Lecture One

Introduction to Heat Exchanger

1- What are Heat Exchangers for?

- ❑ Heat exchangers are practical devices used to transfer energy from one fluid to another
- ❑ To get fluid streams to the right temperature for the next process
  - reactions often require feeds at high temp.
- ❑ To condense vapours
- ❑ To evaporate liquids
- ❑ To recover heat to use elsewhere
- ❑ To reject low-grade heat
- ❑ To drive a power cycle

A 'heat exchanger' *may be defined as an equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running costs.*

2- Main Categories of HE.

In order to meet the widely varying applications, several types of heat exchangers have been developed which are classified on the basis of *nature of heat exchange process*, *relative direction of fluid motion*, *design and constructional features*, and *physical state of fluids*.

A. Nature of HE process.

Heat exchangers, on the basis of nature of heat exchange process, are classified as follows :

(*i*) Direct contact (or open) heat exchangers.

(*ii*) Indirect contact heat exchangers.

(*a*) Regenerators. (*b*) Recuperators.

i. Direct contact HE.

where mixing of two fluids is either harmless or desirable. Examples : (*i*) Cooling towers; (*ii*) Jet condensers; (*iii*) Direct contact feed heaters.

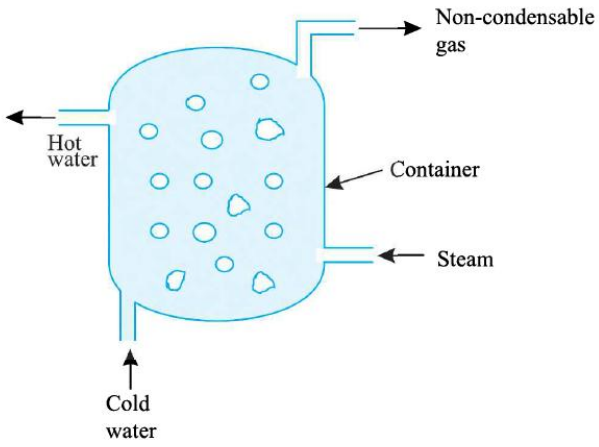


Fig.1 Direct contact or open HE.

ii. Indirect Contact HE.

In this type of heat exchanger, the heat transfer between two fluids could be carried out by transmission through wall which separates the two fluids. This type includes the following :

(*a*) Regenerators.

(*b*) Recuperators or surface exchangers.

a) Regenerators.

In a *regenerator* type of heat exchanger the *hot and cold fluids pass alternately through a space containing solid particles (matrix), these particles providing alternately a sink and a source for heat flow.*

Examples : (*i*) I.C. engines and gas turbines; (*ii*) Open hearth and glass melting furnaces; (*iii*) Air heaters of blast furnaces.

b) Recuperators.

'*Recuperator*' is the most important type of heat exchanger in which the flowing fluids exchanging heat are on either side of *dividing wall* (in the form of pipes or tubes generally). These heat exchangers are used when two fluids cannot be allowed to mix *i.e.*, when the mixing is undesirable.

Examples : (*i*) Automobile radiators, (*ii*) Oil coolers, intercoolers, *air preheaters*, economisers, superheaters, condensers and surface feed heaters of a steam power plant, (*iii*) Milk chiller of pasteurising plant, (*iv*) Evaporator of an ice plant.

B. Relative Direction of Fluid Motion.

According to the relative directions of two fluid streams the heat exchangers are classified into the following *three* categories :

(*i*) Parallel flow or unidirection flow (*ii*) Counter-flow

(*iii*) Cross-flow.

(*i*) *Parallel flow heat exchangers* :

In a *parallel flow heat exchanger*, as the name suggests, the two fluid streams (hot and cold) travel in the *same direction*. The two streams enter at one end and leave at the other end. The flow arrangement and variation of temperatures of the fluid streams in case of parallel flow heat exchangers,

