Thermal Operations in Food Process Engineering: Theory and Applications

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Lecture - 43
Heat Exchangers

Good morning. So, we have completed boiling condensation and earlier all kinds of transfer of heat, 'right' by conduction, convection, radiation all the modes. Now we come to a very vital of course, all are vital I do not say that this is the vital and that is not. So, all our vital and in this thing what we would like to say that heat exchanger because when you are dealing with anything where exchange of heat is there; so, that is nothing, but an heat exchanger, 'right'. So, we come to the lecture number 43 and we start Heat Exchanger, 'right'.

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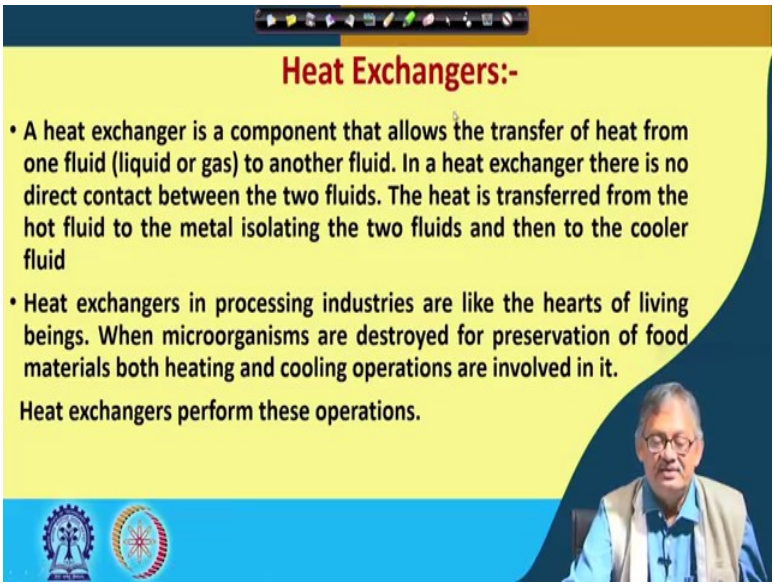

So, to do this let us take, but before we go to the heat exchanger; let me give some preamble of this is that, heat exchanger is anything where you are getting a exchange of heat, 'right'. Suppose this bottle, if it would have been a either cold or hot whatever. So, if it is cold, you are getting in your hand some cold and if it is hot, then you are getting when you are holding you are getting it very hot, 'right'. This is also a heat exchanger obviously, but; obviously, this heat exchanger has no application.

So, anything which is exchanging heat is a heat exchanger, ‘right’; is a heat exchanger, ‘right’ and one of the best heat exchanger is our heart. The nature has made such a beautiful heat exchanger that so, compact which will come across we will come across also sometime that the heat exchanger is really a subject where anywhere the exchange of heat is happening that we will take care off; that will be taken care of, ‘right’.

So, in any processes whether of course, if it is a thermal process; if it is non thermal process; obviously, that heat exchange does not come into picture; but if it is a thermal heat exchanger, then you have lot many things to know, ‘right’. And that is why in many books, you will see the type of handling is different, ‘right’. And the definition of the heat exchanger or the distribution or classification of the heat exchangers, they are also varying from book to book, ‘right’.

However, keeping in mind that majority of our students are from the food including the chemical background or including the mechanical background so, we are handling with the food. So, we would like to differentiate or we would like to classify the heat exchanger keeping that thing in mind, ‘right’. So, let us start that what is a heat exchanger. A heat exchanger is a component that allows the transfer of heat from one fluid or liquid or gas to another fluid in a heat exchanger to another fluid, ‘right’. In a heat exchanger, there is no direct contact between the two fluids, ‘right’.

In this regard, let me also tell you in some of the processes, you may come across that you have a container where you are directly putting steam, ‘right’. So, you are directly putting steam in that for warming, for doing thermal operations whatever it is the process. In that thing, if you are looking at then this is not considered to be a heat exchanger because the liquid is coming directly in contact with the steam flash evaporation, ‘right’.

So, there it is not a heat exchanger by definition. Yes, heat exchanger always where there will be exchange of heat is considered to be heat exchanger, but here also it is consider it is heat is exchange, but it is not in it is directly in contact. So, we cannot tell it to be a heat exchanger, ‘right’.

So, 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 either metal or the container. It generally metal because if you it is a heat exchanger; if you take a nonmetal,

then that nonmetal becomes an insulator. So, heat exchange will be reduced that has no meaning. So, that is why specifically we writing that metal isolating that two fluids and then to the cooler fluid.

