Chemical Process Utilities
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Lecture – 7
Heat Transfer Utilities-II

Welcome to the next part of heat transfer utilities. In the previous lecture, we discussed different types of heat exchangers and their functioning, anatomy, and integral parts of different heat exchangers. What is the concept of heat exchange in this particular aspect, especially we gave the major emphasis to shell and tube heat exchangers then double pipe heat exchanger?

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In this lecture, we will cover the plate and frame heat exchangers corrugation within the heat exchanger. This is again a very important phenomenon.

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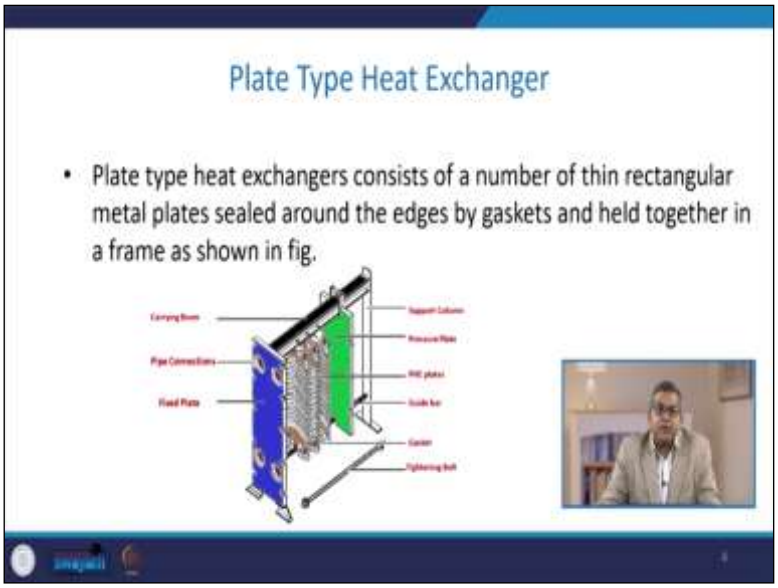

Let us have a look at the plate-type heat exchanger. The plate-type heat exchanger consists of a number of thin rectangular metal plates like this around the edges, and they are supported by the gasket and held together in a frame just like this. Here you see that these are the plate heat exchanger plates. There are certain guide bars to remove or to join all these bits. These are the gaskets, and these are the tightening bolts so that you can make the compact structure. These are the support columns, and here you see that this is the pipe connection. This is the fixed plate for the support, and this is the carry carrying beam or sometimes referred to as a carrying rail. The frame usually has a fixed end cover like here. So, a fixed hand cover is sometimes referred to as a headpiece fitted with the connecting ports, and a movable end cover, sometimes referred to as a pressure plate like this here follower or sometimes tailpiece, etc.

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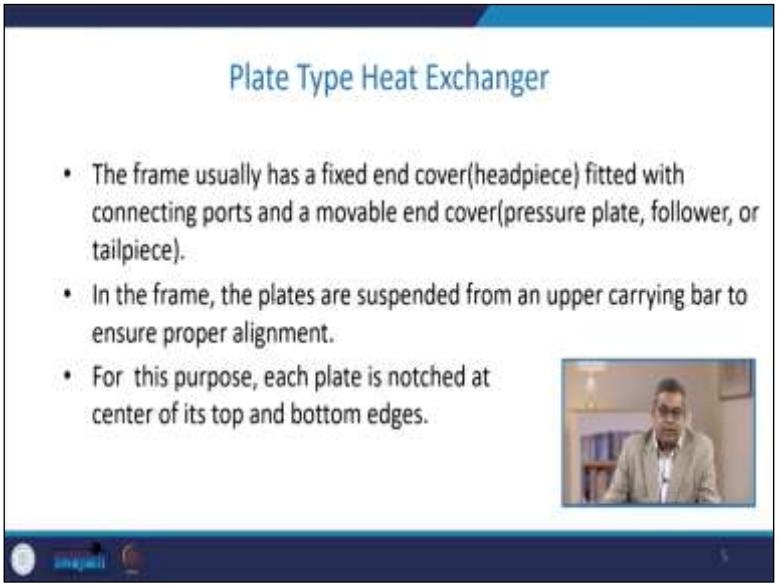

In the frame, the plates are suspended from an upper carrying bar. This is the upper carrying bar to ensure proper alignments. For this purpose, each plate is notched at the center of its top and bottom edge here you can see.

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These plate packs with fixed and movable covers. Here you see that the fixed and movable covers are clamped together by a long bolt. Here you see that this is the long tightening bolt, thus compressing the gasket and forming a seal. So, the fluid or whatever the liquid or any kind of heat transfer material should not get leaked. Carrying bars are longer than the compressed stake. So, when the movable end cover is removed, the plate may be slid along the support bar for inspection and cleaning.

See inspection and cleaning are again very important to have a proper heat transfer; otherwise, the dirt and dust or scales may become part and parcel, and you k that these are not contributing to any kind of heat transfer effect.

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Each plate is made by stamping or embossing a corrugated or wavy this is just like this wavy surface pattern on sheet metal. On one side of each plate special grooves, they are provided along the periphery of the plate and around the port of the gasket. Alternate plates they have assembled in such a manner that the corrugation on successive plate contact or cross each other to provide mechanical support to the plate pack through a large number of contact points. So, in this way, you may enhance the surface area.

