A STUDY ON PLATE HEAT EXCHANGER

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Abstract – *This article presents the study of various thermal concepts behind the functioning of plate heat exchanger. Plate heat exchanger applications is enormous in industries such as food industries, power plants, chemical industries etc., due to its higher heat transfer co-efficient compared with other heat exchangers. The study includes the different types of plate heat exchangers. The constructions and the material used for different components of PHE are to be discussed. The LMTD method of calculation of plate heat exchanger heat transfer is also to be explained. A detailed study on heat transfer in plate heat exchanger for different flow arrangements of hot and cold fluid is to be discussed.*

Key Words: *PHE, LMTD, Effectiveness, Heat transfer co-efficient*

1.INTRODUCTION

Heat exchanger is a thermal equipment that transfers heat from one fluid to another when there is temperature difference between the two fluids flowing in it. The flow of fluids may be parallel or counter or cross flow. In 1920s Dr. Richard Seligman invented the plate heat exchanger. Due to the higher heat transfer co-efficient, plate heat exchanger type finds enormous applications in industries concerned with heating, cooling, heat recovery, condensation and evaporation. Plate heat exchanger are now common and very small brazed versions are used in the hot water sections of so many numbers of combination boilers. The high heat transfer efficiency for a small physical size of PHE finds increased the domestic hot water flow rate of combination boilers.

2.COMPONENTS OF PHE

The plate heat exchanger essentially consists of the following parts.

1. Plates
2. Carrying beam
3. Fixed Plate
4. Support column
5. Pressure Plate
6. Guiding Bar
7. Tightening Unit
8. PHE Plates and gasket

2.1. PLATES

A single-plate heat exchanger can have a maximum number of 700 plates. At each corner of the plate there is a hole. There are four holes in a single plate. When the plate pack compresses, the holes in the plate's corners create a constant manifold that allows fluid to flow through the plate pack and exit the device. The space between the thin plates of the heat exchanger makes a tight channel that alternately traverses by cold and hot fluids and offers very small resistance to heat transfer.

2.2. CARRYING BEAM

The upper part installed between the supporting column and the fixed plate on which the pressure plates and the exchanger plates are connected.

2.3. FIXED PLATE

The fixed plate is a basic part of the plate heat exchanger. It is a fixed frame plate. Generally, the heat exchanger pipes connected with the fixed plates.

2.4. SUPPORT COLUMN

This is a non-moveable part of the PHE. The guiding bar and carrying beam are connected to this part.

2.5. PRESSURE PLATE

The PHE has a movable pressure plate frame connected to the exchanger carrying beam. This frame compresses the plates of the heat exchanger.

2.6. GUIDING BAR

The guiding bar guides the pressure plate and heat exchanger plates downward.

2.7. TIGHTENING UNIT

It is used to compress the frame components of the plate pack. It has tightening washers, nuts and bolts

2.8. PHE PLATES AND GASKETS

The packing of plates is installed between the pressure plate and the fixed frame plate. This plate pack compresses by tightening the screws fastened between the two plates. The gaskets cover the plates to regulate the flow.

