


KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	 Solutions, Standards and Software	Page : 1 of 59
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		Rev 01 – May 2015
KLM Technology Group #03-12 Block Aronia, Jalan Sri Perkasa 2 Taman Tampoi Utama 81200 Johor Bahru. Malaysia	Kolmetz Handbook Of Process Equipment Design Plate Heat Exchanger Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Co Authors Rev 01 – Mela Widiawati
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INTRODUCTION

Scope

This design guideline covers the selection and sizing method for plate heat exchangers which are commonly used in typical industrial processes. It helps engineers, operations and maintenance personnel to understand the basic design of different types of heat exchangers, and increases their knowledge in selection and sizing. A heat exchanger is a device for heat transfer from one medium to another. The personnel needs to understand the terminology of the heat transfer equipment in order to properly design, specify, evaluate bids, and check drawings for this equipment.

Heat transfer is one of the most important, as well as the most applied process, in chemical and petrochemical plants. Economics of plant operation often are controlled by the effectiveness of the use and recovery of heat or cold (refrigeration). The service functions of steam, power, refrigeration supply, and the like are dictated by how these service or utilities are used within the process to produce an efficient conversion and recovery of heat.

The basic plate heat exchanger consist of a series of thin, corrugated plates that are gasketed or welded together (or any combination of these) depending on the liquids passing through and on whether it is practical to be able to subsequently separates the plates, for whatever reason. The plates are then compressed together in a rigid frame to create an arrangement of parallel flow channels. One fluid travels in the odd numbered channels, the other in the even channels. All plate heat exchangers look similar from the outside. The differences lie inside, in the details of plate design and the sealing technologies used.

The basic concept of a heat exchanger is based on the promise that the loss of heat on the high temperature side is exactly the same as the heat gained in the low temperature side after the heat and mass flows through the heat exchanger. Heat exchanger simply exchanges the heat between those two sides; as a result, it is decreasing the temperature of higher temperature side and increasing the temperature of lower temperature side. But designing heat exchanger might be a challenge; it needs iteration for manual calculation. Hence, a guideline to properly select and sizing is needed.

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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. 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. Also, plate heat exchangers can grow with increasing demand for heat transfer by simply mounting more plates. They are well suited for liquid to liquid heat exchange applications, provided that the hot and cold fluid streams are at about the same pressure.

General Consideration

Plate type heat exchangers (PHE) consist of a number of parallel flow channels, formed by adjacent metal plates that are either welded or separated by gasket material around the perimeter of each plate. The plates can be formed from a variety of metals, but typically are made of stainless steel. The manufacturing process presses the plates into a corrugated shape that is different for each plate type and is proprietary to each manufacturer.

The corrugations (sometimes called ribs or chevrons) both increase the mixing of the flow stream and add strength and support to the plate. The flow channel width between adjacent plates ranges from 0.05 to 0.25 in. (1.27 to 6.35 mm) and the ribs of adjacent plates have contact point with each other at regular intervals. PHEs can be designed for true counter flow because the hot and cold flow streams pass through adjacent channels over the entire length of the exchanger.

This design allows closer approach temperatures than are possible with conventional shell and tube exchangers. The assembly of PHE facilities mechanical cleaning and allows the additional or removal of plates to increase or decrease the heat transfer surface area of the exchanger.

The main advantages of PHE are their compact size and high heat transfer effectiveness that allow reduced number of units, smaller spaces and, for offshore platforms, and reduced weight. They are especially attractive in cost when the equivalent shell and tube exchanger would require in alloy shell or tubes. The minimum recommended construction material for all types of PHEs and welded PHEs is type 304 stainless steel.

PHEs are presently operating in such liquid-liquid services as heat recovery loops, chemical process coolers and heaters, oil platform applications, and seawater cooling. Partially welded PHEs make good applications in product coolers using cooling water.

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The plate and frame heat exchanger is not specifically considered, because steady state design follows standard contraflow or parallel flow procedures. It is only necessary to source sets of heat transfer and flow friction correlations before proceeding.

