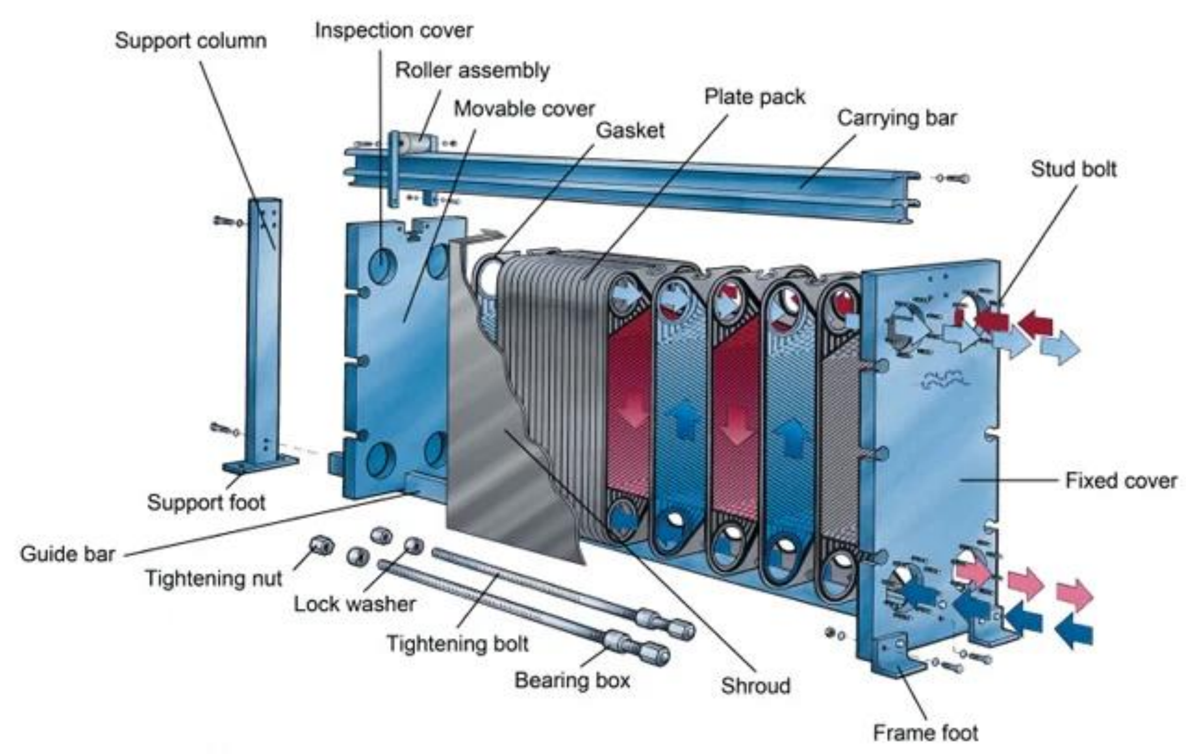
Heat Exchangers

Compact heat exchangers

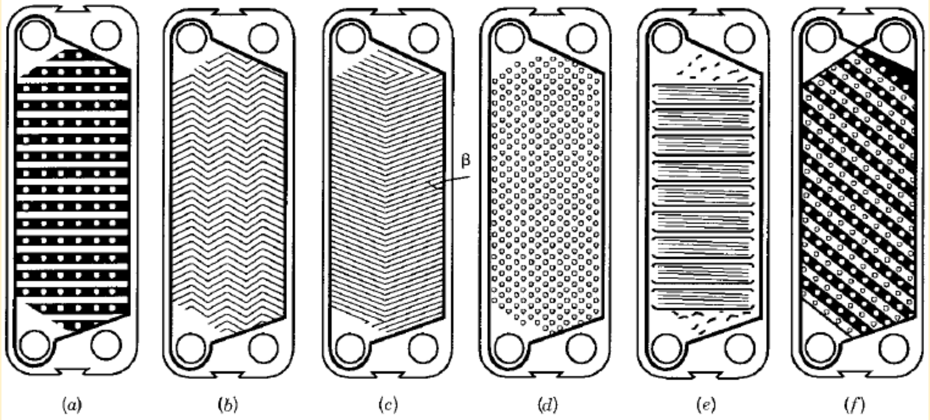
A compact heat exchanger such as a plate and frame exchanger or a spiral exchanger accommodates a large surface area in a small volume

