CHAPTER 3

CHARACTERISTICS OF PLATE HEAT EXCHANGERS

3.1 Construction of Plate Heat Exchanger

3.1.1. General Description

Plate heat exchangers are made up of pressed rectangular metal sheets that are corrugated to increase turbulence and improve heat transfer, as well as to give mechanical rigidity. The sheets are suspended vertically and clamped together in the frame from a top carrying bar and are aligned by a bottom bar. Two plates are shown in Fig. 3.1.

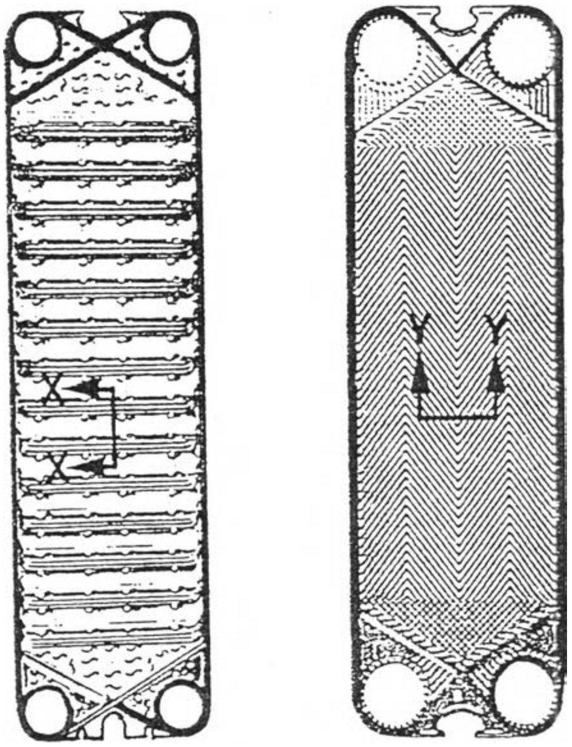


Figure 3.1 Typical plates showing intermating and chevron troughs

The plates are compressed against the stationary head of the frame by a movable follower, which slides along the top carrying bar. The follower and the head are clamped together by lateral bolts. They normally have flow ports in all four corners, which communicate with appropiate connection mounted on the frame as shown in Fig. 3.2.

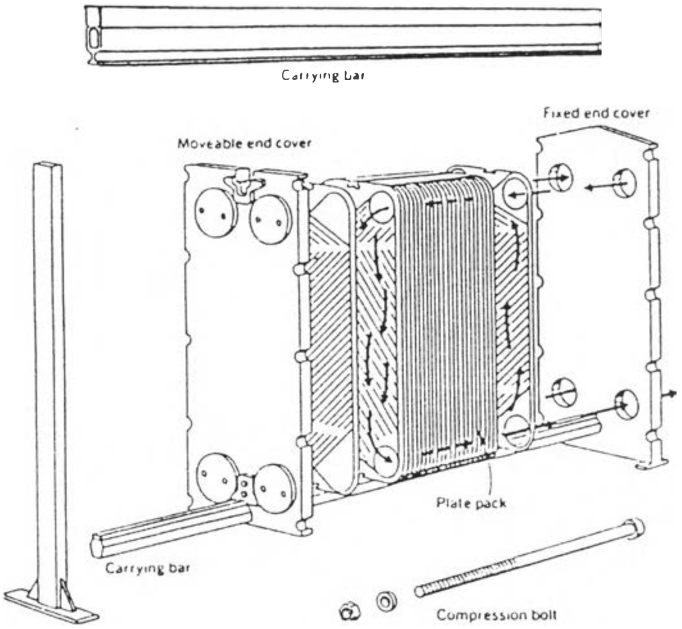


Figure 3.2 Typical Plate and Frame Heat Exchanger

The plates themselves are fitted with gaskets, which are shaped and located both to prevent external leakage and to direct the two liquids normally flowing countercurrently through the relatively narrow passage between alternate pairs of heat transfer plates [19].

3.1.2. Plate Construction Features

Plates generally embody the following features as shown in Fig. 3.3:

