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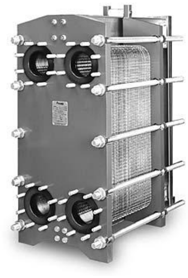
The Purpose, Use and Care of Plate Heat Exchangers

Training For Operators, Maintainers, Technicians and Engineers.





Training Objective

This training teaches users and maintainers of plate heat exchangers why they are used, how they work, what causes them to go wrong and what is necessary to keep them operating properly.

Training Contents

- Purpose of the equipment.
- The principles of how the equipment works.
- Important parts and assemblies.
- In-service design and operation.
- How the equipment achieves its purpose and the necessary operating conditions.
- Most likely failure modes, their causes and what to do about them.
- On-Site, workshop or test bench observations of an equipment installation.
- Conduct site tests and trails on the equipment operation.
    - Compare the installation to the minimum design required.
    - Predict effect of changes.
    - Observe actual changes.
    - Identify impact of changes to the equipment operation.
- Learning Assessment
    - Explain purpose and use of equipment.
    - Identify how the equipment achieves its purpose.
    - Specify the required operating conditions for proper performance.
    - List what failures are possible at the workplace and how to fix them.
    - Training Supervisor review.

Outcomes of the Training

This training will introduce the trainee to the proper use, care and maintenance of plate heat exchangers. It gives them a deeper knowledge of the equipment and factors that affect its operation. They will use the new know-how to better operate, care-for and maintain such equipment in future.

Time Required

The training takes one hour to complete for able people with some industry experience.

Training in the Purpose, Use and Care of Plate Heat Exchangers

Purpose of the Equipment

Plate heat exchangers (PHE), often called plate-and-frame heat exchangers, are used to change the temperature of a liquid, vapour or gas media. As the name implies, and as shown in Figure 1, a thin, corrugated plate is used to transfer the heat from the media on one side of the plate to the media on the other side.

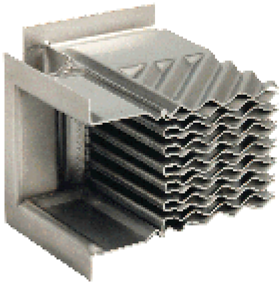


Figure 1 Cross-section of a Plate Stack

The plate heat exchanger consists of a frame with end plates which squeeze the corrugated heat transfer plates. Figure 2 shows a plate pack of corrugated plates with portholes for the media to flow. The plates are placed side by side in a solid frame and compressed by tightening bolts. The plates form a series of channels for the two media. The channels are sealed by gaskets which direct the media into alternate odd and even number channels. One fluid flows in the odd number channels and the other in the evenly numbered channels.

Figure 2 A Plate and Frame Heat Exchanger

Principles of How the Equipment Works

Plate heat exchangers use the thin plates to keep two media of different temperatures apart while allowing heat energy to flow between them through the plate. The heat energy transfer across the plate acts to change the temperatures of the two media. The hotter one becomes cooler, and the colder one becomes hotter. Figure 3 shows a graphic detail of the flow across each side of the plate.

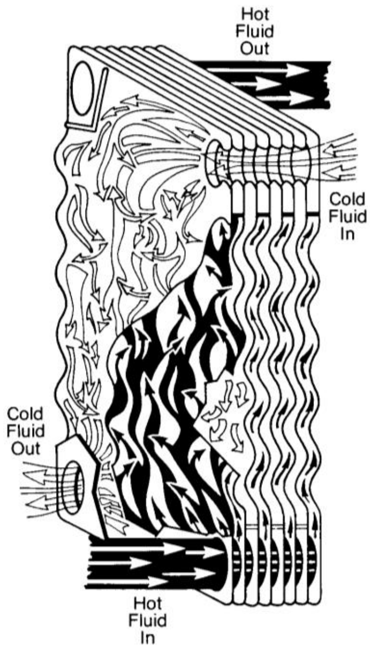


Figure 3 -Flow Over Plates

In Figure 3 note that one of the media flows between every second plate and the other media flows through on the other side of the plate. The flow directions shown in Figure 3 are counter-current. In counter-current arrangements the flows of each media are against the direction of the other. When the two media both flow in the same direction it is known as concurrent flow. Figure 4 shows the flow through a plate stack of a heat exchanger.

