Chemical Process Utilities
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Lecture – 8
Plate and Frame Heat Exchangers Types

Welcome to the new lecture on a plate and frame heat exchanger. This particular lecture will discuss the different types of plate and frame heat exchangers. So, earlier, we had discussed the plate and frame heat exchangers, different types of anatomy, the integral parts of these plate and frame heat exchangers, and the different applications of these plate and frame heat exchangers.

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In this particular lecture, we are going to continue with the plate and frame heat exchangers and thereafter, we will discuss the spiral plate exchangers, we will discuss the various aspects of heat exchanger designs, and we will discuss the MTD that is called the mean temperature difference.

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Continuation with the plate-type heat exchanger let us discuss the welded and braised pleat plate exchanges. This particular group of plate exchangers has been used for a great variety of designs for various applications, from normal gasketed plate exchanger services to air preheater service or on-fire heaters or boilers. See the preheater services are extremely important to prevent thermal shock.

Imagine the scenario your boiler is working under the specified pressure at say 200 degrees Celsius, and if you introduce the water at say 40 degrees Celsius or 50 degrees Celsius, then there may be a chance of thermal shock. So, therefore preheating services are essential. So, you can have a range of temperatures through which you can minimize the impact or adverse thermal impact to the boiler or fire heaters.

The intent here is to discuss more traditional heat exchanger designs, not the heat recovery design on the fire equipment or fluid gas streams. These flue gas streams are again very important because they carry a substantial quantity of heat. And if you let it go, it is definitely a great loss, and simultaneously, you have to maintain an adequate temperature so that it can pass through the desired barrier.

Therefore, you must have a proper heat exchanging device to extract the excess amount of heat inherent to the flue gas stream, which is also up to the different norms. We will discuss the various parameters attached to this particular concept. Many similarities exist between these products, but the manufacturing techniques are quite different due to the normal operating condition under these units they are experiencing.

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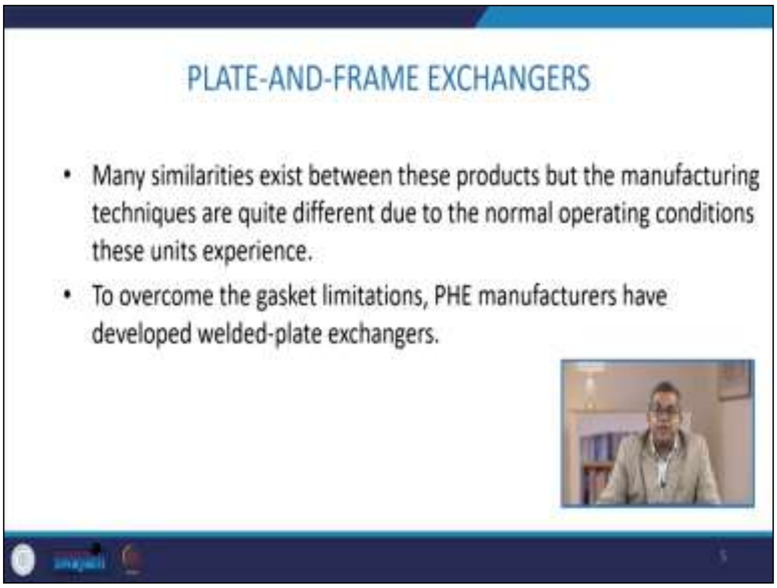

The plate heat exchanger manufacturer manufacturers have developed welded plate exchangers to overcome the various gasket limitations.

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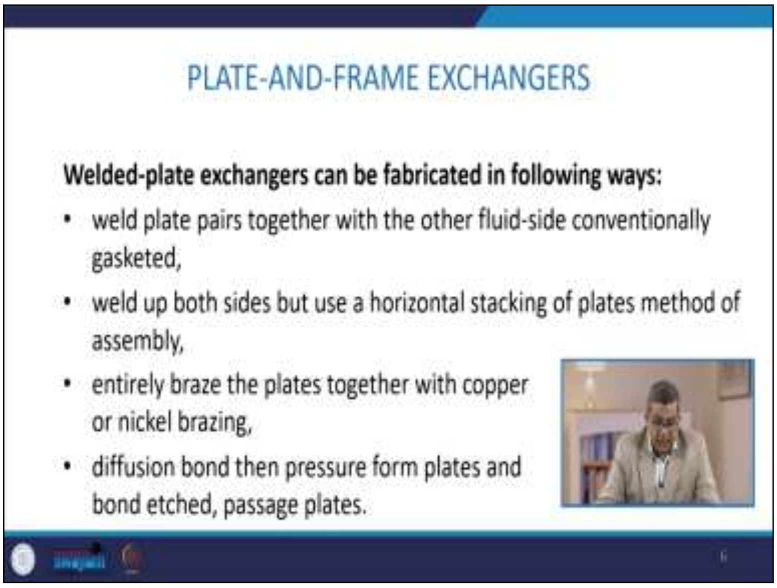

What are these welded plate exchangers? These can be fabricated in different ways; weld plate pairs together. These are the plate pair pairs, and then they weld together with the other fluid side conventionally gasketed. Weld up both sides but sometimes use horizontal stacking of plate method for assembly entirely brace the plates together with the copper or nickel brazing and diffusion bond then the pressure from plates and bond itches passage plates.

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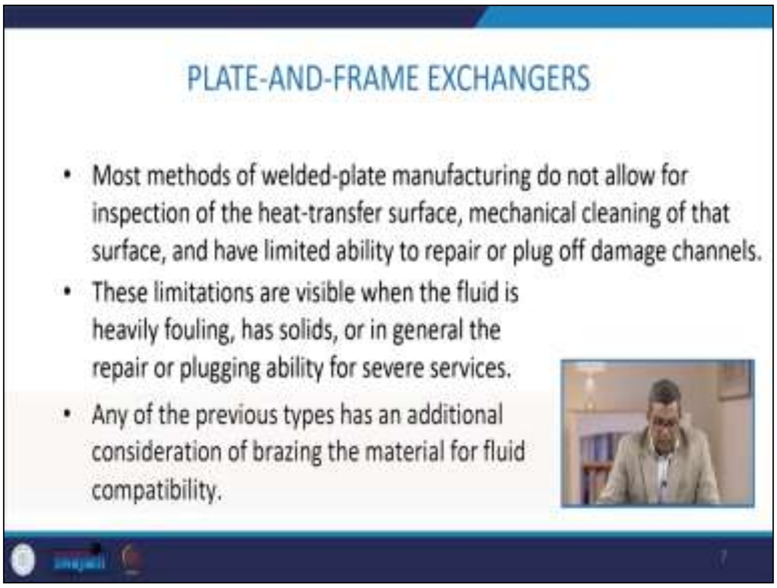

Most methods of these welded plate manufacturing do not allow for inspection of heat transfer surface mechanical cleaning of that surface and have a limited ability to repair or plug off damage channels, and these are extremely important because over time with use, this kind of deficiency may occur. These limitations are usually visible when fluid is heavily fouled; it may have solid or the repair or plugging ability of severe services.

If you have any previous type, then there is an additional consideration of brazing the material for fluid compatibility. The brazing compound entirely coats both the fluid heat transfer surface as well as the entire surface. Another category is the Compabloc type of heat exchanger. It has the advantage of removable cover plates similar to air-cooled exchanger headers or observing the fluid surface area—the fluid flow at a 90-degree angle to each other on a horizontal plane.

