Heat Exchanger Fundamentals

An Online Continuing Education Course for Engineers

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TYPES OF HEAT EXCHANGERS

Introduction

A heat exchanger is a component that allows the transfer of heat from one fluid (liquid or gas) to another fluid. Reasons for heat transfer include the following:

1. To heat a cooler fluid by means of a hotter fluid
2. To reduce the temperature of a hot fluid by means of a cooler fluid
3. To boil a liquid by means of a hotter fluid
4. To condense a gaseous fluid by means of a cooler fluid
5. To boil a liquid while condensing a hotter gaseous fluid

Regardless of the function the heat exchanger fulfills, in order to transfer heat the fluids involved must be at different temperatures and they must come into thermal contact. Heat can flow only from the hotter to the cooler fluid.

In a heat exchanger there is no direct contact between the two fluids. The heat is transferred from the hot fluid to the metal isolating the two fluids and then to the cooler fluid.

Types of Heat Exchanger Construction

Although heat exchangers come in every shape and size imaginable, the construction of most heat exchangers fall into one of two categories: tube and shell, or plate. As in all mechanical devices, each type has its advantages and disadvantages.

Tube and Shell

The most basic and the most common type of heat exchanger construction is the tube and shell, as shown in Figure 1. This type of heat exchanger consists of a set of *tubes* in a container called a *shell*. The fluid flowing inside the tubes is called the tube side fluid and the fluid flowing on the outside of the tubes is the shell side fluid. At the ends of the tubes, the tube side fluid is separated from the shell side fluid by the tube sheet(s). The tubes are rolled and press-fitted or welded into the tube sheet to provide a leak tight seal. In systems where the two fluids are at vastly different pressures, the higher pressure fluid is typically directed through the tubes and the lower pressure fluid is circulated on the shell side. This is due to economy, because the heat exchanger tubes can be made to withstand higher pressures than the shell of the heat exchanger for a much lower cost. The support plates shown on Figure 1 also act as baffles to direct the flow of fluid within the shell back and forth across the tubes.