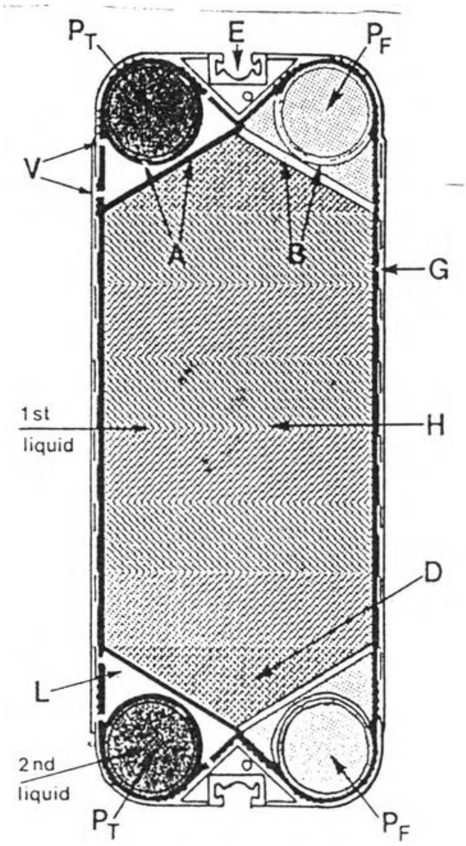


Figure 3.3 Diagram of heat exchanger plate

1. Two flow ports P_F, which provide the inlet and outlet for one process liquid to one interplate passage, and two transfer ports P_T, which introduce the other process liquid to the adjacent passage.

2. A rectangular corrugated area H, where the main heat transfer takes place.

3. End heat transfer zones D, approximately triangular in shape, which distribute the liquid from the ports P_F to the area H.

4. Port leakage areas L, between the transfer port P_T and the area H, which are vented to the atmosphere through grooves V, so

that direct leakage cannot take place between the two process liquids.

5. End guides E, which suspend and locate the plates in the frame.

6. A gasket G, normally elastomeric, which is cemented into a suitably shaped groove, and which seals both peripherally and around the transfer ports.

The ports may be arranged in two ways.

1. Vertical flow takes place between ports located on the same side of the plate (Fig. 3.4).

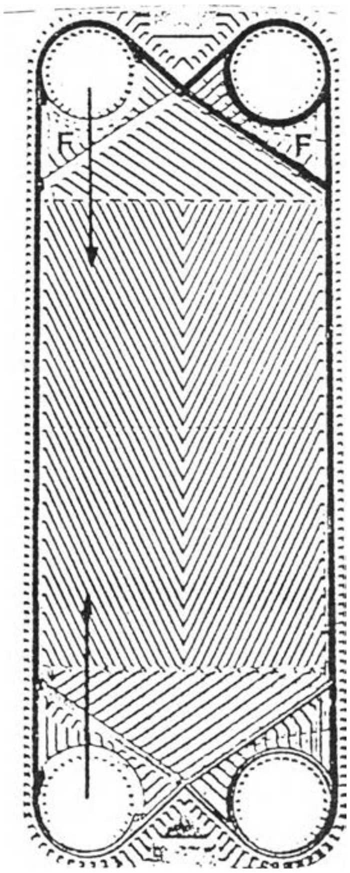


Figure 3.4 Vertical flow plate with chevron troughs

2. Diagonal flow takes place between opposite corners (Fig. 3.5).

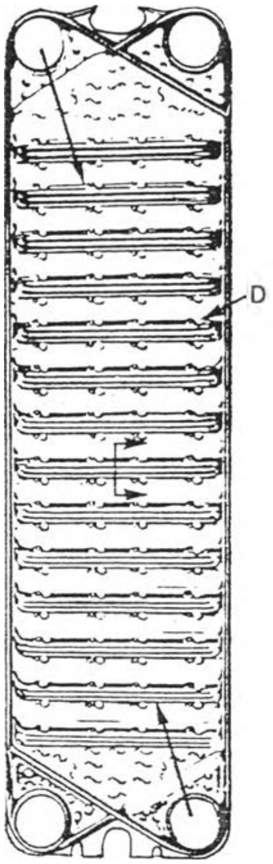


Figure 3.5 Diagonal flow plate with intermating troughs

The plates are mounted so that there is metal to metal contact at intervals throughout the plate area. The flow in each channel is divided and recombined and greatly agitated by the corrugations. Because of the support provided by plate to plate contacts, the plates can be made quite thin, often as fine as 0.6 mm. Nominal plate separation varies from 2 to 5 mm.

Common plate materials are SS304, SS316, Titanium, Astelloy, Incoloy 825, Inconel, Tantalum, Palladium.

3.1.3. Gasket

The polymers commonly used for gaskets are given in Table 3.1.

Table 3.1 Gasket material applications

Rubber type and max. temp.	Suitable for	Unsuitable for
Styrene-butadiene (SBR) 87°C	General-purpose rubber for a wide range of aqueous solutions, dilute acids, etc.	Strong acids and many organic liquids
Acrylonitrile-butadiene (nitrile) 137°C	Aqueous liquids, dilute acids, fats, and mineral oils	Strong oxidizing solutions, strong acids, polar organic solvents
Isobutylene-isoprene copolymer (butyl) 152°C	Organic liquids, such as aldehydes, ketones, inorganic acids, and organic acids	Fats, oils, aromatic hydrocarbons, and concentrated mineral acids
Ethylene-propylene rubber (EPDM) 152°C	Similar chemical resistance to butyl but frequently superior	Fats, oils, aromatic hydrocarbons, and concentrated mineral acids
Fluorocarbon (Viton) 177°C	A wide range of organic liquids; fats and oils (at high temperatures) and some mineral acids	Esters, ketones
Silicone	Specific chemical duties and low-temperature applications	Many organic liquids

Of these the two standard rubbers for plate heat exchangers are butyl rubber and nitrile rubber[16]. The gasket is the weakest component in the plate heat exchangers, so we must consider the rate and degree of attack on rubber gasket materials in contact with fluids which depend on a number of factors: fluid composition, gasket material, maximum operation temperature, operating pressure, compressive and other mechanical stresses as experienced by the elastomer during the operation of plate heat exchangers, and time of exposure.

