Heat Exchangers Fundamentals and Design Analysis
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Lecture – 13
Tubular Heat Exchanger: Shell - and - Tube

Welcome to this lecture Tubular Heat Exchanger. And today we will be talking about the shell and tube heat exchangers in details, but before going to that in details we first of all like to solve that incomplete numerical problem that we have taken up in the last class.

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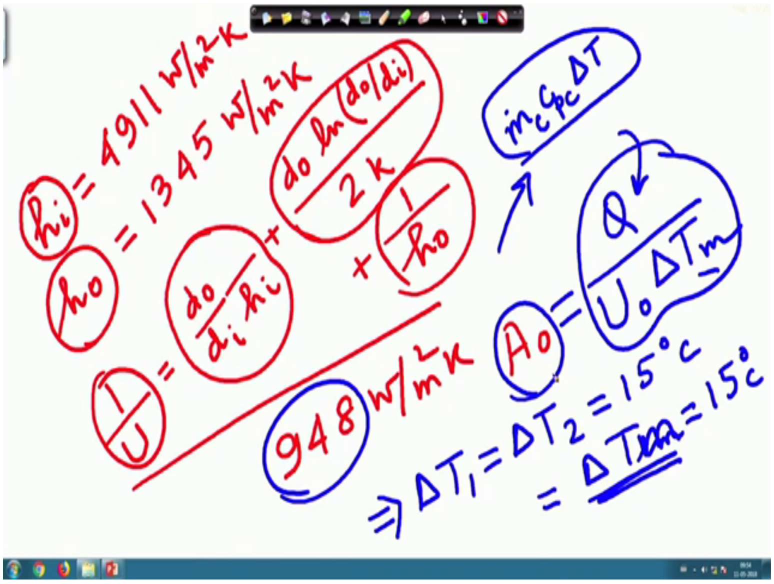

So, we will go first to that. And, if you remember we have calculated the internal heat transfer coefficient. And we have also calculated the external heat transfer coefficient using the appropriate correlations. And we have obtained a h i and h 0. So, we have got in h i as 4911 watt per meter square Kelvin and we have obtained 1345 watt per meter square as the heat transfer coefficient of the annuli space.

So, based on this data we would be able to calculate the overall heat transfer coefficient that is equals to 1 by U, is equals to 1 by, this is in terms of the external diameter and this is d 0 by d i by h i plus this is d 0 and then l n d 0 by d i. So, where we are taking care of the resistance of the wall and this is the thermal conductivity part of it. And then we have 1 by h 0 this is the heat transfer resistance offered by the external um, I mean the annuli fluid. This is the resistance offered by the fluid, I mean the metallic part and this is the heat transfer offered by the internal fluid flowing through it.

So, this is how do we calculate the overall heat transfer surface I mean overall heat transfer coefficient. And then this will come out to be 948 watt per meter square Kelvin. So, once we know this overall heat transfer coefficient then we would be able to calculate the heat transfer surface area A 0, that will come out to be A 0 is equals to Q already we know and U 0 and then we have the delta t log mean.

So, delta 2 delta 2 log mean here in this case, if you look at you will find that delta t1 is equal to delta t 2. And that is equal to 15 degree centigrade. And so, we have both delta t log mean is equals to delta t mean and it is coming out to be 15 degree. We do not go for the log mean temperature difference; we go for only the mean temperature difference.

So, here this comes out to be 15 degree. And from there we would be able to find out the heat transfer area a 2 b, Q what is that Q, we have obtained Q we obtained already mc dot c pc multiplied by delta t. And that we have to put here, then we have already obtained this 9 40 8 and 15 and from there we will be able to calculate the A0.

So, once we calculate the A0 we will find out what is the heat transfer surface area per unit pin per pin.

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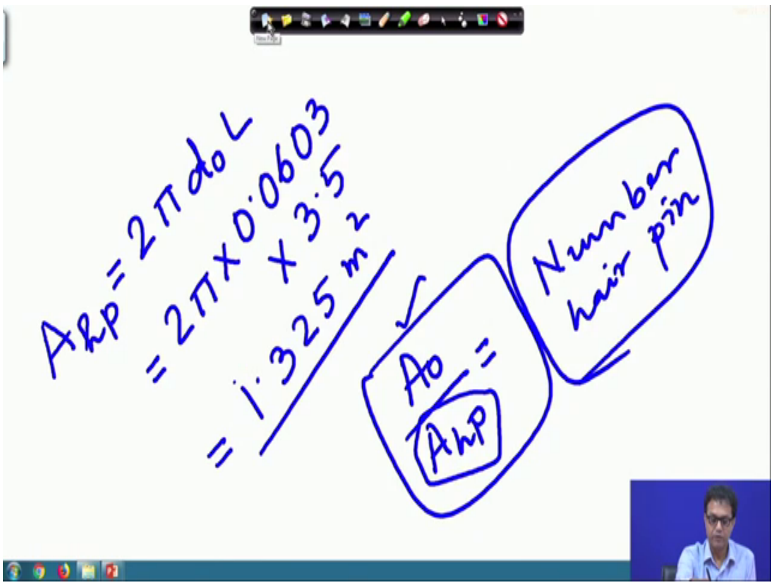