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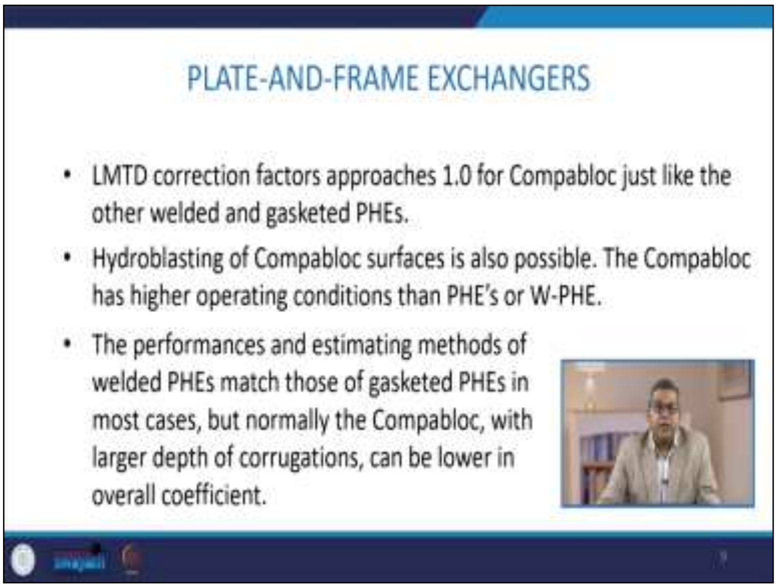

Logarithmic mean temperature distribution LMTD correction factor approaches one for Compabloc just like the other welded and gasketed plate heat exchangers. Hydro blasting of a compact block surface is also possible. Compabloc has higher operating conditions than plate heat exchangers or welded date heat exchangers. In most cases, the performances and the estimation method of welded plate heat exchangers match those of gas gated plate heat exchangers. But normally, the Compabloc with a larger depth of corrugation can be lower in overall coefficient.

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Some extensions of the design operating conditions are sometimes possible with welded plate heat exchangers, and most notably, cryogenic applications are sometimes possible. Pressure vessel code acceptance is available in most units. Now, pressure vessels because of the application of pressure in different types of vessels, so, pressure vessel codes are developed in due course of time.

So, it is necessary that they must have some acceptance of these special vessel codes. let us have a look at the spiral plate heat exchangers SHE.

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The spiral plate heat exchanger may be one exchanger selected primarily on its virtues and not on its initial cost. The spiral plate heat exchangers offer high reliability and online performance in many severely fouling services; sometimes, you may experience such situations in various slurries. This spiral heat exchanger is formed by rolling two strips of a plate with welded on spacer studs upon each other into a clock spiring shape.

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It forms the two passages. The passages are sealed off on one end of the spiral heat exchanger by welding a bar into the plate; hot and cold fluid passages are sealed off on the opposite end of the spiral heat exchangers. A single rectangular flow passage is formed for each fluid producing very high shear rates compared to the tubular design. Removable usually removable covers are provided on each end to access and clean the entire heat transfer surface.

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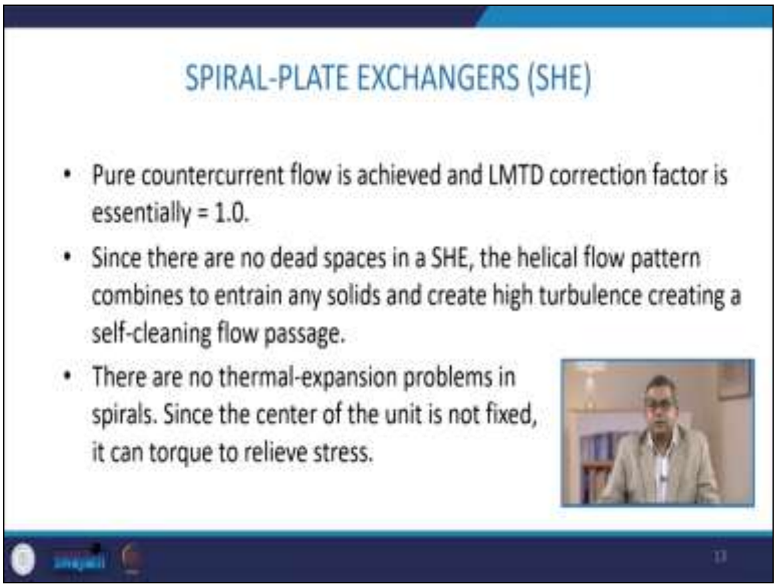

Pure counter-current flow is usually achieved, and LMTD correction factor is essential to 1. since there is no dead space in the spiral heat exchanger, the helical flow pattern combines the in train any solid or creates high turbulence creating a self-cleaning flow passage. So, this is the added benefit. There is no thermal expansion problem in spirals since the center of the unit is not fixed; it can torque to relieve stress.

But the spiral heat exchangers can be expensive when only one fluid requires high alloy materials. Since the heat transfer plate contacts both fluids, it is required to be fabricated out of the higher alloy of the spiral heat exchangers. These can be fabricated out of any material that can be cold worked and welded. The channel spacing can be different on each side to match the flow rates and pressure drops in the process design.

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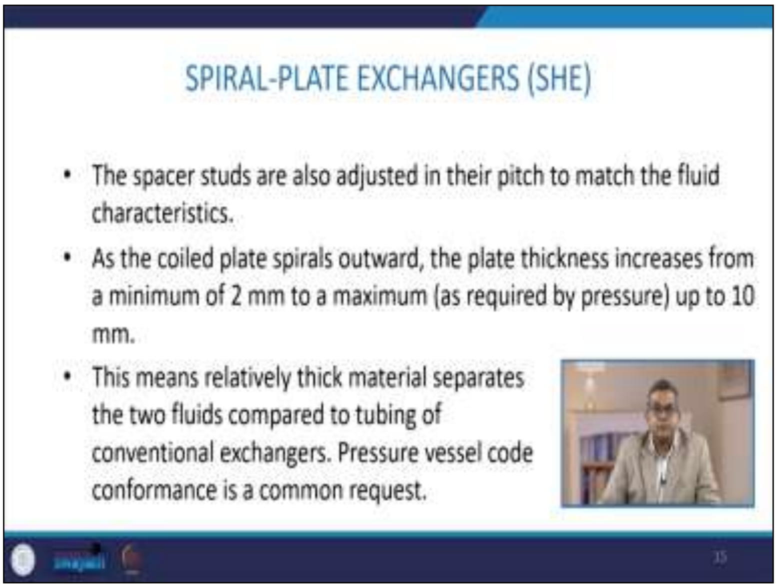

The spacer studs usually adjusted their pitch to match the fluid characteristics. As the coiled plate spirals, they are outward, and the plate thickness increases from, say, a minimum of 2 mm to a maximum (as based on the pressure), and it can go up to say 10 mm. So, therefore the relatively thick material separates the two fluids compared to the tubing of conventional heat exchangers. Again pressure vessel code compliance is a common requirement in this type of thing.