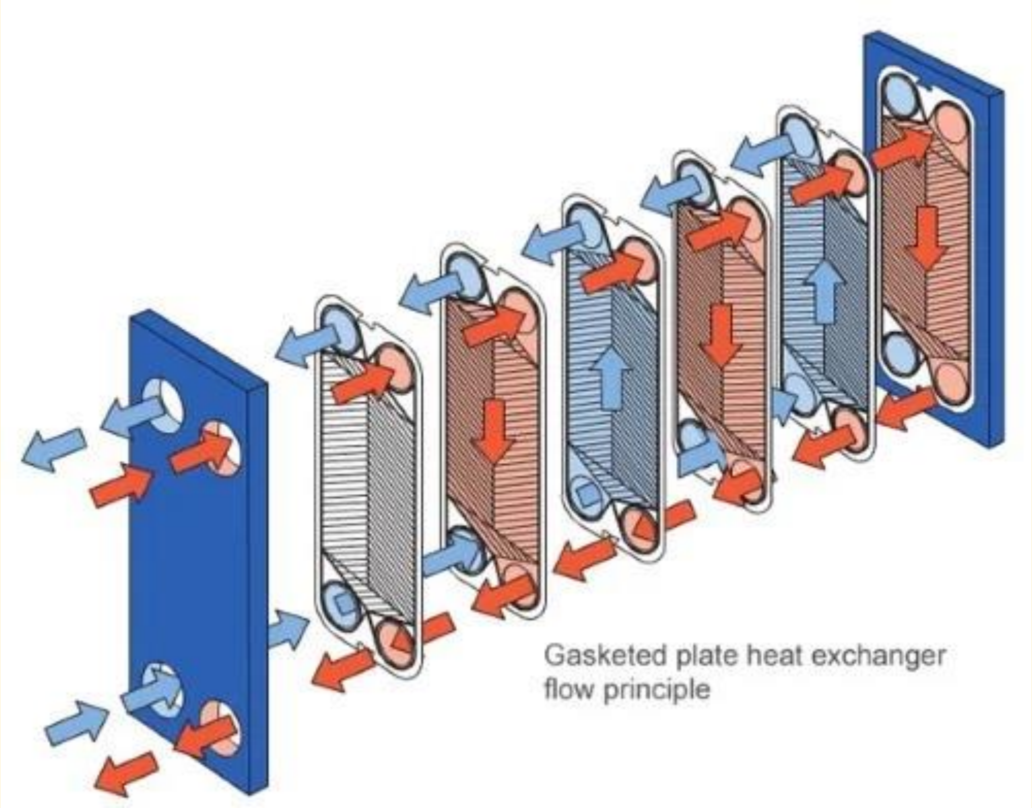
Plate and Frame Exchanger (PHE)

- A plate heat exchanger is a compact type of heat exchanger that uses a **series of thin, cold pressed, corrugated plates to transfer heat between two fluids**
- The pack of thin rectangular plates are **sealed around the edges by gaskets and held together in a frame**
- They are **supported and aligned by an upper and lower carrying bars**
- In addition to the corrugation, each plate has a depression in the form of a channel near the periphery of a plate into which a gasket is placed
- Any two plates have **an intervening gasket which prevents mixing of the liquids and directs the fluids into the respective flow paths**, through the portals at the corners