So, per pin the area of hairpin for each one is 2 pi d 0 into l. So, this is nothing but 2 into pi, into point 0 6 0 3 and we have the l given as 3.5 meter. So, this will be about 1 point 3 to 5 meter square. So, once we know the A0 and once already we know the hairpin. So, this will be able to calculate it that will give you the number of hairpin. So, you can try calculating this A0 from that and we can then you know this is already given. So, that will give you the total number of a hairpins.

So now with that, we will now shift to the next discussion, where we are talking about the shell and tube heat exchangers and you have already learned about it in the earlier classes. Now we will try to go in details about this shell and tube heat exchangers.

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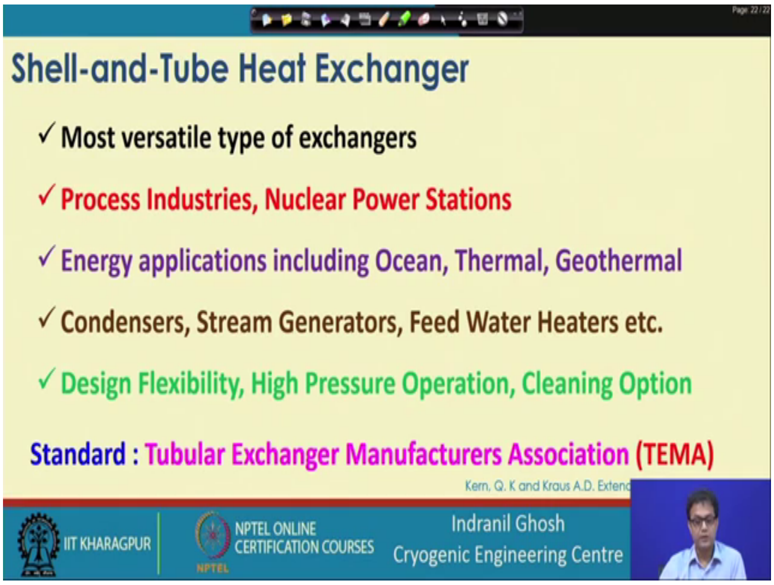

So, we know it is the one of the most versatile type of heat exchanger used in the process industries or even in the nuclear plants. And they can be used as a pre heaters water heaters then you know condenser. And it also it is used as the kettle boilers. And they can also find applications where including in the geothermal or in the ocean or in the then many thermal applications. Particularly, whenever we are using heat exchangers where it needs occasional cleaning.

So, that gives us I mean these are the some of the heat exchangers, where we typically use the shell and tube type heat exchangers. As I told you that condenser stream generators and the feed water heaters and the advantage of this type of exchangers are that it gives very good design flex flexibility.

We have a different type of heat exchangers geometry possible. We will discuss about that part and the advantage lies not only with the design flexibility, it also gives us a pretty good opportunity to use some of the fluid streams where the pressure are very high. And as I told you that the cleaning option is again another big advantage of this particular type of heat exchangers. Whenever we need whenever we are using some dirty fluids and which often generates scales on the heat transfer surfaces. And thereby it gives some kind of fouling resistances to the heat transfer. We have to often clean the exchangers. And that it is not possible for many it is not possible with many exchanges to regularly clean, it particularly when the hydraulic diameter of the heat exchanger is very small.

But in case of shell and tube heat exchangers it is it gives that opportunity to clean it at regular basis, but again it is. So, versatile that any kind of heat exchanger design I mean we have a guideline given by the tubular exchanger manufacturer association that is in short form. We call it TEMA and they tell you exactly; what are the standards that are to be followed for design of the heat exchanger.

So, we have taken up the heat transfer coefficient for the shell side at in some of our earlier classes or in earlier lectures. And there we might have told you how to evaluate the heat transfer coefficient, but as you can understand from the lectures in details of this classes that, that is the normal simplification of the actual process, but in reality we will find that the processes are much more complicated.

So, we will look into the first of all the design of the heat exchangers. How it looks like?