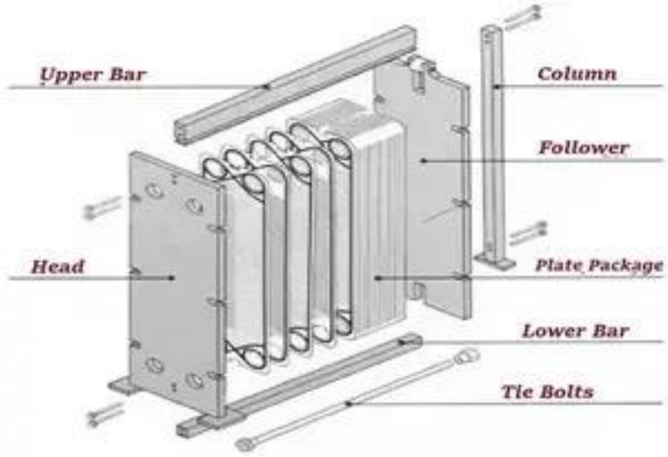

Fig.1 Exploded view of PHE

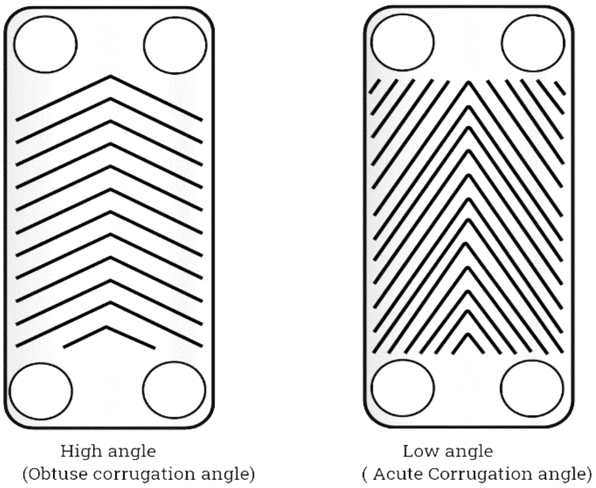

Fig.2 A typical plate of a PHE

3.COMPONENT MATERIALS OF PHE

Plates are made of stainless steel or titanium or titanium-palladium or nickel. Frames are made of carbon steel with a synthetic resin finish or stainless steel. The various gasket materials are NBR, EPDM, FKM and HNBR.

4.TYPES OF PHE

There are five types of plate heat exchanger

1. GASKETED PHE
2. BRAZED PHE
3. WELDED PHE
4. SEMI-WELDED PHE
5. PLATE AND FRAME PHE

High quality gaskets are used for the construction of gasketed plate heat exchanger. The gasketed plate heat exchanger mainly consists of pack of thin rectangular plates sealed around the edges by gaskets and held together in a frame. This gasket seals the plate and stop leakage. The plates can be removed easily from the heat exchanger for replacement, expansion or cleaning purpose which greatly reduces the maintenance cost. The brazed plate heat exchanger are economically superior then other types because of their compactness in design and better efficiency.

The brazed PHE is a gasket less brazed structure which enables tight sealing performance. The brazed PHE are compact, efficient and maintenance-free solution for heating, cooling, evaporation and condensation in large number of applications. The unique feature is the longest possible service life even under extremely high design pressure condition. Its major application in process chillers, industrial refrigeration, district heating, energy storage systems etc.,

In welded plate heat exchanger, the plates are welded together. The operation of welder PHE is similar to gasketed heat exchanger.

Semi-welded heat exchanger is a combination of gasketed plates and welded plate heat exchanger. It has a brace of two plates welded together and also a gasket with another brace of plates so that one fluid can flux through the welded part and the other can flux through the gasketed part.

The heat exchanger in which the plates produce a frame is called as plate and frame heat exchanger. It has corrugated plates in the frame. Due to this construction the plate and frame heat exchanger produces high wall shear stress and turbulence that leads to high heat transfer rate. This heat exchanger has gaskets. In addition to the sealing effect the gasket also guides the flux and it is installed along the grew on the plate edge.