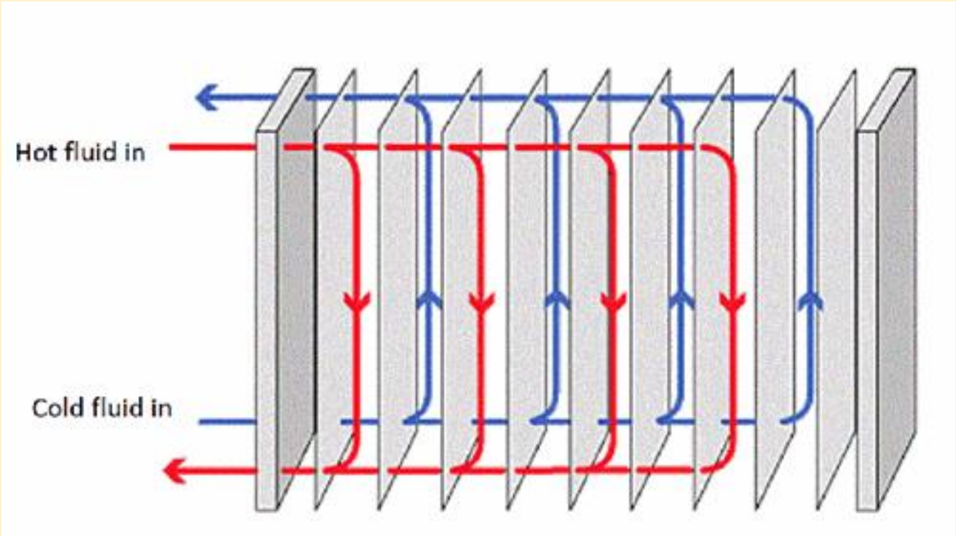
- Each plate has **four corner holes**
- When the plates are packed with gaskets in between, these **corner holes form four continuous flow lines for the two fluids** – two of these serve as the inlet and outlet of the hot fluid and the other two of the cold fluid
- After the plates are put in position, **two cover plates are put at the two ends and the entire assembly is fastened by tie rods** in order to press the corrugated plates over the gasket
- The **plates act as a barrier between the hot and cold fluids flowing in counter current fashion on two sides of the plate**
- The **corrugated plates help in inducing turbulence in the fluids, increasing effective surface area and providing mechanical strength and rigidity to the plates**
- Individual plates may have an area as high as 3 m^2 or more
- The nominal gap between the plates ranges from 2 mm to 5 mm providing a hydraulic mean diameter in the range between 4 to 10 mm

