Heat Exchangers: Fundamentals and Design Analysis

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Lecture – 26
Plate fin heat exchanger (Contd.)

Welcome to this lecture. This is in continuation to our earlier discussion on the Plate fin heat exchanger. And, today we will be trying to discuss about the fabrication techniques of the plate fin type heat exchangers.

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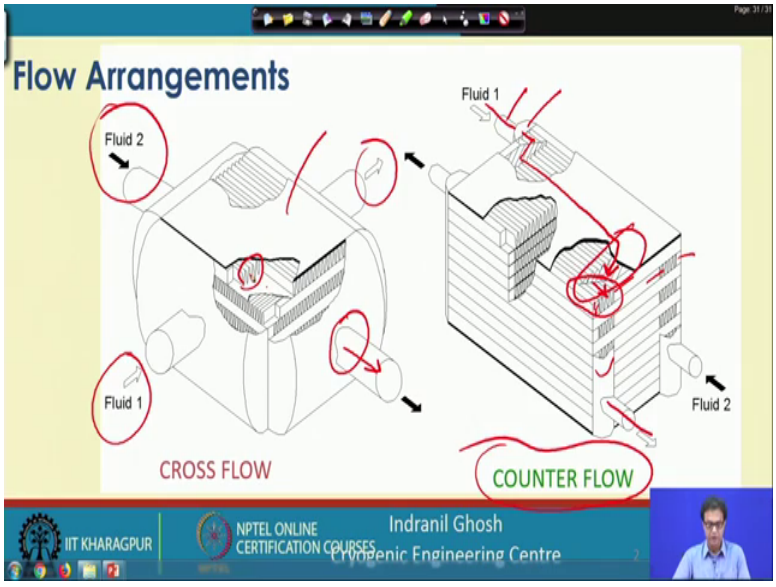

So, here we have talked about the cross flow type, and the counter flow type heat exchanger and these are two fluid stream heat exchangers. So, here in this case only fluid 1 and fluid 2 are seen. Now, with this is fluid 1 this is fluid 2 moving out; and this is fluid 2, which is coming in and coming out through this is the exchanger this is a cross flow type.

And we also discussed about the counter flow heat exchanger configuration, where we have seen that we need a distributor of to distribute the flow, I mean from when it is coming this is the nozzle, then we have the header, then we have the distributor to allow the flow to come in, and then getting distributed and coming like this. Finally, this moves out from this distributor fin, and this distributor fin assembly. And finally, it is getting collected to this header and the nozzle and moving out. So, when it is happening in this

layer we have this is the side bar. And in the next layer we have some different fluid, fluid number 2 which is flowing in this direction, and they are forming a counter current pattern to each other.

So, how do we fabricate this kind of heat exchangers? So, while fabricating this kind of exchangers, we need to concentrate on quite a few things and one of them is the frame, we need separating plate, we need headers, we need the side bars, we need the cap sheets, cap sheets at the top cover and the bottom cover, and of course, the header and the nozzles. So, and in case of counter current exchanger, we need this is a distributor fins appropriate a distributor fins on each side and each layer.

So, how do we fabricate this kind of exchangers we will briefly discuss about those techniques. And as you can understand that we have the primary heat transfer surface area and with that one we have to connect the fins. And we need a good thermal contact otherwise they are going to introduce some kind of resistances, which will ultimately degrade the thermal performance of the heat exchanger.

So, we need to ensure a good contact, at the same time we need to also ensure that there is no leakage or puncture of the separating plate, so that you know the fluid 1 and fluid 2 or any other fluid they are mixing with each other so that we also have to ensure. So, we have a very stringent requirement particularly in terms of the aluminum based aluminum plate fin heat exchanger as we have discussed earlier, because the solidus and the liquidus temperature of aluminum is very close. And we need a very stringent temperature requirement in the furnace or in the deep bridging, I mean we will discuss about that in the later I mean slides.

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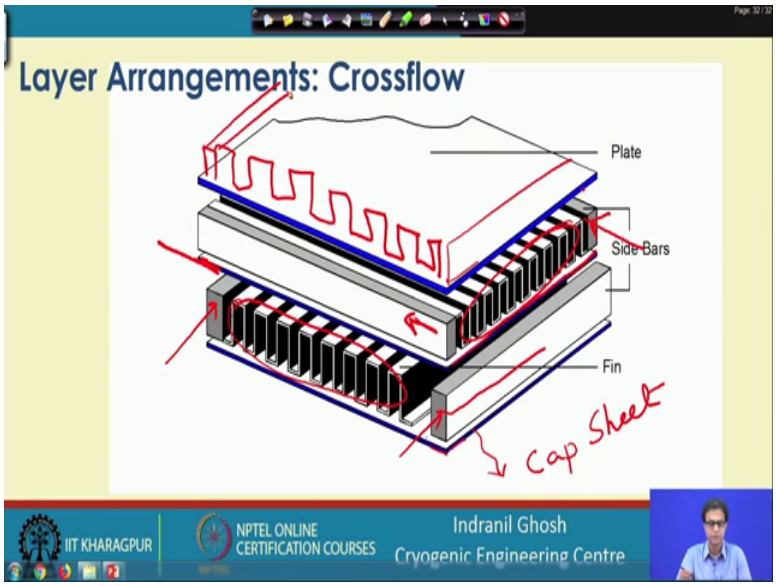

So, if you now look into this construction wise the cross flow as you have understood I mean this is a very simple arrangement where one layer will you know we have a separating sheet or the last one will be termed as the cap sheet. So, this cap sheet will be there on the bottom and on the top. And we have one cap sheet on top of it we have the side bar on both the sides. We have the sidebars, it is placed on top of the cap sheet. Then we have the fin, this fin, this fin as I mean this is a complete fin which is placed on top of this cap sheet.

