For LNG baseload applications it is important to know that typically the coil-wound heat exchangers are designed standing "cold side up - warm side down". This is another difference in comparison with plate-fin heat exchangers. This arrangement allows proper 2-phase distribution of refrigerant vaporizing downwards on the shell side of a coil-wound heat exchanger. It is well suited for turndown operation.

A plate-fin heat exchanger in similar service usually vaporizes upwards. It requires a lot of know-how and experience to design such a plate-fin heat exchanger for turn-down operation. If the design does not consider this properly, the vaporization in turn-down can create fluid fluctuations causing cyclic thermal and mechanical stresses.

[1)] A "cold box" is understood to be a carbon steel casing containing various process equipment like heat exchangers, columns, instrumentation, all interconnecting piping, etc. The thermal insulation is typically expanded perlite.

Outlook.

Plate-fin heat exchangers

Since Linde has entered into the business of vacuum brazed plate-fin heat exchangers in 1981, block sizes and design pressures have increased step-wise. With a new vacuum furnace recently commissioned Linde is now in position to serve the market with single plate-fin heat exchanger blocks of about 1.5 x 3 x 8 m in modular construction. Such extremely large blocks drastically reduce the need for interconnecting piping and subsequently the danger of maldistribution between parallel blocks.

At the same time the maximum design pressures have reached a level of about 100 bar-g. However it is important to know that the maximum possible design pressure depends on the respective block size. In order to further increase the efficiency and compactness of plate-fin heat exchangers new types of fins are being developed applying e.g. smaller fin pitches, etc.

Coil-wound heat exchangers

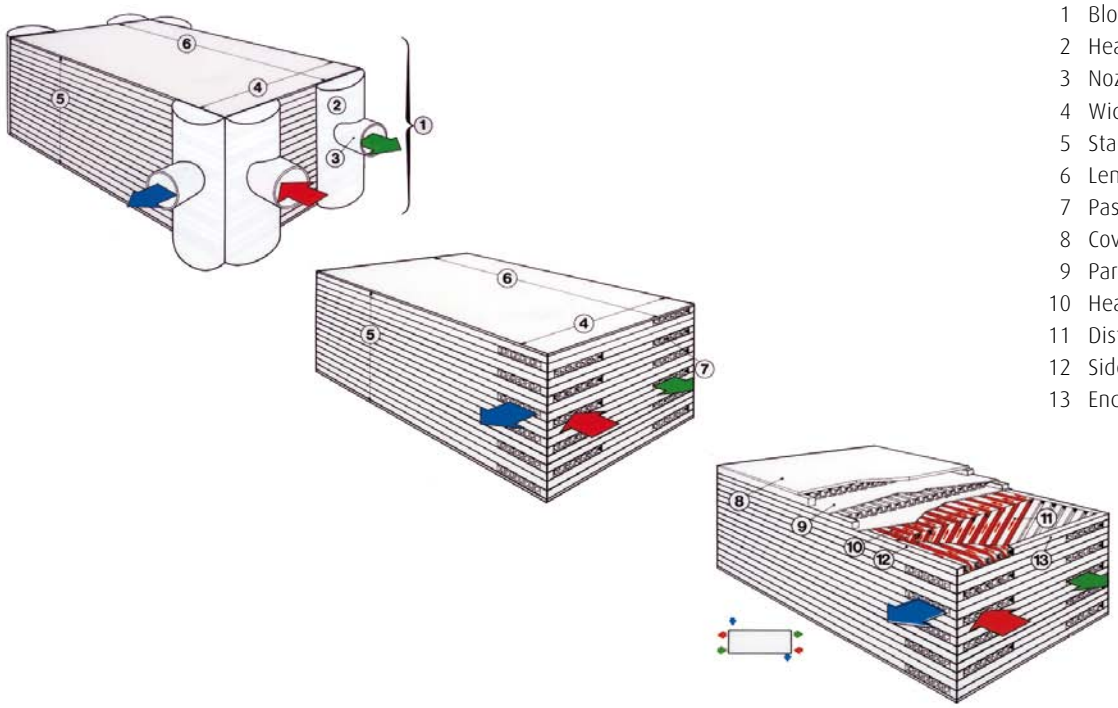
Linde's own test facilities and the R&D department are the major sources of new ideas for improvements. The development of new technical features is driven by the valuable feedback from plant operators and lessons learnt on current jobs.