3.1.4. Frame

A plate heat exchanger frame is based on the following units, as shown in Fig. 3.6 and Fig. 3.7.

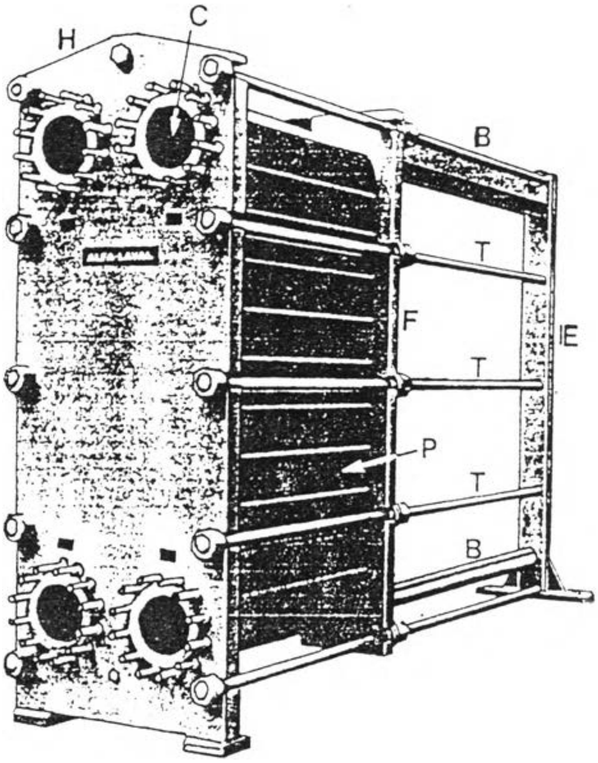


Figure 3.6 Industrial frame with tie bar tightening

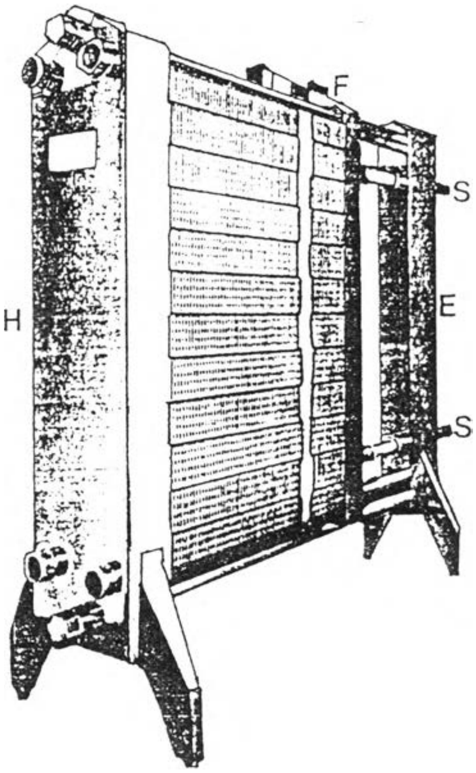


Figure 3.7 Stainless steel-clad hygienic frame with screw closure

1. Two vertical members, and end support E and head H, which carries four liquid connections or nozzles C.

2. Top and bottom bars BB, carried between these vertical

members, which support and guide the plate pack P.

3. A follower F, which compresses the plate against the head H, and which can also carry additional liquid connections.

4. A means of clamping the plates between the head and the follower.

This clamping is normally done in one of the following two ways:

1. The head and followers are compressed together by a number of tie bars T (Fig 3.6).

2. The compressive load is applied to the follower by one or two tightening screws S carried by the end support (Fig 3.7).

3.1.5. Channel Construction

In a plate heat exchanger, a channel is bounded by two adjacent, identical plate elements. The channel has a fixed thermal length, defined as [20]:

$$\theta = \frac{(T_i - T_o)}{\triangle T_{lm}} = \frac{2aU}{wC_p}$$

Total θ (a dimensionless number) is the sum of the θ values of channels connected in series, and is thus limited to multiples of the uniform θ value of a given channel. As a result, it is almost impossible to match the thermal length of a duty exactly, and a certain over-dimensioning is necessary.