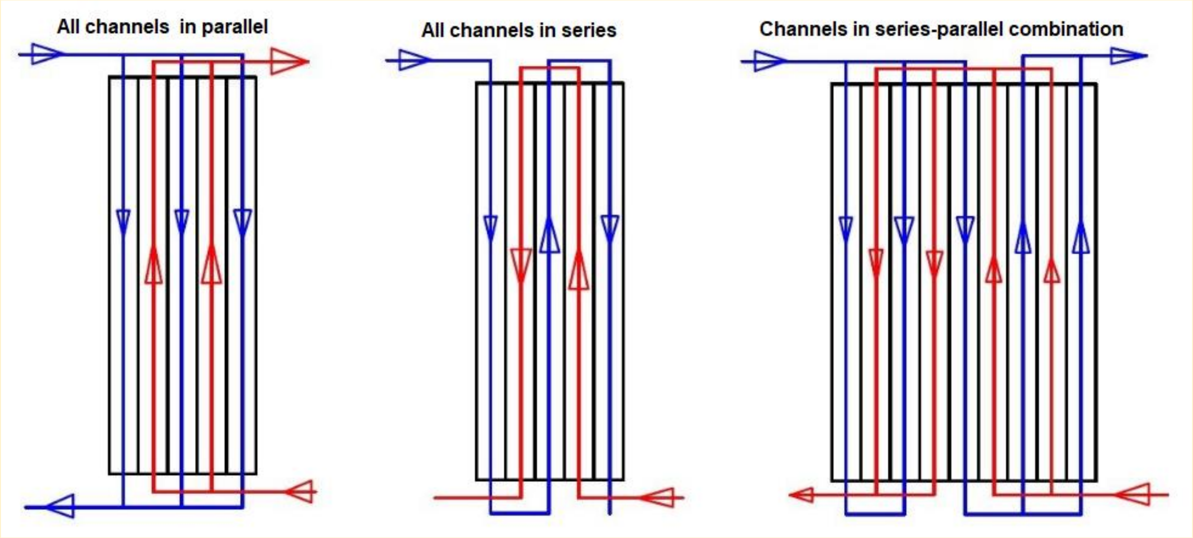


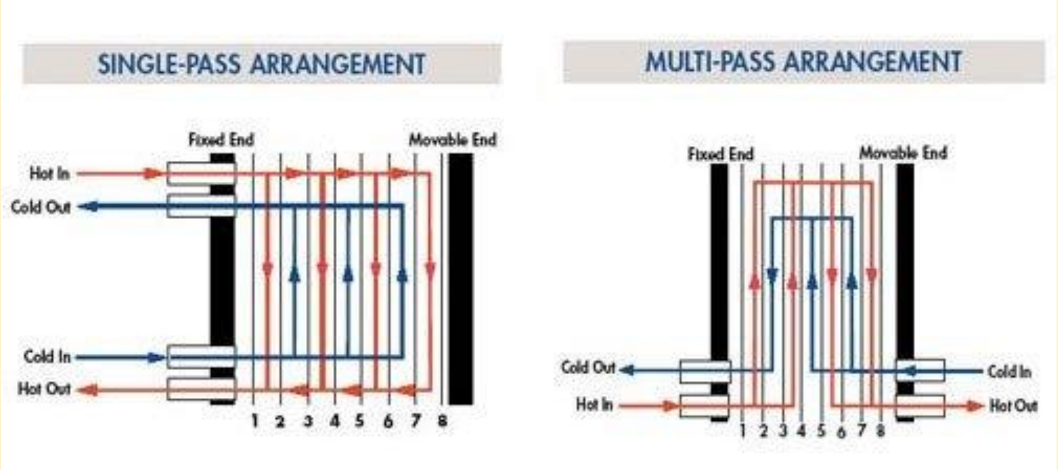


Working:

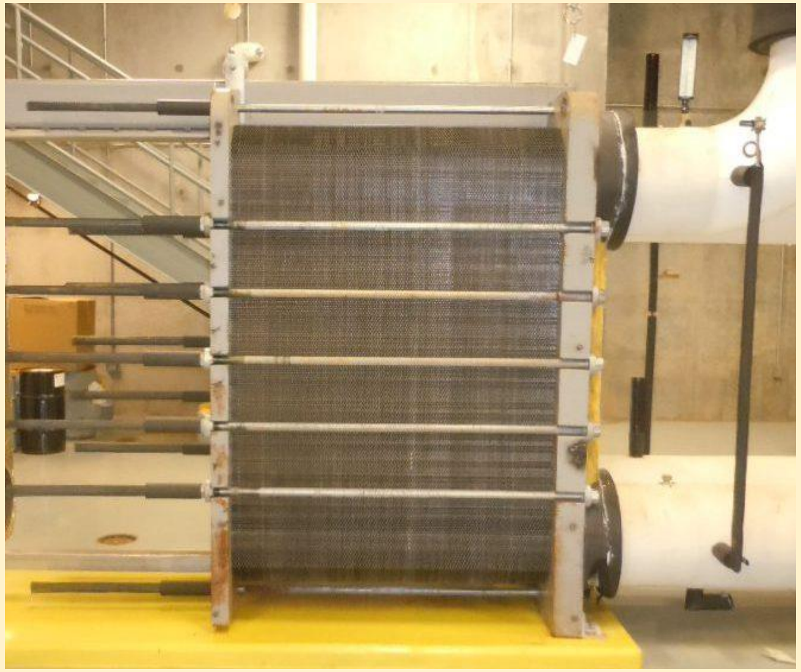
- The **hot and cold fluids flow in alternate passages** and thus **each cold fluid stream is surrounded by two hot fluid streams**, resulting in effective heat transfer
- If the **demand for heat transfer is very high**, it can be **achieved by adding more plates**
- Plates can be easily **separated for cleaning**
- The fluids can flow through the channels in the **series mode, parallel mode or the combination of series-parallel arrangement**
- Also, multi-pass arrangements can be implemented, depending on the arrangement of the gaskets between the plates