Then we have another layer of this plate and then we have this side bar arranged on this side and this is another fin it may be of similar type or it may be of different type. Then we have another plate. And on top of it again, we have this kind of fin arrangement like this. So, depending on the fluorite and the calculation of the number of layers, we have to put those many number of layers; one on top of the other and this whole assembly has to be put inside a fixer, so that they can be hold permanently or you know rigidly within a small volume or in a volume.

And then the whole assembly has to be placed either in a furnace or in a molten bath. So, this is how it is you know done in a cross flow exchanger, this is the layer arrangement and this is relatively simpler, because we have only 4 directions to designate it say for fluid 1 this is the fluid 1 in and fluid 1 out.

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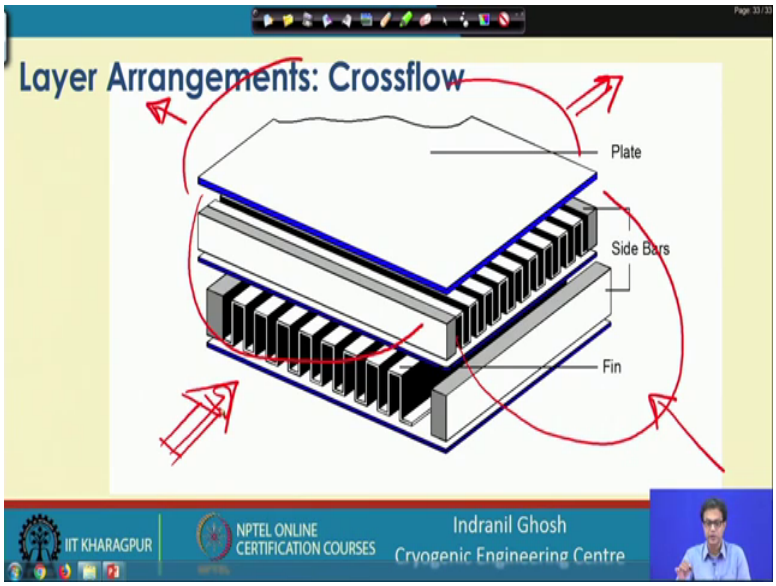

Similarly, we have another two layers I mean two sides, you know this is another side from which one fluid can come out and this moves out this is with, this will come in and this will this is how it moves out. So, we have 4 sides necessary 4 sides for the flow in and out for the two fluids. So, this is possible in a cross flow exchanger, but in case of a counter current exchanger, you know that this geometry is bit different.

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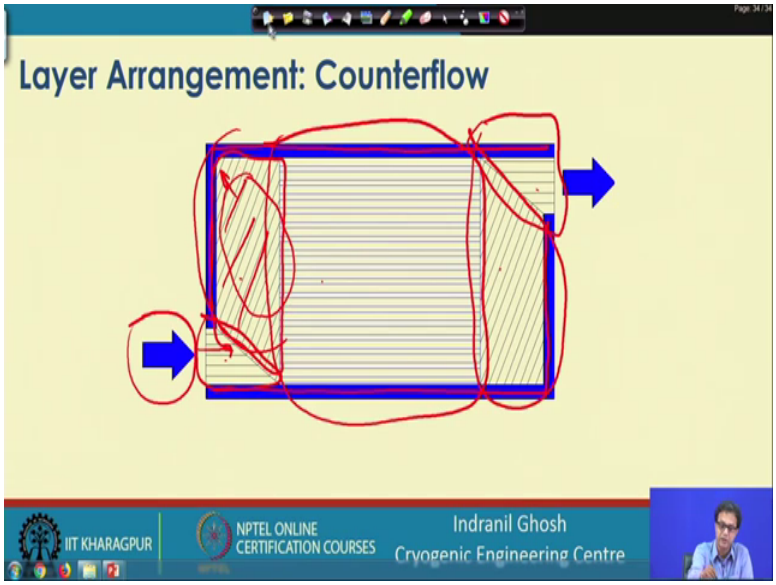

So, what do we do in counter current exchanger, we first put say this is imagine, this is the cap sheet of one end and this is blue in colour. So, that you know it is a you just need

to remember this blue one is a cap sheet for the bottom one. And then we put another layer of say what is called for fluid 1, which is we have designed it with the blue colour one, and this blue colour one fluid is just on top of the cap sheet, we have placed this is the side bar, we have arranged it like this. And another side bar is like this. This is another side bar.

And we have the distributer fin, one distributer fin is from here to here. Then we have another distributor fin we have arranged it like this, then we have the main you know fin in this region. Then we have another distributor fin like this, and this is the other distributor fin. So, as a result we find 1, 2, 3, 4, 5 you know different sections of the fins cut into appropriate, you know dimension, and this distributor fin as you can understand that this flow will be coming over here and this may not reach to this part. So, what we need to do, we need to select a type of fin such that you know this fluid will come in and will be coming out of this region to this region.

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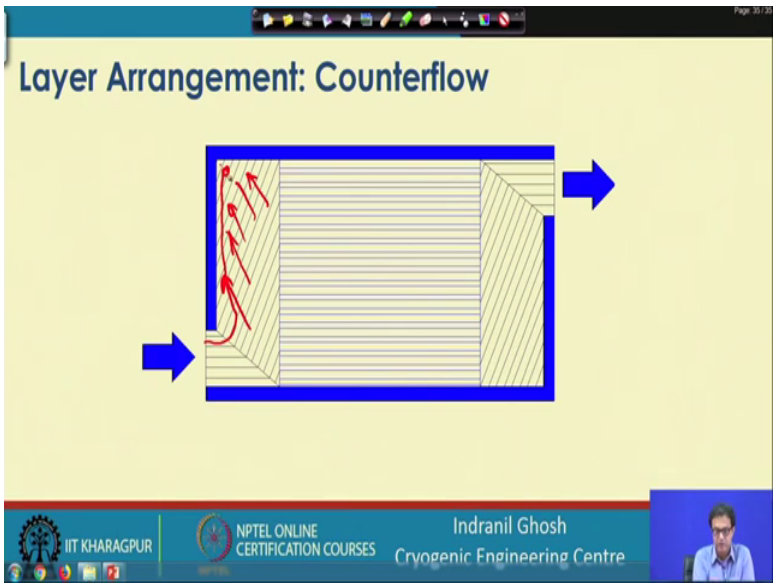

So, we need to put some kind of perforated fin, so that you know this fluid will be flowing up to this last end of this one.

