Introduction to Heat Exchangers

An Online Continuing Education Course for Engineers

Course Number: M-1060

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Introduction to Heat Exchangers

A ***heat exchanger*** is a component that allows the transfer of heat from one medium (liquid or gas) to another. Reasons for heat transfer include the following:

1. To heat a cooler fluid by means of a hotter fluid.
2. To reduce the temperature of a hot fluid by means of a cooler fluid.
3. To boil a liquid by means of a hotter fluid.
4. To condense a gaseous fluid by means of a cooler fluid.
5. To boil a liquid while condensing a hotter gaseous fluid.

Regardless of the function the heat exchanger fulfills, in order to transfer heat, the mediums involved must be at different temperatures, and they must come into thermal contact. Heat can flow only from the hotter to the cooler fluid when they come into thermal contact.

In a heat exchanger, there is no direct contact between the two fluids. The heat is transferred from the hot fluid to the barrier, isolating the two fluids and then to the cooler fluid.

Types of Heat Exchangers

Although heat exchangers come in every shape and size imaginable, the construction of most heat exchangers falls into one of two categories: **shell and tube** or **plate**. As with most equipment, each type has its own advantages and disadvantages.

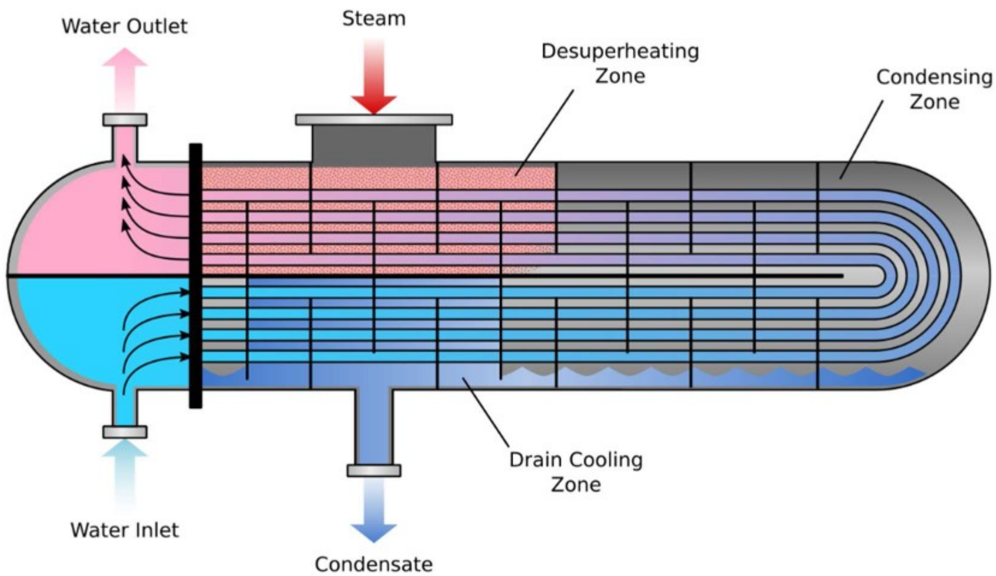
Shell and Tube

The most basic and the most common type of heat exchanger construction is the shell and tube type. This type of heat exchanger consists of a set of tubes in a container called a shell. The fluid flowing inside the tubes is called the tube side fluid and the fluid flowing on the outside of the tubes is the shell side fluid.

Shell and Tube Heat Exchanger

At the ends of the tubes, the tube side fluid is separated from the shell side fluid by the tube sheet(s). The tubes are rolled and press-fitted, or welded, into the tube sheet to provide a leak-tight seal.

In systems where the two fluids are at vastly different pressures, the higher-pressure fluid is typically directed through the tubes, and the lower-pressure fluid is circulated on the shell side. This is due to economy because the heat exchanger tubes can be made to withstand higher pressures than the shell of the heat exchanger for a much lower cost. The support plates act as baffles to direct the flow of fluid within the shell back and forth across the tubes.