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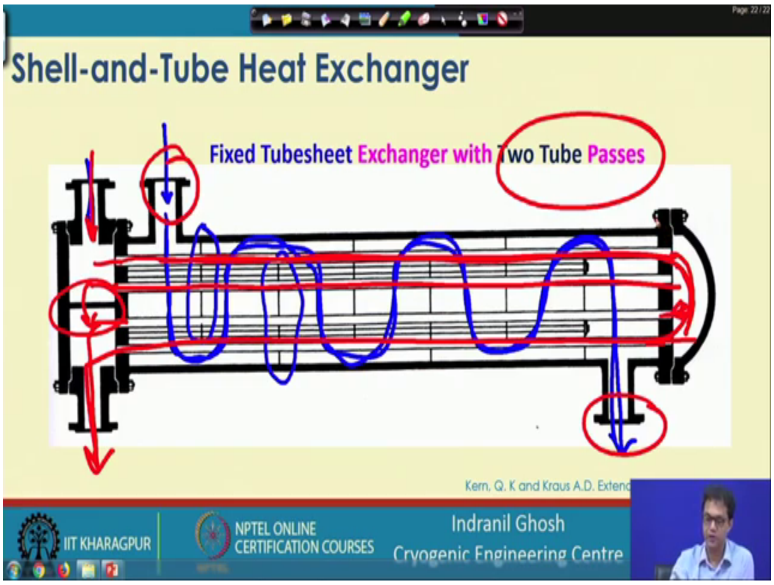

For example, there are different type of shell and tube heat exchangers as we have told. And there are we will only show some of them in this in the in this lecture. Here you can see this is the shell side fluid. So, the fluid will come like this. Then it will be flowing on top of the fluid of the tubes and then again it will come like this. It will come like this, and then finally it will have a exit from this end.

So, here we have the baffles. So, these baffles will allow or rather not allow the continuous flow of the fluid along the tube length. So, it will make the flow a like following this particular zigzag path or like this and it will finally, come out. On the other hand, we have the sheet side fluid or the tube side fluid which may enter from here and then what will happen this will this will enter over here this will enter through this space. And then you see we have a divided at this place. So, it is not able to come from here to this point. So, it has to go through the tube side, it will flow like this then it will take a diversion and the same thing this is getting distributed coming over here. At this point they will get diverted and they will follow this path. And finally, come out of it and then it will follow this path.

So, it is like 1 and then 2 pass; 2 pass for the tube. So, 2 tube passes that is why we call it 2 tube pass, but this is a single cell pass. So, this is single cell to tube pass heat exchanger. And here another specialty is that of this particular type of exchanger is that the tube sheet. This is where we have the tube sheet and this tube sheet is drilled with the holes to fit in all the tubes. And here finally, we get them welded at those corners. So, this will be finally, welded and all these points will be finally welded and like that we have this parts are getting welded. So that means, these tubes are fixed rigidly with the tube sheet.

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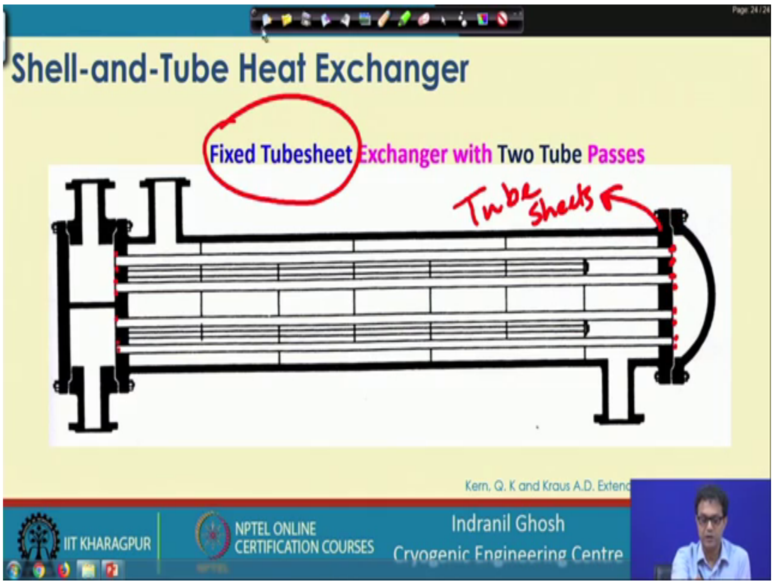

So, this is the tube sheet. This tube sheet and the tubes are rigidly connected and that is why this is fixed tube sheet exchanger with 2 t passes.

So, it has obviously, gives an advantage, in the sense, that whenever we remove this part this 2 ends if we remove if we unbolt this part. And if we unbolt this part you can understand that this is these tubes are now exposed. And if we have any kind of scaling formed inside this tube we would be able to physically clean them. So, that gives the advantage of using this kind of shell and tube type exchangers.