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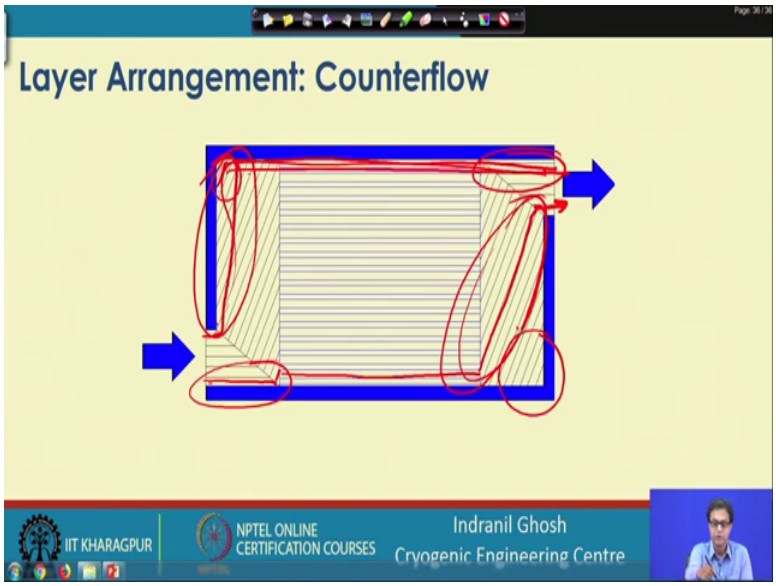

And, if you look carefully into this part that you will find that this length, if it is like this, this is where it is having the least length; and here it will find the longest path to move out. Now, what happen to this there you will find this is having the smallest length, but here you have the least length. So, as a result here you have some kind of length, this is quite longer. And here this fluid has to travel all the way over here. And then you know here it finds small path, so this path is longer on this side for this fluid which is flowing from this end to this end, this path is longer.

As a result you will find the total length travelled by the fluid from this end to this end whether or from this path to this path, if almost equal, so that there is least amount of mal distribution of the fluid. Otherwise, the people will have the tendency to follow the least path and it will try you know, if it finds more resistance to this path, it will try to avoid that corner and; obviously, we will not have the enough heat transfer occurring in this regions. So, we need to take into account of that one.

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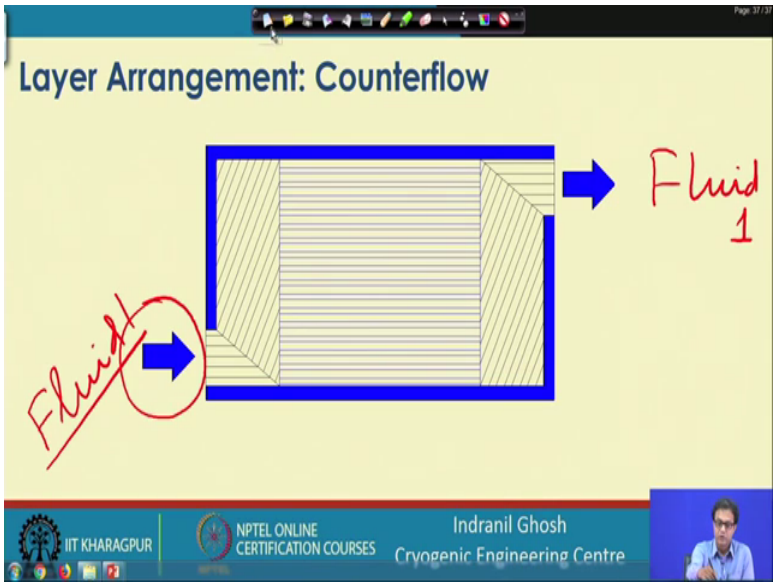

So, this is the first layer where we find that the fluid say we this blue fluid we call it fluid 1. And this fluid 1 is entering from this end to this end, and it is moving out from this to this end. We defined it as fluid number 1. And just on top of it, what we need to put is another separating plate.

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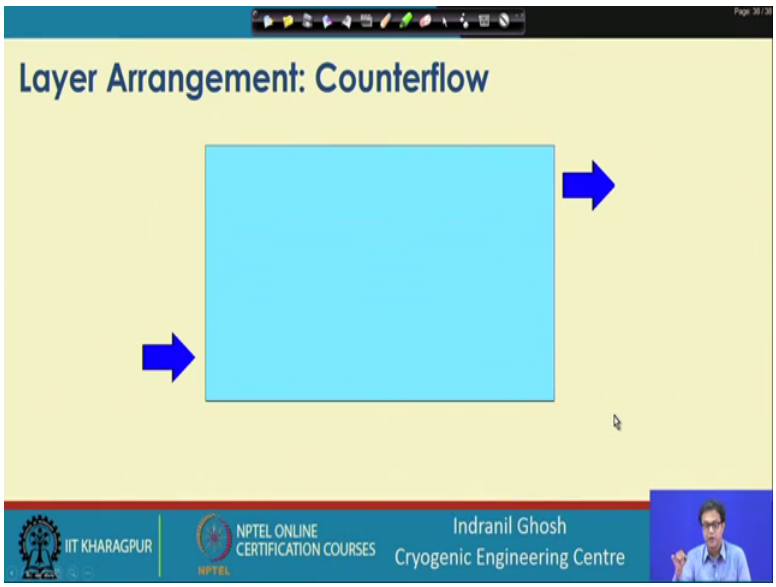

So, if we now put another separating plate on top of it, now the separating plate this whole part I mean the cap sheet, then we have the fin assembly, then we have put another

layer of I mean plate. So, this plate is you know this whole part is a particular layer for this fluid 1; and on top of it, now what we do is that we want to put for the second fluid.