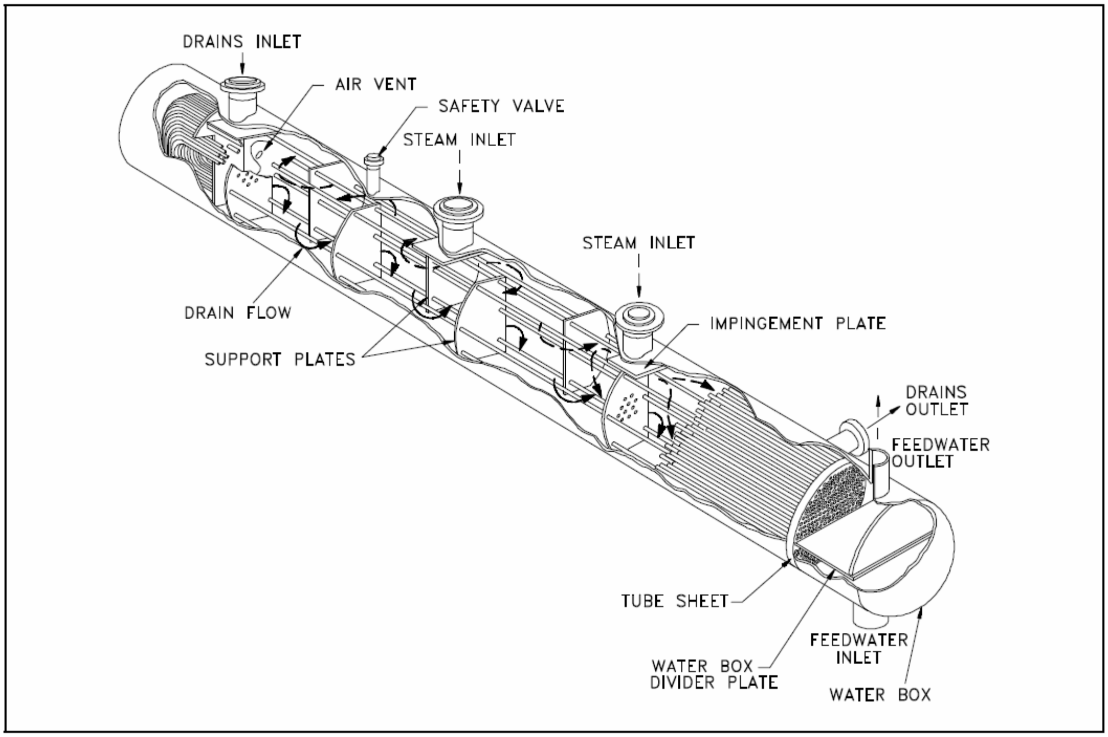

Figure 1 Tube and Shell Heat Exchanger

Plate

A plate type heat exchanger, as illustrated in Figure 2, consists of plates instead of tubes to separate the hot and cold fluids. The hot and cold fluids alternate between each of the plates. Baffles direct the flow of fluid between plates. Because each of the plates has a very large surface area, the plates provide each of the fluids with an extremely large heat transfer area. Therefore a plate type heat exchanger, as compared to a similarly sized tube and shell heat exchanger, is capable of transferring much more heat. This is due to the larger area the plates provide over tubes. Due to the high heat transfer efficiency of the plates, plate type heat exchangers are usually very small when compared to a tube and shell type heat exchanger with the same heat transfer capacity. Plate type heat exchangers are not widely used because of the inability to reliably seal the large gaskets between each of the plates. Because of this problem, plate type heat exchangers have only been used in small, low pressure applications such as on oil coolers for engines. However, new improvements in gasket design and overall heat exchanger design have allowed some large scale applications of the plate type heat exchanger. As older facilities are upgraded or newly designed facilities are built, large plate type heat exchangers are replacing tube and shell heat exchangers and becoming more common.