Plate and frame designs can be similar in flow arrangement to plate fin designs, but there is restriction on the piping manifold geometry. Optimization may proceed in a similar way as for compact plate fin heat exchangers, but is likely to be less comprehensive until universal correlations for the best plate panel corrugations become available.

Significant features are composed of metal formed thin plates separated by gaskets. Compact, easy to clean. Application best suited are viscous fluids, corrosive fluids, slurries, high heat transfer. Limitation are not well suited for boiling or condensing; limit 35-500°F by gaskets. Used for liquid-liquid only; not gas-gas. Approximate relative cost in carbon steel construction 0.8 – 1.5.

Inlet and return headering for plate and frame designs, and the same arrangement for plate fin designs, may add a phase shift to the outlet transient response following and inlet disturbance.

Plate type exchangers consist of a number of parallel flow channels, formed by adjacent metal plates that are either welded or separated by gasket material around the perimeter of each plate. The plates can be formed from a variety of metals, but typically are made of stainless steel. The manufacturing process presses the plates into a corrugated shape that is different for each plate type and is proprietary to each manufacturer. The corrugation (sometimes called ribs or chevrons) both increase the mixing of the flow stream and add strength and support to the plate.

The Frame

The plate heat exchanger, as shown in Figure 1, consists of a stationary head and end support connected by a top carrying bar and bottom guide rail. These form a rigid frame, which supports the plates and moveable follower. In most units, plates are securely compressed between the head and follower by means of tie bars on either side of the exchanger.

In a few models, central tightening spindles working against a reinforced end support are used for compression. When PHEs are opened, the follower moves easily along the top bar with the aid of a bearing supported roller, to allow full access to each individual plate. With the expectation of some sanitary models, which are clad with stainless steel, PHE frames are fabricated of carbon steel and finished in chemical resistant epoxy paint. Frame ports accept bushings of stainless steel or alternative metals, which with various

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types of flanged or sanitary connections, from the inlet and outlet nozzles. By using intermediate connector plates as shown in Figure 2, units can be divided into separate sections to accommodate multiple duties within a single frame.