It is possible to install more than one kind of channel in the same plate pack. With differing values of θ , the channels could be mixed to produce any desired values of θ between the highest and lowest channel values. Two basic kinds of plates are used: a high-θ plate with obtuse angle corrugations, which yields a comparatively large pressure drop, and a low-θ plate with acute angle corrugations, which yield less flow resistance and therefore a smaller pressure drop. These two plates can be combined into three types of channels-H, M, and L [20], as presented in Fig. 3.8.

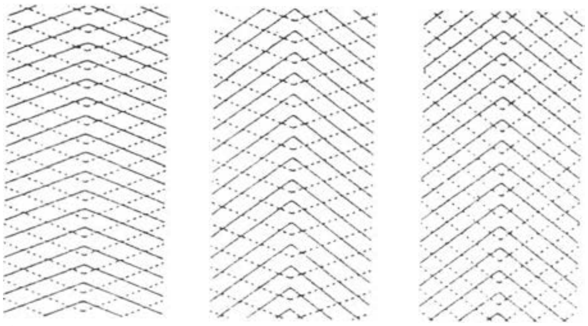

H channel (high + high)
M channel (high + low)
L channel (low + low)

Figure 3.8 Schematic representation of mixed plates

3.2 Operation

Not only plate heat exchangers are suitable for food or simple water/water applications but improvements in the thermal and mechanical design of plate heat exchangers, coupled with development in elastomer technology, now make them suitable for applications involving hazardous chemicals such as acids, alkalis, oils, solvents, hydrocarbons and aqueous solutions[21]. Such exchangers fit into any flowsheet where heat are to be exchanged between fluids under all conditions up to 2,000 kN/m^2 and 150 °C. Maintenance records show very low levels of fouling and corrosion. Process engineers often prefer plate exchangers to conventional heat exchangers solely because of its low initial costs[22], which may run 40% to 60% less than that of comparable shell and tube heat exchangers.

3.3 Plate Arrangements

3.3.1. Type of Pass Arrangements

In a plate exchanger, there exists a large number of feasible multipass flow arrangements. Essentially, these are combinations of parallel flow and counterflow arrangements with heat transfer taking place in adjacent channels. These arrangements can be obtained by blanking flow ports or by properly gasketing around the ports in the plates. There are three fundamental ways in which plates can be arranged: single pass, multipass with equal passes, and multipass with unequal passes [4].

3.3.1.1. Single Pass

Both liquids are in counterflow through parallel passages that make up a single pass.

3.3.1.2. Multipass With Equal Passes

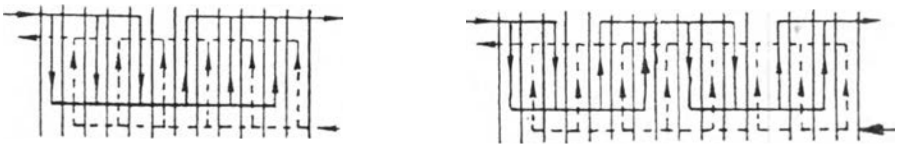
When NTU values greater than those given by a single plate are required, multipass arrangements can be used.

3.3.1.3. Multipass With Unequal Passes

When flow ratios are high or there is some other reason for minimizing the pressure drop on one side, unequal passes can be used with fewer passes on the low pressure drop side.

Some of the n-parallel plates multipass arrangements are shown in Fig. 3.9 [6].

(a) Single Pass (b) n Pass - n Pass



(c) 2 Pass - 1 Pass (d) 4 Pass - 1 Pass

(e) 4 Pass - 2 Pass (f) 3 Pass - 6 Pass

Figure 3.9 n-parallel plate single and multipass arrangements

The number of parallel passages is set by the exchanger output and the allowable pressure drop. Of course, the larger the number of parallel passages, the lower the pressure drop. The number of serial passages is determined by plate efficiency and heat exchange requirements.

3.3.2. End Effects

The LMTD correction factor F assumes that the size of the passes is infinite. For small plates, however, certain additional factors become important.

3.3.2.1. End Passages

In all plate arrangements, every passage transfers heat in both directions except the end passages, which transfer heat in one direction only.

3.3.2.2. Equal Number of Passes

From Fig. 3.9(b) it is seen that although the flows are basically countercurrent, the plate that separates passages at the end of each pass is subject to parallel flow.

3.3.2.3. Unequal Passes

The two pass/one pass system in Fig 3.9(c) has five parallel-flow and six counterflow plates. This inequality, which applies to all pass arrangements, must be taken into account.

The factors can be denoted as end effects, because they result from passages at the end of each pass. Their magnitude increases with the following parameters.

1. Increase in plate NTU.
2. Decrease in size of pass.
3. Increase in number of passes.

The end effect is not serious when the number of thermal plates is about 20 or more.