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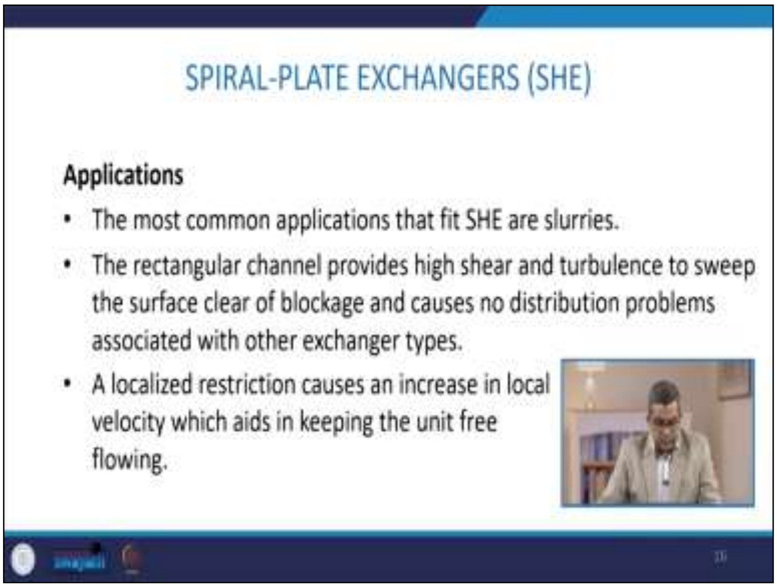

Let us talk about the various application of these spiral plate heat exchangers. The most common application that fits the spiral heat exchanger is slurry. As you notice or as we discussed that this is, it is more fruitful to use the spiral heat exchanger for different types of studies. The rectangular channel provides the high shear and turbulence to sweep the surface clear of any kind of blockage and causes no distribution problems associated with the other type of heat exchanger.

A localized restriction sometimes causes an increase in local velocity, which keeps the unit free-flowing. Only long and stringy fibers cause spiral heat exchangers to have a blockage, and it cannot clear motive as an additional anti-fouling measure. These spiral heat exchangers have been coated with a phenolic lining. So this provides some degree of corrosion protection, but it is not guaranteed due to the pinholes in the lining process.

There were three different types when we discussed spiral plate heat exchangers. So, there are various types of these heat exchangers. So, usually, three types of spiral heat exchangers fit various applications.

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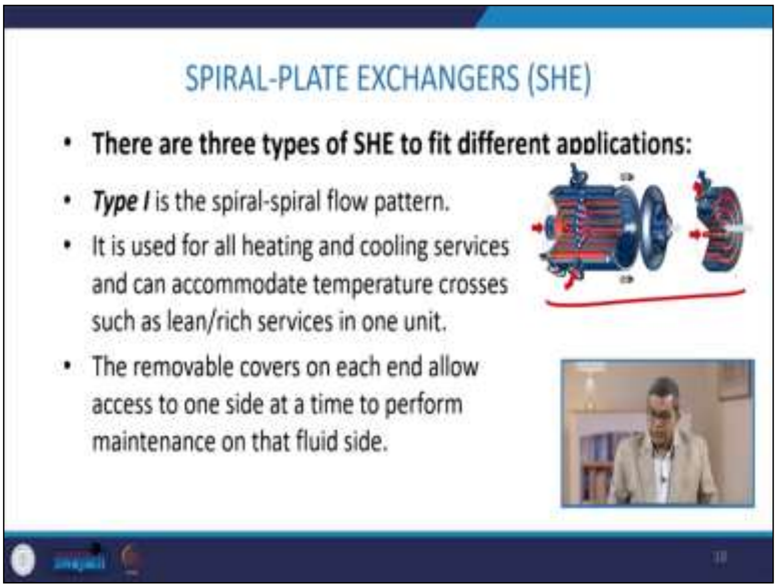

Here you see the anatomy of spiral heat exchanges. Type1 is the spiral-spiral flow pattern. It is used for heating and cooling services and can accommodate temperature crosses such as lean-to-rich services in one particular unit. The removable cover on each end allow access to one side at a time to perform maintenance on the fluid side.

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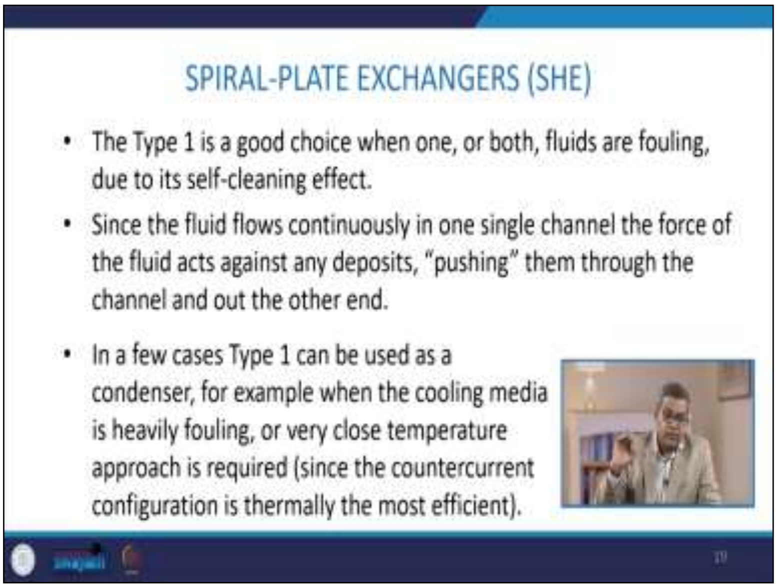

Type-1 is a good choice when one or both fluids are fouling. This is a very common phenomenon in chemical engineering applications. This is just because of its self-cleaning effect. Since the fluid flows continuously in one single channel, the force of the fluid acts against any kind of deposit, pushing them through the channel and out the other end.

In a few cases, this type of this type can be used as a condenser, like when the cooling media is heavily fouled or a very close temperature approach is required since the counter-current configuration is thermally most efficient. The compact nature of the type-1spiral heat exchanger often allows several large shell and tube units to be replaced by one single spiral heat exchanger.

It gives considerable infrastructure benefits and a reduction in maintenance and cleaning activities.

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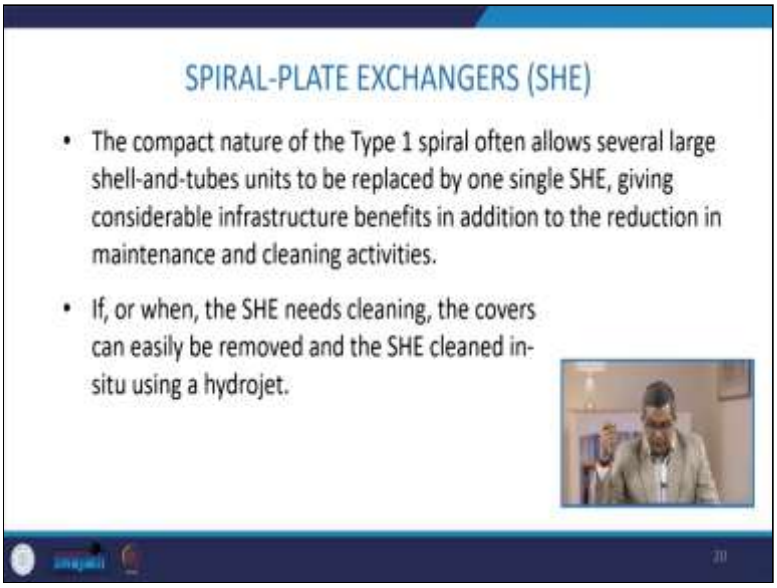

So, if we see the feasibility, especially the economic feasibility, they are a good candidate. If or when the spiral heat exchanger needs cleaning, the cover can easily be removed, and SHE can be cleaned in-situ using the hydro jets. There are various benefits associated with this. Virtually you may find no fouling or clogging; they possess various reliable operations with maximum uptime. You can easily open it clean it they offer the very low maintenance cost by this way.

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Energy saving is due to the high heat recovery, and above all, they are very compact in nature. You may find various applications, especially with respect to fouling liquids.