Shell and Tube Heat Exchanger Cross Section

Plate

A **plate-type** heat exchanger consists of plates instead of tubes to separate the hot and cold mediums. The hot and cold mediums alternate between each of the plates. **Baffles** direct the flow of fluid between plates. Because each of the plates has a very large surface area, the plates provide each of the fluids with an extremely large heat transfer area. Therefore, a plate-type heat exchanger, as compared to a similarly sized tube and shell heat exchanger, is capable of transferring much more heat. This is due to the larger contact surface area the plates provide over tubes.

Plate Heat Exchanger

Due to the high heat transfer efficiency of the plates, plate-type heat exchangers are usually very small when compared to shell and tube-type heat exchangers with the same heat transfer capacity. Plate-type heat exchangers are still widely used despite having the inability to reliably seal the large gaskets between each of the plates. Because of this sealing problem, plate-type heat exchangers are primarily used for low-pressure systems. However, new improvements in gasket design and overall heat exchanger design have allowed for some higher-pressure applications of the plate-type heat exchanger.

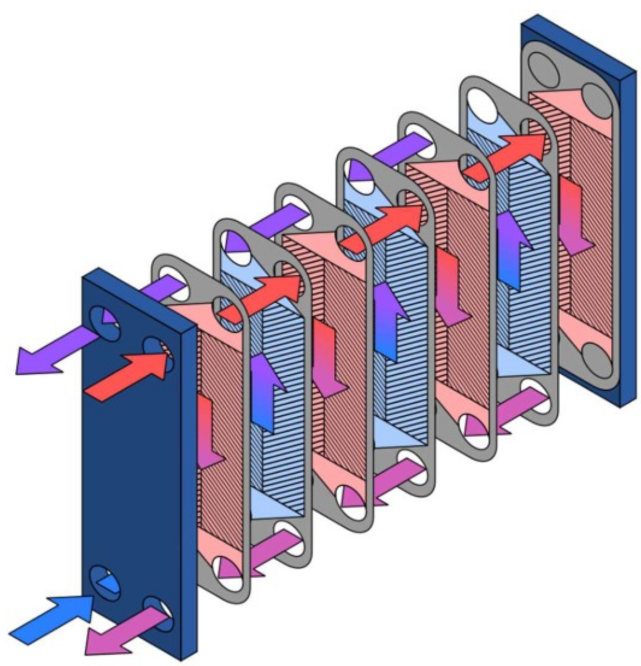
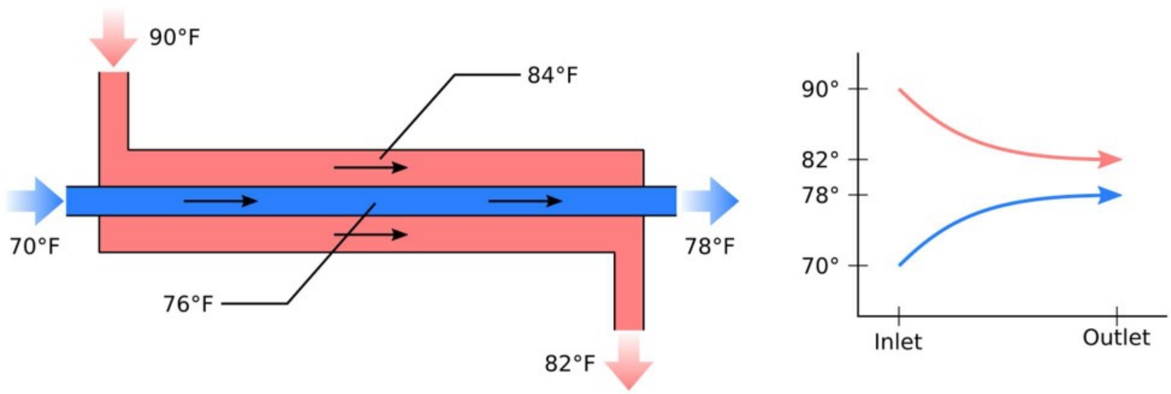