So, from the hot fluid to the metal and then to the cold fluid that is how it is being propagated. So, hot fluid and the metal and the cold fluid, 'right'; this is how q is following, 'right'. So, heat exchangers are in processing industries are like the hearts of living beings like a living being cannot survive without the heart, 'right'. Living being; I mean macro level not the micro, 'right' whose heart is there; if heart is not at all there, then how could that be.

So, a living thing we are having heart; in that, the heart is considered to be the most vital one, 'right'. Similarly the in industry, a heat exchanger is also is considered to be the most vital one, 'right'. When micro organisms are destroyed for preservation of food materials both, heating and cooling operations are involved in it and in both the cases heating also and cooling also are done with the help of heat exchangers, 'right'. Heat exchangers perform these operations.

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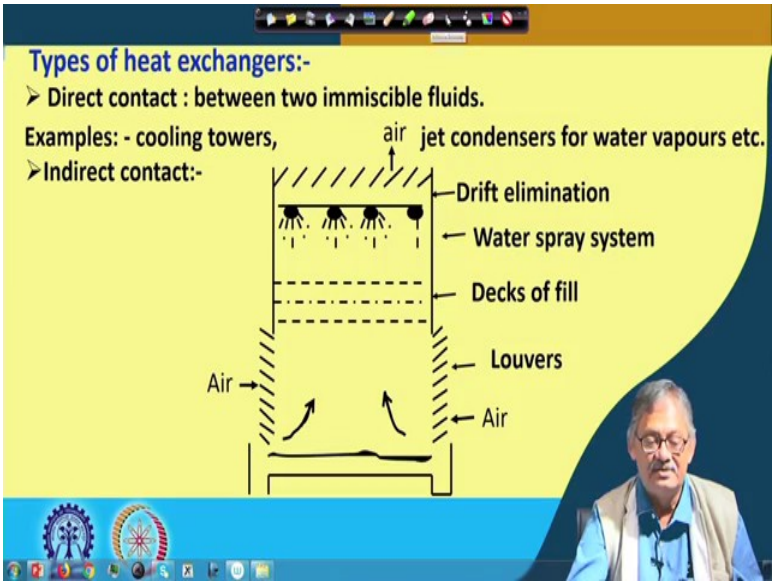

So, if we from this definition of heat exchanger, 'right' let us go into that types of heat exchangers, how many types of heat exchangers we normally come across in the industry. Number 1, direct contact between two immiscible fluids, 'right'; so, direct contact between two immiscible fluids, you remember the other one which I said that

when you are flushing with the steam, this was also water, ‘right’. So, there it is not immiscible.

So, if it is immiscible fluids, ‘right’ like air and water. Air is obviously, soluble in water, but in very very low quantity; solubility is very low, ‘right’. So, that can be assumed to be a immiscible air in water, ‘right’. So, between two fluids which are in directly contact?

For example, cooling towers, ‘right’; cooling towers, you will come across in most of the big buildings where it may be that that cooling tower is in front of the building and a picture as you are seeing here things like that there is a pond and there are some beautiful sprays and that many many cases beautifies that building, ‘right’ that is also there.

But; however so, when this two immiscible liquids for example, cooling towers is there, then jet condensers for water vapors etcetera. They are used when two immiscible fluids are directly in contact, ‘right’ or it can be indirect contact also. So, two fluids are indirect contact means one fluid is flowing like this and the other fluid is flowing within this, ‘right’.

So, this is one fluid and the other fluid is flowing like that. So, in that case, it is not coming in direct contact. So, in terms of contact of the two fluids which are exchanging heat, it can be first divided whether it is in direct contact or it is not in direct contact, ‘right’.

So, in that if we look at the cooling tower, ‘right’; in most of the cooling tower, you will see that a draught of air is going from the bottom and liquid is being spread from the top, ‘right’. And there is a liquid through which this air is going in and coming in contact with the droplets of the water. And there the water is giving away the latent heat of vaporization to this water or air, ‘right’ and then this air goes out to that.

Thereby the temperature of the water is gradually going down which is maybe this cold water may be used in many many other heat exchangers, ‘right’. For example, in our institute there is one cryogenic engineering center where we have liquid nitrogen liquid helium they are being produced. So, lot many heat exchangers are there. In that, this there is outside the one cooling tower like this and that cooling tower cools the air. This cold air is utilize in those heat exchangers, ‘right’.