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Those containing the solids fibers liquor slurries sludges etc liquid-liquid like preheating heating cooling interchanging and when you require any kind of a heat recovery from any fluid.

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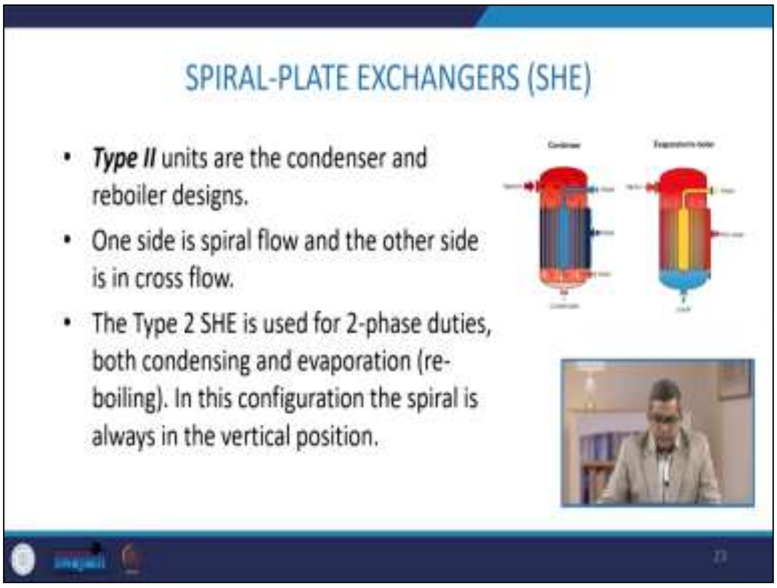

Let us discuss the type 2 units. They are the condenser and reboiler designs. Here you see these are the condensers and reboilers. They are very common in chemical engineering operations like reboiler refineries this more common condenser again the refinery operation. So, here you are introducing the vapor water inlet water outlet and the condensate outlet.

Similarly, you are introducing the liquid hot water, you are getting the vapors that are the reboiler, and obviously, whatever water this is coming out. one side is the spiral flow, and the other side is in crossflow. So, this type, type 2 spiral heat exchanger, is used for two-phase duties, both condensing and evaporation, that is, the reboiling. In this configuration, the spiral is always in the vertical position you can see over here.

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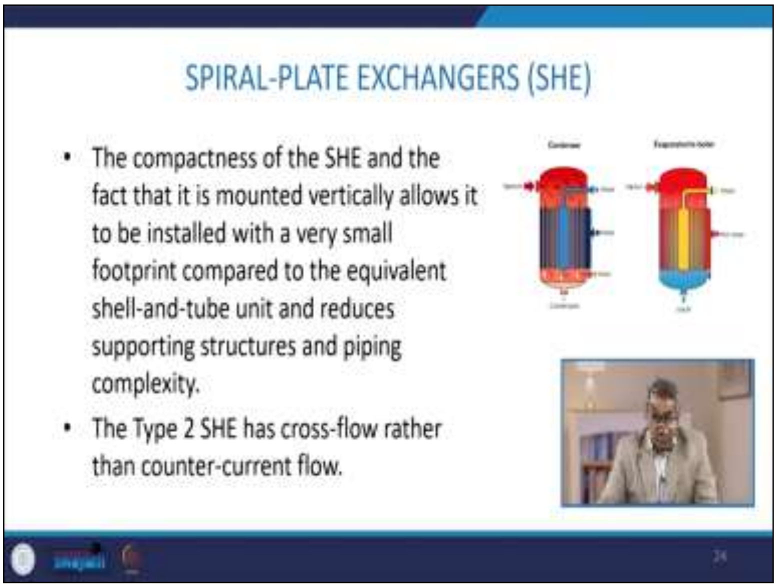

The compactness of the spiral heat exchanger and the fact that it is mounted vertically, allows its installation with a very small footprint compared to the equivalent shell and tube unit and reduces supporting structure and piping complexity. The type 2 spiral heat exchanger has cross-flow rather than counterflow.

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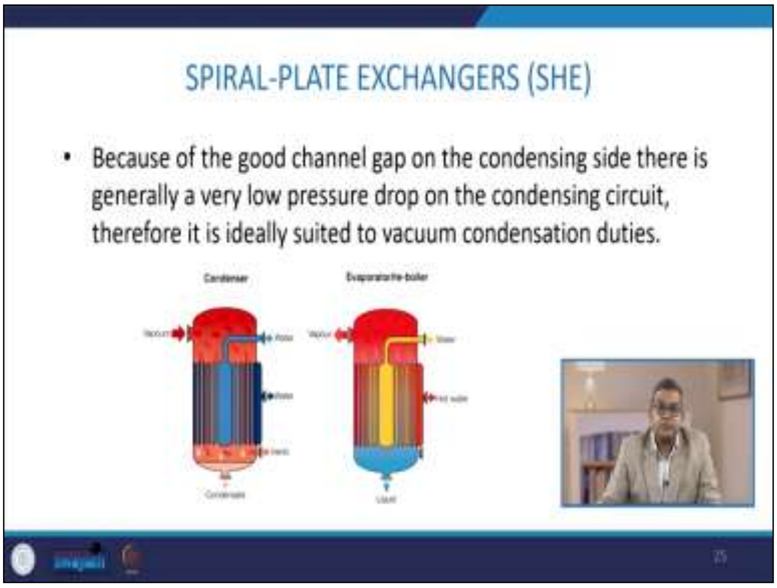

Because of the good channel gap on the condensing side, there is generally a very low-pressure drop on the condensing circuit. This is a very common problem because when there is condenser condensation, there is a drastic pressure change. So, when we have a very low pressure drop on the condensing circuit, it is ideally suited for vacuum condensation duty. So, again one broad spectrum of its applications is covered.

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These spiral heat exchangers provide a very stable design for vacuum condensing and reboiling services. A spiral heat exchanger can be fitted with a special mounting connection for a reflex-type vent condenser application. The vertically mounted spiral heat exchanger directly attaches to the column or tank.

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There are several benefits associated with the spiral plate heat exchanger that is type 2. They have a low-pressure drop which is ideal for vacuum condensation. They possess a reliable operation with maximum uptime, low maintenance cost and are compact and easy to install.

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They offer a wide spectrum of applications like in gases pure vapor and mixture with inert gases.

Vapor/liquid: the top condenser, reflux condensers, vacuum condensers, vent condensers, reboiler with fouling fluid, and gas coolers.

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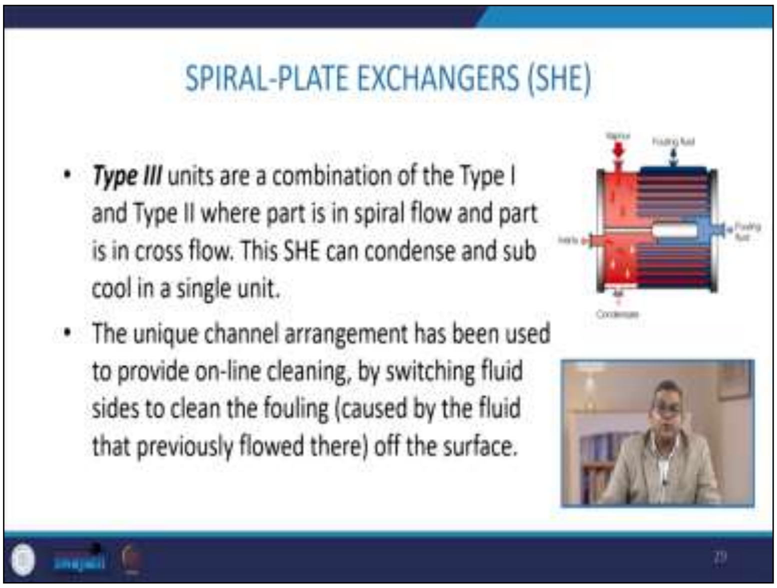

Let us discuss the type 3 type of spiral plate heat exchanger. These units are the combination of type 1 and type 2, where part is in the spiral flow, and the part is in the cross-flow you can see this figure over here. These spiral heat exchangers can condense and sub-cool in a single unit. The unique channel arrangement has been used to provide online cleaning by switching fluid side to clean the fouling and sometimes caused by the fluid which has been previously floating there, and that is to the of the surface.

