Basic knowledge

Heat exchangers

Heat exchangers are used for heating, cooling, evaporation or condensation of media at different temperatures. The basic function is to transfer the thermal energy of a medium with a higher temperature level to a medium with a lower temperature level.

According to the second law of thermodynamics, heat transport always goes from the medium with a higher temperature to the medium with a lower temperature.

Heat exchangers are used in energy engineering, the chemical industry and the food industry, but heat exchangers are also of great importance for computer technology and the automotive sector. Heat transfer can be both the main and auxiliary process. A distinction is made between direct and indirect heat exchangers depending on whether the media involved come into direct contact with each other or not.

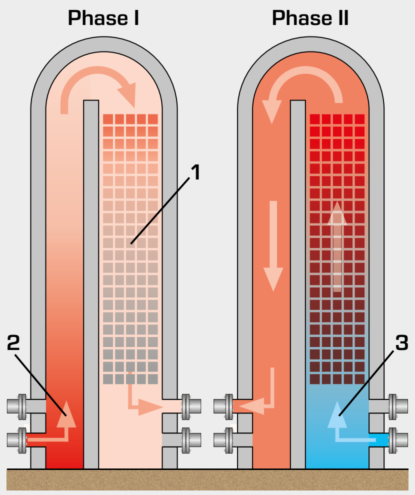
Classification of heat exchangers according to the operating principle

Indirect heat exchangers

Regenerators

- hot-blast heaters in blast furnaces
- rotary heat exchangers

In **regenerators**, the hot and cold medium flows through the storage tank **alternately**. The heat transfer is indirect, since the heat flux to be transferred is first transferred to a storage medium and then passed to the target medium after a delay.



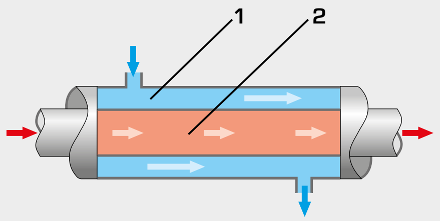
Hot-blast heater in discontinuous operation

Phase I: storage mass **1** is heated by flue gas **2**,
Phase II: cold air **3** is led past the previously heated storage mass and heats up in the process.

Recuperators

- tubular heat exchangers
- shell & tube heat exchangers
- plate heat exchangers

In **recuperators**, two media flow through **simultaneously** in a steady state. The media flows can be guided in parallel flow, counterflow and cross-flow. There is a partition between the media flows, which serves as a transfer surface. The heat is transferred indirectly from the hot medium to the partition and from the partition to the cold medium, without time lag.



Tubular heat exchanger in parallel flow operation

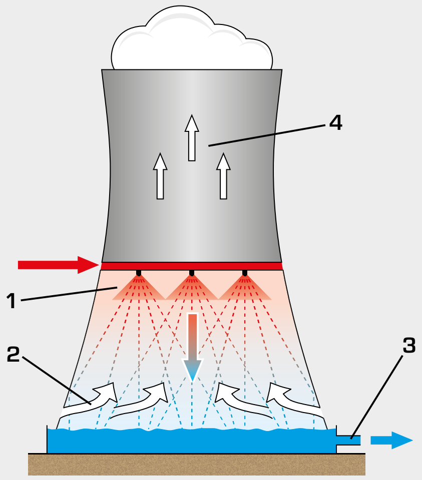
1 outer tube,
2 inner tube;
hot medium,
cold medium

Direct heat exchangers

Mixed heat exchangers

- wet cooling tower
- intercooling in rolling mills

Direct-contact heat exchangers bring two media with different temperatures **into contact** and mix them together. The heat and mass transfer takes place directly.



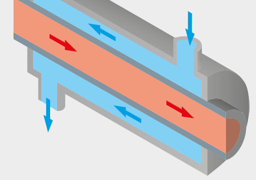
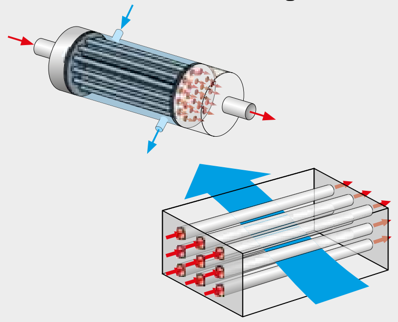
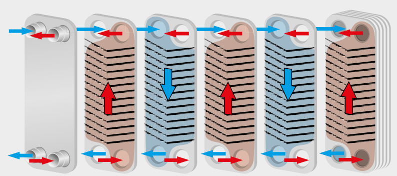
Wet cooling tower

1 atomized spray of hot water,
2 air inlet,
3 cooled water,
4 humid air

Liquids or gases are usually used as **working media**, in special cases also evaporating liquids or condensing vapours.