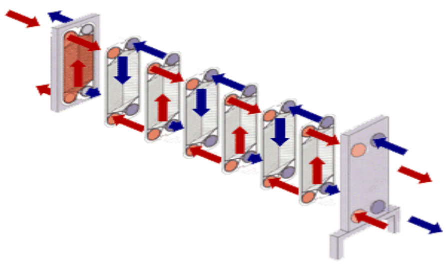


Figure 4 Flow In A Plate Stack

Counter current flow is usually preferred because there is more heat transfer achieved for the same flow rates of media than in concurrent flow. Figure 5 shows the temperature changes for the two flow directions.

Close Approach Temperatures

Because of plate thinness, a plate heat exchanger can work with a much closer temperature difference between the two media than other heat exchangers and still get a good heat transfer at lower flow rates, thereby saving pumping and operational costs. It is possible to cool a liquid down to nearly 1°C (2°F) of the hot medium. Heat recovery of up to 85% to 90% is quite common, making the plate heat exchanger the most efficient heat exchanger for heat recovery, particularly for applications where the temperature difference between the media is small.

Important Parts and Assemblies

Plate heat exchangers consist of pressed plates; the separating gaskets between each plate; the end plates used to clamp the plate stack together and the frame to hold the plate stack in place. The plate is pressed metal. A wide range of metals and corrugation shapes can be used that suit the chemical, flow and corrosive properties of the media passing across the plates.

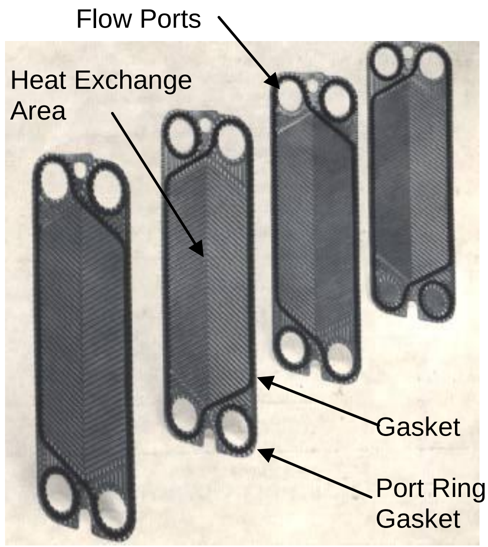
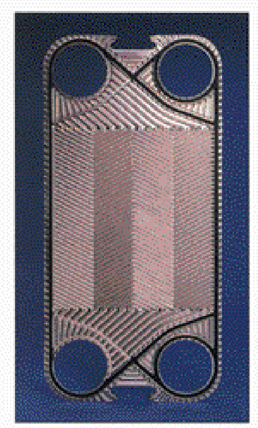


Figure 5 Plates with Gaskets

Plates for an exchanger have indentations and corrugations to encourage more turbulent flow across them and to make thinner films of media to promote better heat transfer. The headers to feed and remove the fluids pass through all plates. Unwanted headers are blocked off on a plate.



Gasket Arrangement
Figure 6

The gaskets separate the plates and create the thin chamber through which the fluid film swirls and flows. They also serve the purpose of directing the media from the entry port to the exit port. Can you trace the flow path in Figures 5 and 6?

In-Service Design and Operation

Figure 7 shows a common in-service arrangement for a plate heat exchanger.