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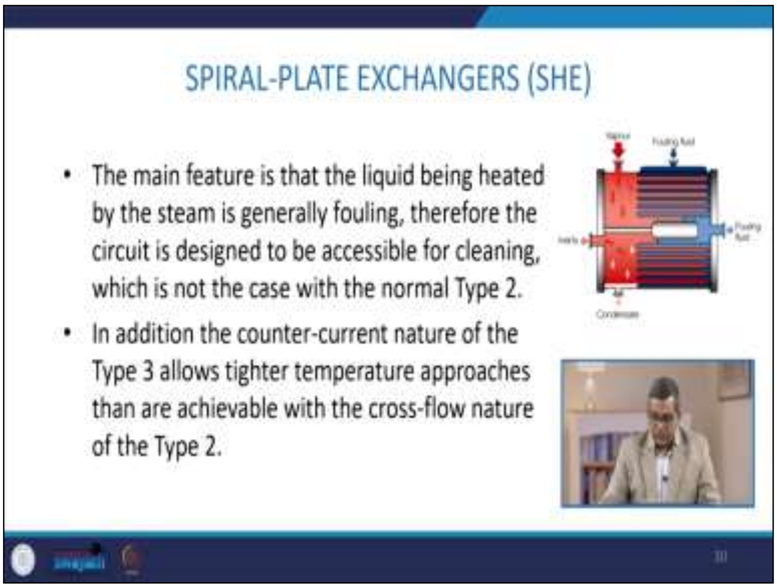

The main feature is that the liquid being heated by the steam is generally fouling; therefore, the circuit is designed to be accessible for cleaning, which is not the case with the normal type 2 we discussed earlier. So, this offers an added benefit. The counter-current nature of type 3 allows the tighter temperature approaches than the achievable with the cross-flow nature of type 2.

So, again it offers the added benefit. The phosphoric acid coolers use pond water for cooling, and on both sides falls water. As you can expect that phosphoric acid deposits crystals. So, by reversing the flow side, the water dissolves the acid crystals and the acid clean clears up the organic fouling.

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So, the spiral heat exchangers are also used as oleum cooler sludge cooler heater stop oil heaters and other services where the multiple flow passage design has not performed well.

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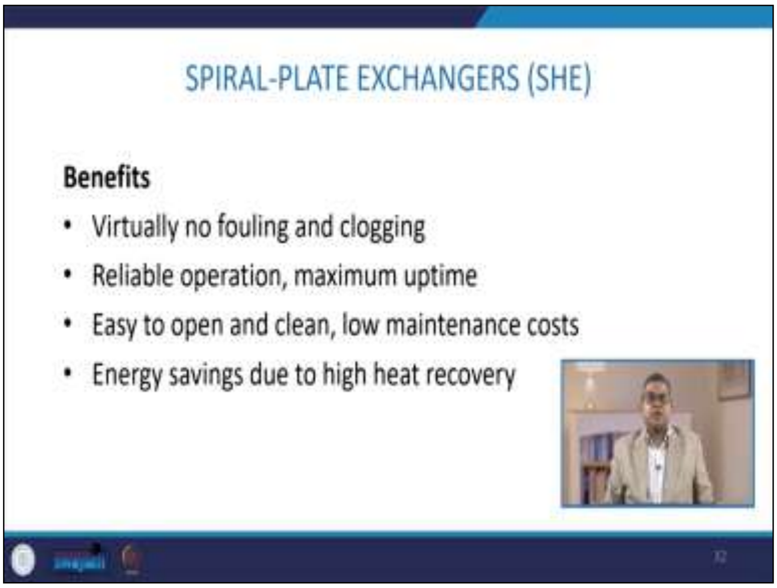

There are various benefits associated with the spiral plate heat exchangers especially type three. Virtually no clogging, no fouling, it is again the reliable operation with the maximum uptime, you can easily open and clean with a low maintenance cost, and because of the high heat recovery, you can save substantial quantum of energy.

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The application is quite obvious as we discussed that fouling liquid containing solids fibers, liquors slurries, sludges requiring heating by steam. We have discussed significantly different types of heat exchangers. Question arises that what should be the approach to design the heat exchanger.

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Usually, it is anticipated that one must have basic heat transfer knowledge or proper heat transfer knowledge in the design of practical heat equipment, and usually, this is an art. Designers must be constantly aware of the differences between the idealized conditions for and under which the basic knowledge need to be obtained and these needs to be in line with the real condition of the mechanical expression of their design and its environment.

All the results must satisfy the process and the operational requirement because sometimes the operational requirements may be different compared to the theoretical requirement. These are such that like availability, flexibility, maintainability, etc. Above all, the economic feasibility needs to be addressed.

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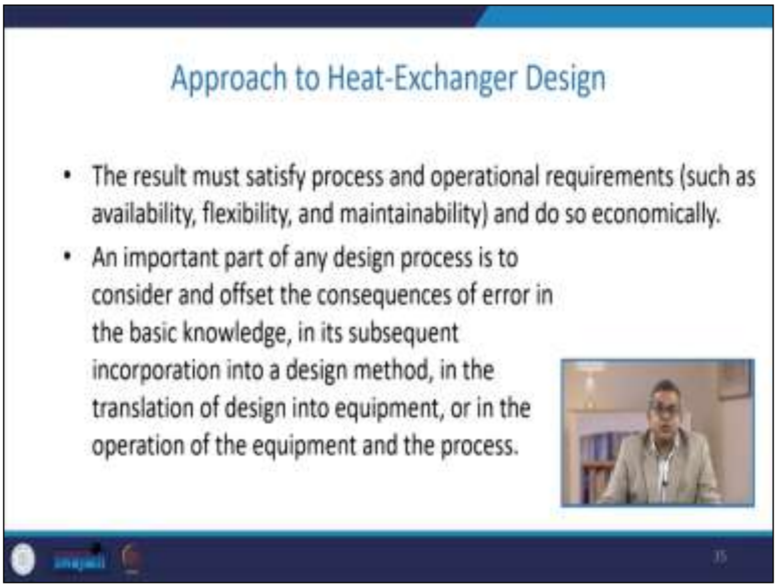

An important part of any design process is to consider and offset the consequences of error in the basic knowledge and its subsequent incorporation into a design method. Now, in the translation of the design into equipment or in the operation of the equipment and in the process.