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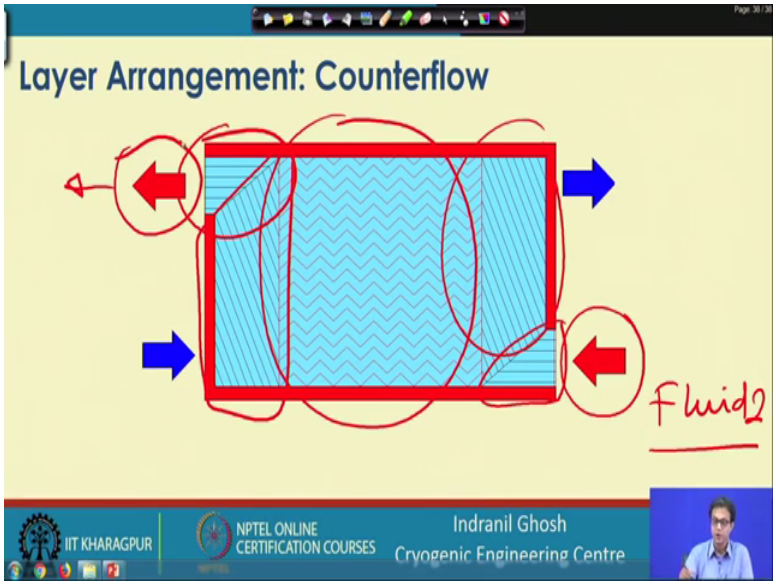

Now, second fluid is it is coming from this end, this is fluid 2, this is fluid 2. And this fluid 2 is entering from right side to and it is moving out from this end. So, now, here also as you can see we have a distributor on this side, then we have distributor on this end, and this is the main fin. This main fin you know it is a kind of a wavy fin or you can say it is a hidden bound type of fin, then we again have a distributor on this side and distributor on this side to take it out of this 1.

So, now, what we have is basically one layer of the I mean the cap sheet, then one layer of fluid 1 layer, then we have separating plate, then we put another layer for the second fluid 2. And then as usual you can understand that we have to put separate I mean separating plate. So, we will have this separating plate. So, this is constituting now one complete layer of fluid 1 and fluid 2 with the cap sheet at the bottom and we have a separating plate on top of it.

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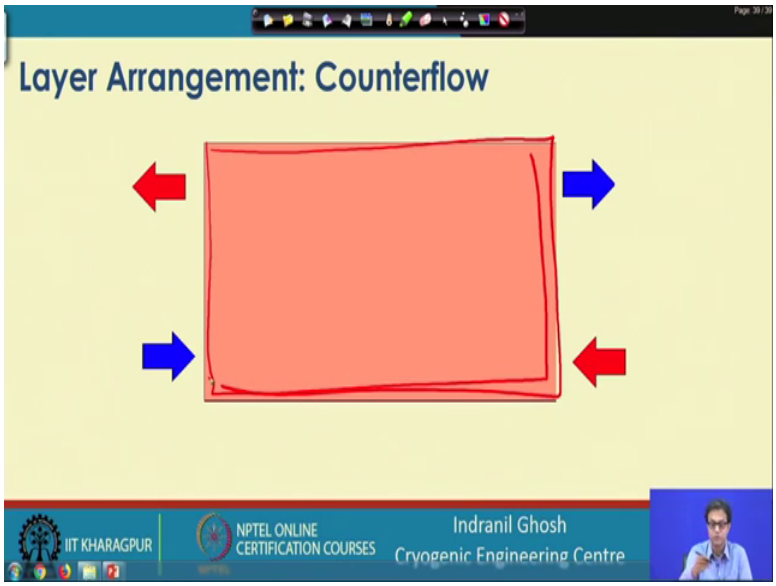

Now, if you wish we can terminate on this one, and we have to just put on top of it another you know this cap sheet; if we put on top of it this will constitute heat exchanger with the single layer of fluid a, and fluid 1 and fluid 2. But often we will find that a single layer of such I mean flow or fluid flow is not good enough. So, we need to put multiple layers of these two fluids.

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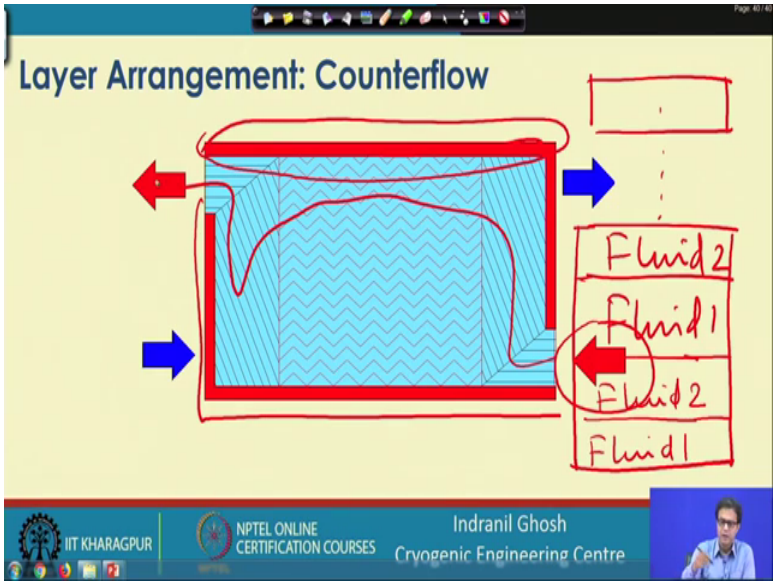