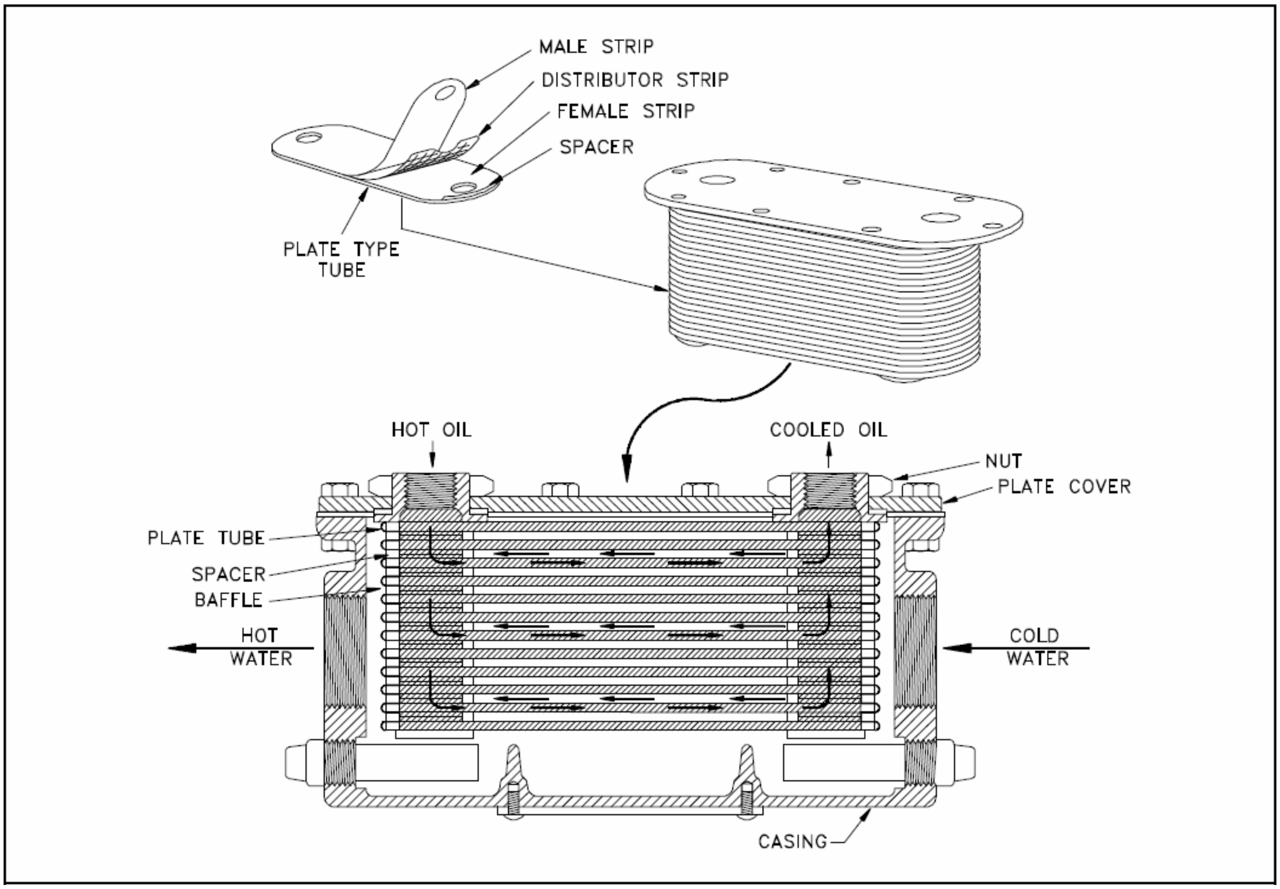

Figure 2 Plate Heat Exchanger

Types of Heat Exchangers

Because heat exchangers come in so many shapes, sizes, makes, and models, they are categorized according to common characteristics. One common characteristic that can be used to categorize them is the direction of flow the two fluids have relative to each other. The three categories are parallel flow, counter flow and cross flow.

Parallel flow, as illustrated in Figure 3, exists when both the tube side fluid and the shell side fluid flow in the same direction. In this case, the two fluids enter the heat exchanger from the same end with a large temperature difference. As the fluids transfer heat, hotter to cooler, the temperatures of the two fluids approach each other. Note that the hottest cold-fluid temperature is always less than the coldest hot-fluid temperature.

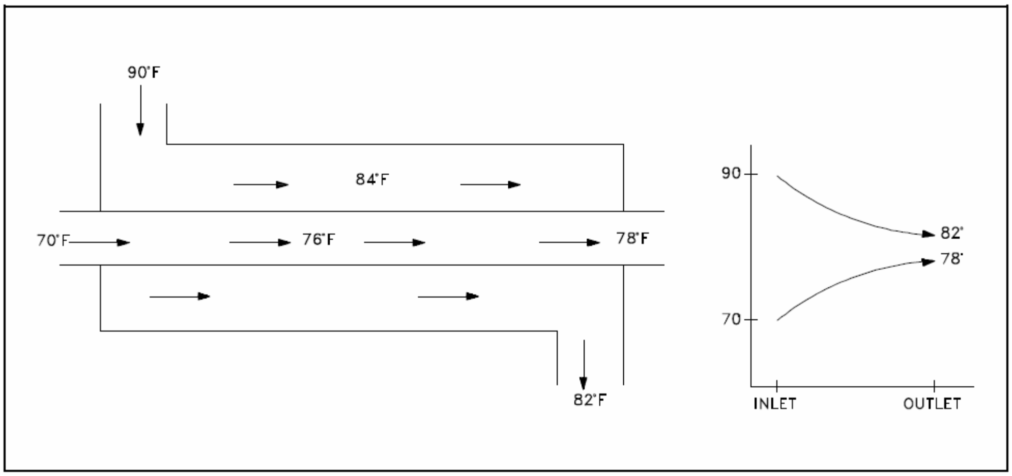

Figure 3 Parallel Flow Heat Exchanger

Counter flow, as illustrated in Figure 4, exists when the two fluids flow in opposite directions. Each of the fluids enters the heat exchanger at opposite ends. Because the cooler fluid exits the counter flow heat exchanger at the end where the hot fluid enters the heat exchanger, the cooler fluid will approach the inlet temperature of the hot fluid. Counter flow heat exchangers are the most efficient of the three types. In contrast to the parallel flow heat exchanger, the counter flow heat exchanger can have the hottest cold- fluid temperature greater than the coldest hot-fluid temperature.