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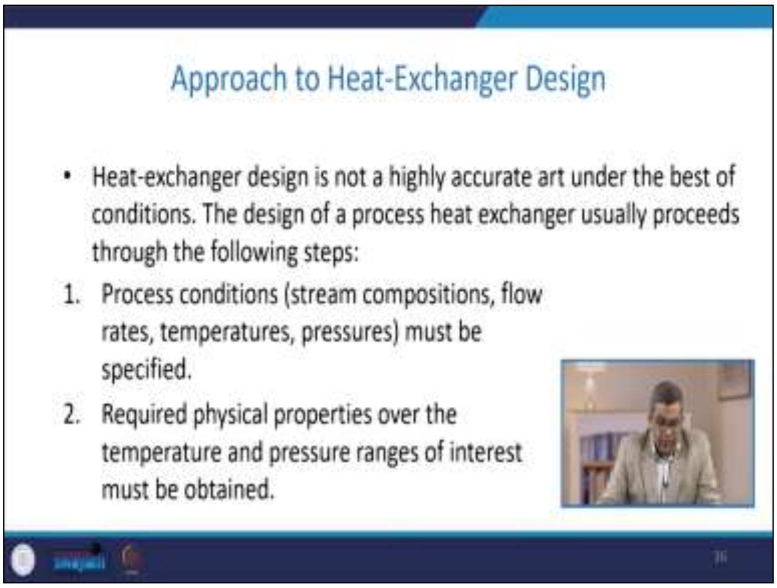

Heat exchanger design is not a highly accurate art under the best condition. The design of the process heat exchanger usually proceeds through different steps like process condition, what is the stream composition, flow rate temperature pressure all these things must be specified. Next is the required physical properties over the temperature and pressure ranges of interest. These must be obtained.

Then you are as you see that you have wide choices of heat exchangers. So, the appropriate type of heat exchanger needs to be employed for that particular application.

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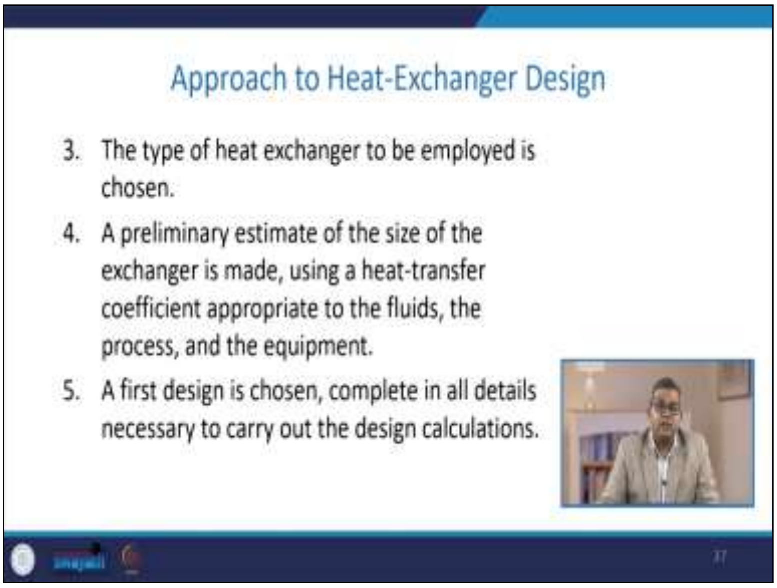

A preliminary estimate of the size of the exchanger is usually made using the heat transfer coefficient appropriate to that particular flute or galaxy of fluids. The process and the equipment also need to be addressed. Usually the first design is chosen completely in all detail necessary to carry out the design calculation.

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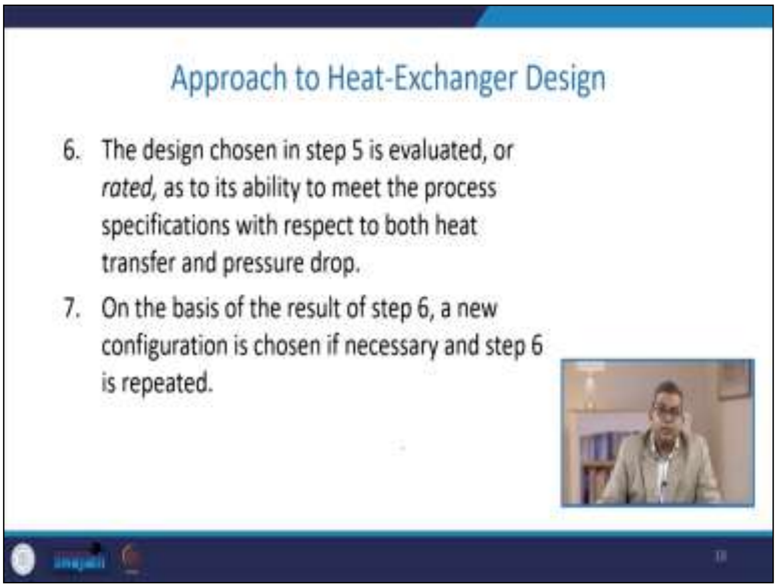

The design chosen in this particular previous step needs to be evaluated or rated as to its ability to meet the process specification with respect to both heat transfer and pressure drop. on the basis of the result of this particular step, a new configuration is chosen if required I mean that all depends on your calculation and if it is not acceptable then again this step needs to be repeated.

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If the first design is inadequate to meet the required heat load, it is usually necessary to increase the size of the exchanger while still remaining within the specified or feasible limit of pressure drop tube length, shell diameter etcetera. This sometimes means going to a multiple exchanger configuration.

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If first design more than meets the heat load requirement or does not use all the allowable pressure drop or a less expensive exchanger can sometimes be usually designed to fulfill the process requirement. One final design should meet the process requirements within the reasonable expectations of error, and this must be based on the process requires it must be of a lower cost or the lowest cost.

The lowest cost should include operation and maintenance cost credit for the ability to meet the long-term process changes as well as installation or the capital cost.

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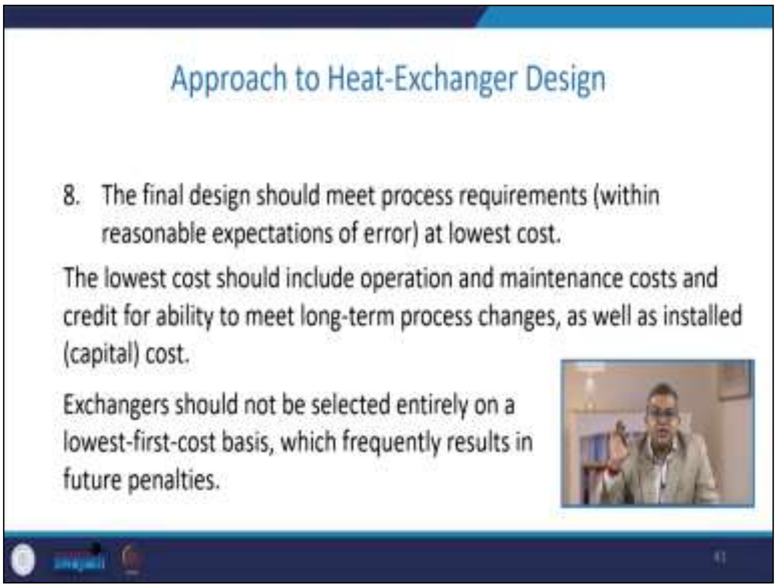

Exchanges should not be selected entirely on a lowest first cost basis which frequently results in the future penalties because sometimes, if you go for various kind of say, flexibility another thing, then probably your exchanger will not work adequately.