So, first of all that was a fluid number 1, then on top of it we have fluid number 2, and this is like that we are going to arrange them. So, on top of it again we need fluid 1 and

fluid 2 and like that it will continue. So, we have to I mean according to the thermal hydraulic design of this heat exchangers, we need you know such a number of layers, and such kind of layers with the appropriate headers I mean sorry the side bars and all. If you, if, if we go back to this earlier slide earlier one previous one, you will find that here the side bus are arranged in such a way that you know it is on this side, this is here this side is like this and we have this side around this side, so that the fluid 2 is guided like this and it is coming like this.

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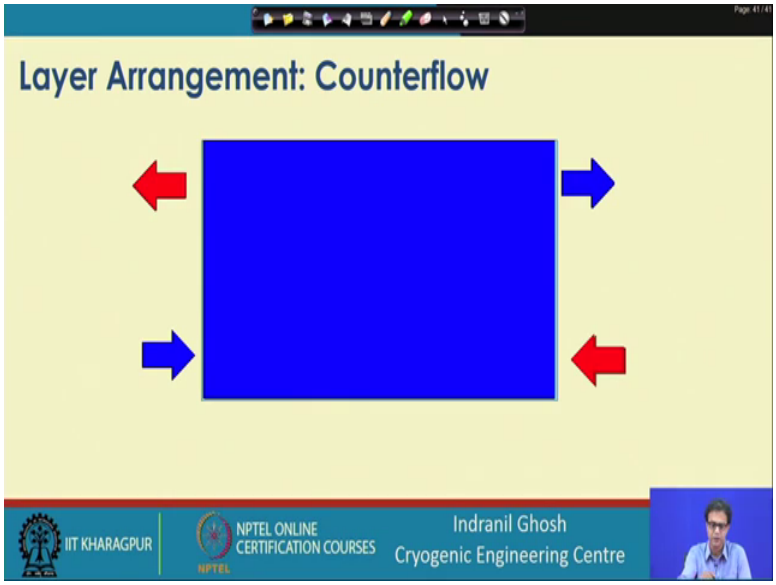

So, now if we look into the other layers, so as we have said that there will be multiple layers. So, we need we may need another fluid 1 and on top of it, we will put another separating plate on top of it, again we put another fluid. So, then probably you know we have to put I mean, if it is you know a all the re required number, when the required number of layers that put, then we put again the cap sheet and that cap sheet will terminate or complete the assembly.

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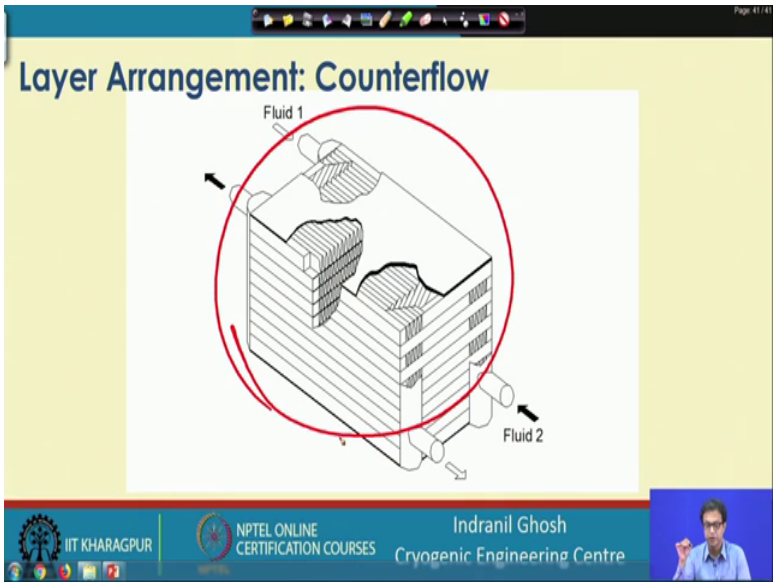

And the whole assembly will look like this, and finally, they will have we will have this kind of counter current exchanger arrangement. So, this is what is the counter current exchanger, but this exchanger we do not get really in this form from the beginning so, as I was telling in the earlier slide that we first of all make the layers require requisite number of layers.

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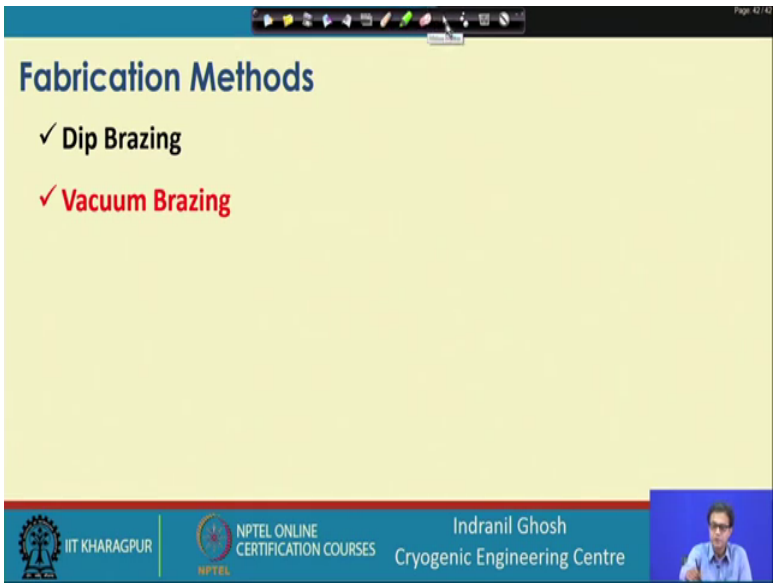

Then we take help of the brazing processes where there different type of brazing really it is the dip brazing, and another part is the vacuum brazing. So, these are the two typical

type of brazing we take help of to fabricate this kind of brazed aluminum plate fin type of heat exchangers. So, we will try to look into these processes you now quickly.