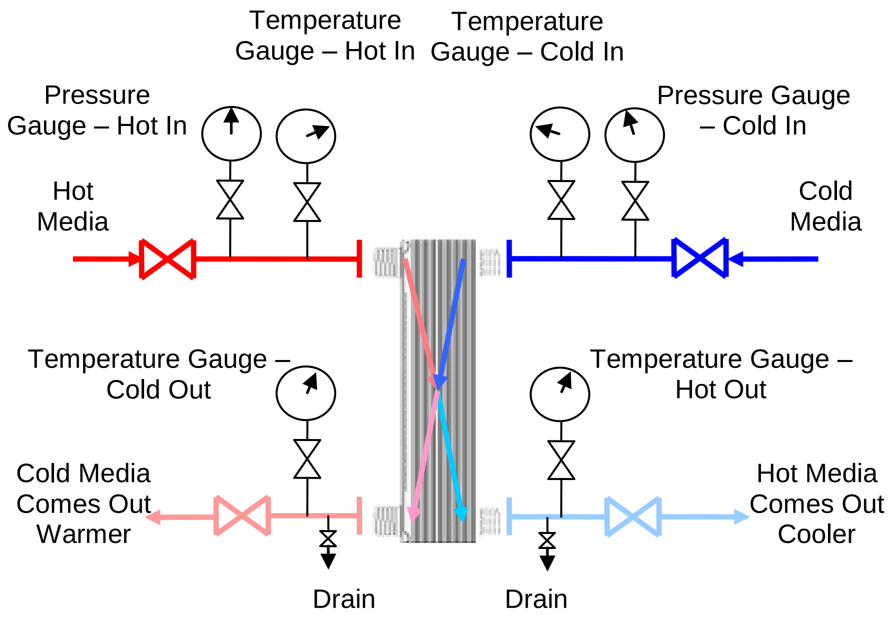


Figure 7 – Typical Arrangement for a Plate Heat Exchanger

Note the temperature gauges and pressure gauges at the ports to provide vital operating information.

How The Equipment Achieves Its Purpose And The Necessary Operating Conditions.

Basic Heat Transfer Requirement

Each heat exchanger is designed with a particular heat transfer, or temperature change, requirement in mind. Formulas are used to calculate the heat energy transfer needed between the media to deliver the outlet temperatures required by the system. The calculations give the needed surface area for heat transfer and from this the number of plates in the stack can then be set.

Energy flows from levels of high energy to levels of low energy. In a PHE the energy flows from hot to cold. As the energy leaves the hot media it cools off, and as it enters the cold media it warms it. In the sizing calculation the heat energy transfer through the plates has to factor-in how difficult it is for the energy to get from one channel, through the plate and into the neighbouring channel.

This difficulty, or resistance, to transferring energy is known as the 'overall heat transfer coefficient'. A diagram through several heat exchanger plates is shown in Figure 8. The energy has 'difficulty' getting from one media to the other when it passes through the plate and any fouling on the plate.

Heat energy has to get through media film boundary layers, process deposit layers and the plate before changing the temperature in the chambers. These hindrances produce a resistance to energy flow.

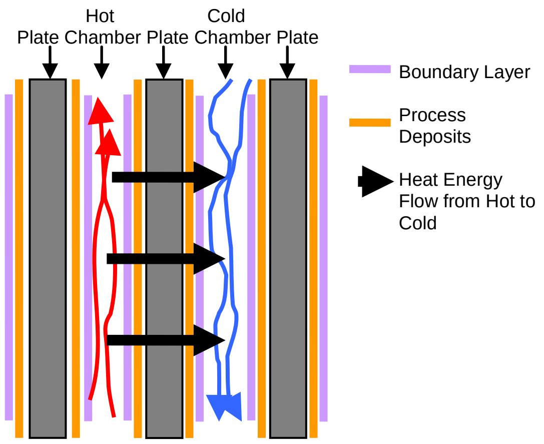


Figure 8 - Heat Transfer Resistance Between Chambers of a Plate Heat Exchanger

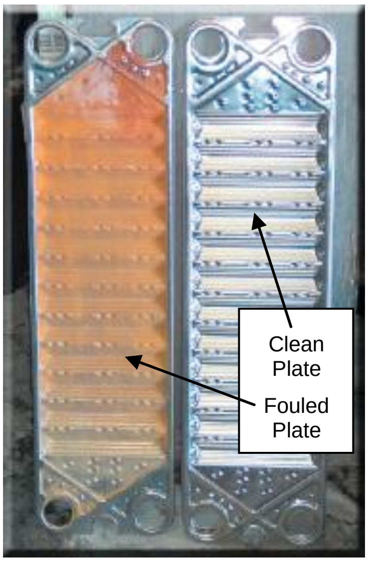


Figure 9 Deposits on a Plate

As the HXCH is used, deposits from contamination in the media form on the plates, as shown in Figure 9. These act to both stop the energy flow and block the passage of media through the chamber. Any deposit (including any thin protective film on the metal) is an insulator that reduces heat transfer. A loss of heat transfer causes higher energy consumption and eventual HXCH performance failure.