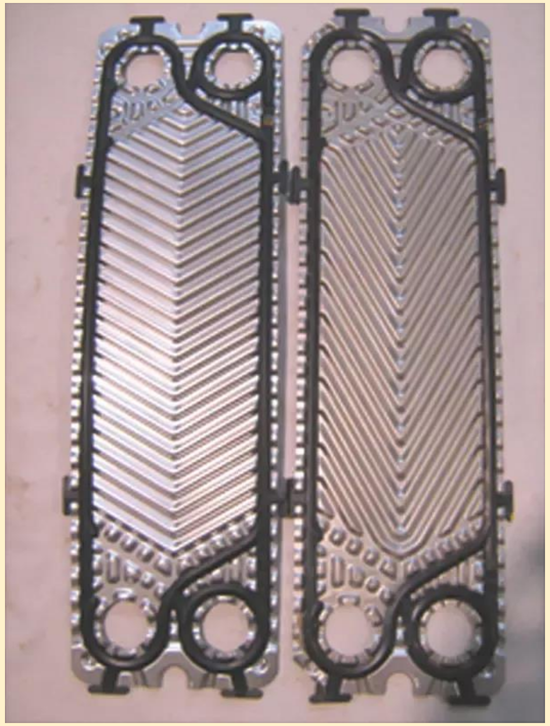




- **Applications**:
- PHEs are **suitable for** a wide variety of applications in **various industries such as oil, gas, chemical, food processing and milk pasteurization**
- Apart from liquid-liquid exchangers, these are also **used for evaporation, reboiling or condensing services**
- **Maximum temperature** in PHEs is (limited by gasket material) is **~ 190°C**
- **Maximum pressure** is about **25 kg/cm^2**
- PHEs are very **effective for viscous fluids** with **viscosity up to 300 poise** and for **slurries up to 40% concentration**
- PHEs can also **handle corrosive fluids** by **selecting suitable material of construction**



Material of construction:



- The **plates are made from thin-gauge sheets varying from 0.5 mm to 1 mm in thickness**
- **Stainless steel** is the **lowest grade material used**
- Other materials include special alloys such as **Hastelloy, Incoloy , Inconel, titanium, nickel, aluminum, and tantalum**
- Plates are never made from carbon steel
- **Gaskets are typically molded elastomers**, selected based on their fluid compatibility and conditions of temperature and pressure
- Common elastomeric materials such as **nitrile rubber, ethylene-propylene-diene monomer (EPDM), resin-cured butyl rubber, neoprene, silicone rubber etc**., are used as materials for the gaskets. Gaskets are usually glued to the plates to prevent leakage

Fouling:

- **Fouling which may occur** in PHE **due to scaling, deposition of solids by crystallization, corrosion** etc play a more important role than in shell and tube exchangers
- The **allowable fouling resistance is 1/10th of that in a shell and tube exchanger** under similar applications

Advantages of plate heat exchanger (PHE):

- PHE offers **very high heat transfer coefficient on both sides of the plate**

  The heat transfer coefficient for water-water system is about 6000 kcal/hm^2^{o}C as compared to 2000 kcal/hm^2^{o}C in a shell and tube heat exchanger (STE) at the same pressure drop

- PHE is **suitable for close temperature approach, as low as 2^{o}C**
- PHEs are very flexible - the **heat transfer area** in a PHE can be **increased or decreased by adding and removing plates**
- PHE **requires much less floor space** - for the same area of heat transfer, PHEs can often **occupy 80% less floor space (sometimes 10 times less), compared to shell-and-tube heat exchangers**
- PHE **offers low hold up volume of fluids**
- PHEs offers **ease of inspection, cleaning and maintenance** - since the PHE components can be separated, it is possible to clean and inspect all the parts that are exposed to fluids. This **feature is essential in the food processing and pharmaceutical industries**
- PHE **costs less than STE even when expensive material is used**

Disadvantages of plate heat exchanger (PHE):

- **Upper limits of temperature and pressure not very high** – limited by the allowable temperature for the gasket
- If steam is used, fluctuations in steam temperature and pressure reduce gasket life
- Since the plates in a PHE is corrugated with small flow space between them, the **pressure drop due to friction is high in such exchangers, which increases pumping costs**
- Processing of **highly viscous fluids that contain fibrous material is not recommended** because of the high associated pressure drop and flow distribution problems within the PHE

Design considerations of plate heat exchangers

- Very limited data is available in the open literature
- Reynolds No is defined as,

$$Re = \frac{GD_H}{\mu}$$

where G is the mass flow rate

- Now,

$$G = \frac{W}{bs}$$

where W = mass flow rate per channel
b = breadth of the plate
s = nominal gap between two adjacent plates

- Equivalent diameter for plates,

$$D_H = \frac{4bs}{2(b+s)}$$

- Heat transfer correlation for plates

$$Nu = 0.374(Re)^{0.67}(Pr)^{1/3}\left(\frac{\mu}{\mu_W}\right)^{0.15}$$