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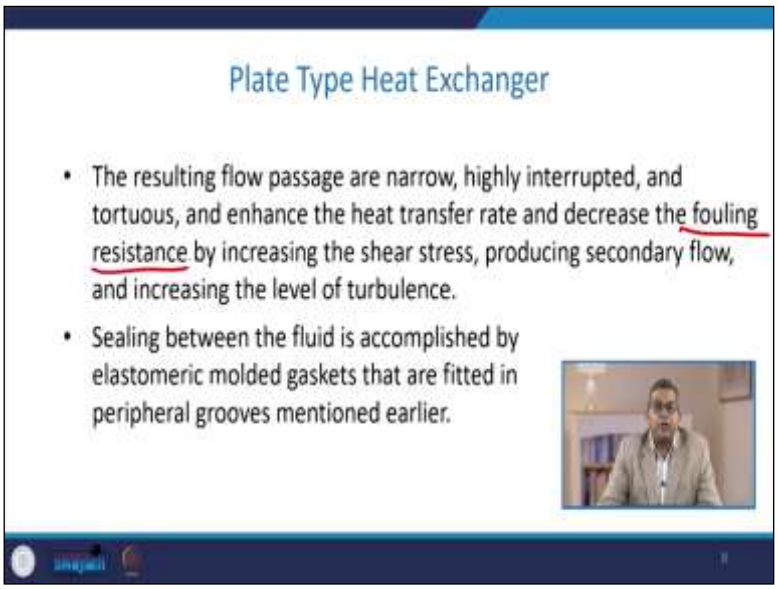

The resulting flow passage is narrow, highly interrupted, and tortuous, enhances the heat transfer rate, and decreases the fouling resistance by increasing the shear stress-producing secondary flow and the level of turbulence. Sealing between the fluids is usually accomplished by elastomeric mold gasket, and these are fitted in the peripheral grooves which we have already shown in the figure.

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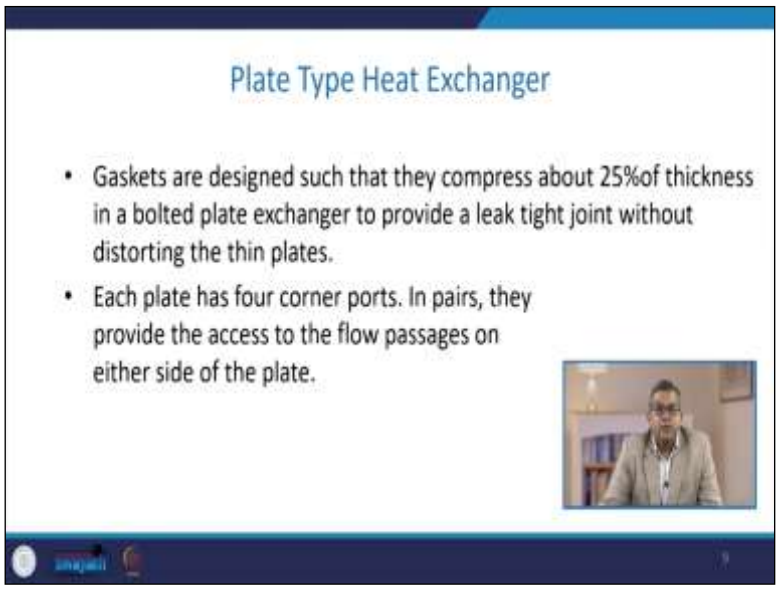

These gaskets are designed such that they compress about 25 of thickness in a bolted plate exchanger to provide a leak-tight joint without distorting the thin plates. Each plate has four corner ports in pairs to provide access to the flow passage on either side of the plate.

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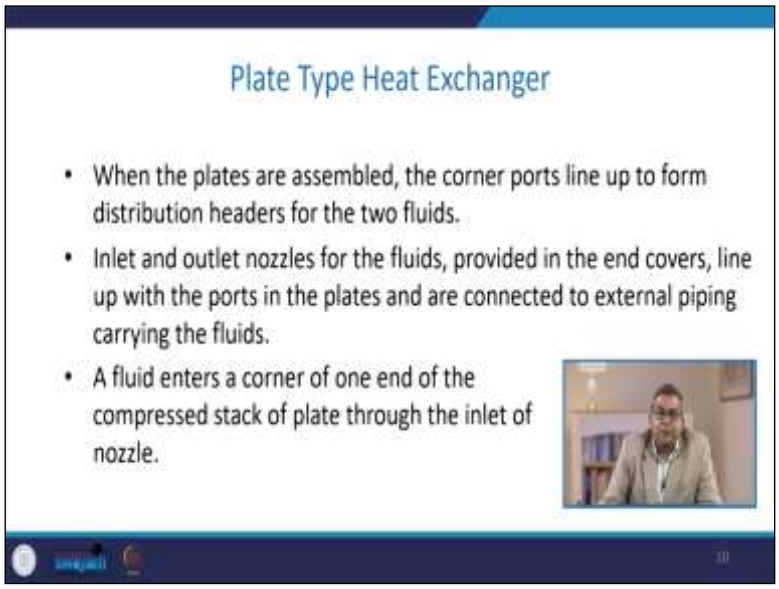

When these plates are assembled, the corner plate corner port line up to form a distribution header for the two flutes inlet, and outlet nozzles for the flute provided in the end cover line up with the port in the plates are connected to external piping carrying the fluids. Fluid enters a corner of one end of a compressed state plate. So, these are the compressed stack stake plates.