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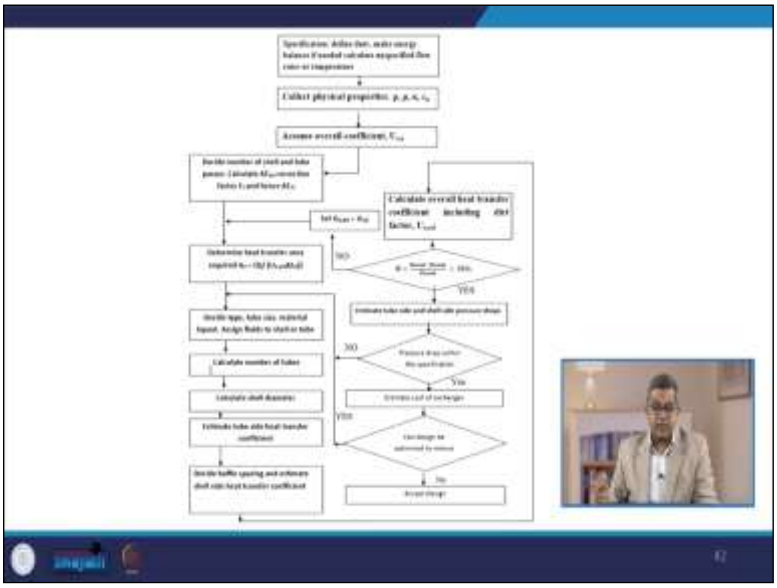

Here you see the entire flow chart that is the first-hand specification you need to define the duty sometimes make energy balance to calculate the unspecified flow rates or a temperature. Then you need to collect all the physical properties required for carrying out the calculation. Assume the overall heat transfer coefficient, then you decide the number of shells and two passes you need to calculate the LMTD correction factor and delta T medium.

Determine the heat transfer area which is required based on your standard heat transfer equation, then you decide the different type of tube size material layout you may assign fluids to a shell or a tube that all depends on the choice, then you calculate the number of tubes. Then shell diameter needs to be calculated, then you need to estimate the tube side heat transfer coefficient and decide the spacing and estimate the shell side heat transfer.

Simultaneously you need to calculate whether your system or blocks are acceptable or not if not, then you need to carry out all these things accordingly, and finally you may go to accept the design.

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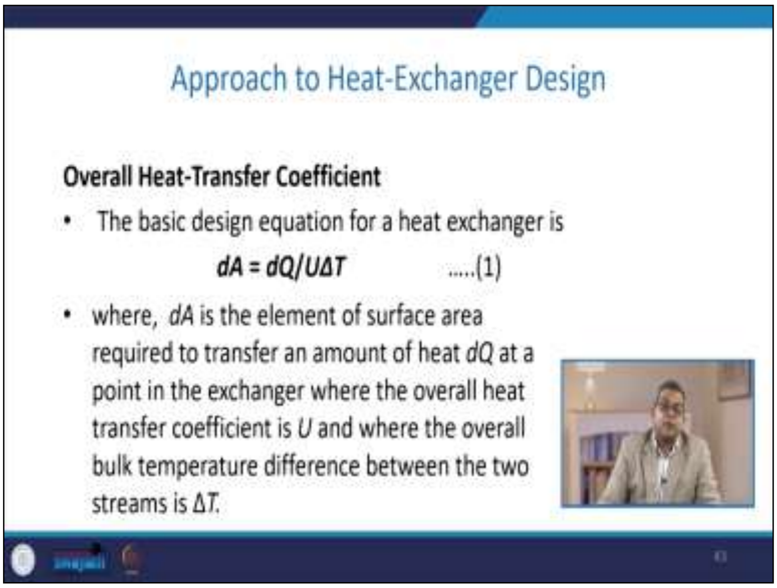

While designing the important factor is the overall heat transfer coefficient. the basic design equation for the heat exchanger as we can discuss here that is

$$dA = dQ/U\Delta T$$

where dA is the element of surface area because surface area plays a vital role in the heat exchanger this required to transfer an amount of heat which is represented as dQ.

At a point in the exchanger where the overall heat transfer coefficient is represented by U and overall bulk temperature difference between the two stream is delta T.

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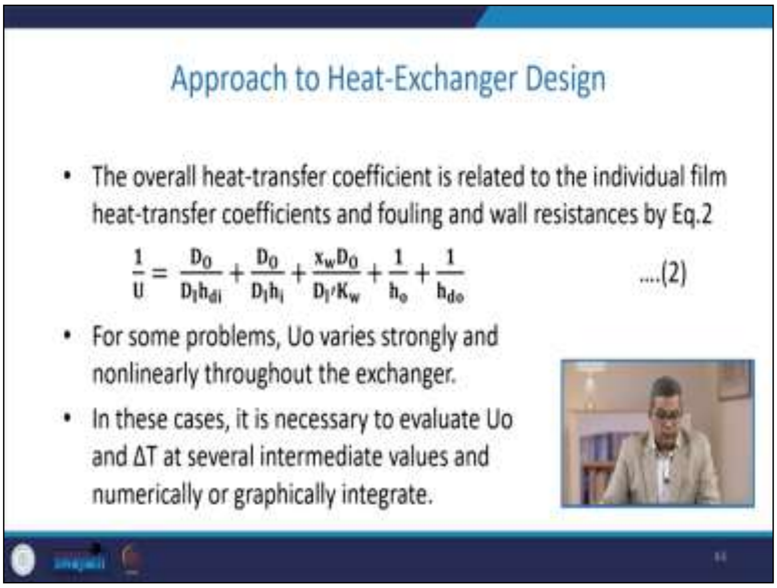

So, when we talk about the overall heat transfer coefficient, this is related to the individual film heat transfer coefficient and the fouling and a wall resistance. So, in this particular equation,

$$\frac{1}{U} = \frac{D_O}{D_I h_{di}} + \frac{D_O}{D_I h_i} + \frac{x_w D_O}{D_I' K_w} + \frac{1}{h_o} + \frac{1}{h_{do}}$$

you can see that we have incorporated all these things. For some problems this U_0 varies strongly and non-linearly throughout the exchanger. In these cases, it is necessary to evaluate heat transfer coefficient and a delta T at several intermediate values and numerically or graphically, you need to integrate all these things.

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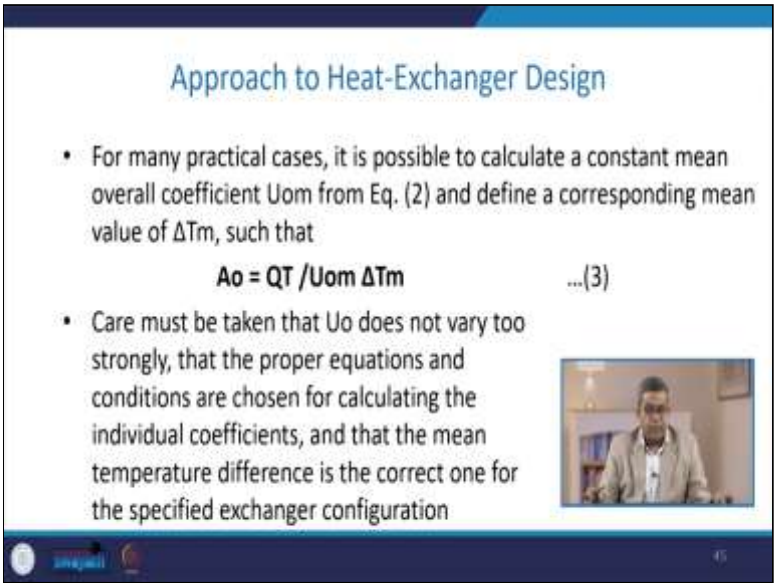

For many practical cases it is possible to calculate a constant mean overhaul coefficient that is U naught m from this previous equation and define the corresponding mean value of delta T m like

Ao = QT /Uom ΔTm

Care must be taken that U_0 does not vary too strongly that the proper equations and conditions are chosen for calculating the individual coefficients and that the mean temperature difference is the correct one for the specified exchanger configuration.