Plate Heat Exchanger

Heat Exchanger Categories

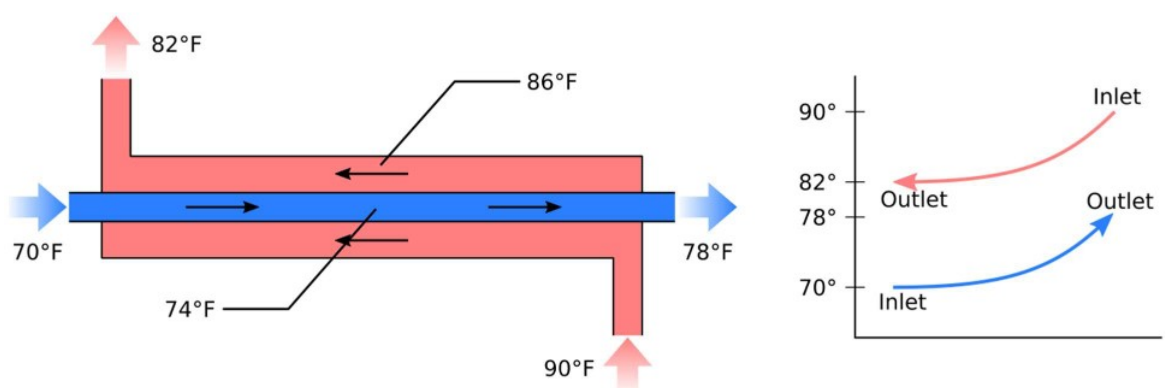
Because heat exchangers come in many shapes, sizes, makes, and models, they are categorized according to common characteristics. One common characteristic that can be used to categories them is the direction of flow the two fluids have relative to each other. The **three** categories are **parallel flow, counter-flow, and crossflow.**

Parallel Flow (illustrated on the next page) exists when both the tube-side fluid and the shell-side fluid flow in the same direction. In this case, the two fluids enter the heat exchanger from the same end with a large temperature difference. As the fluids transfer heat, hotter to cooler, the temperatures of the two fluids approach each other. Note that the hottest cold-fluid temperature is always less than the coldest hot-fluid temperature.



Parallel Flow Heat Exchanger

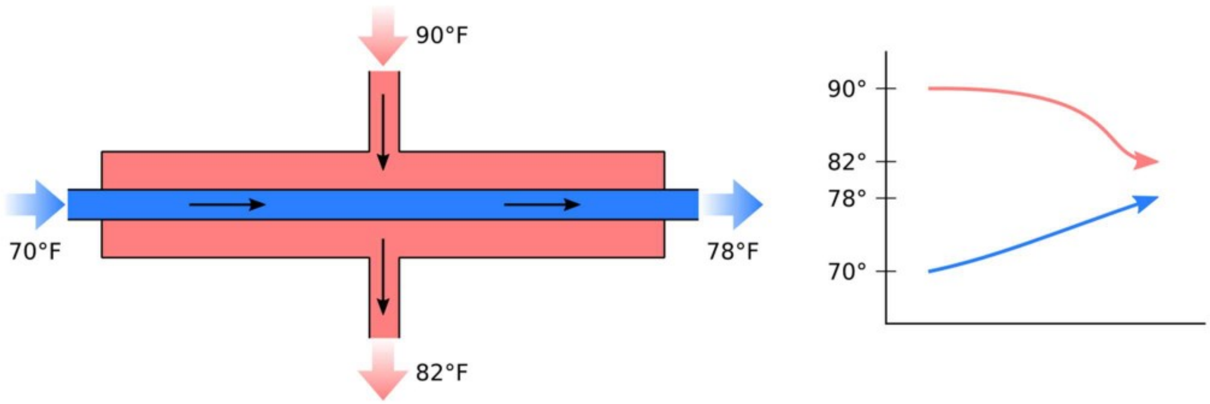
Counter-flow exists when the two fluids flow in opposite directions. Each of the fluids enters the heat exchanger at opposite ends. Because the cooler fluid exits the counter-flow heat exchanger at the end where the hot fluid enters the heat exchanger, the cooler fluid will approach the inlet temperature of the hot fluid. **Counter-flow heat exchangers are the most efficient of the three flow types**. In contrast to the parallel flow heat exchanger, the counter-flow heat exchanger can have the hottest cold-fluid temperature greater than the coldest hot-fluid temperature.