Heat exchanger types

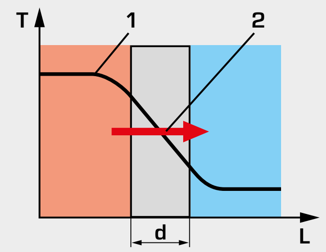
Due to the large number of different applications, different designs have been developed for recuperators, some of which work in very different ways.

Type	Application / media	Advantages and disadvantages
Tubular heat exchanger 	■ use with low cooling/heating power ■ transfer between two liquids ■ suitable for highly viscous fluids	Advantages ■ simple design ■ high pressures can be transferred ■ easy to clean Disadvantages ■ large design, high costs per heat transfer area
Shell & tube heat exchanger 	■ use with very wide temperature and pressure range ■ transfer between liquids and gases, between two liquids or between two gases	Advantages ■ simple structure ■ ideal for heat transfer from steam to water Disadvantages ■ large design
Plate heat exchanger 	■ use even with minimal temperature differences ■ transfer between liquids and gases, between two liquids or between two gases ■ with and without phase change	Advantages ■ large exchange area due to embossing of the plate surface ■ compact design, low filling volume ■ good convective heat transfer due to turbulent flow Disadvantages ■ high pressure loss ■ maintenance intensive

Heat transfer

The entire transferred heat flux is directly dependent on the transference surface. This is why different wall geometries (e.g. fins) are used, in order to increase the transfer surface. Heat transfer is divided into three stages: convective heat transfer from the hot medium to the wall, thermal conduction through the wall and convective heat transfer from the wall to the cold medium.

The convective heat transfer from the medium to the wall or from the wall to the medium is dependent upon the material type, the flow velocity and the aggregate states of the media, amongst other things. The thermal conduction in the wall depends on the wall thickness and the wall material, described by the overall heat transfer coefficient **k** or the length-related overall heat transfer coefficient **k***.



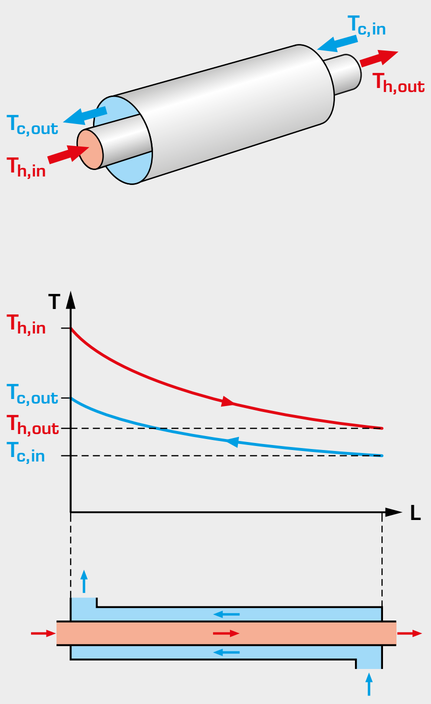
1 temperature profile, **2** resulting heat flux;
hot medium, cold medium,
T temperature, **L** length, **d** wall thickness

Basic knowledge
Heat exchangers

Flow conditions in the heat exchanger

The flow condition in the device can vary depending on the design of the heat exchanger. However, the two media flows are never mixed; there is only heat transfer between the media.

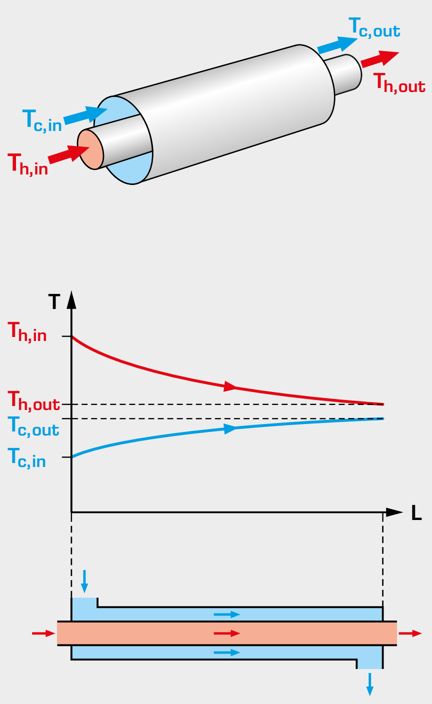
The possible flow conditions are counterflow, parallel flow, cross flow or combinations thereof.