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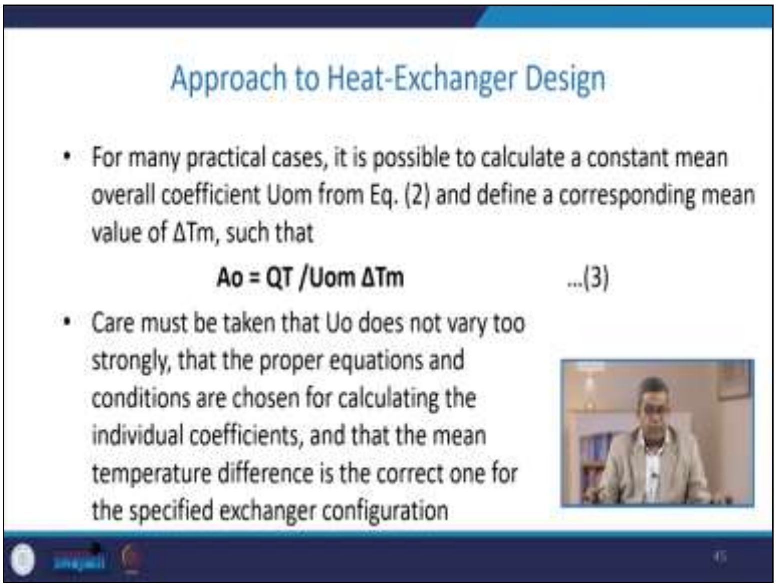

Let us have a look at the mean temperature difference. The temperature difference between the two fluids in the heat exchanger, in general, vary from point to point. The mean temperature difference is sometimes referred to as delta T m or MTD. This can be calculated from the terminal temperature of the two-stream. For this you need to assess the validity of different assumptions.

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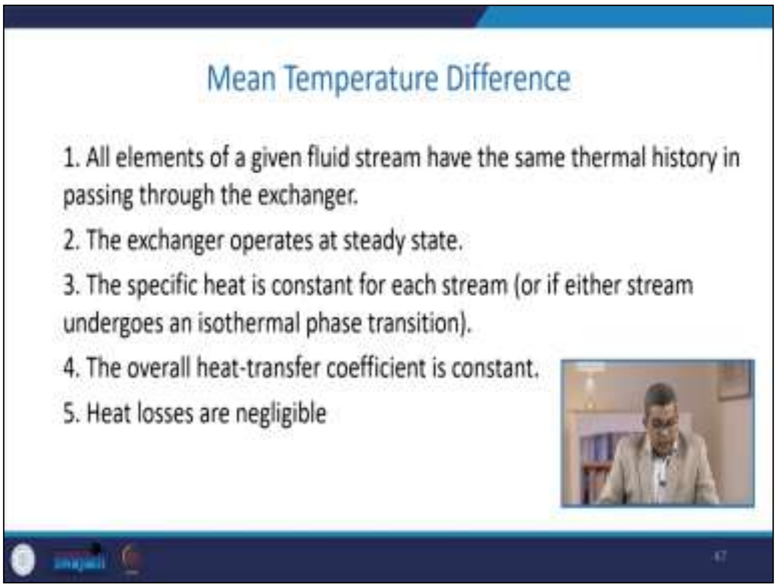

1. All elements of a given fluid stream have the same thermal history in passing through the exchanger.

2. The exchanger operates at steady state.

3. The specific heat is constant for each stream (or if either stream undergoes an isothermal phase transition).

4. The overall heat-transfer coefficient is constant.

5. Heat losses are negligible

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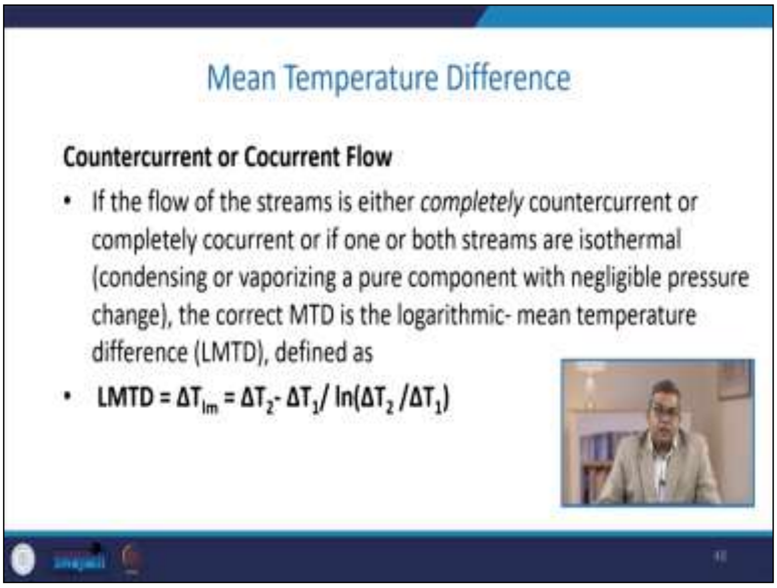

Again the question sometimes arises that counter-current or co-current flow. If the flow of the stream is either completely counter-current or completely co-current or if one or both streams are isothermal condensing or vaporizing in a pure component with negligible pressure change the correct mean temperature difference is the logarithmic mean temperature difference that is LMTD and it is defined as

$$\mathbf{LMTD = \Delta T_{lm} = \Delta T_2 - \Delta T_1 / \ln(\Delta T_2 / \Delta T_1)}$$

So, in this particular lecture, we had discussed the remaining part of our heat exchanger plate heat exchanger, and we discussed the spiral type of heat exchanger then, see all these heat exchangers needs to be designed rigorously. So, we discussed various elements of designing for heat exchangers.

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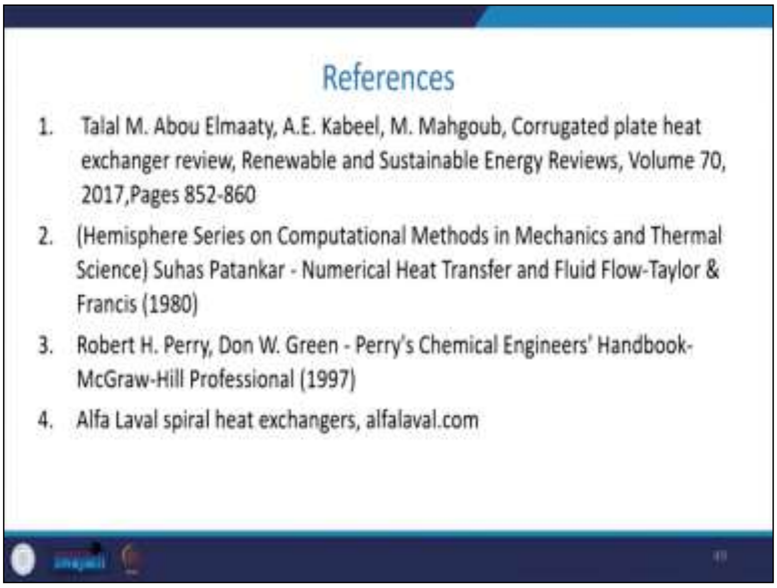

And if you wish to have further studies then we have enlisted couple of references for your convenience, thank you very much.