For Linde's coil-wound heat exchangers in LNG baseload applications of the required performance demands are continually increasing. Linde has already brought the corresponding developments on the way in order to be able to offer the most compact and highly efficient heat exchangers.

The installation of coil-wound heat exchangers on floating barges is another challenge. The exposure of the tall heat exchanger structures to the corresponding motions requires special measures. Linde is thoroughly investigating this issue, applying new ideas and experience to finding the optimal solution.

The extremely compact design of the plate-fin heat exchangers versus the inherently robust design of the coil-wound heat exchangers.

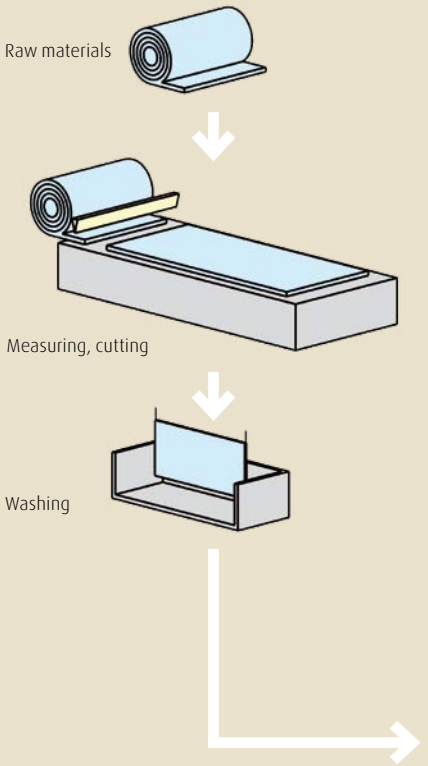
Plate-fin heat exchanger structure (Attachment A)



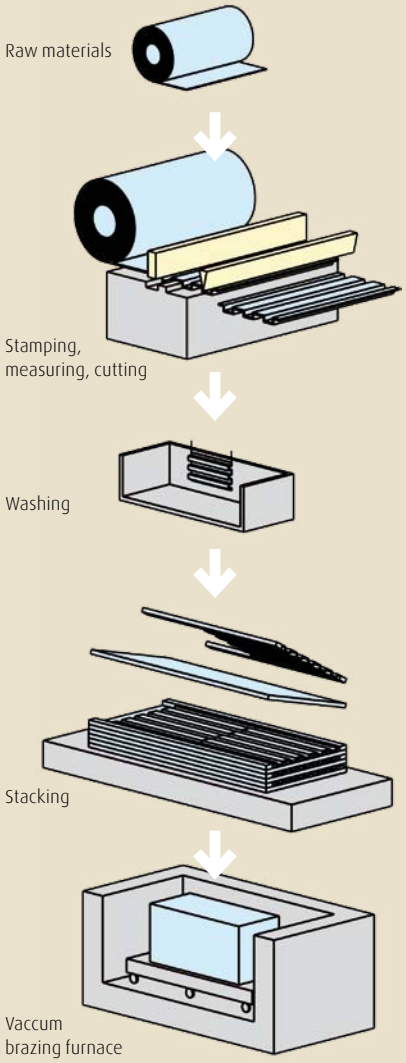
1 Block
2 Header
3 Nozzle
4 Width
5 Stacking height
6 Length
7 Passage outlet
8 Cover sheet
9 Parting sheet
10 Heat transfer fin
11 Distribution fin
12 Side bar
13 End bar

With a new vacuum furnace recently commissioned, Linde is now in position to serve the market with single plate-fin heat exchanger blocks of about 1.5 x 3 x 8 m in modular construction.