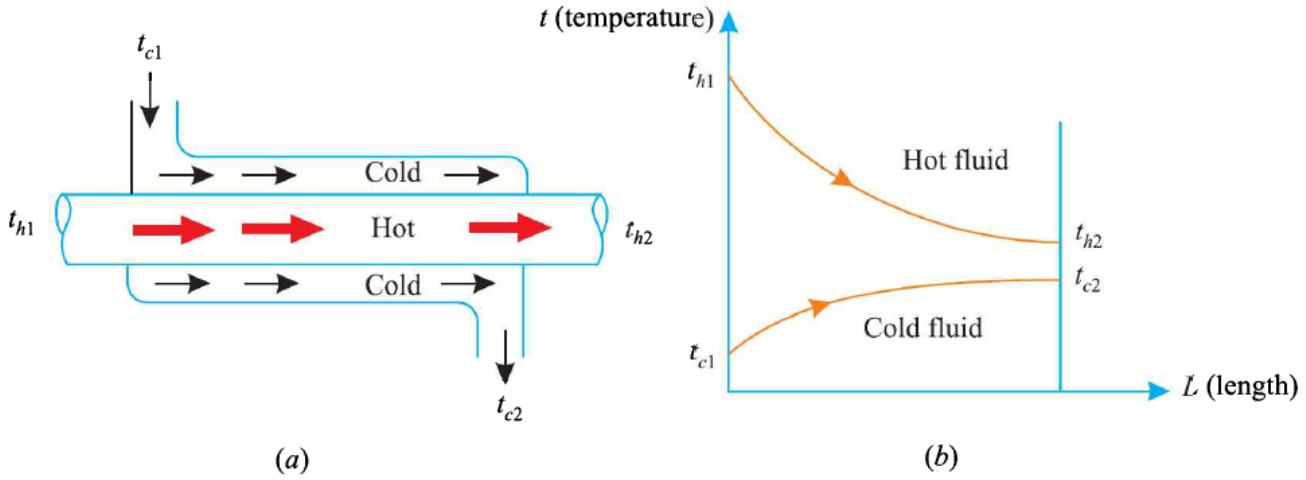


Fig.2 Parallel flow HE.

Examples : Oil coolers, oil heaters, water heaters etc.

As the two fluids are separated by a wall, this type of heat exchanger may be called parallel flow recuperator or surface heat exchanger.

(*ii*) *Counter-flow heat exchangers* :

In a counter-flow heat exchanger, the two fluids flow in opposite directions. The hot and cold fluids enter at the opposite ends. The flow arrangement and temperature distribution for such a heat exchanger are shown schematically The *temperature difference* between the two fluids remains more or less *nearly constant*. This type of heat exchanger, due to counter flow, gives *maximum rate of heat transfer for a given surface area*. Hence such heat exchangers are *most favoured* for heating and cooling of fluids.

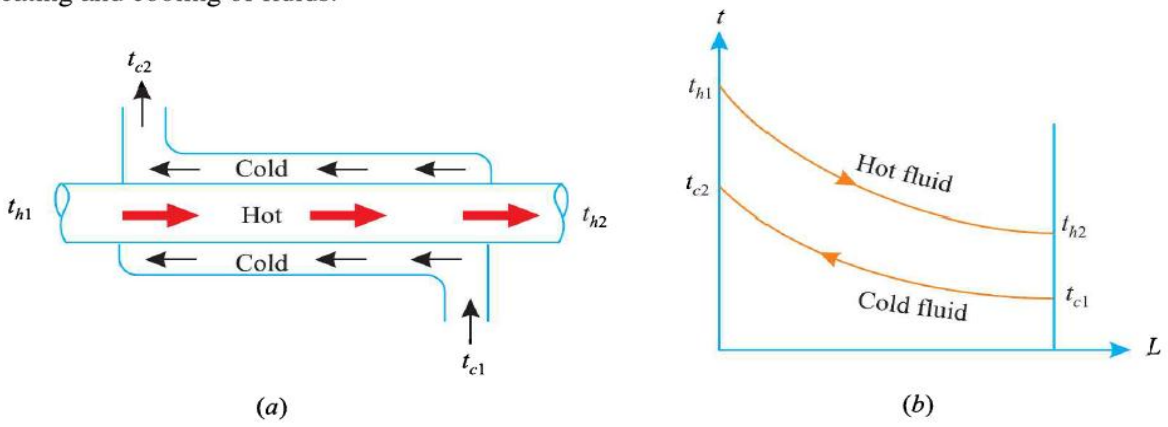


Fig.3 Counter flow HE.

