Heat Exchangers (Kinds of Heat Exchangers)

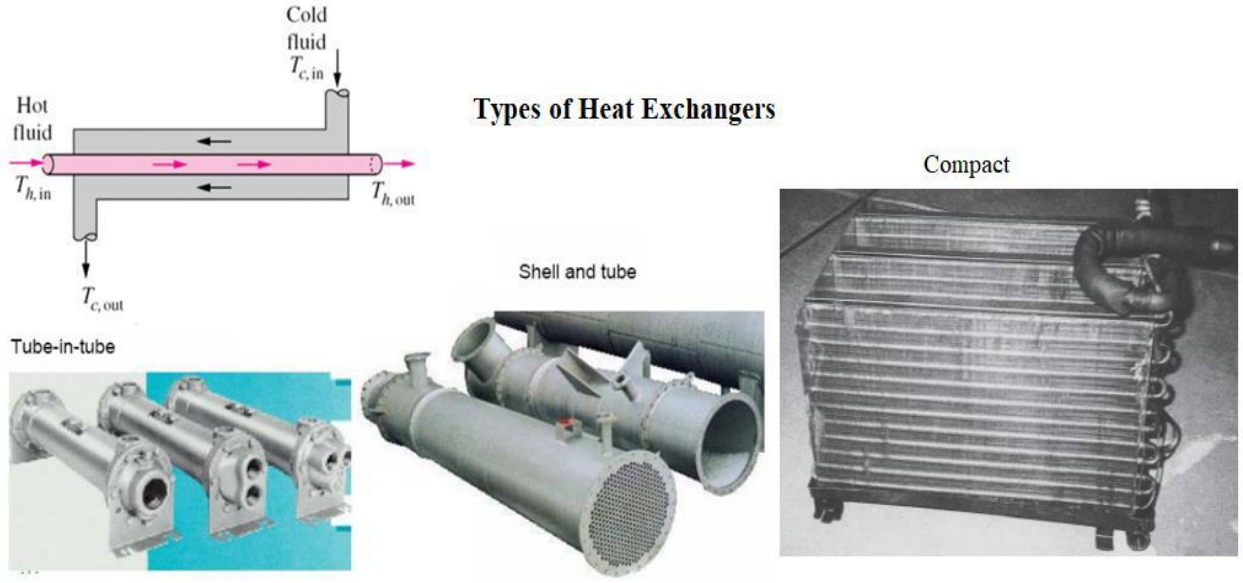
The Objective: Studying the function and types of heat exchangers.

Introduction:

Heat exchangers are devices that facilitate the ***exchange of heat*** between ***two fluids*** that are at ***different temperatures*** while keeping them from mixing with each other. Heat exchangers are commonly used in practice in a wide range of applications, from heating and air-conditioning systems in a household, to chemical processing and power production in large plants. Heat transfer in a heat exchanger usually involves ***convection*** in each fluid and ***conduction*** through the wall separating the two fluids. In the analysis of heat exchangers, it is convenient to work with an ***overall heat transfer coefficient U*** that accounts for the contribution of all these effects on heat transfer.

Types of heat exchangers:

Different heat transfer applications require different types of hardware and different configurations of heat transfer equipment.