So, the and there it may be in this is air it is directly indirectly in contact they are also; this is air it is in direct contact and there it may be in not in direct contact, 'right'. So, this type of heat exchangers are very useful where heat is being accessed by the two immiscible fluids; in this case water and air, 'right' ok.

So, we are not going of course into detail of the description of the cooling tower because if we put our mind into that, then the general approach or the idea of the course that the exchange of heat thermal that we are not able we will not be able to cover. So, we are not saying how these things are being constructed. It is true that in operation this air is sucked in and then that exchanges heat with the liquid or water droplets which are coming from the top.

And these air goes out exchanging the heat along with some vapour which is formed due to the latent heat of vaporization of water which it gives to the remaining water and this air water, they are the two fluids which are exchanging the heat, 'right'; this is in cooling tower.

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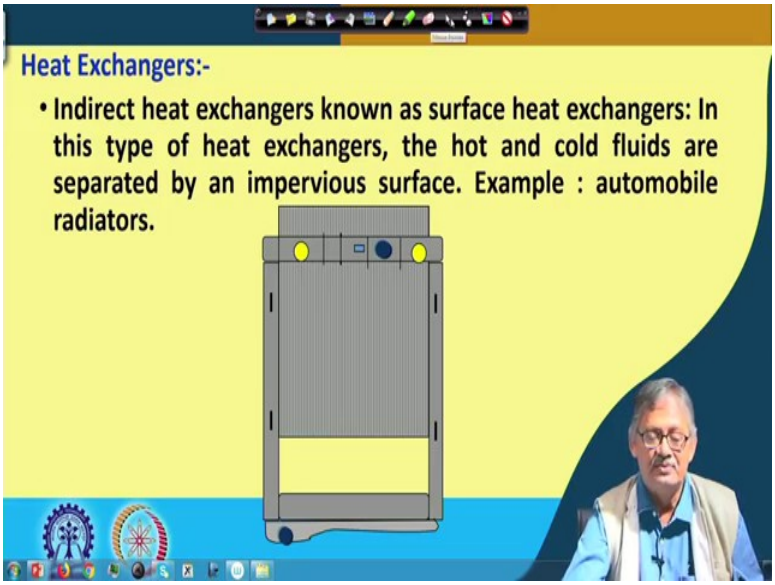

Similarly, other heat exchangers which you come across very very frequently is that is the indirect heat exchanger 'right' and known as surface heat exchangers in this type of heat exchangers; the hot and cold fluids are separated by a impervious surface.

For example, automobile radiators; in the car radiator that is also another very very great example of heat exchanger where the engine heat is car engine heat is being dissipated or is being exchanged through a car radiators where a cold fluid is inside and the hot fluid is outside or they are exchanging the heat and thereby cooling the engine, ‘right’.

So, this is the of course, the radiator not the engine, ‘right’. So, car radiator is another great example the earlier one for direct contact. We had shown you the great example as a cooling tower and here for indirect exchange where it is the car radiator, ‘right’. These are the two great examples for the two cases, ‘right’.

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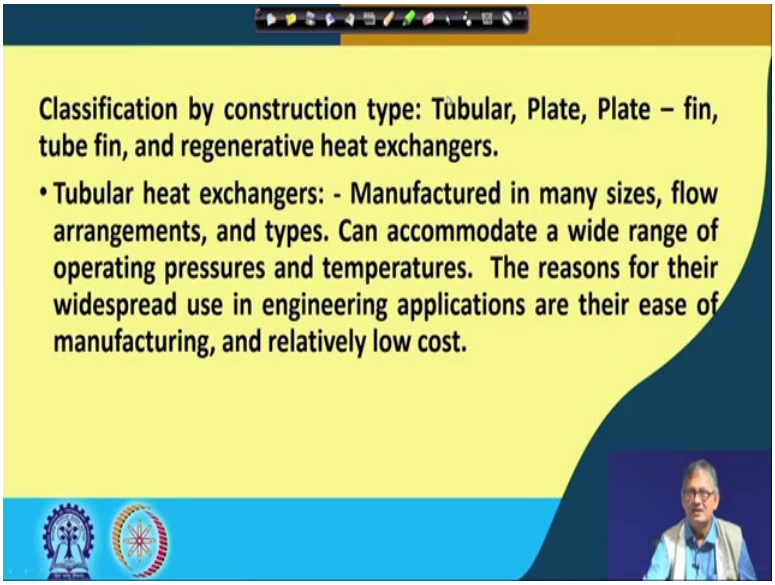

So, if we look at further, then we see that the classification by construction also can be done, ‘right’. The type of construction which is there based on that can be classified as the tubular type or plate type or plate and fin type a tube and fin type and regenerative heat exchangers, ‘right’. So, they are based on the type of construction; the heat exchanger is classified, ‘right’.