So, fluid enters from a corner of one end of the compressed stick plate through the inlet nozzle. It passes through the alternate channel in a series of parallel passages. The gasket does not surround the internal inlet port between two plates in one of the channels. Fluid enters through the port, flows between the plate, and exits through the port at the other end.

So, you may see that this is a thing, and it may go out on the same side of the plate. The gasket blocks the other two sides with a double seal so that the other fluid cannot enter the plate on that side.

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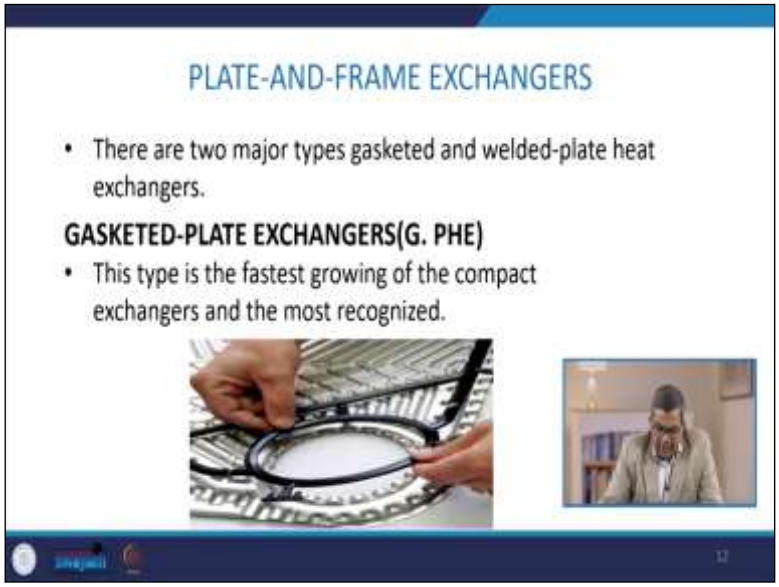

There are two major types of gasket and welded plate heat exchangers. One is the gasket plate heat exchanger. This type is the fastest-growing compact exchanger The most recognized you can see this is the gasket. A series of corrugated alloy material channel plates bounded by elastomeric gaskets are usually hung off and guided by the longitudinal carrying bars. These are the longitudinal carrying bars.

Then compressed by large diameter tightening bolts here, you see that these are the tightening bolts between the two pressure-retaining flame plates. Here, if you visualize that these are the two retaining flame plates or sometimes referred to as cover plates, the frame and channel plates have potholes that allow the process fluids to enter alternating flow passage, which is the space between the two adjacent channel plates.

A gasket around the periphery of a channel plate prevents any kind of leakage into the atmosphere because, ultimately, it creates an economic loss. They also prevent the process fluid from coming in contact with the frame plates to prevent contamination. No inter-fluid leakage is possible in the port area due to the dual gasket seal of the frame plate. They are typically epoxy-painted carbon steel materials and can be designed per most pressure vessel codes. So, different types of codes are applicable. So, through which it can be, it can be designed.

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The channel plates are always an alloy material with the SS304 as a minimum. These channel plates are typically 0.4 to 0.8 millimeters in thickness and have a corrugation depth of 2 to 10 millimeters. Special wide gap WG PHE plates or plate heat exchangers are available in limited sizes for slurry application with a depth of approximately 16 millimeters. Usually, these channel plates are compressed to achieve metal-to-metal contact for pressure-retaining integrity.

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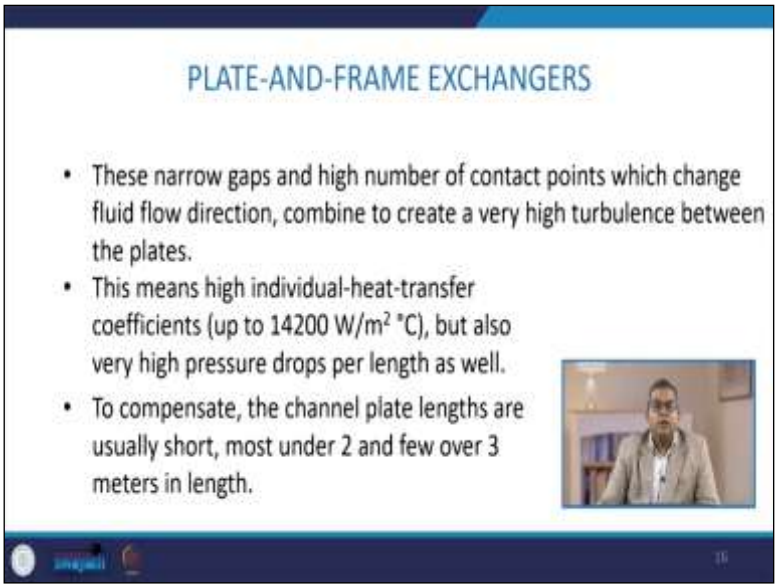

These narrow gaps and a high number of contact points that change fluid flow direction combines to create very high turbulence between the plates. So, the inference is that the high individual heat transfer coefficient is sometimes up to 14200 watts per meter square degree Celsius. But also, it creates a very high-pressure drop per length as well. Channel plate lengths are usually very short to compensate for this, mostly under two or a few over three meters in length.