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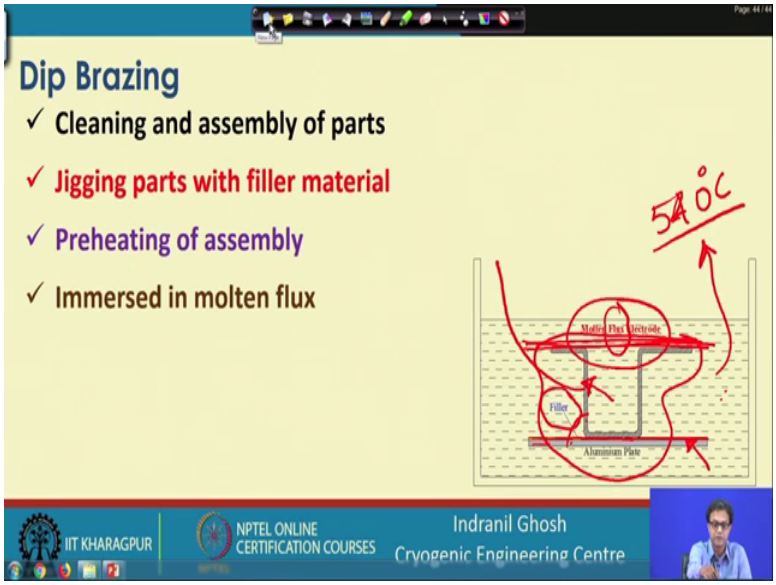

First of all, if, if we look into the dip brazing process we will find that we I mean first of all we make an assembly of this separating plate, then fin, then distributors, and this I mean that is all and the with the cap sheets. All these things are first cleaned. And then this clean parts are assembled together and when we it is assembled I mean with the separating plate what we do is that we put the appropriate filler material.

So, here we have the appropriate filler material, we will find that this is necessary, when we do brazing, if you are aware of you will find that we need flux, we need the filler material, then we need the heating, so that I mean the filler material will melt in presence of the appropriate flux. And then that will join the parent material with the auxiliary part that we are going to attached to this separating plate.

Now, here these first of all as we have said that clean parts are assembled together. And they are jigged I mean I mean jigging parts with the filler material jigging part with the filler material, all these separating plates. And a filler materials are you know the fill parts will have the filler material associated with that one and that complete assembly is then preheated I mean else we have noticed that that assembly that we have talked about say imagine that the separating plates are filled with a layer of say filler material. And on top of it, we have put the fin and that whole assembly is within a fixer I mean it is a

within a I mean we have a fixer to hold that one tightly in position and that whole assembly has been preheated.

So, once we have preheated it, we put it in a I mean salten flux bath and that is kept nearly about 540 degree centigrade, but why do we need a preheating we will come to that part. So, like this one as we have as we were saying that the aluminum plate, if this is the aluminum plate we will find that the plate on top of it is filled with or we have a filler material cladded on top of the aluminum material this yellow colour one is a filler material. It is I mean integrated with that one. And this filler material this fin this is just only one you know fin that is on top of it, there will be another filler material field separating plate.

So, like that this whole assembly which has been preheated and then we have put it in the molten flux electrolyte electrode. So, this whole assembly I mean it has been preheated and this temperature is nearly 540 degree centigrade or 538 centigrade. So, why preheating is necessary, otherwise that will unnecessarily cool down depending on the size of this heat exchanger, it will unnecessarily cool down this molten bath ok. So, if it is preheated just you know few degrees below the 540 degree centigrade temperature, so it will not necessarily change the molten bath temperature, and it will quickly achieve the temperature of the molten bath.

And in presence of this molten flux, this filler material will now melt and they will bond this fin with the parent material aluminum. This is also made of aluminum and this is also I mean mostly this is 3000 series we have already talked about it. So, this is immersed in that molten flux, and this flux will help to I mean make a bond between the filler and the parent material. So, this that is how you know we will be getting joined between.

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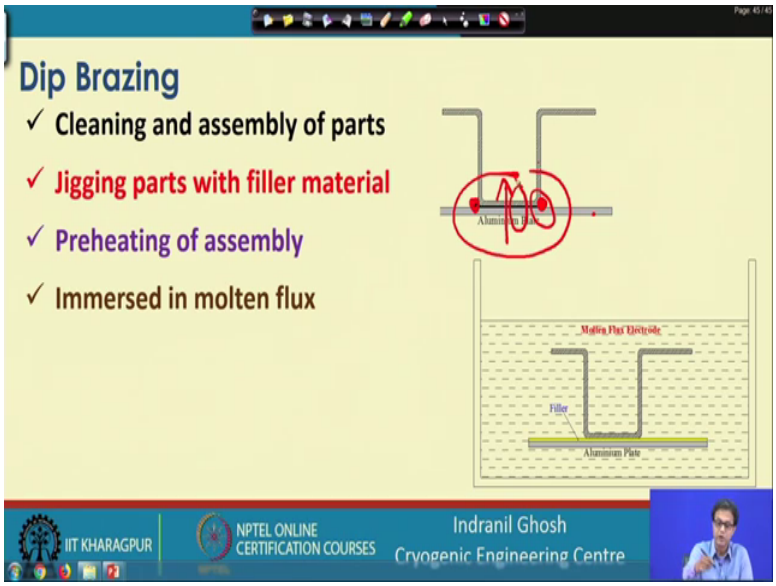

So, finally, when it is taken out of this molten bath, we will find that we have a kind of joint between I mean joint will be formed between the plate and the fin. So, automatically this will be I mean this is where is the joint between the aluminum plate and the fin. So, this will ensure that there is a good thermal contact between this plate and the fin, which is necessary, otherwise we will have a kind of a thermal contact resistances between the between the fin and the plate. So, to ensure that we have a good thermal contact and to have a good mechanical assembly or I mean construction. So, we put a I mean we allow it to go through this brazing process ok.