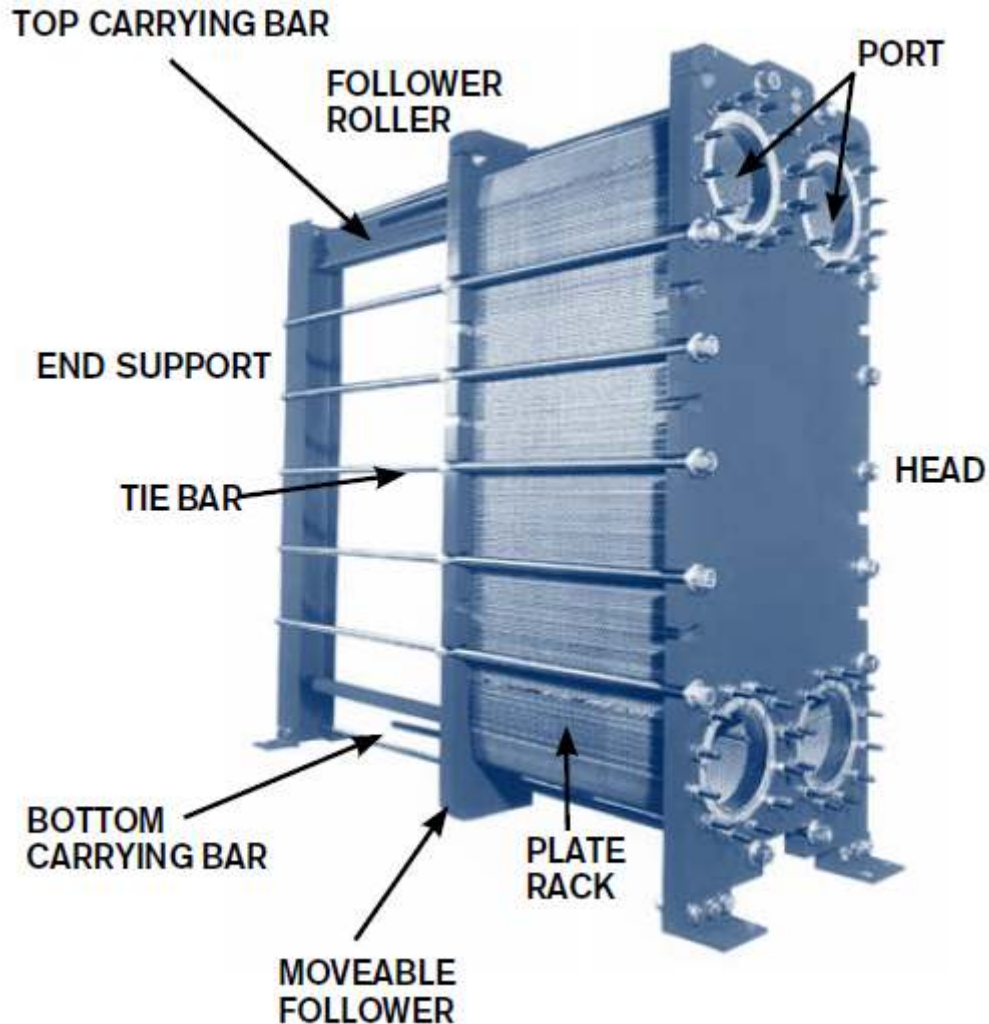


Figure 1. Plate Heat Exchanger

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The Plates

The closely spaced metal heat transfer plates have through or corrugations, which induced turbulence to the liquids flowing as a thin stream between the plates. The plates have corner ports, which in the complete plate pack form a manifold for even fluid distribution to the individual plate passage.

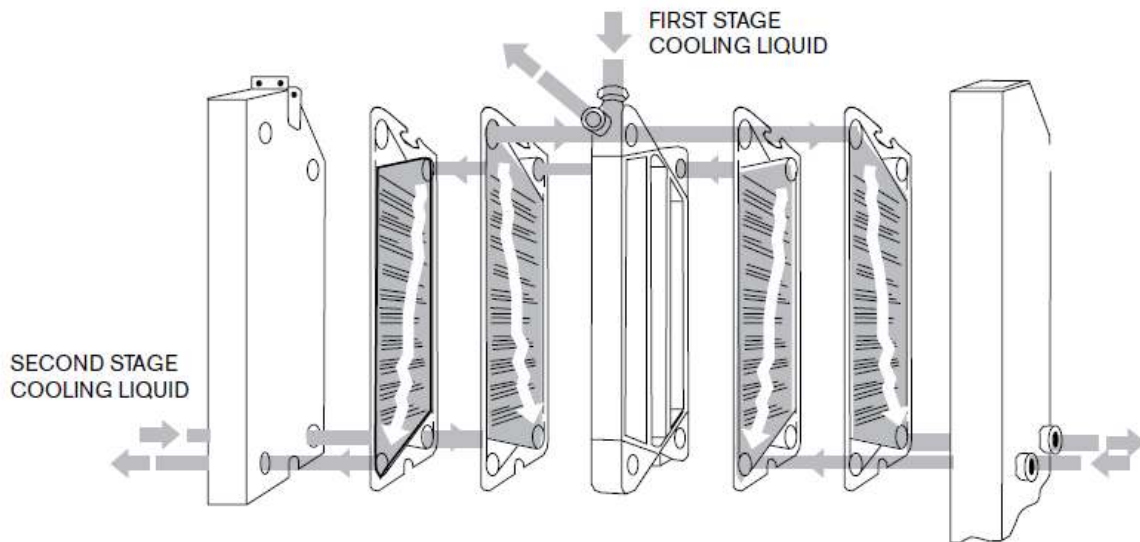


Figure 2. Two Section PHE with Connector Plate

The Gaskets

The seal between the plates is established by a peripheral gasket which also separates the thru port and flow areas with a double barrier. The interspace is vented to atmosphere to prevent cross-contamination in the event of leakage.