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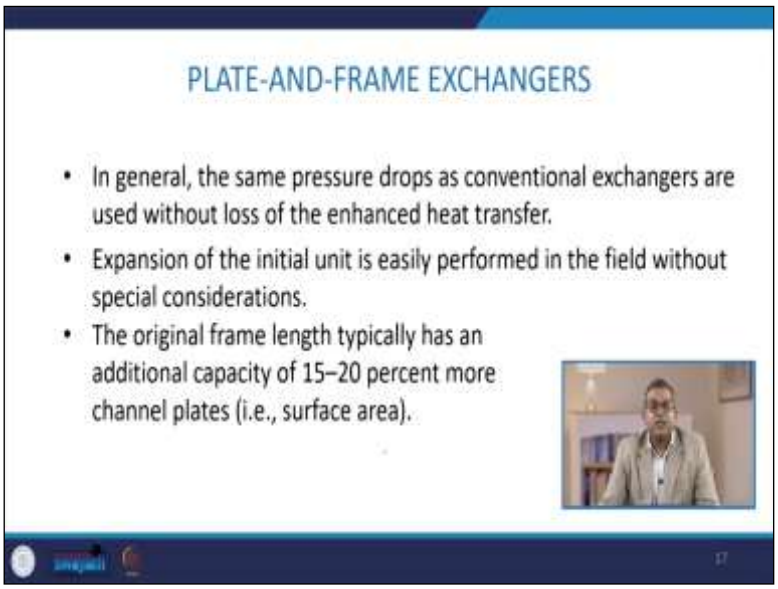

So, in general, the same pressure drop as a conventional exchanger is used without loss of the enhanced heat transfer. Expansion of the initial unit is easily performed in the field without special consideration. The original flame frame length typically has an additional capacity of 20% or 15 to 20% to be more precise, more channel plate that is surface area.

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In fact, if a known future capacity is available during the fabrication stage because that is in the designing stages, a longer carrying bar could be installed, and later increasing the surface area would be easily handled. When one is scaling up or enhancing the capacity or increasing the capacity, they need not bother to have the entire setup again. They may increase the surface area by putting more plates and tightening the frame.

So, you can put a longer carrying bar at the start or at the initial fabrication stage. But if you are not certain, then if and at initially you are putting longer carrying bar it may create a problem because sometimes the pressure as well as it will be an uneconomical affair. So, when you have the longer carrying bar, the expansion is needed simply untighten the carrying bolt, pull back the frame plates you can put the additional channel plates, and tighten the frame plate.

So, it is just like that you are having the different plates initially you are having like this you just open up insert couple of plates and then again tighten it.

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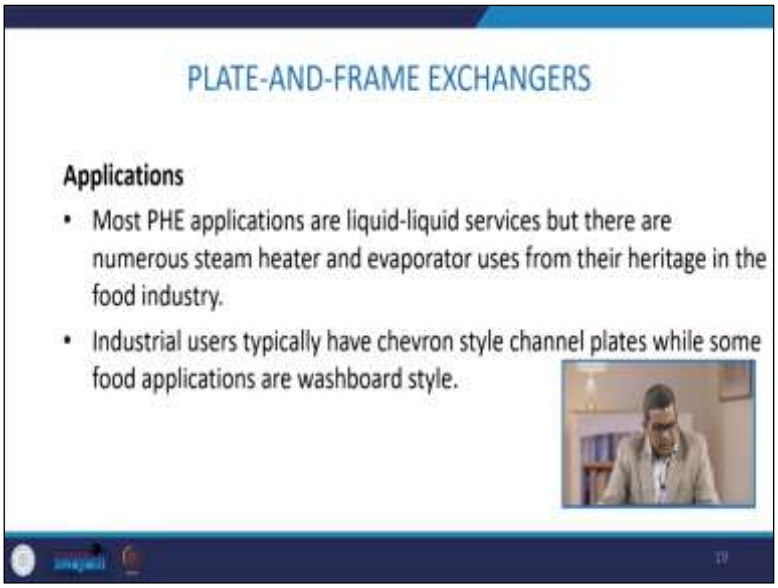

Let us discuss the various applications. Most plate types of heat exchanging applications are liquid-liquid service, but there are numerous steam heaters and evaporators used from their heritage in the food industry pasteurization of milk is one example. Industrial users typically have chevron-style channel plates, while some food applications are washboard style.