Counter-Flow Heat Exchange

Crossflow exists when one fluid flows perpendicular to the second fluid; that is, one fluid flows through tubes, and the second fluid passes around the tubes at a 90°angle. Crossflow heat exchangers are usually found in applications where one of the fluids changes state (2-phase flow).

An example is a steam system's condenser, in which the steam exiting the turbine enters the condenser shell side, and the cool water flowing in the tubes absorbs the heat from the steam, condensing it into water. Large volumes of vapor may be condensed using this type of heat exchanger flow.



Crossflow Heat Exchanger

Comparison of The Types of Heat Exchangers

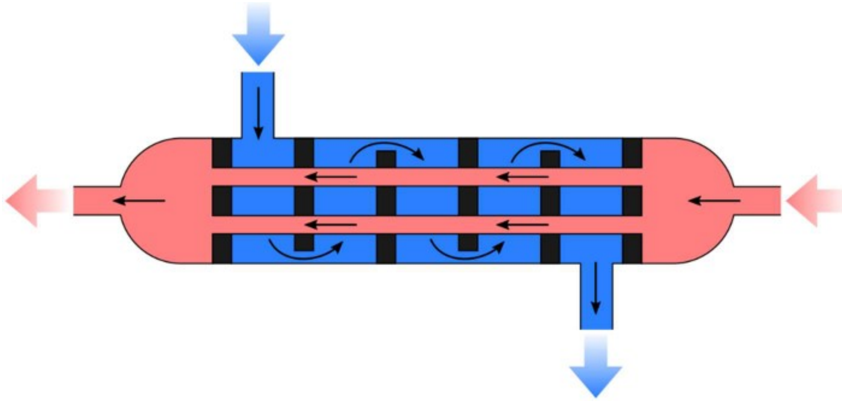
Each of the three types of heat exchangers has advantages and disadvantages. But of the three, **the counter-flow heat exchanger design is the most efficient** when comparing heat transfer rate per unit surface area. The efficiency of a counter-flow heat exchanger is due to the fact that the average ΔT (difference in temperature) between the two fluids over the length of the heat exchanger is maximized.

It has been proven that given the same operating conditions, operating the same heat exchanger in a counter-flow manner will result in a greater heat transfer rate than operating in parallel flow.

In actuality, most large heat exchangers are not purely **parallel flow, counter-flow, or crossflow.** They are usually a combination of the two or all three types of heat exchanger designs. This is due to the fact that actual heat exchangers are more complex than their simple idealized counterparts. The reason for the combination of the various types is to maximize the efficiency of the heat exchanger within the restrictions placed on the design. Size, cost, weight, required efficiency, type of fluids, operating pressures, and temperatures all help determine the complexity of a specific heat exchanger.