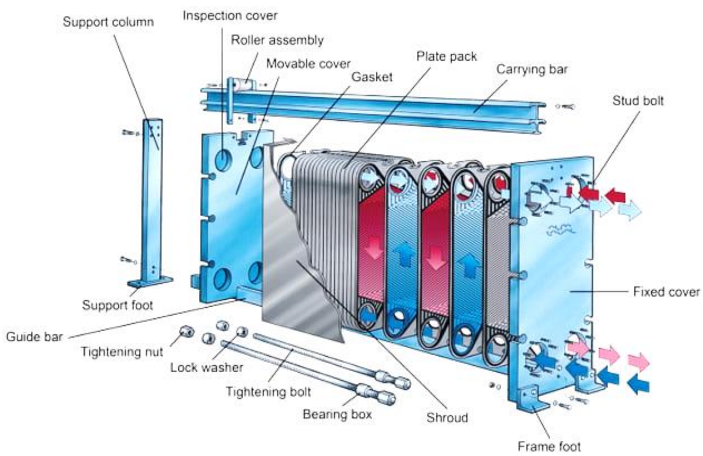

Fig.3 gasketed PHE

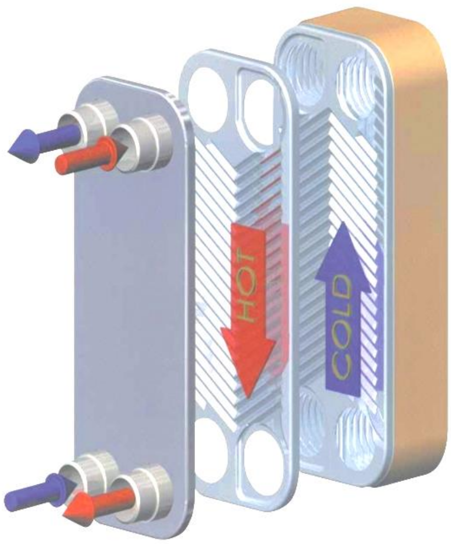

Fig.4 Brazed PHE

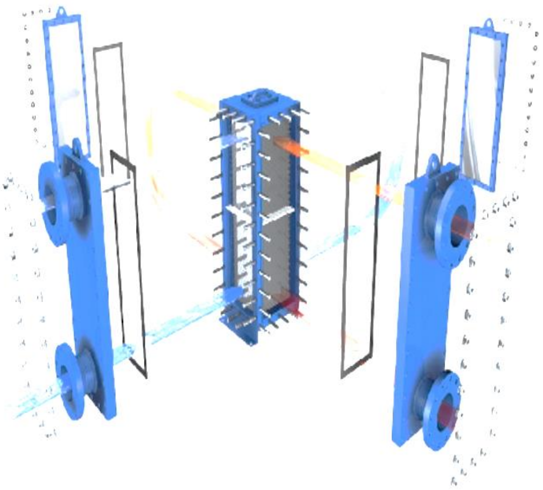

Fig.5 Welded PHE

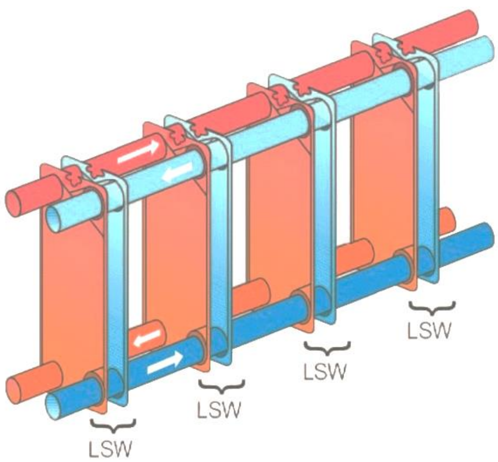

Fig.6 Semi-welded PHE

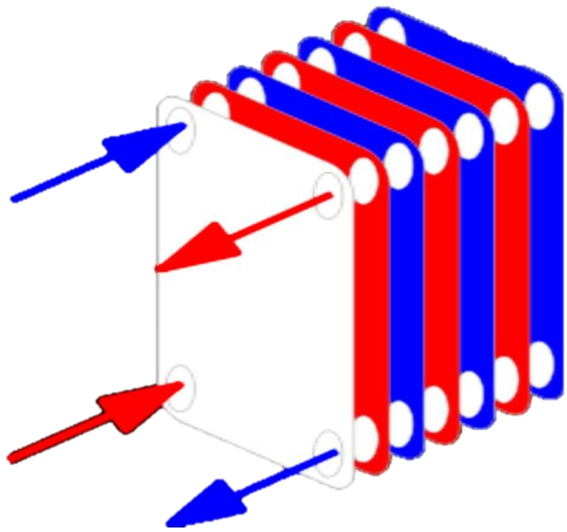

Fig.7 Plate and frame PHE

5.WORKING OF PHE

A plate heat exchanger is a type of heat exchanger that has number of metal plates to transport heat between a higher temperature fluid and a lower temperature fluid. The temperature difference between two fluids flowing through the PHE is the main criteria for heat transfer to takes place. In PHE, each plate has a confined hollow tubular shell. The plates are also arranged that thin rectangular channels are developed to exchange heat through half pieces. The operating fluid moves between these twisted and narrow channels. The cold and hot fluid flows through alternate plates such that heat transfer takes place from hot fluid to cold fluid. Even though there are different types of flow arrangements in heat exchangers such as parallel flow, counter flow and cross flow most of the plate heat exchangers provided with counter flow arrangement to enhance more heat transfer rate compared with other two types of flow arrangement. The hot fluid enters at the hole provided at the top of the plate heat exchanger and travels in the top tube and it comes down through the rectangular channels provided in the plates alternatively and reaches bottom pipe and exits out through another hole provided in the bottom of the plate heat exchanger. The cold fluid enters at the hole provided at the bottom of the plate heat exchanger and travels in the bottom tube and it goes up through the rectangular channels provided in the plates alternatively and reaches top pipe and exits out through another hole provided in the top of the plate heat exchanger. The plates have a large surface area and provide an excellent heat transfer rate normally the hot fluid travels from top to bottom and the cold fluid travels from bottom to top of the heat exchanger. Due to the temperature difference between the two fluids, large surface area and the heat transfer takes place and the quantity of heat transfer is equal to Q= U x A_s x LMTD