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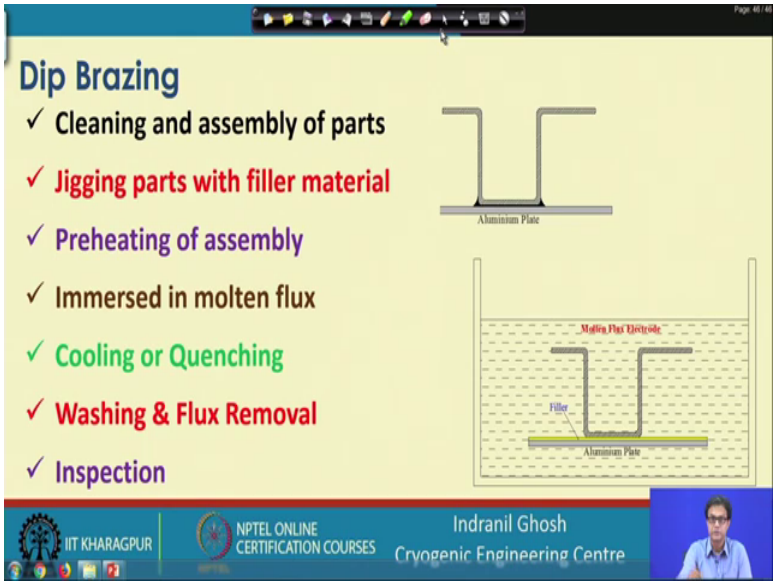

So, now, if we look at it, it will taken out of this bath and it will remain at quiet high temperature so 540 degree centigrade temperature. So, we need to quench it and cool it, and then we what we need to do is that we need to remove the additional flux. And we have to wash it appropriately before we tick the whole I mean whole assembly for the next kind of operation or the inspection whether we have got a good joint or not. So, we will talk about that inspection part later on.

So, this is in a nutshell about the deep breathing technique we have quiet good I mean quiet some advantages with this molten flux electrolyte, but one of them is that a there is less chance of I mean distortion, which often we find in it may occur due to different kind of what it is called preheating due during the or that brazing techniques, but this molten flux material cost becomes may be substantial I mean or depending on the size of the heat exchanger we often go for it brazed aluminum I mean brazing by deep brazing or by vacuum brazing.

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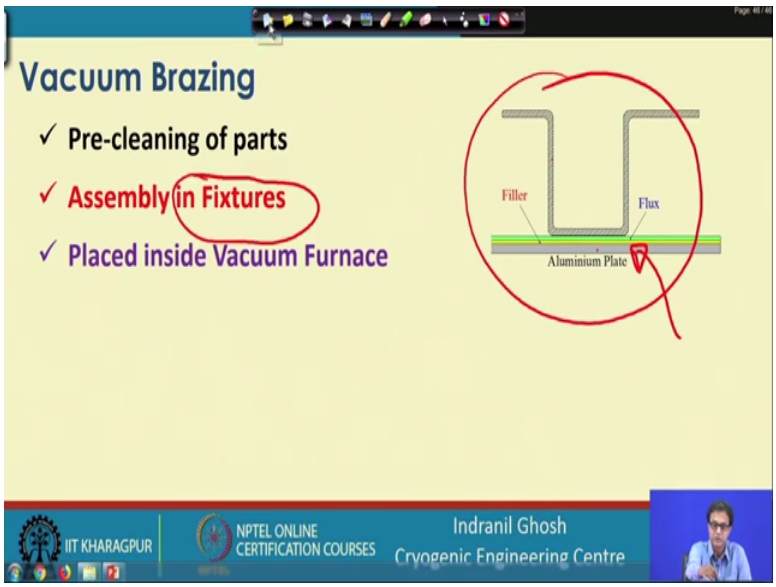

So, the next one is about the next one is about the vacuum brazing. So, here the pre-cleaning of the parts is again necessary else and we need to take appropriate action, so that there is no breeze and all now on this plate fin surfaces. Afterwards, we need to again assemble them as we have said appropriate I mean for the cross flow or counter current configuration. Then we put a I mean here this is in contrast to the I mean dip

brazing technique here, we put the filler both the filler and flux on top of it, it is cladded basically on the aluminum, this is cladded on top of the aluminum plate.

And then this whole assembly I mean one this is just a single layer we have shown where we have a fin and this is the plate cladded with filler and the flux. And, this whole unit is within a fixer I mean this, this is within a fixer and this fixer will replaced inside what is called vacuum brazing furnace. And, why we need a vacuum, because we know that in presence of the oxygen if we try to raise the temperature to a high degree, we will find that aluminum plates may be getting oxidized easily. So, and that will be very very difficult to break that oxidize layers and to make a good joint between the plate and fin. To ensure that there is I mean no oxygen I mean we create a vacuum or sometimes we put an inert gas in the system, so that there is no oxygen to you now create aluminum oxidize layers.