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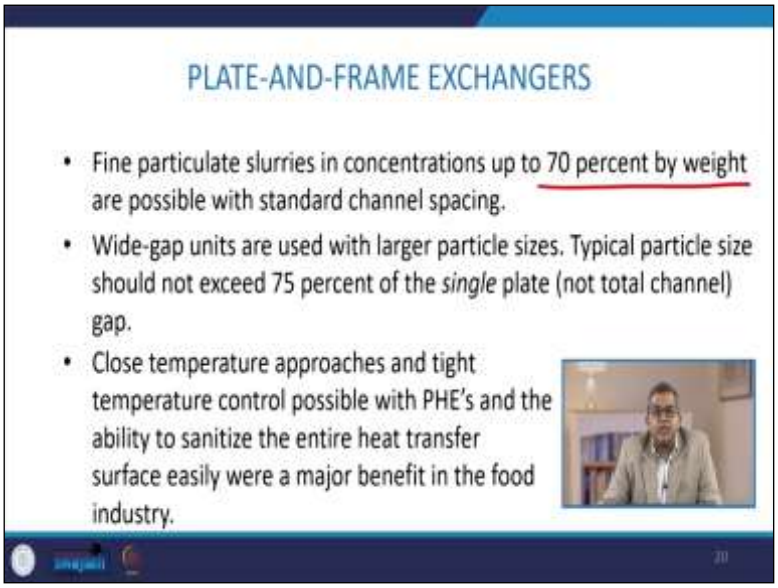

In this, the fine particles slurries in concentration up to 70% by weight are possible with standard channel spacing wide gap units used with larger particle size. Typical particle size should not exceed 75% of the single plate. Closed temperature approaches, the tight temperature control possible with the plate heat exchangers, and the ability to sanitize the entire heat transfer surface easily were major benefits in the food industry.

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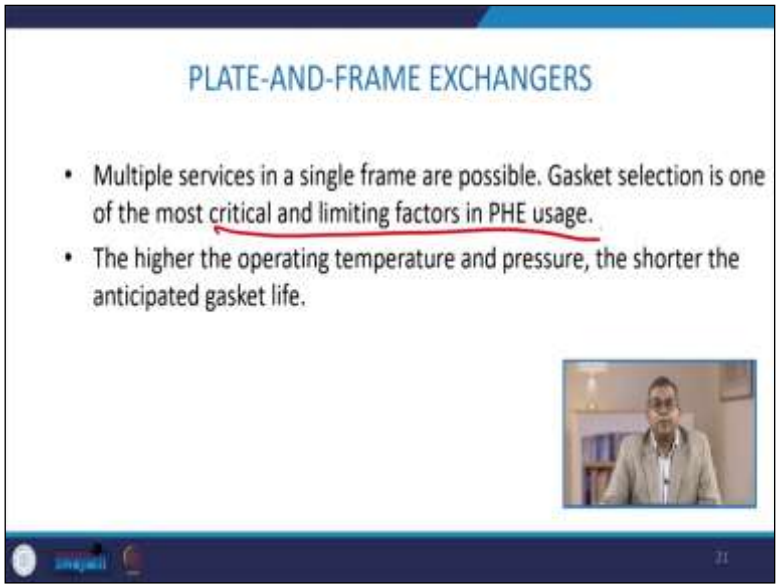

There are multiple services in a single frame that are possible. Gasket selection is one of the most critical and limiting factors in plate heat exchanger use. The higher the operating temperature and pressure, the shorter the anticipated gasket life because the fluctuation and sometimes the plasticizers may go away, and the shelf life of the gasket will be reduced drastically. So, during the maintenance operation, one should have a closer look at this gasket life.

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The major applications are but not limited to they are the temperature cross applications for lean and rich solvent closed approaches applicable to freshwater to see for seawater to fresh water and different type of viscous fluids. For this, there are certain sometimes you require the sterilized surface polished surface sometimes required sometimes you may

require the future expansion. So, that the bars and other things you may look into the aspect.

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There may be a certain type of limiting aspect with respect to the space restriction may have a barrier coolant system or services some sort of the slurry application and the pharmaceutical emulsions.

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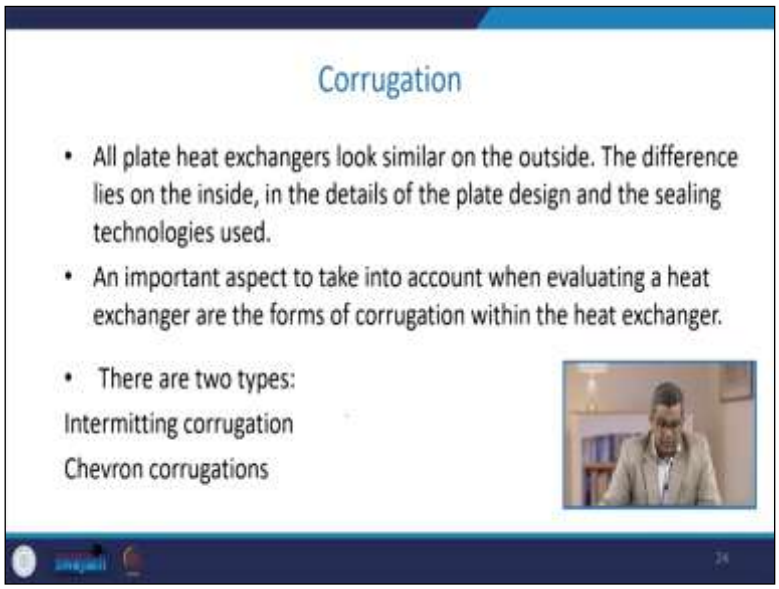

Let us talk about the corrugation. All plate heat exchangers look similar on the outside. The difference lies on the inside in detail of the plate design and the sealing technology used. So, it all depends on what kind of ceiling technology, gasket, and other things you are using. An important aspect to take into account is that while evaluating a heat exchanger, they are in the form of corrugation within the heat exchanger.