Gasketed plate and frame exchanger, in this type the plates are sandwiched together by an outside frame with tie rods that provide uniform sealing of the plate gaskets. The plates are 0.02 to 0.04 in (0.6 to 1 mm) thick. The size of the individual plates ranges from a minimum of approximately 0.5 ft x 1.5 ft (0.15 m x 0.46 m) to as large as 4 ft x 10 ft (1.220 m x 3.05 m). Plate and frame exchangers have heat transfer surface areas ranging from 5 to 13,000 ft² (0.5 to 1210 m²).

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The maximum temperature and pressure limits on a gasketed PHE are approximately 450°F and 350 psia [230°C and 2400 kPa(a)].

Profile and Structure

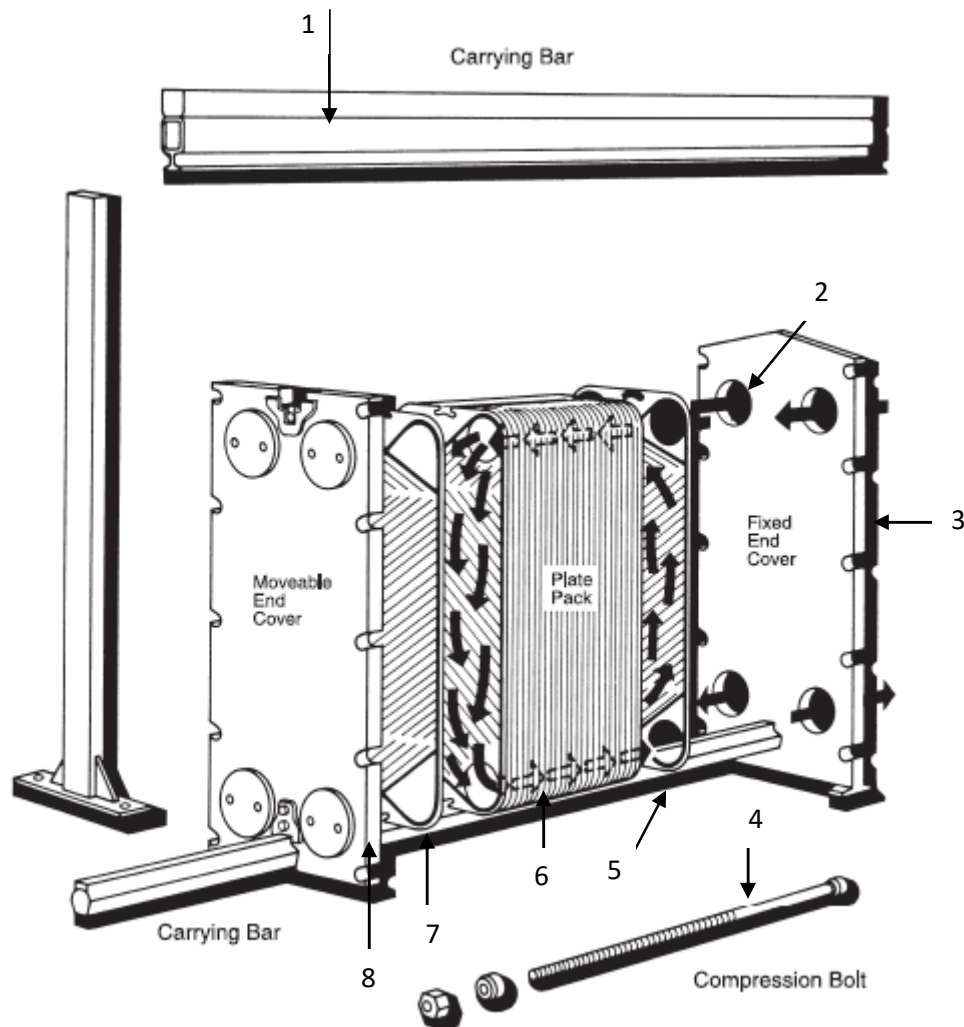
A typical plate and frame heat exchanger (sometimes referred to as a gasketed plate heat exchanger) is shown in an exploded view in **Figure 3**. The PHE consist of an arrangement of gasketed pressed metal plates (heat transfer surface), aligned on two carrying bars, secured between two cover by compression bolts. Inlet and outlet ports for both hot and cold fluids are stamped into the corners of each plate. The ports are lined up to form distribution headers through the plate pack.