A plate HXCH works at its best performance when the plates have a clean surface.

Looking at an Operating Exchanger

When designing HXCH's the formulas used allow for the thermal resistance properties of the materials used in the plates and for the presence of a minor amount of fouling. The deposit film coefficient, also called the fouling factor, changes according to both the deposit composition and thickness. As fouling deposits get thicker it eventually exceeds the design allowance resistance and the heat exchange between media fall below design requirements.

By measuring the temperature change of the two media flows between the inlet and outlet ports you can gauge the effect of plate fouling on the heat exchange rate compared to what was designed. The log mean temperature difference between the inlet and outlet ports of both media is important to record and trend on a graph. Often the 'U' value or the 'overall heat transfer coefficient' is trended instead.

In all cases the temperature difference equation shown below is used in the calculation. The best thing to do is have an engineer put it into a spreadsheet so that all you need do is enter the temperatures and the spreadsheet graphs it for you.

$$\Delta T_{lm} = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln \frac{(T_1 - t_2)}{(T_2 - t_2)}}$$ = log mean temperature difference between fluids

Where: T_1, T_2 = hot fluid in and out, respectively
t_1, t_2 = cold fluid in and out, respectively

When in operation the HXCH should be taken out of service and cleaned when fouling or deposit build-up causes the temperature difference to fall to far below the design temperature difference.

Heat Exchanger Start-up from Cold

A cold plate pack needs to be brought up to temperature gradually to allow expansion take-up to compress the gaskets and to check for leaks. Normal practice is to introduce the cooler medium first and bring it to operating pressure. The hot medium is then introduced gradually till full operating conditions are present.

In a totally new installation it is best to install strainers up-stream of the inlet ports to capture loose materials and rubble left during construction. They are removed several months after commissioning.

Possible Failure Modes Causes, Prevention and Corrective Actions

Gaskets

The design of plate HXCH's produce their own set of concerns that must be addressed. In a plate HXCH a gasket separates the thin metal plates. The gasket acts to stop the contents escaping from the HXCH and to direct the flows within the HXCH. If incompatible gasket material is selected for the process chemicals and conditions then it will fail early.

For example rubber gaskets have a limited temperature range. If the design selection assumes both liquids will be present and a rubber is selected because it will stay cool in the fluid flows then that will be a recipe for disaster. You can be certain that at some stage the hotter fluid will be put through the HXCH alone and it will cook the rubber gaskets. Gaskets need to be rated for the hottest temperature.

Uneven Plate Pack Clamping

Gaskets on large plate HXCH's are very expensive and costly to replace. In-the-field maintenance of large plate HXCH's is difficult and often unsuccessful. The plates must be evenly loaded and kept square and flat by screwing the thick end plates together to a set measurement. It is difficult to insure correct, even torque application to the tensioning screws and the plate pack leaks. Where possible send the HXCH to a certified repair shop which has the right equipment and experienced people.

Steam Overloading

Flooding is another common problem with plate heat exchangers using steam. The steam condenses into liquid (condensate) and unless the condensate is removed faster than it condenses the HXCH floods and heat transfer is lost. It is necessary to size the discharge piping and in-line equipment adequately for the worst load condition and not the average load condition.

Pressure Losses are High

Another important factor in ensuring plate HXCH's under steam operate well, is to be sure the condensate piping produces little back-pressure. Because of all the thin, winding channels, a plate HXCH's produces a large pressure loss across itself. To prevent condensate build-back the pressure at the outlet must allow free flow away from the HXCH.