(*iii*) *Cross-flow heat exchanger :*

In cross-flow heat exchangers, the *two fluids* (*hot and cold*) *cross one another in space*, *usually at right angles*. Fig.4 shows a schematic diagram of common arrangements of cross-flow heat exchangers.

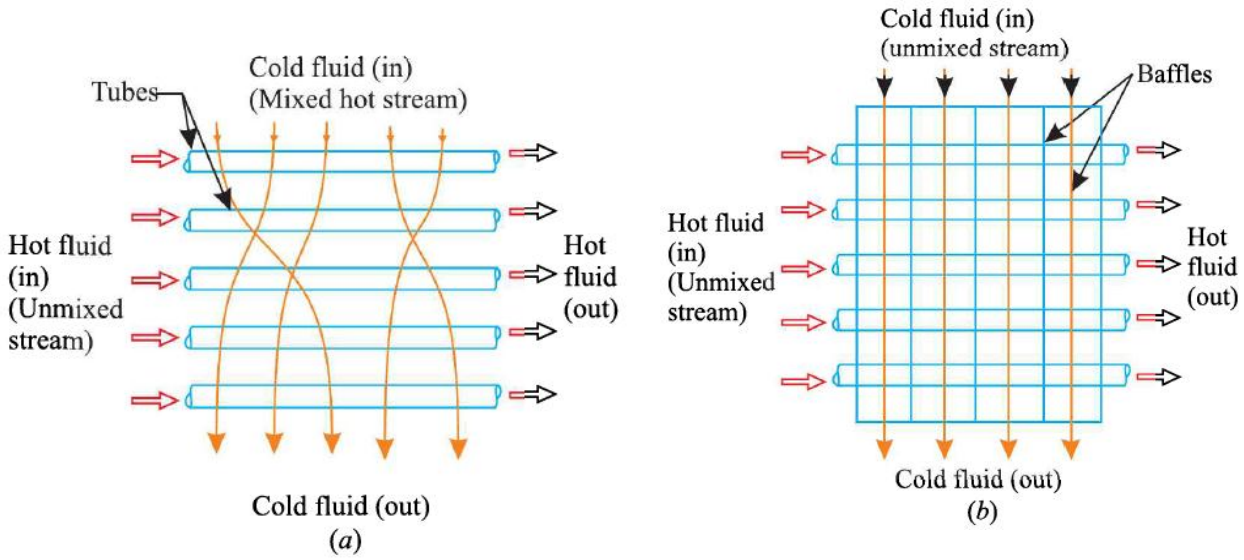


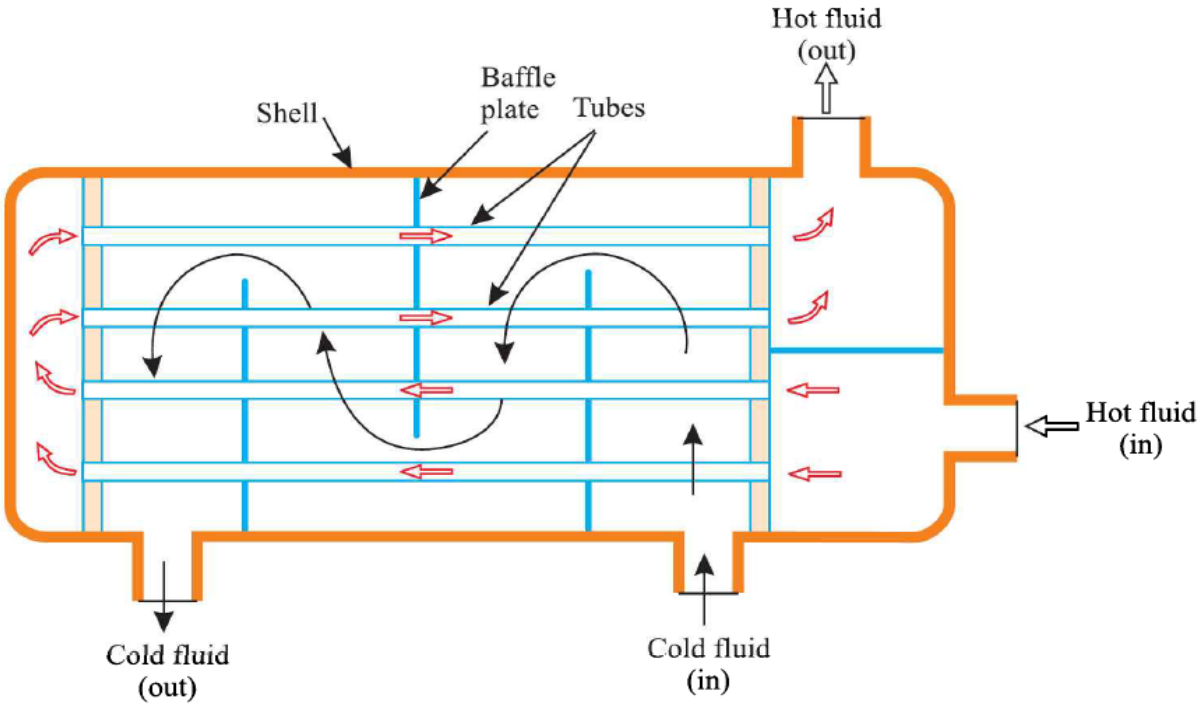
Fig. 4. Cross-flow heat exchangers

C. Design and constructional features :