There are two types of corrugation: the intermittent type of corrugation and the second is chevron corrugation.

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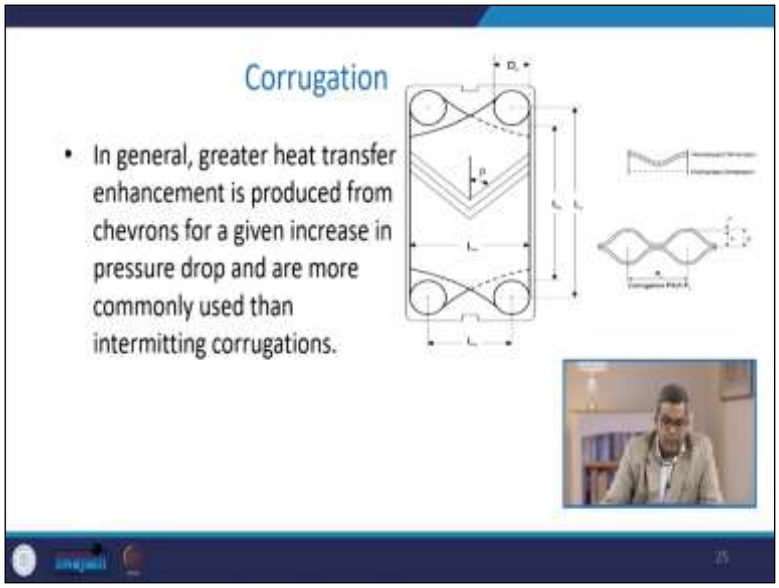

In general, the greater heat transfer enhancements are produced from chevron for a given increase in the pressure drop and are more commonly used than intermitting corrugation.

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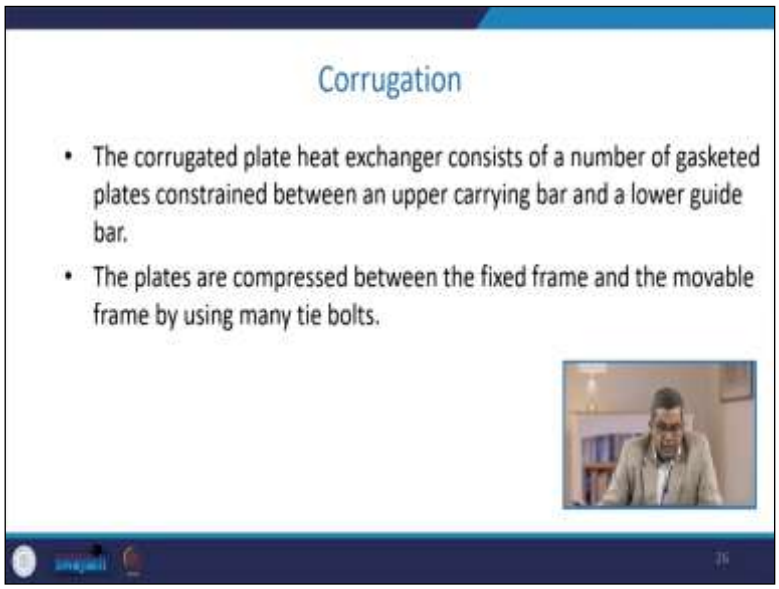

If you recall the figure and the lower guide bar, the corrugated plate heat exchanger consists of a number of gasketed plates constrained between the upper carrying bar. This is the lower guide bar and the upper carrying bar. So, it depends on the number of gasketed plates constrained. The plates are compressed between the fixed frame, and if you recall, these are the fixed frames and the movable frame by using many tie bolts. So, there are

various tie bolts, if you recall, in the figure. So, these tie bolts are attached here. So, you can tighten them and make them more and more compact in nature.

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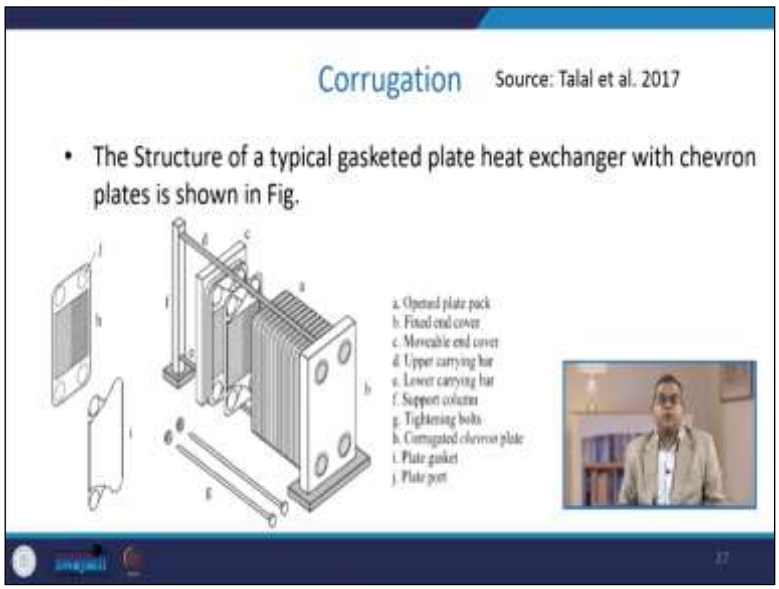

Here you see the structure of a typical gas scattered plate heat exchanger with chevron plates. Here this is open on a plate pack. This is the fixed end cover, which is fixed, and here you can see if this is movable. So, with the help of a bolt, you can tie it. This is the upper carrying bar over which all these plates are attached, and this is the lower carrying bar and the support column.