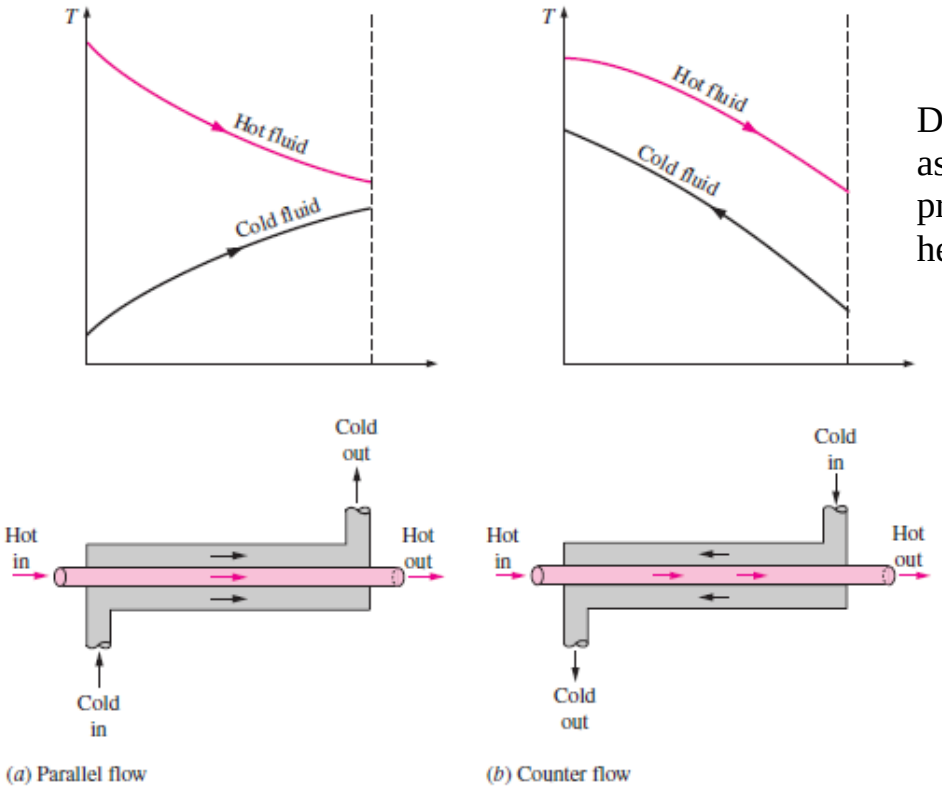


1- Double-pipe heat exchanger:

It is the simplest type of heat exchangers which is consists of two concentric pipes of different diameters, as shown in the Figure. One fluid in a double-pipe heat exchanger flows through the smaller pipe while the other fluid flows through the annular space between the two pipes. Two types of flow arrangement are possible in a double-pipe heat exchanger:

a- Parallel flow, both the hot and cold fluids enter the heat exchanger at ***the same end*** and move in the ***same direction***.

b- Counter flow, the hot and cold fluids enter the heat exchanger at ***opposite ends*** and flow in ***opposite directions.***



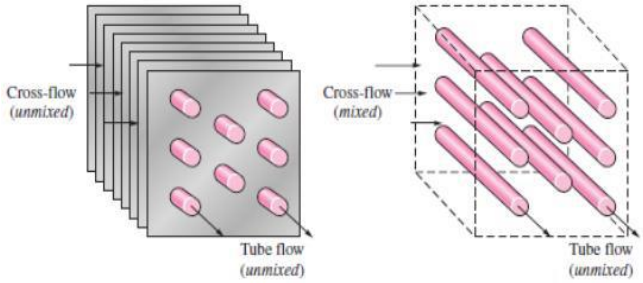
Different flow regimes and associated temperature profiles in a double-pipe heat exchanger.

2- Compact heat exchanger:

This type of heat exchanger is specifically designed to realize a ***large heat transfer surface area per unit volume.*** The ratio of the heat transfer ***surface area*** of a heat exchanger to its ***volume*** is called the ***area density*** β . A heat exchanger with β = 700 m**2**/m**3** is classified as being compact.

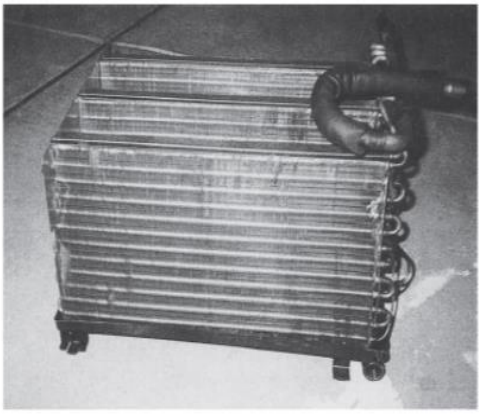
Examples of compact heat exchangers are ***car radiators*** (β = 1000 m2/m3), glass

- ***ceramic gas turbine*** heat exchangers (β = 6000 m**2**/m**3**), the regenerator of a Stirling engine (β = 15,000 m2/m3), and the ***human lung*** (β = 20,000 m**2**/m**3**). Compact heat exchangers enable us to achieve ***high heat transfer rates*** between two fluids in a ***small volume***, and they are commonly used in applications with strict limitations on the ***weight*** and ***volume*** of heat exchangers.
- The large surface area in compact heat exchangers is obtained by attaching closely spaced ***thin plate*** or ***corrugated fins*** to the walls separating the two fluids. Compact heat exchangers are commonly used in **gas-to-gas** and **gas-to-liquid** (or liquid-to-gas) heat exchangers to counteract the low heat transfer coefficient associated with gas flow with increased surface area.
- In a car radiator, which is a water-to-air compact heat exchanger, for example, the fins are attached to the air side of the tube surface. In compact heat exchangers, the two fluids usually move perpendicular to each other, and such flow configuration is called cross-flow. The cross-flow is further classified as unmixed and mixed flow, depending on the flow configuration, as shown in the Figure.