All four fluid connection are usually located in the fixed and cover. This permits opening the exchanger without disconnecting any piping. Plates can be added and removes in the field should service requirements change. The plates are pressed into one of a number of available patterns and may be constructed of any material which can be cold formed to the desired pattern. The welding characteristics of the plate material are not prime importance since very little or no welding is involved in plate construction.

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1. Carrying bar
2. Connections
3. Fixed frame
4. Tightening bolt
5. End plate with 4 holes
6. Channel plates with 4 holes
7. End plate with all 4 ports blind
8. Pressure plate

Figure 3. Plate and Frame Heat Exchanger

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Gasket grooves are pressed into the plates as they are formed. The gaskets are generally made of elastomers such as natural rubber, nitrile, butyl, neoprene, etc. the gasket material chosen depends on the temperature, pressure, and chemical characteristics of the fluid to which it will be exposed. The gasket cross section varies with different plate designs and sizes. Rectangular, trapezoidal, or oval cross section are the most common. The width is generally 5-15 mm, depending on spacing.

The height of the gasket before it compressed is 15 to 50% higher than the spacing, depending on material, cross section of gasket, gasket track, and gasket hardness. When the plate stack is compressed, the exposed surface of the gasket is very small. The gasket are generally arranged in such a way that the through pass portal is sealed independently of the boundary gasket. Leaks from one fluid to the other cannot take place unless a plate develops a hole. Any leakage from the gaskets is to the outside of the exchanger where it is easily detected.

Since the plate are generally designed to form channels giving highly turbulent flow, the PHE produces higher heat transfer coefficients for liquid flow than most other types. The high heat transfer coefficients are developed through the efficient use pressure drop.

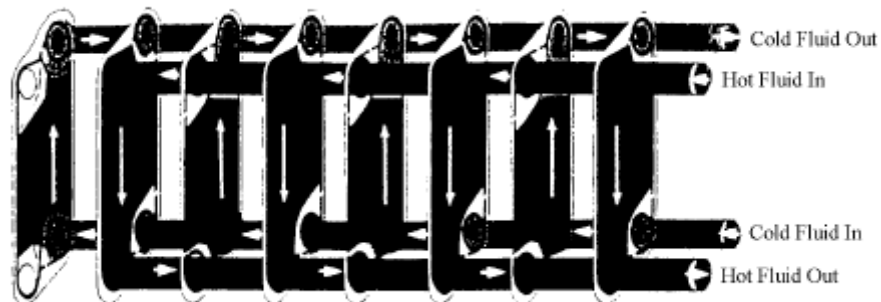


Figure 4. The Process and Service Fluid Flow Counter Currently Between The Plates

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By means of gaskets, the two fluids can be arranged in countercurrent flow, and flow volumes can be divided into a number of parallel streams. Gaskets seal the plates at their outer edges and around the ports, which are designed so that the inlet port can be at the top or bottom. Gaskets provide a double seal between the liquid streams.

The interspace between the seals is vented to atmosphere, giving a visual indication of leakage and an escape path for the fluid.

Some of the possible flow patterns in plate exchangers are illustrated in **Figure 5.** : (a) series flow, in which a continuous stream changes direction after each vertical path; (b) parallel flow, in which the stream divides and then re-converges; (c) a loop system, in which both streams flow in parallel; (d) and (e) other complex flow patterns.

The number of parallel passages is mainly determined by the allowable pressure drop. Of course, the larger the number of parallel passages, the lower the pressure drop. The number of series passages is determined by plate efficiency and heat exchange requirements. If a liquid is cooled into viscous flow, the number of passages can be reduced to increase velocity.