So, if you have the upper and a lower carrying bar a bit larger in length, you can insert more and more plates. These are the tightening bolts. So, you can introduce these tightening bolts, and here you see that this is the corrugated chevron plate. Here you see the corrugation. They are clearly visible, and these are the plate gaskets. So, these are all these things, and here you see the plate ports.

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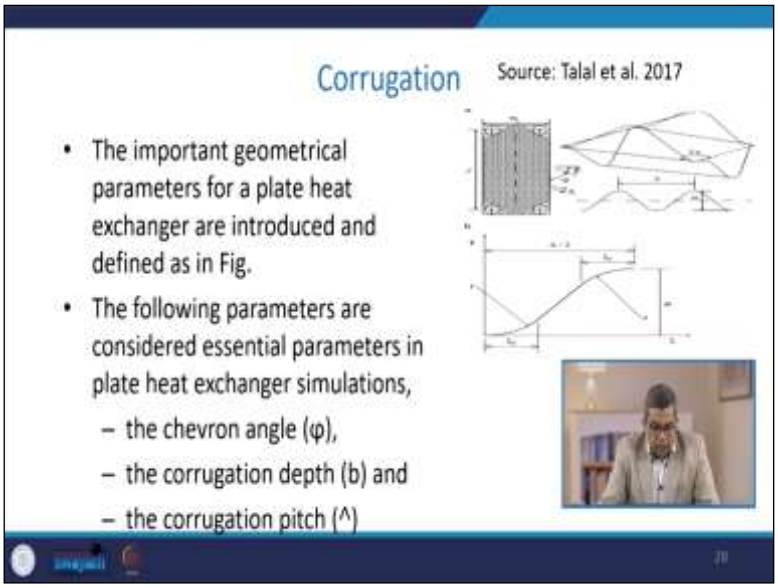

It is the important geometrical parameter for plate heat exchangers. They are introduced and defined as per the previous figure. Usually, while considering these aspects, the following parameters must be considered essential in plate heat exchanger simulation. The chevron angle is phi the corrugation depth referred to b, and the corrugation pitch.

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Here you see that difference you can visualize the different types of corrugation. It is more and more visible, and here you see that this is the corrugation depth, the chevron angle you see here, and the corrugation pitch.

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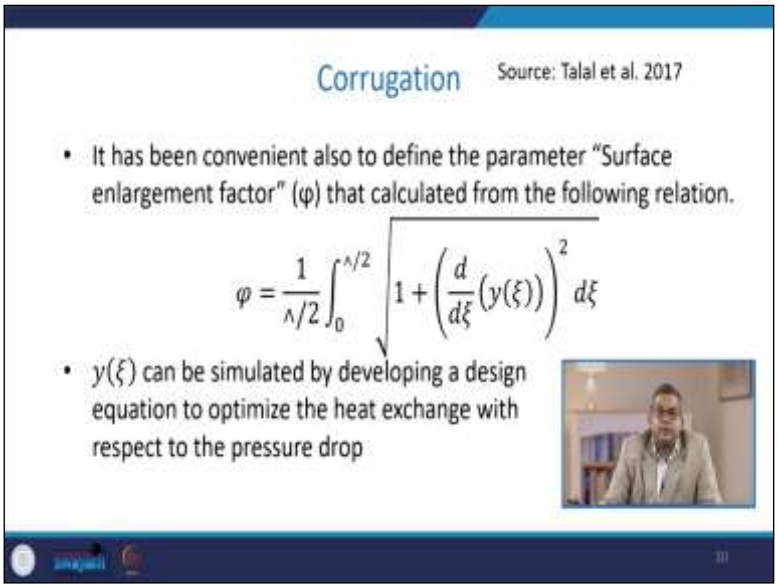

It has been convenient to define the different parameters like surface enlargement factor (φ) and that calculated from this following relation that is

$$\varphi = \frac{1}{\wedge/2}\int_0^{\wedge/2}\sqrt{1+\left(\frac{d}{d\xi}(y(\xi))\right)^2}\,d\xi$$

$(y(\xi))$ can be simulated by developing a design equation to optimize the heat exchange with respect to the pressure drop.