In the tubular heat exchanger, this is manufactured in many sizes and flow patterns or flow arrangements and types also. This can accommodate a wide range of operating pressures and also temperatures tubular type heat exchangers. The reasons for their widespread use in engineering applications are there ease of manufacturing and relatively low cost, ‘right’. Like as I gave the example our heart, ‘right’, our heart is one of the great example of the heat exchangers this is done by the nature.

Now, if you want to replicate it; number 1, it is still now it is not it could not have been possible by any engineering anywhere in the world, 'right'. Nature has made such a beautiful thing which is yet not possible to replicate, but assuming if it could be then the cost would have been so high that the application could be virtually negligible.

So, if we do something, you also have to look into the price; cost. So, that is there one of the vital reasons, why the tubular heat exchangers are commercially very widely used, 'right' because of two reasons. Number 1, it is very easy to manufacture and number 2, the cost of manufacturing is comparatively means comparison to others; other type of heat exchangers it is so, not so costly, 'right'.

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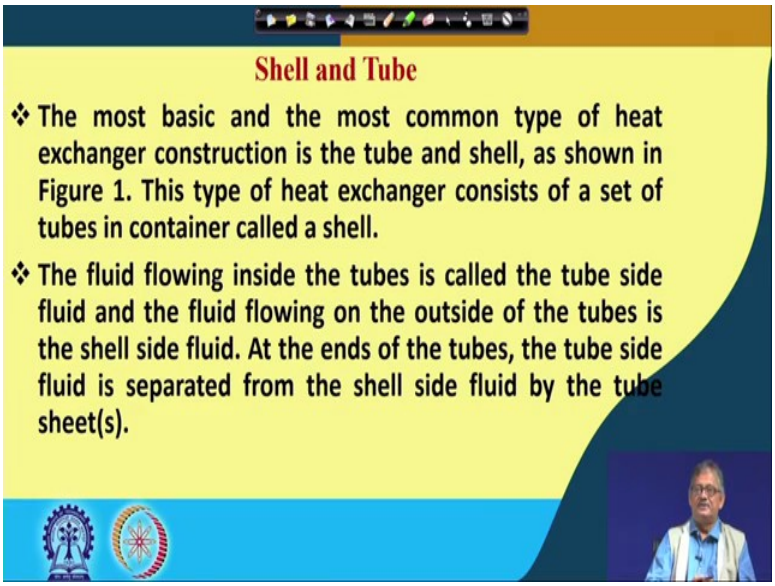

Then after the tubular tab that tubular we can say shell and tube is one of the best example. So, shell and tube heat exchangers are like this is the most basic and the most common type of heat exchanger is the in construction is the tube and shell as ok. We will be showing in a picture or figure which is drawn afterwards it is shown. So, this type of heat exchanger consist of set of tubes and in container called a shell. So, set of tubes and in container with a shell, 'right'.

So, outer one will be the shell and the inner ones are the tubes. So, that is why it is called shell and tube, 'right'. The thing is like tortoise that is if they have a shell, 'right'; those kind of thing which there is a coating outside, 'right' whereas, inside is very very I mean preserved or it can be said that safe. So, here also from that point of view or angle, this

has come that the shell is from the outside and the inner things are made of many tubes and that is how the tubes are safe or tubes are not under threat of any damage. So, that can be because of this shell which is protecting it; so, that is how it is shell and tube heat exchanger, 'right'.

The fluid flowing inside the tubes is called the tube side fluid and the fluid flowing on the outside of the tube of the shell is called shell side fluid, 'right'. At the ends of the tubes, the tube side fluid is separated from the shell side fluid by tube sheets, 'right'. Example we said that we will show the picture and that comes like this perhaps afterwards, it will come let me tube and shell this is one, 'right'.