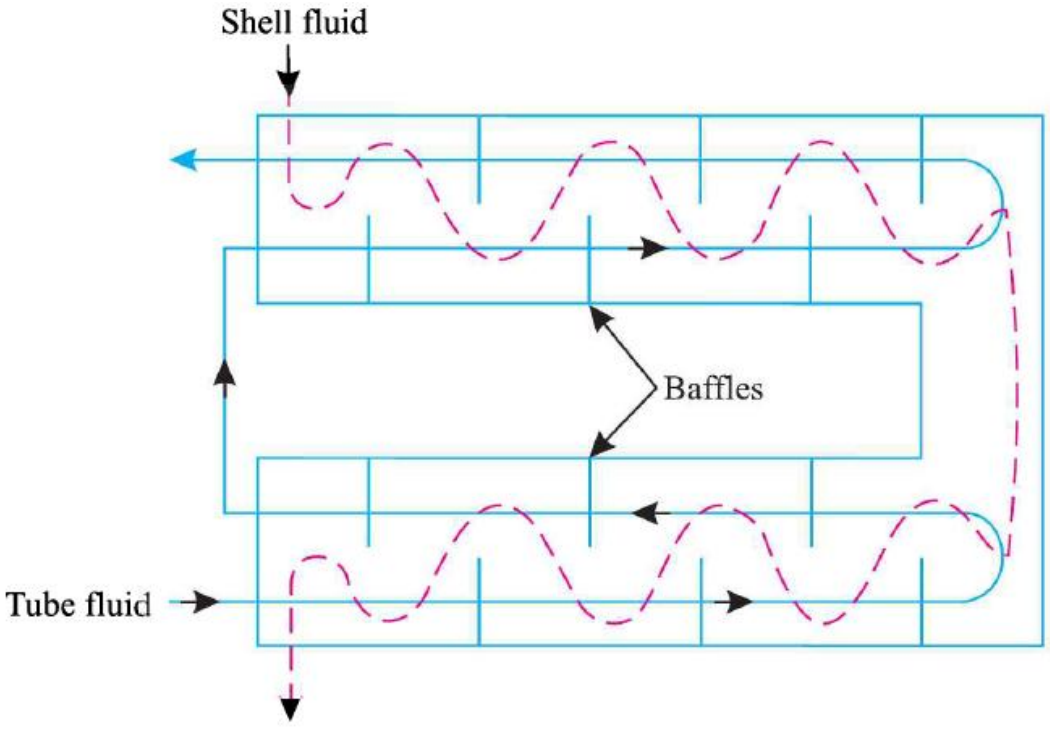
On the basis of design and constructional features, the heat exchangers are classified as under :

(*i*) *Concentric tubes* :

In this type, two concentric tubes are used, each carrying one of the fluids. The direction of flow may be parallel or counter as depicted in Fig. 2 (*a*) and Fig. 3 (*a*). The effectiveness of the heat exchanger is increased by using swirling flow.