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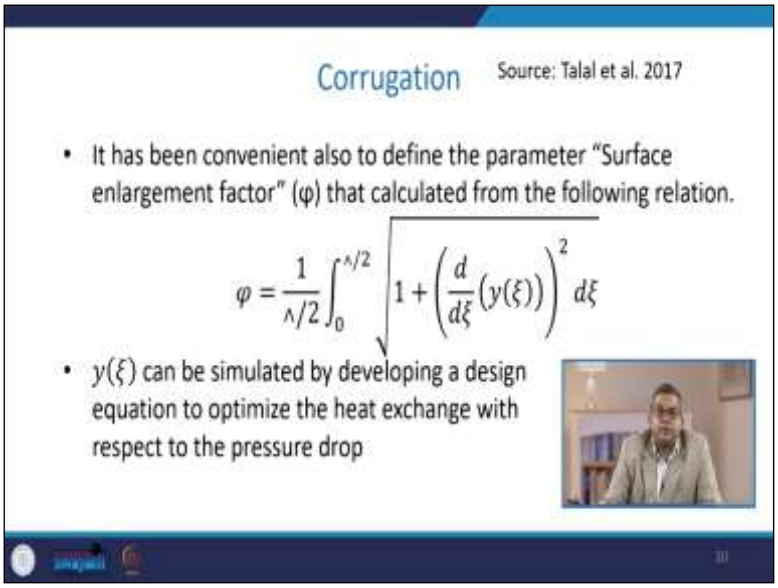

For the chevron corrugation plate heat exchanger, the chevron angle is the most influential geometric parameter. Here you see that we have represented three different combinations one is the high chevron angle that is high theta you can see 120 degrees here. This is the

low theta one. The chevron angle is sixty degrees. Here you see that it will be a mixed chevron angle 120 and 60.

Similarly, in the single-phase heat transfers, both the heat transfer and pressure drop increase with the increase of the chevron angle. Here you see the pitch and theta over here. So, this is the surface corrugation.

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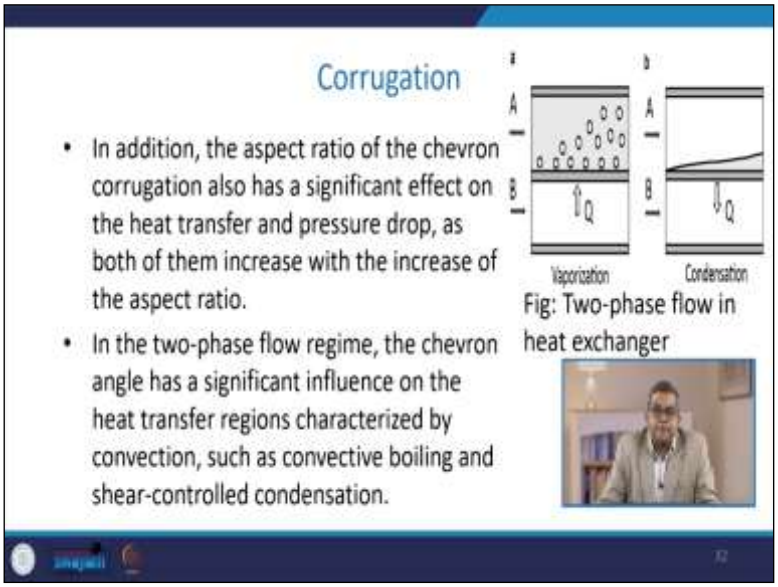

The aspect ratio of the chevron corrugation has also played a significant role in the heat transfer and pressure drop because both of them increase with the increase of the aspect ratio. In the figure that the two-phase flow regime, the chevron angle significantly influences the heat transfer region usually characterized by convection such as convective boiling or shear control condensation.

Here you see the two-phase flow in the heat exchanger. In this chapter, we have discussed various anatomies of the plate and trim heat exchanger. What is the importance of a different type of angle chevron, especially the chevron angle? We have discussed the broad spectrum of corrugated plate structures.

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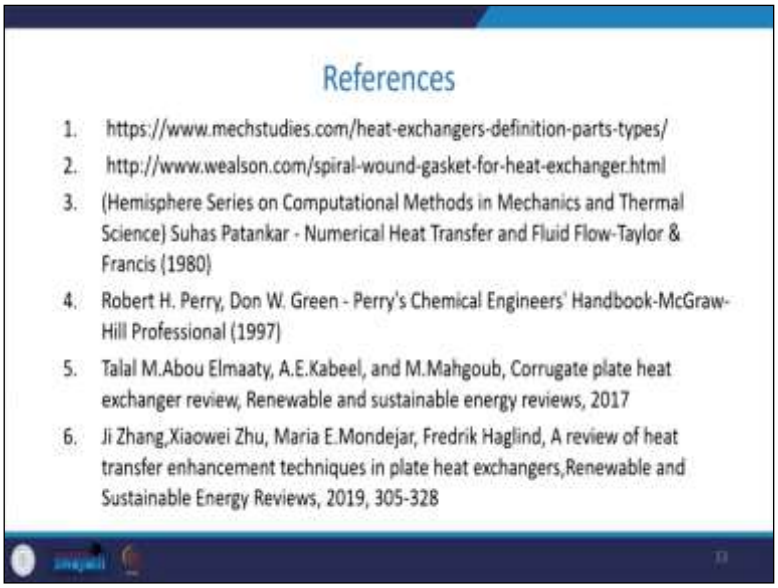

If you wish to have further reading, we have enlisted various references for convenience. Thank you very much.