(a) Both fluids unmixed (b) One fluid mixed, one fluid unmixed

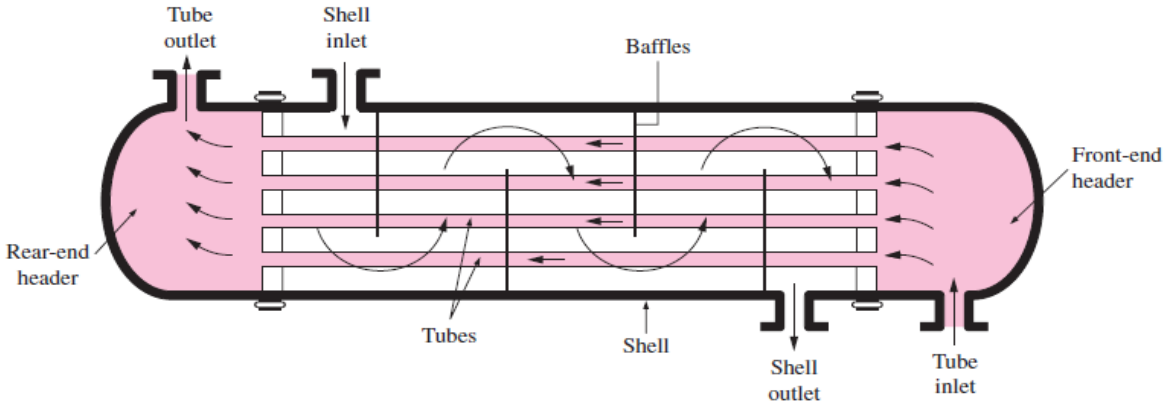
Different flow configurations in cross-flow heat exchangers.



Gas-to-liquid compact heat exchanger for a residential air conditioning system.

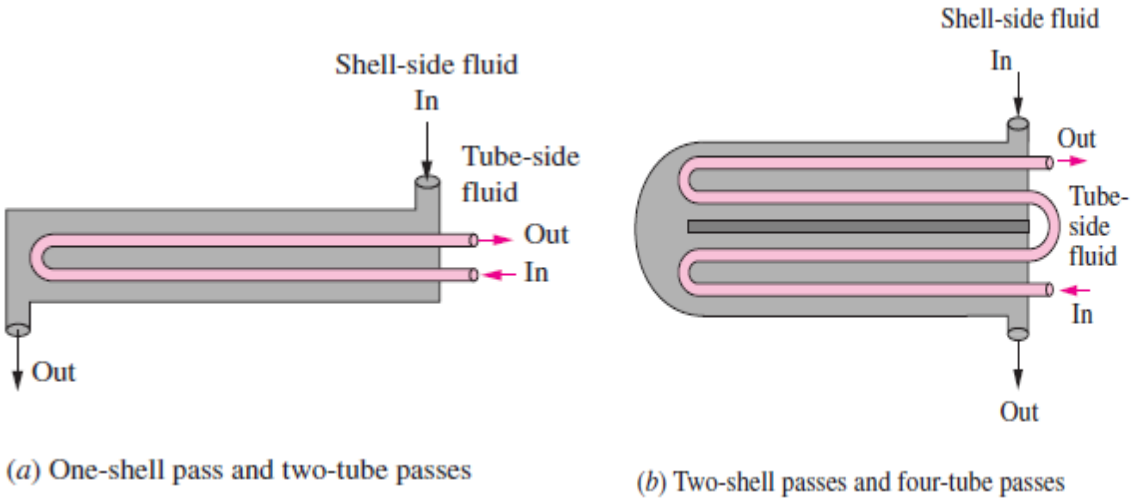
3- Shell-and-tube heat exchanger:

The most common type of heat exchanger in ***industrial applications*** is the **shell and- tube** heat exchanger, shown in the Figure. Shell-and-tube heat exchangers contain a large number of tubes (sometimes several hundred) packed in a shell with their axes parallel to that of the shell. Heat transfer takes place as one fluid flows ***inside the tubes*** while the other fluid flows outside the tubes ***through the shell***. *Baffles* are commonly placed in the shell to force the shell-side fluid to flow across the shell to enhance heat transfer and to maintain uniform spacing between the tubes.



The schematic of a shell-and-tube heat exchanger (one-shell pass and one-tube pass).

Shell-and-tube heat exchangers are further classified according to the number of shell and tube passes involved.