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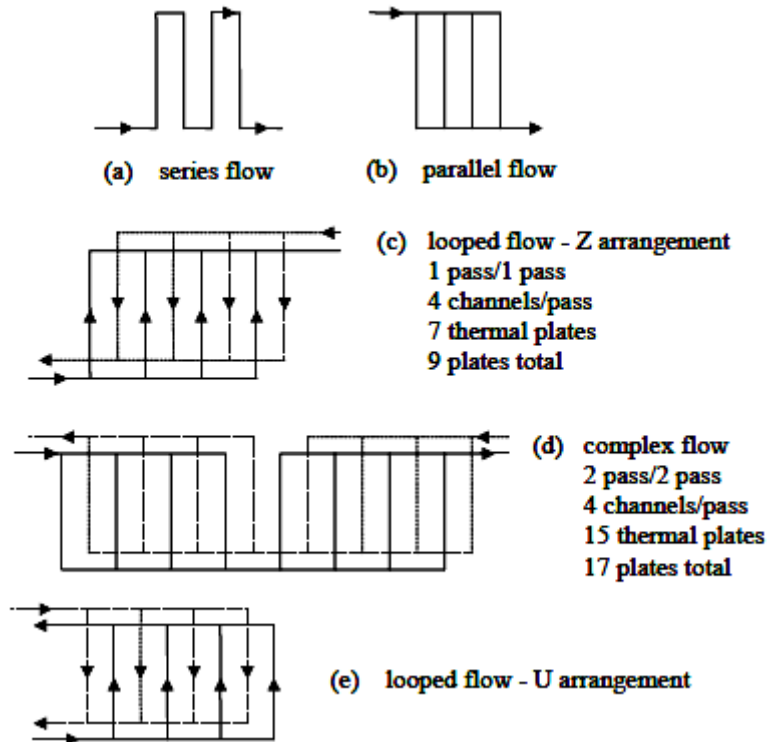


Figure 5. Double Gasketed Prevent Fluids Mixing

The advantages and disadvantages of gasketed plate heat exchangers, compared with conventional shell and tube exchangers are listed below :

Advantages

1. It can be easily be disassembled for cleaning.
2. The plates can be rearranged, added to, or removed from the plate rack for difference service conditions.
3. The fluid residence time is short (low fluid volume to surface area ratio).
4. No hot or cold spots exist which could damage temperature sensitive fluids.
5. Fluid leakage between streams cannot occur unless plate material fails.
6. Fluid package due to a defective or damaged gasket is external and easily detected.
7. Low fouling is encountered due to the high turbulence created by the plates.
8. A very small plot area is required relative to a shell and tube type heat exchanger for the same service.

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9. The maintenance service area required is within the frame size of the exchanger.

Table 1. Typical Fouling Factors for PHEs

Fluid	Fouling Factor (m ² .h. °C/Kcal)
Water	
Determinalized or distilled	0.000002
Municipal supply (soft)	0.000004
Municipal supply (hard)	0.00001
Cooling tower (treated)	0.000008
Sea (coastal) or estuary	0.00001
Sea (ocean)	0.000006
River, canal, borehole, etc.	0.00001
Engine jacket	0.000012
Oils, lubricant	0.000004 to 0.00001
Solvents, organic	0.000002 to 0.000006
Steam	0.000002
Process fluids, general	0.000002 to 0.000012

Disadvantages

1. Care must be taken by maintenance personnel to prevent damage to the gaskets during disassembly, cleaning, and reassembly.
2. A relatively low upper design temperature limitation exists.
3. A relatively low upper design pressure limitation exists.
4. Gaskets materials are not compatible with all fluids.

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Plate Heat Exchanger Design

The approximate method given below can be used to size an exchanger for comparison with a shell and tube exchanger, and to check performance of an existing exchanger for new duties.

Procedure

The design procedure is similar to that for shell and tube exchangers.