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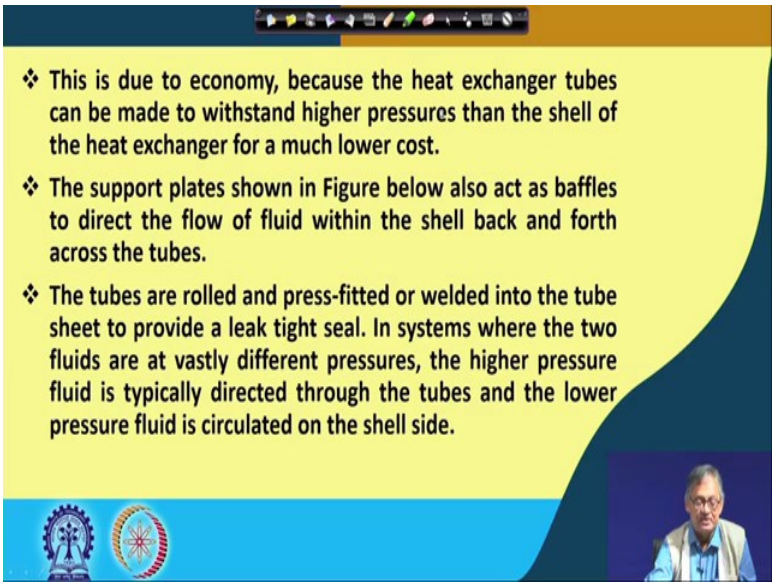

This is a commercial one, 'right' tube and shell we will go back to that, but before that you see number of tubes are there and this outside one is the shell, 'right'.

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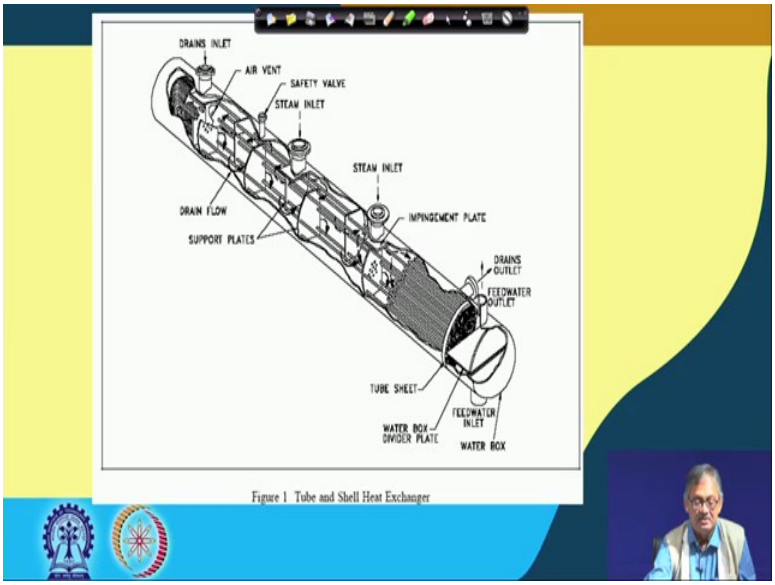

So, tube and shell that is what? Yes there are different aspects also; drain flow, support plates, then steam if it is one fluid is steam and if the other fluid is may be water, 'right'. So, drain outlets or all these are part of the construction of the bigger heat exchanger, 'right'.

So, of course, this is a commercial one, 'right'. Hopefully we will show you afterwards; another flow diagram picture afterwards, 'right'. So, if we go back to that 'right'.

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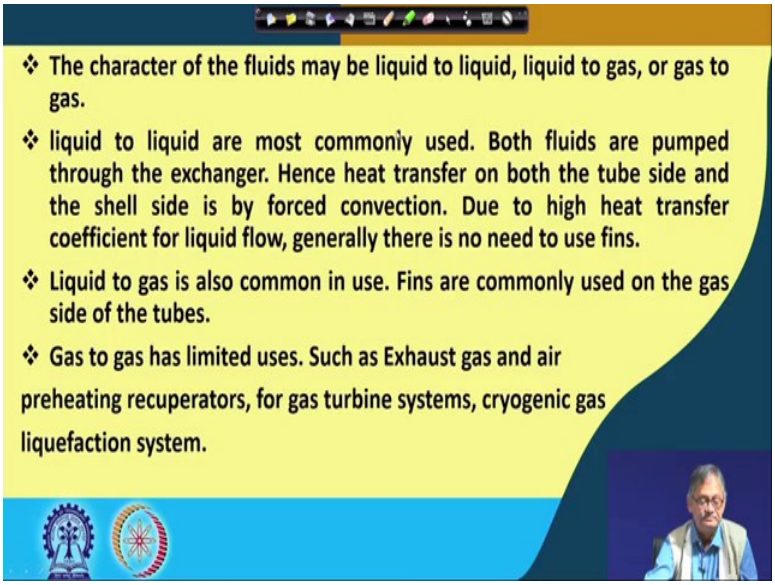

This is due to the economy that is which we said that low cost because the heat exchanger tubes can be made to withstand higher pressures than the shell of the heat exchanger for a much lower cost, ‘right’. So, high pressures also you can utilize.