Temperature profiles in **counterflow operation** in a tubular heat exchanger

In **counterflow operation**, two media flow in the opposite direction to each other. The entry point of one medium is the exit point of the other medium running in the opposite direction.

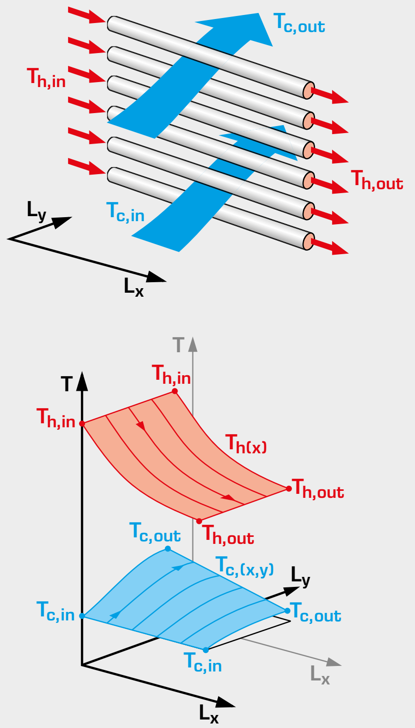
If the heat exchanger is well designed, the outlet temperature of the cold side can even be higher than the outlet temperature of the hot side.



Temperature profiles in **parallel flow operation** in a tubular heat exchanger

When operating a heat exchanger in **parallel flow**, both media flow in the same direction and enter the heat exchanger at the same point.

The maximum outlet temperature of the cold side can be equal to the outlet temperature of the hot side.



Temperature profile for a single row of tubes with single-sided mixed **cross flow**

In **cross-flow operation**, the directions of the media intersect.

Cross flow is used in particular to accurately control the temperature of temperature-sensitive products.

In order to use the advantages of all flow conditions, combinations of the basic forms are common. For example, a multiple-channel shell & tube heat exchanger can be used in cross-flow operation for quick and safe temperature control of large quantities of aggressive chemicals. Plate heat exchangers operated in counterflow are often used when a space-saving design is required.

In practice, heat exchangers are either **designed, recalculated** or **evaluated.**

The **design** determines the transference capacity at known material flows and temperatures in order to decide the geometry of an optimum heat exchanger.

Recalculation determines the outlet temperatures of the media and the transferred heat flux. This is used to check to what extent the outlet temperatures of the selected heat exchanger deviate from the required or limiting outlet temperatures. It is also common to recalculate existing heat exchangers for comparison with real measurement data.

Evaluation enables a statement to be made about the over- or under-dimensioning of the selected heat exchanger where it is to be installed in the process stage. When evaluating a heat exchanger, its geometric data and all process engineering data are taken into consideration.

The "Heat exchangers" section first looks at the convective heat transfer between the surface of a body and a fluid. Furthermore, indirect heat exchangers, recuperators, with their different designs and a wet cooling tower are presented as examples of direct heat exchangers. One special feature is the heat transfer by means of fluidised bed technology, which is investigated using a fluidised bed reactor.

Topics	GUNT products
Convective heat transfer	
Forced convection	WL 314
Parallel flow	WL 314.01
Mixed flow	WL 314.02
Flow profiles	WL 314.03
Indirect heat transfer – recuperators	
Tube heat exchangers	WL 312.01
Tubular heat exchangers	WL 302, WL 308, WL 110.01, WL 315C
Plate heat exchangers	WL 110.02, WL 315C
Shell & tube heat exchangers	WL 110.03, WL 315C
Stirred tank with double jacket and coiled tube	WL 110.04, WL 315C
Finned tube heat exchangers	ET 300, WL 312.02, WL 312.03, WL 315C
Direct heat transfer	
Wet cooling tower	WL 320
Heat transfer in the fluidised bed	
Heat transfer in the fluidised bed	WL 225