1. Calculate duty, the rate of heat transfer required.
2. If the specification is incomplete, determine the unknown fluid temperature or fluid flow rate from a heat balance.
3. Calculate the log mean temperature difference, ΔT_{lm} .
4. Determine the log mean temperature correction factor, F_t .
5. Calculate the corrected mean temperature difference $\Delta T_m = F_t \times \Delta T_{lm}$.
6. Estimate the overall heat transfer coefficient.
7. Calculate the surface area required.
8. Determined the number of plates required = total surface area/area of one plate.
9. Decide the flow arrangement and number of passes.
10. Calculate the film heat transfer coefficients for each stream.
11. Calculate the overall coefficient, allowing for fouling factors.
12. Compared the calculated with the assumed overall coefficient. If satisfactory, say -10% to +10% error, proceed. If unsatisfactory, return to step 8 and increase or decrease the number of plates.
13. Check the pressure drop for each stream.

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Table 2. Characteristics of Some Gaskets Materials

Gasket material	Temperature (°C)	Service	Remarks
Styrene-butadiene rubber	To 85	General-purpose for aqueous systems	
Acrylonitrile butadiene rubber	To 140	Excellent resistance to aqueous systems fats and aliphatic hydrocarbons	
Ethylene-propylene co-polymer	To 150	High-temperature resistance for a wide range of chemicals	
Resin-cured butyl rubber	To 150	Excellent resistance to wide range of chemical, including acids, alkalis, ketones and amines	Poor, resistance to fats
Silicon rubber	Low	Limited to sodium hypochlorite and low temperatures generally	
Fluoro-elastomer	Above 150	Excellent for oils	Use limited by high cost
Compressed asbestos fiber	To 250	Resistant to organic chemical mixture	Plates and frames must be stronger because of poor elasticity
Klingerlte	To 250		

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Plate Heat Exchanger Construction

A plate heat exchanger consist of a number of heat transfer plates which are held in place between a fixed plate and a loose pressure plate to form a complete unit. Each heat transfer plate has a gasket arrangement which provides two separate channel systems.

The arrangement of the gaskets (field and ring gaskets) results in through flow in single channels, so that the primary and secondary media are in counter-current flow. The media cannot be mixed because of the gasket design.

The plates are corrugated, which creates turbulence in the fluids as they flow through the unit. This turbulence, in association with the ratio of the volume of the media to the size of heat exchanger, gives an effective heat transfer coefficient.

Plate heat exchanger components

The components consist of a fixed end plate, connections and a loose pressure plate, with carrier bars mounted between them. The plates are hung from the top carrier bar. The carriers bar also serve to position the heat transfer plates. The single plates are pulled together to form a plate pack by means of tightening bolts.

Gasketed plate heat exchangers are available in standard sizes or can be individually prepared.

Gaskets

Material available

Nitrile rubber	General purpose, oil resistant
EPDM	General purpose, elevated temperatures
Heat Seal	For high temperatures, specially heating by steam

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Brazed plate heat exchangers

A brazed plate heat exchanger is small, light and compact. It does not need gaskets. Instead, it is brazed together using copper to give a strong, compact construction.

This heat exchanger is especially suitable for pressure up to 50 bar and temperatures from -196°C to +550°C.

Working Principle

Channels are formed between the plates and the corner ports are arranged so that two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.

Evaluating plate heat exchangers

All plate heat exchangers look similar on the outside. The difference lies on the inside, in the details of the plate design and the sealing technologies used. Hence, when evaluating a plate heat exchanger, it is very important not only to explore the details of the product being supplied, but also to analyze the level of research and development carried out by the manufacturer and the post commissioning service and spare parts availability.

An important aspect to take into account when evaluating a heat exchanger are the forms of corrugation within the heat exchanger. There are two types: interlocking and chevron corrugations. In general, greater heat transfer enhancement is produced from chevrons for a given increase in pressure drop and are more commonly used than interlocking corrugation.