Mechanical Stressing causes Cracks

The thin plates can vibrate due to the flow of fluid past them. The vibration will work harden the metal and make it brittle. Pressure hammers causing pressure spikes also damage the plates. Cracks develop in the plates and cross-contamination between media occurs.

Solids Blockage

Some media have the property of precipitating, or forming crystals, when they cool below a certain temperature. If this happens in the plate heat exchanger chambers it blocks the chambers solid and the plates must be removed and cleaned.

Plate Fouling

The build-up of flow stream deposits can happen on both sides of the plate. As these deposits thicken they reduce the heat transfer and the media do not reach their required temperatures. By measuring the two flow stream's inlet and outlet temperatures and finding the log mean temperature difference, you can watch the fouling effect. It is best to trend it on a graph and when it is unacceptable clean the plates or replace them.

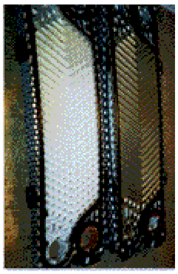


Figure 10 Fouling Deposits on Plate

Plate Heat Exchanger Repair

Plate clean requires:

- Removal of old gaskets material and adhesive. (Scrubbing or high pressure water blasting can be used where deposits are easily removed. It is not recommended to use carbon steel wire brushes on stainless steel plates, as a scratch will deposit carbon steel in the stainless and galvanic corrosion will cause pitting.)
- Chemical cleaning to remove oil and scale deposits on the plate surface.
- Dye penetrate crack detection and inspection for mechanical damage, stress cracks and corrosion.
- Re-gasketing with new gaskets on a clean plate.
- Final inspection for correct application prior HXCH assemble.

Re-gasketing Clean Plate
Figure 11

On-Site Test, Workshop or Lab Test of an Installation and Learning Assessment

It is now time to do some ‘hands-on’ training in the field, or with a spare, or on the test-bench. To thoroughly understand this topic it is best to see what happens in a working situation and practice by making and controlling changes. You will better understand what the equipment does, and how to run it well, if you can operate it. Locate suitable equipment in your plant or spares to adjust and inspect.

1. Locate the manufacture’s operating manual if available or find it on-line over the Internet. Take the time to read it. Tag anything you don’t understand and come back to it at the end of the training to see if you come to know what they mean.

2. Hand-sketch below the chosen plate heat exchanger installation at your workplace and write the name of the individual equipment items on the sketch. Name the parts of the HXCH and explain their purpose. If there is more equipment used in the station than the minimum basic design previously shown, write down what each extra items of equipment is used for in the space under the drawing and why they are there.

3. Close Inspection

3.1. Get a clean HXCH plate and look at it. If that is not possible get a manufacturer’s manual for the equipment you use. Using the manufacture’s manual or from experience or by talking with experienced people, name and describe each pat of the plate.

3.2. Write a short description of how the plate is built and how it is designed to work.

3.3. Describe how plate stack performance is monitored in your facility. What is the best way to do it?

4. If at all possible, and once you have supervisor permission, operate the equipment to see what effects happen as the operating conditions change. If you cannot operate a real item of equipment, then describe as best you can using information from your reading and discussion with others, what will happen to the process because of the change.

4.1. Operating Conditions.

Gradually reduce hot media flow into the heat exchanger by closing a downstream valve to mimic blockage or fouling. Describe what you notice. How does the cold media temperature change? Return the hot media to original flow and repeat the same for the cold media.

4.2. Start-up Requirements.

Describe how to start-up a plate heat exchanger and put it into service.

5. Possible Modes of Failure

5.1. List the ways that control valves have failed to perform properly at your workplace. Talk to the experienced operators and maintainers if necessary.

5.2. Getting the Equipment Back to Proper Operation.

For each failure mode listed above, describe in detail what needs to be done to correct them.

This is the end of this training. Please record the following details and hand your answers back to the supervisor in charge of this training.

Trainee ________________________________ **Signature** ______________________________
(Print Name) (Trainee)

Supervisor ______________________________ **Signature** _____________________________
(Print Name) (Supervisor)

Assessment Result: ☐ Pass
☐ Repeat

Completion Date ___________________ 'Pass' recorded in the Trainee's training records ☐