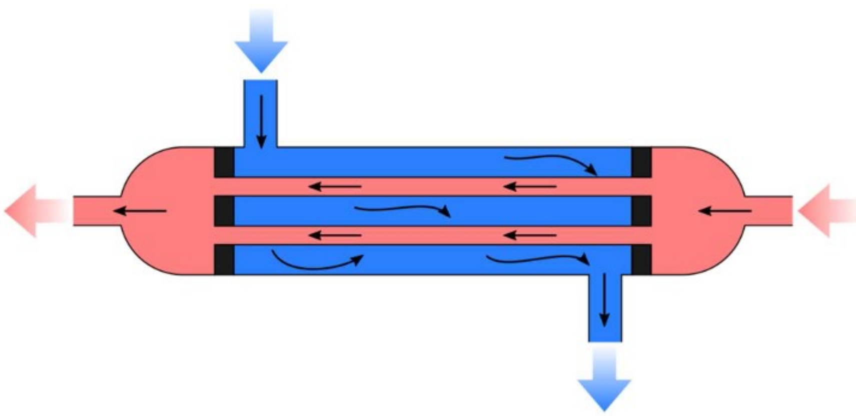
Single and Multi-Pass

One method that combines the characteristics of two or more heat exchangers and improves the performance of a heat exchanger is to have the two fluids pass each other several times within a single heat exchanger. When a heat exchanger's fluids pass each other more than once, a heat exchanger is called a **multi-pass** heat exchanger.



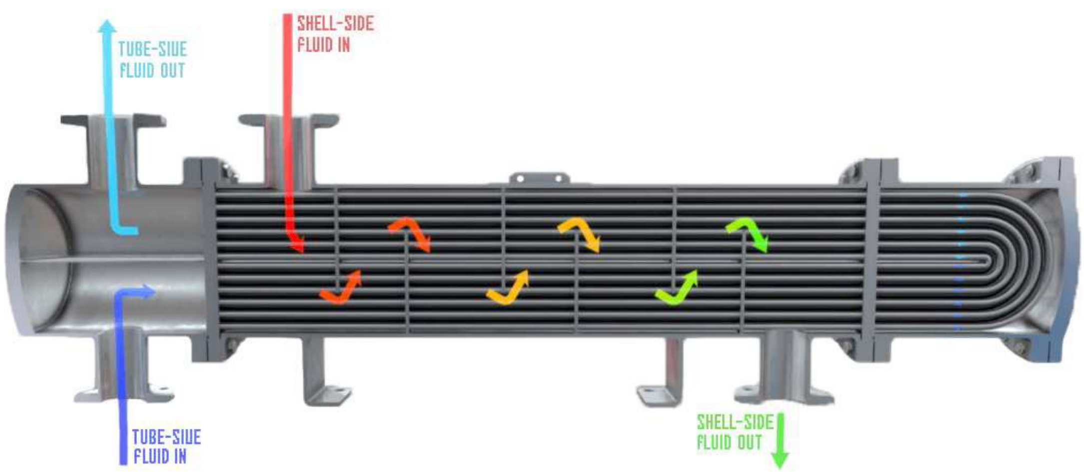
<u>Multi-Pass Heat Exchanger Design</u>

If the fluids pass each other only once, the heat exchanger is called a **single-pass** heat exchanger.



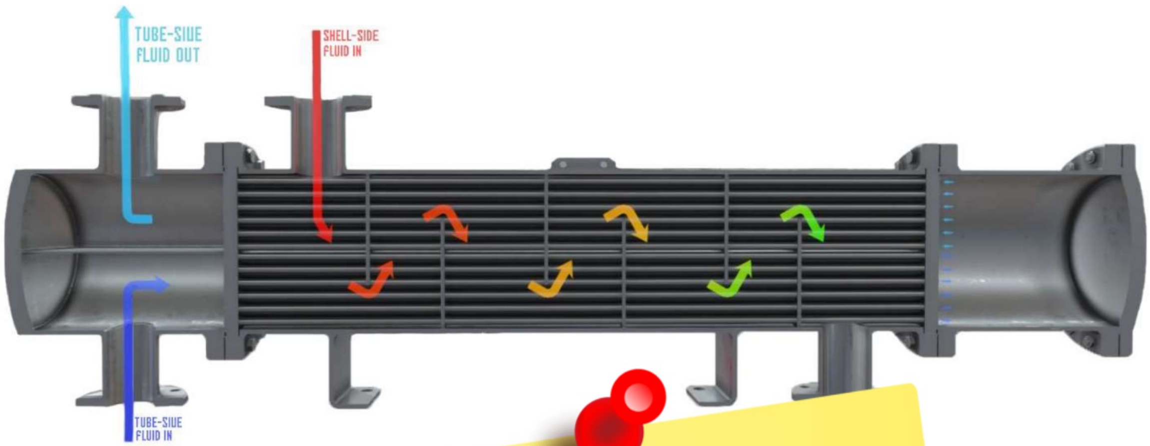
<u>Single Pass Heat Exchanger Design</u>