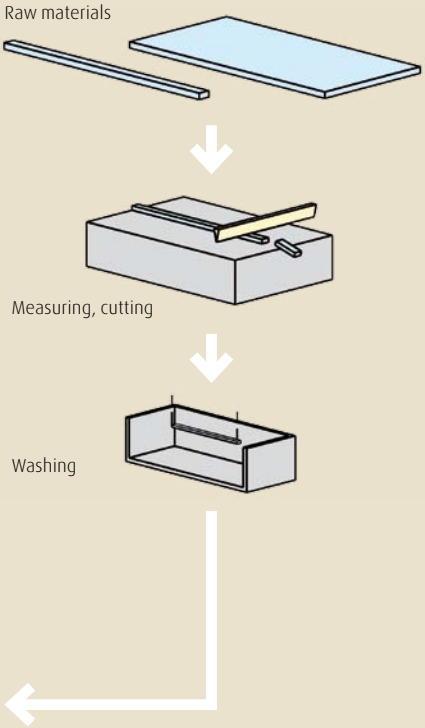
Parting sheets, cover sheets

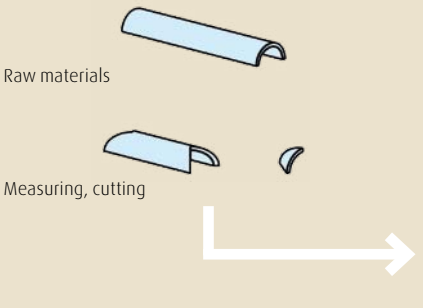


Fins

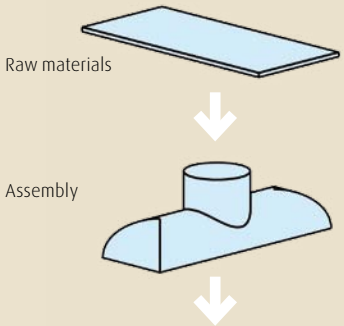


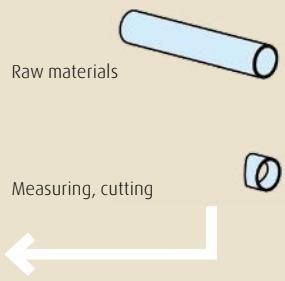
Side bars



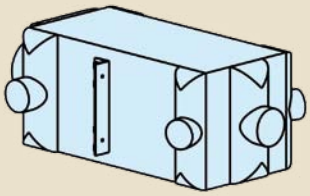


Header and nozzles





Completion of heat exchanger



Testing

Plate-fin heat exchanger piped in cold box

Brief comparison (Attachment C)

	Plate-fin heat exchanger	Coil-wound heat exchanger
Features	Extremely compact Up to ~10 streams	Extremely robust Compact
Fluids	Very clean Non-corrosive	
Heating surface	300 - 1000 m^2/m^3	50 - 150 m^2/m^3
Materials	Al	Al, SS, CS etc.
Design temperatures	-269°C to +65°C	all
Applications	smooth operation limited installation space	temp. gradients ↑ temp. differences ↑
Prices	~25 - 35 % (without manifolds / steel casings)	100 %

With more than one century of experience, Linde is one of the major players in this business and the only company fabricating both types of heat exchangers in its own facilities.

Coil-wound heat exchanger

Designing Processes – Constructing Plants.

Linde's Engineering Division continuously develops extensive process engineering know-how in the planning, project management and construction of turnkey industrial plants.

The range of products comprises:

- Petrochemical plants
- LNG and natural gas processing plants
- Synthesis gas plants
- Hydrogen plants
- Gas processing plants
- Adsorption plants
- Air separation plants
- Cryogenic plants
- Biotechnological plants
- Furnaces for petrochemical plants and refineries

Linde and its subsidiaries manufacture:

- Packaged units, cold boxes
- Coil-wound heat exchangers
- Plate-fin heat exchangers
- Cryogenic standard tanks
- Air heated vaporizers
- Spiral-welded aluminium pipes

More than 3,800 plants worldwide document the leading position of the Engineering Division in international plant construction.

LNG/3.2.e/09

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