The support plates shown in that figure also acts as baffles to direct the flow. Baffle means so, you have a flow like this. So, if you have a baffle like that so, what will happen? This will come and then go like this, ‘right’ so; that means, it is acting as a barrier, ‘right’; baffles are nothing but barriers, ‘right’.

So, these baffles to direct the flow of the fluid within the shell back and forth across the tubes. The tubes are rolled and press-fitted or welded into the tube sheet to provide a leak tight seal. Obviously, if the tubes which you are using if there is some leak then there will be mixing of the fluid of the tubes or maybe with the shell which is not desirable.

So, that is to be prevented by properly making leak tight or the leak should not be there or leak proof it should be. 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, ‘right’.

Since these tubes which we are referring to they are made of maybe whatever the material of construction, you take depending on what you were processing or what you were doing you are use induce. By that you are doing it, but as we said that they are made in such a way that they are very sturdy, ‘right’. So, they can take care of high pressure. So, ‘right’ p at any higher pressure.

So, that tubes assembly are within a shell and shell is 1. So, that is why the pressure which P can or P shell can withstand is much less than P of the tube, ‘right’. So, that is why shell side pressures are much low compare to that of the tube sides. So, when you are using high pressure that should be in the tube side. The character of the fluid may be liquid to liquid or liquid to gas or gas to gas. So, exchange of heat can be neon of those fluid.

Fluid as we said earlier also it is nothing, but are there a liquid or gas, ‘right’ or maybe vapors, ‘right’. So, it can be a liquid liquid, liquid gas or gas gas heat exchanged. Liquid to liquid are most commonly used both fluids are pumped through the exchanger. Hence heat transfer on both tube side and the shell side is by forced convection.

Obviously afterwards also we will see that there is a much we have we know that much difference between the forced convection and natural or free convection which we have said earlier also. Due to high heat transfer coefficient for liquid flow; generally there is no need to use fins, 'right'. Earlier we also had shown while fin were being taught that when you are going to apply fin, 'right'. Liquid to gas and also common to in use, 'right'; liquid to gas is also a common in use. Fins are commonly used on the gas side because the gas is having less conductivity or less thermal coefficient or heat transfer coefficient.

So, that is why the fin at all between liquid and gas; if fin is to be use fin should be on the gas side. Gas to gas has limited uses such as exhaust gas and air preheating recuperators. For gas turbine systems cryogenic gas liquefaction systems gas to gas may be used, 'right'.

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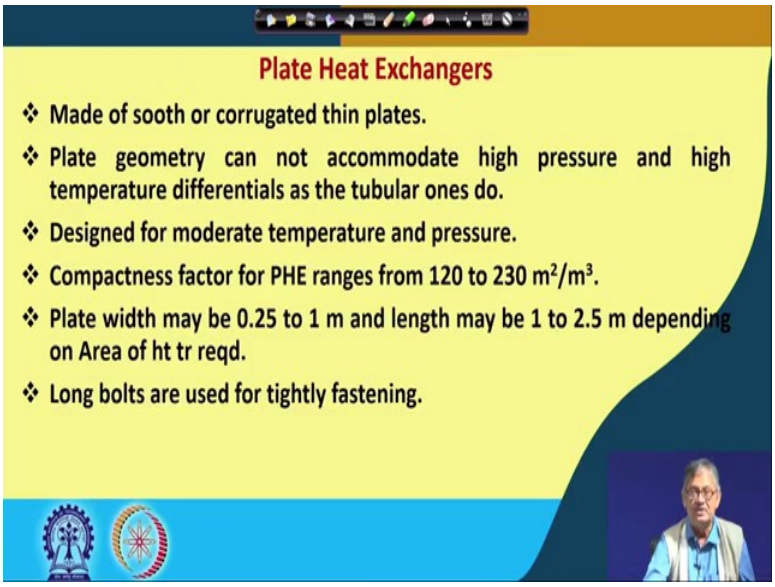

So, we then come to that this one; we then come to that this is the our heat exchanger or tube shell and tube heat exchanger where we had shown you as the commercial unit one, 'right'. So, today our time is over. So, we will continue heat exchanger in subsequent classes and yeah, we will try to do the heat transfer analysis also. We will do of course, and today we finish it here.

Thank you.