Commonly, the multi-pass heat exchanger reverses the flow in the tubes by use of one or more sets of "U" bends in the tubes. The "U" bends allow the fluid to flow back and forth across the length of the heat exchanger.



<u>U-Shape Heat Exchanger</u>

A second method to achieve multiple passes is to insert baffles on the shell side of the heat exchanger. These direct the shell side fluid back and forth across the tubes to achieve the multi-pass effect.



Regenerative & Non

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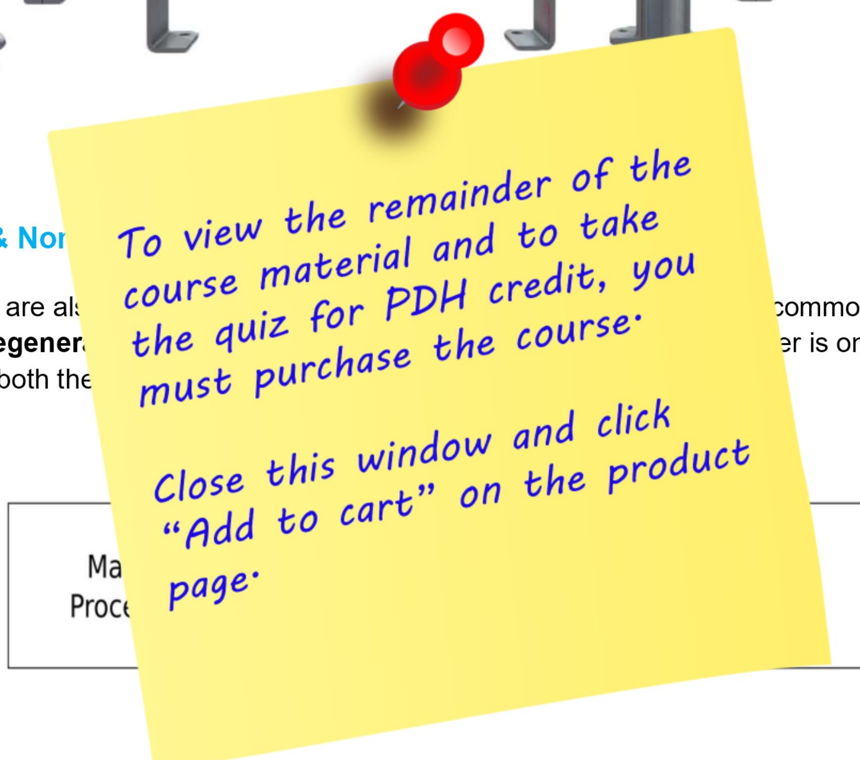

Regenerative Heat Exchanger

That is, the hot fluid leaving a system gives up its heat to "regenerate" or heat up the fluid returning to the system. **Regenerative** heat exchangers are usually found in high-temperature systems where a portion of the system's fluid is removed from the main process and then returned. Because the fluid removed from the main process contains energy (heat), the heat from the fluid leaving the main system is used to reheat (regenerate) the returning fluid instead of being rejected to an external cooling medium to improve efficiency. It is important to remember that the term regenerative/non-regenerative only refers to "how" a heat exchanger functions in a system and does not indicate any single type of heat exchanger characteristic (tube and shell, plate, parallel flow, counter-flow, etc.).

In a **non-regenerative** heat exchanger, the hot fluid is cooled by fluid from a separate system, and the energy (heat) removed is not returned to the system.