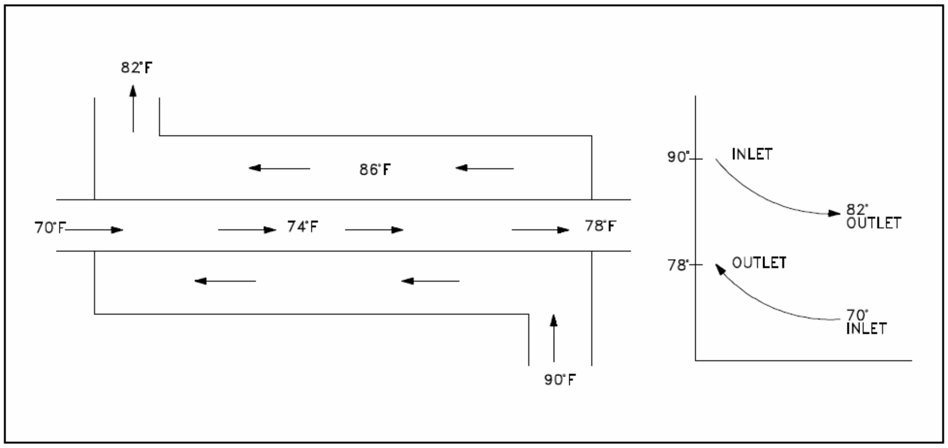

Figure 4 Counter Flow Heat Exchange

Cross flow, as illustrated in Figure 5, exists when one fluid flows perpendicular to the second fluid; that is, one fluid flows through tubes and the second fluid passes around the tubes at 90 angle. Cross flow heat exchangers are usually found in applications where one of the fluids changes state (2-phase flow). An example is a steam system's condenser, in which the steam exiting the turbine enters the condenser shell side, and the cool water flowing in the tubes absorbs the heat from the steam, condensing it into water. Large volumes of vapor may be condensed using this type of heat exchanger flow.

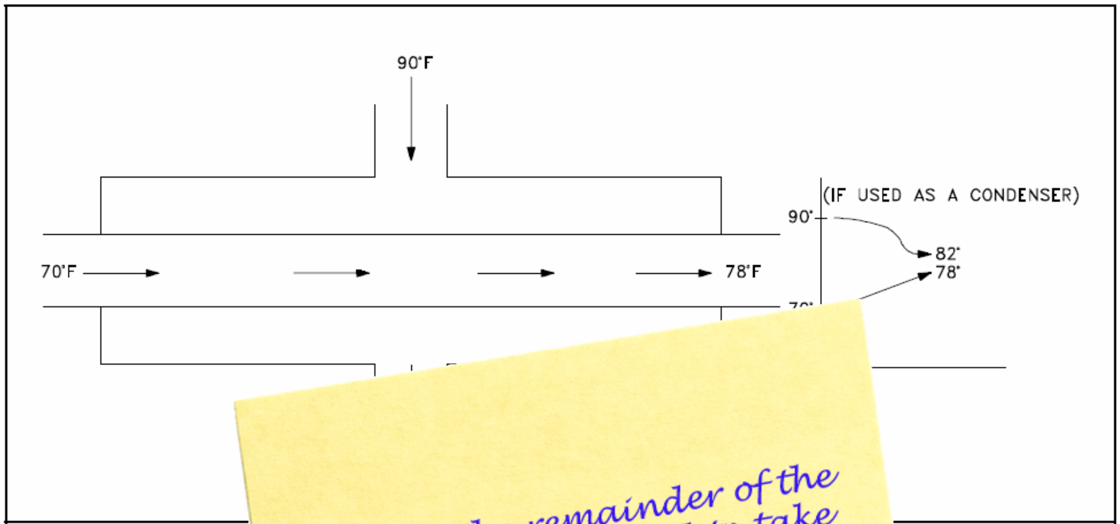

Figure 5 Cross Fl

Comparison of the

Each of the three typ ntages. But of the three, the counter flow heat paring heat transfer rate per unit surface a er is due to the fact that the average Δ T (ds over the length of the heat exchanger is he log mean temperature for a cou ean temperature for a similar parallel or cros ing the graphs in Figure 3, Figure 4, and v the higher log mean temperature of th heat transfer rate. The log mean temperature f using the following equation.

$$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln \frac{\Delta T_2}{\Delta T_1}} \tag{1}$$

Heat transfer in a heat exchanger is by conduction and convection. The rate of heat transfer, "Q", in a heat exchanger is calculated using the following equation.

$$\dot{Q} = U_o A_o \Delta T_{lm} \tag{11}$$

where $\dot{Q}$ = Heat transfer rate (BTU/hr)

U_o Overall heat transfer coefficient (BTU/hr-ft^2- ^{o}F)