(*a*) One-shell pass and two-tube pass heat exchanger



(*b*) Two-shell pass and four-tube pass heat exchanger

Fig.5 Shell and Tube HE.

(*ii*) *Shell and tube* :

In this type of heat exchanger one of the fluids flows through a bundle of tubes enclosed by a shell. The other fluid is forced through the shell and it flows over the outside surface of the tubes. Such an arrangement is employed where *reliability* and *heat transfer effectiveness are important.* With the use of multiple tubes heat transfer rate is amply improved due to increased surface area.

(*iii*) *Multiple shell and tube passes* :

Multiple shell and tube passes are used for *enhancing the overall heat transfer. Multiple shell pass* is possible where the fluid flowing through the shell is re-routed. The shell side fluid is forced to flow back and forth acros the tubes by baffles. *Multiple tube pass* exchangers are those which re-route the fluid through tubes in the opposite direction.

(*iv*) *Compact heat exchangers* :

There are special purpose heat exchangers and have a very large transfer surface area per unit volume of the exchanger. They are generally employed when convective heat transfer coefficient associated with one of the fluids is much smaller than that associated with the other fluid.

Example : Plate-fin, flattened fin tube exchangers etc.

D. Physical State of Fluids.

Depending upon the physical state of fluids the heat exchangers are classified as follows :

(*i*) Condensers (*ii*) Evaporators

(*i*) *Condensers.* In a condenser, the condensing fluid remains at constant temperature throughout the exchanger while the temperature of the colder fluid gradually increases from inlet to outlet. The hot fluid loses latent part of heat which is accepted by the cold fluid Refer Fig.6

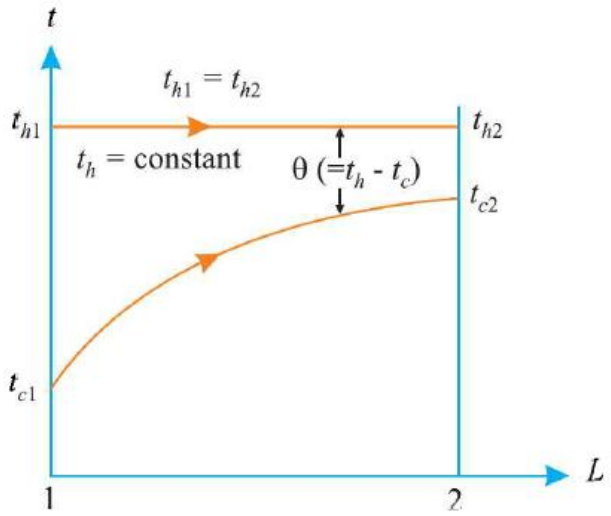


Fig.6. Temperature distribution in a condenser.

(*ii*) *Evporators.* In this case, the boiling fluid (cold fluid) remains at constant temperature while the temperature of hot fluid gradually decreases from inlet to outlet. Refer Fig.7

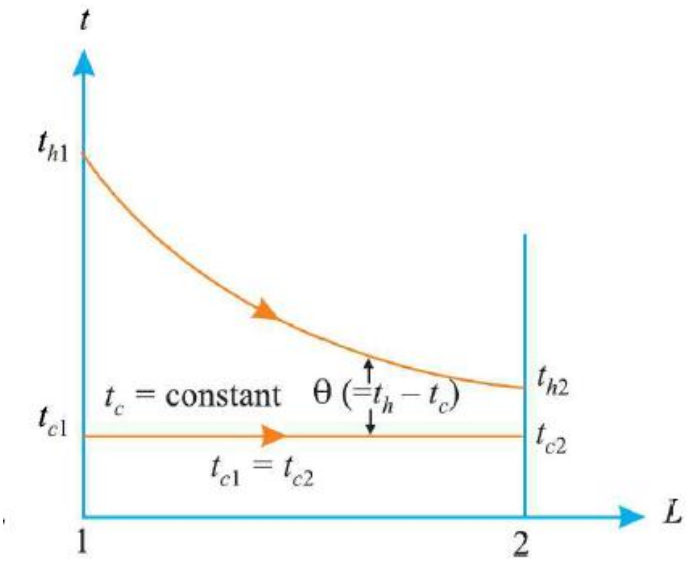


Fig. 7. Temperature distribution in an evaporator.