Where, Q is heat transfer rate

U is Overall heat transfer heat transfer

A_s is Total surface area of the plate

LMTD is Logarithmic Mean Temperature Difference

6.HEAT TRANSFER MECHANISM IN PHE

During the fluid flows in the adjacent plates where the hot and cold fluids are travelling the heat transfer is accomplished within the two fluids due to its temperature difference. Due to the corrugated configuration of the plates more turbulence will be created. The mode of heat transfer is by convection followed by conduction to the plate material to another fluid. The heat transfer coefficient of the fluid flowing in the plate heat exchanger can be calculated using the formula

$$U = 1/\{(1/h_{hot}) + (1/h_{cold}) + (t_p/k_p) + (R_{f\ hot} + R_{f\ cold})\}$$

Where

hhot = hot fluid's convective heat transfer coefficient

hcold = cold fluid's convective heat transfer coefficient

tp = plate thickness

kp = plate conductivity

Rf, hot = hot fluid fouling factor

Rf, cold = cold fluid fouling factor

The LMTD can be calculated using the formula

$$\Delta T_{lm} = (\theta_i - \theta_o) / \ln(\theta_i / \theta_o)$$

Where

θ_i = Temperature difference between hot fluid inlet and cold fluid outlet

θ_o = Temperature difference hot fluid outlet and cold fluid inlet

The heat transfer can be calculated using the formula

$$Q = U \times A \times F \times \Delta T_{lm}$$

Where

A = Area of the plate surface

F = Correction factor

APPLICATIN OF PHE

The plate heat exchangers are used in the following applications

- Heat pump isolation
- Mash coolers
- Glycol coolers
- Cooling tower isolation
- Oil refinery plants
- Batch heating & cooling
- Free cooling
- Heat recovery interchangers
- Process heating & cooling
- Water heaters
- Waste heat recovery
- Beverage processing
- District cooling
- Co-generation
- HVAC
- Milk dairy plants

7.ADVANTAGES AND LIMITATIONS OF PHE

The plate heat exchanger has the following advantages and limitations

7.1ADVANTAGES

- Compactness
- Flexibility
- Very high heat transfer coefficients on both sides of the exchanger
- Close approach temperatures and fully counter-current flow
- Ease of maintenance. Heat transfer area can be added or subtracted without complete dismantling
the equipment
- Ease of inspection on both sides
- Ease of cleaning
- Savings in required flow area
- Low hold-up volume
- No local overheating and possibility of stagnant
- Fouling tendency is less

7.2LIMITATIONS

- Low Pressure upto 300 psi
- Low temperature upto 300 F
- Limited capacity
- Limited plate size 0.02 sq.m to 1.5 sq.m
- Large difference between flow rates can't be handled
- High pressure drops
- Potential for leakage

8. CONCLUSIONS

This article concluded with

- The PHE require less space due to its compactness.
- When compared with other types of heat exchanger PHE have numerous advantages.
- The counter flow of both hot and cold fluids offers more heat transfer than parallel and cross flow arrangements.
- Since the heat transfer depends on the turbulence created during flow of both hot and cold fluid the configuration of channel of a PHE plays a vital role in heat transfer.
- There are different types of PHEs that are suitable for different applications and each having its own advantages and limitations.
- The awareness of specifications of PHE must be clearly known while selecting this heat exchanger for a particular application.
- The life of PHE depends mainly on the proper periodic maintenance of the heat exchanger.
- Research areas were identified, by changing the channel configuration the PHEs heat transfer can be enhanced.

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BIOGRAPHIES

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