Flow distribution and heat transfer equation

Design calculations of a plate heat exchanger include flow distribution and pressure drop and heat transfer. The former is an issue of flow distribution in manifolds. A layout configuration of plate heat exchanger can be usually simplified into a manifold system with two manifold headers for dividing and combining fluids, which can be categorized into U-type and Z-type arrangement according to flow direction in the headers, as shown in manifold arrangement.

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DEFINITION

Brazing – is a metal joining process whereby a filler metal is heated above melting point and distribute between two or more close fitting parts by capillary action. The filler metal is brought slightly above its melting temperature while protected by a suitable atmosphere, usually a flux. It then flows over the base metal (known as wetting) and is then cooled to join the workpieces together. It is similar to soldering, except the temperatures used to melt the filler metal are higher for brazing.

Condensing – is the change of the physical state of matter from gas phase into liquid phase, and is the reverse of evaporation.

Evaporation – is a type of vaporization of a liquid that occurs from the surface of a liquid into a gaseous phase that is not saturated with the evaporating substance.

Fouling - The increased resistance to both heat transfer and fluid flow caused by deposits on a heat transfer surface. Fouling works as an insulating layer on the heat transfer surface, reducing heat transfer efficiency (reduced duty) or decreasing available flow area (reduced throughput). The increased resistance to heat transfer is represented by a quantity referred to as the fouling thermal resistance, which is added to the total thermal resistance. The values of fouling thermal resistance have generally been observed to increase with time. To account for the effect of fouling on pressure drop requires an estimate of the fouling layer thickness.

Furnace – is a device used for high temperature heating.

Gasket is a mechanical seal which fills the space between two or more mating surfaces, generally to prevent leakage from or into the joined objects while under compression.

Heater -A heater is any object that emits heat or causes another body to achieve a higher temperature. In a household or domestic setting, heaters are commonly used to generate heating

Pressure Drop – is defined as the difference in pressure between two points of a fluid carrying network. Pressure drop occurs when frictional forces, caused by resistance to flow, act on a fluid as it flows through the tube.

Superheater- is a device in a steam engine that heats the steam generated by the boiler again, increasing its thermal energy and decreasing the likelihood that it will condense

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inside the engine. Superheaters increase the efficiency of the steam engine, and were widely adopted. Steam which has been superheated is logically known as superheated steam; non-superheated steam is called saturated steam or wet steam. Superheaters were applied to steam locomotives in quantity from the early 20th century, to most steam vehicles, and to stationary steam engines including power stations.

Turbulence – is a flow regime characterized by chaotic property changes. This includes low momentum diffusion, high momentum convection, and rapid variation of pressure and flow velocity in space and time.

Welding – is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence.

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NOMENCLATURE

A	= area, (ft ²)
C _p	= specific heat, (Btu/lb.°F)
C _{max}	= maximum heat capacity (W/K)
C _{min}	= minimum heat capacity (W/K)
D	= diameter, (in)
F	= LMTD correction factor
f	= friction factor
G	= mass velocity, (lb/ft ² .s)
H	= height, (in)
H _c	= average heat transfer coefficient of cold fluid (W/m ² K)
H _h	= average heat transfer coefficient of hot fluid (W/m ² K)
h	= specific enthalpy (J/kg)
k	= thermal conductivity, (Btu/h.ft ² .°F)
L	= length, (in)
LMTD	= Log Mean Temperature Difference, °F
ṁ	= mass flowrate, (lb/h)
n	= number constant
N	= number of exchangers
N _p	= number of passes
Nu	= nusselt number
NTU	= number of heat transfer units
ΔP	= pressure drop, (lb/in ²)
P	= pressure, (lb/in ²)
Pr	= Prandtl number
p	= temperature efficiency
PHE	= plate and frame heat exchanger
Q	= heat transferred, (Btu/h)
R	= heat capacity rate ratio
Re	= Reynolds number
T	= temperature, (°F)
t	= temperature, (°F)
U	= overall heat transfer coefficient, (Btu/h.ft ² . °F)
W	= width, (in)
μ	= viscosity, (centipoise)
ρ	= density,

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