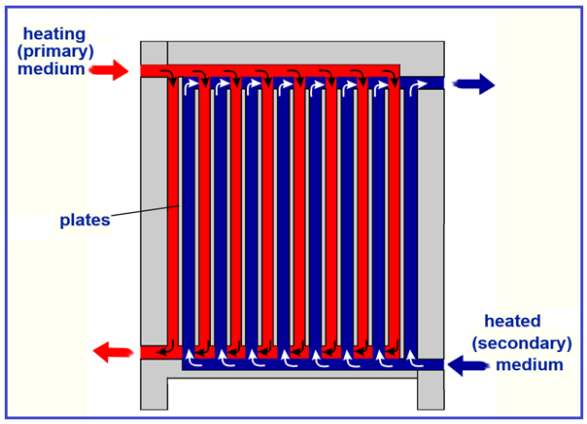


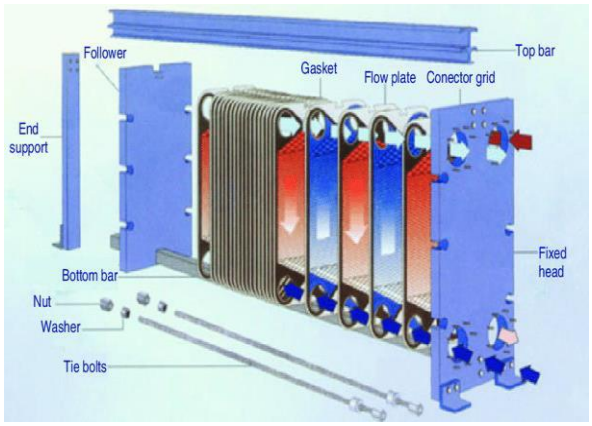
(*a*) One-shell pass and two-tube passes

(*b*) Two-shell passes and four-tube passes

4- A plate-and-frame liquid-to-liquid heat exchanger:

An innovative type of heat exchanger that has found widespread use is the ***plate and frame*** (or just plate) heat exchanger, which ***consists of a series of plates with corrugated flat flow passages*** (as in the Figure). The ***hot*** and ***cold fluids*** flow in ***alternate passages*** and thus each ***cold fluid stream is surrounded by two hot fluid streams,*** resulting in very effective heat transfer. They are ***well suited for liquid-toliquid heat exchanges applications***, provided that the hot and cold fluid streams are at about the same pressure.



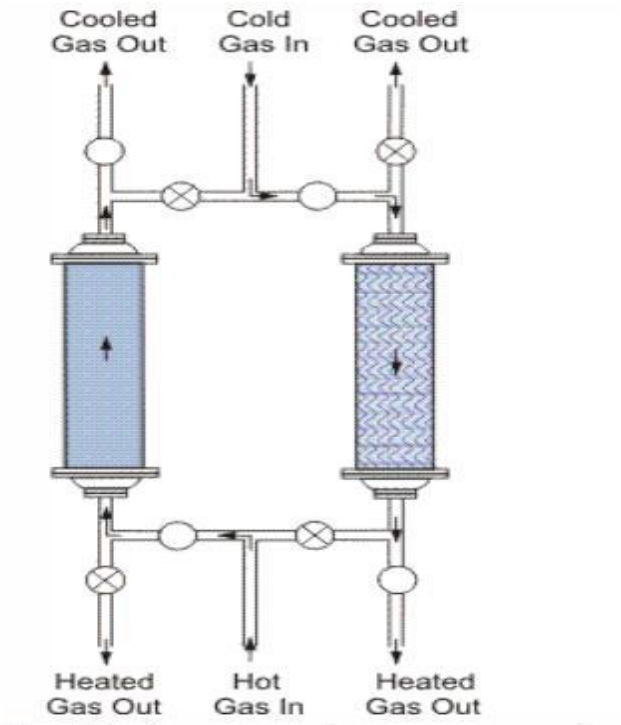


5- Regenerative heat exchanger:

This type of heat exchanger ***involves the alternate passage of the hot and cold fluid streams through the same flow area***. The ***static*-type regenerative heat exchanger** is basically a porous mass that has a large heat storage capacity, such as a ceramic wire mesh. Hot and cold fluids flow through this porous mass alternatively.

Heat is transferred from the hot fluid to the matrix of the regenerator during the flow of the hot fluid, and from the matrix to the cold fluid during the flow of the cold fluid. Thus, the matrix serves as a temporary heat storage medium.

Heat exchangers are often given specific names to reflect the specific application for which they are used. For example, a ***condenser*** is a heat exchanger in which one of the fluids is cooled and condenses as it flows through the heat exchanger. A ***boiler*** is another heat exchanger in which one of the fluids absorbs heat and vaporizes. A ***space radiator*** is a heat exchanger that transfers heat from the hot fluid to the surrounding space by radiation.



Fixed bed regenerator arrangement.