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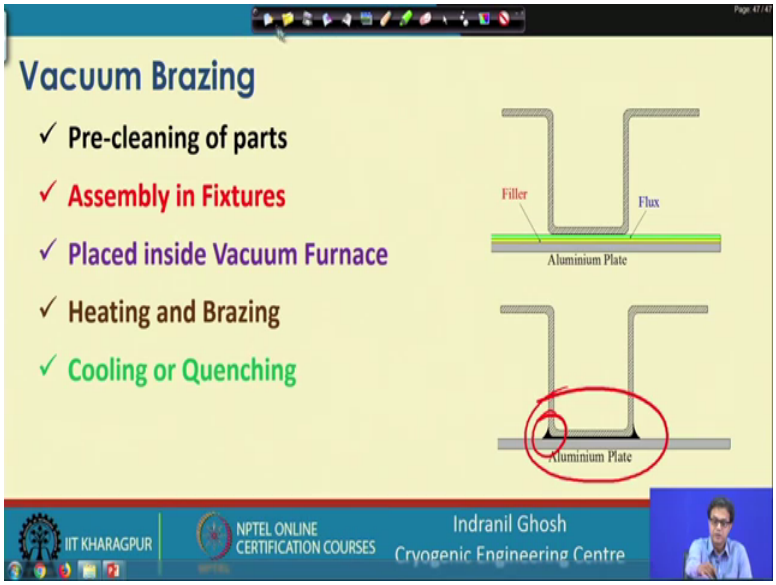

So, now, we place it a inside the vacuum and gradually we raise the temperature of this whole assembly depending on the size of the assembly. We slowly heat it up and sometime we give some kind of heating. And followed by I mean soaking time so that the whole assembly is getting heated up to a prerequisite time. And when it is I mean reaching to that desired temperature as we have set nearly about 540 degree centigrade and around. So, we give a ramp and then soaking time in the vacuum brazing furnace so to reach so as to reach the desired temperature.

And when it reaches that temperature, we allow it to be there for sometimes. And then again we need to cool it down some time we cool it down allow, it to naturally cool down or otherwise we often do it quench. We quench it and then I mean we go for the cooling or quenching and then you know so finally, we will have an a brazing of this kind of brazing at between the plate and the fin and then we go for the inspection.

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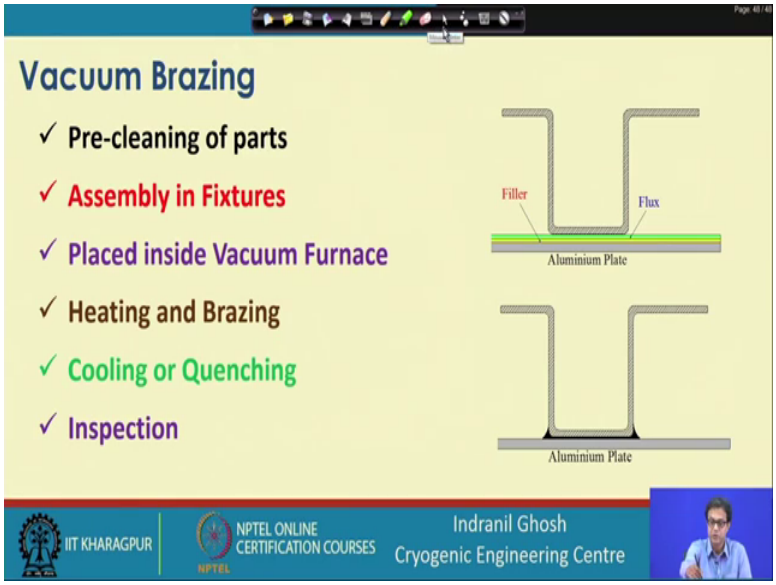

So, this inspection is basically we need to ensure whether there is any kind of leakage or not. So, we will discuss about that part sometime later.

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So, when we get finally, this is the kind of heat exchanger core we will get we call it heat exchanger core. So, we have only the side bars and the fins and the plates. So, it is not just, because I mean it is not like a heat exchanger, a bit this is only a heat exchanger only when we put you now the heeders on four sides or I mean different sides, it becomes it behaves like a heat exchanger.

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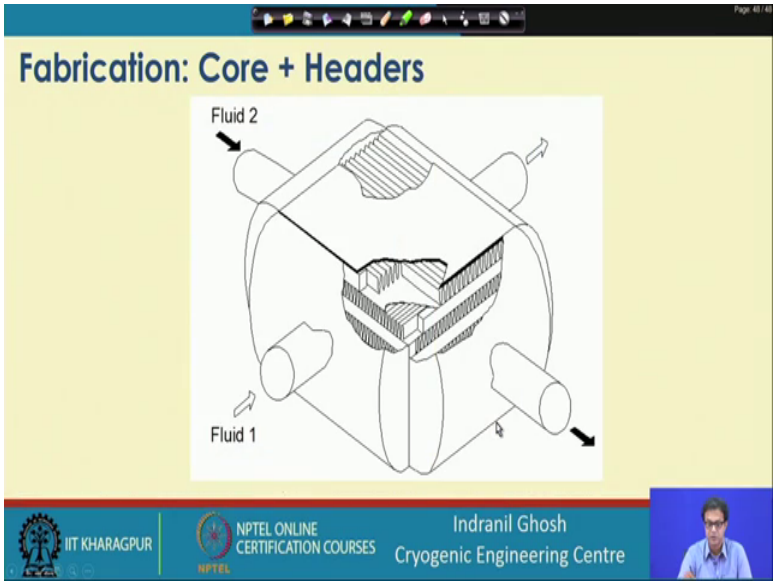

So, this is I mean when we have this heat exchanger core fitted with the side bars and the headers, we will get a appropriate heat exchanger. I mean depending on the I mean construction it maybe a cross flow exchanger, it may be a counter current exchanger.

Thank you for your attention.