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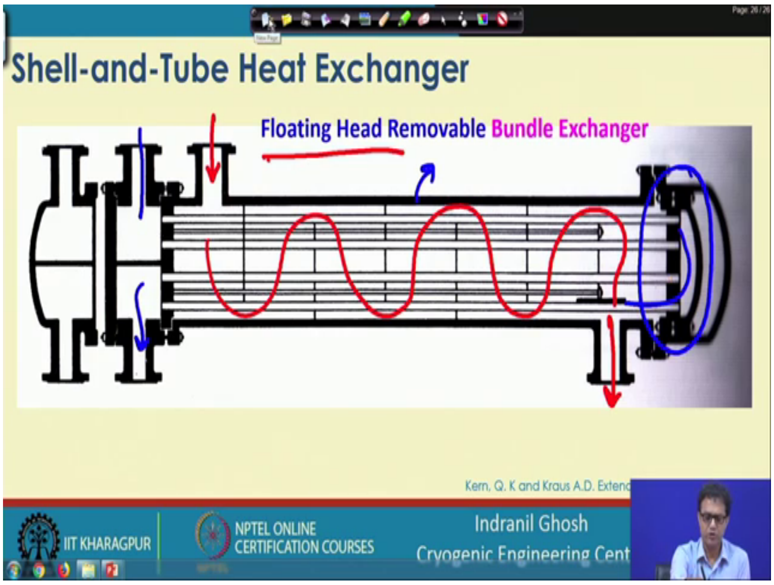

So, here we will go to the next particular type of exchanger, where we find that this is a floating head. Now you see this is this has become a floating head bundle removable bundle heat exchanger. So, here in this case what we find is that this is again the shell side tube fluid there is no problem, it will enter and depending on the number of depending on the number of this baffles or the type of baffles will be diverted. And finally, come out of it, but what is about the tube side fluid this is coming over here. They will get and come out of it from here this is the double pass. So, that is up to that part, but why this complicacy we have in the design of this exchanger.

So now you can understand that there may be situation where the tube side and the shell side fluids are of pretty different temperature. And that may result some kind of thermal stress generation. So, thermal stress will be generated means the shell and the tube if they are getting elongated at a different rate, then it will generate some kind of thermal stress. That means, we have to allow the tubes to expand, I mean if such situations occur then the tubes will be able to expand as contract in contrast to our the shell side.

So, this allows this particular type of exchanger design allows expansion of the tubes in contrast to the shells. So, they are not rigidly fixed up with the tube side. And this is how we how it looks like.

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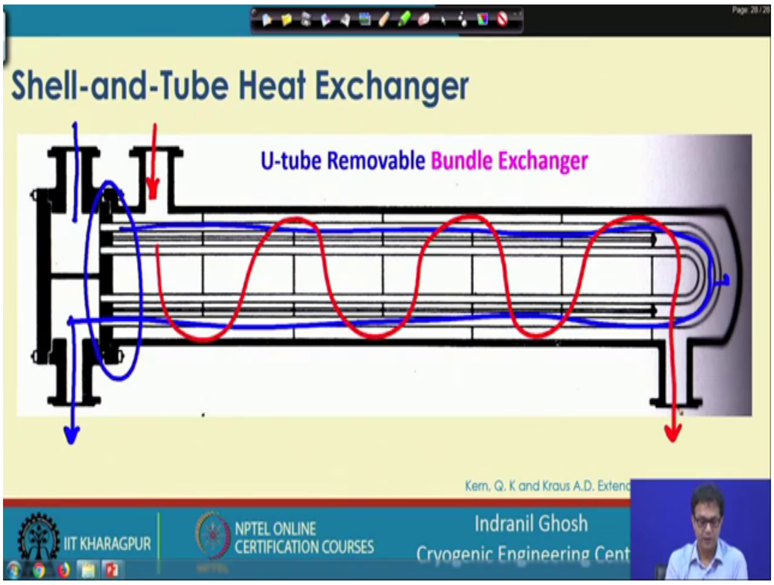

Then we have another common type, but this is this is what we call as the U tube removable bundle. This is one of the simplest geometry that is possible say here the shell side fluid as usual, you can see that depending on that depending on the baffles this fluid will be entering here and it will come out from this end.

Now, about the about the about the tube side fluid; it is simple it will enter over here and this is just like that they will come out and move out of this space. The advantage of this one is that the expansion or differential expansion of the tube it is automatically taken into account. It is already U bend and that if it is differentially expanding it has the possibility to expand it on this side.

Then, only one tube seat is good enough to accommodate all the tubes. And if you look into the other fluid stream you will find that is coming over there and then you know it is coming over there. And finally, it is moving out like this, but that disadvantage of this particular type of heat exchanger is that, if there is any kind of fouling occurring inside the tube we are not in a position to clean it. So, that is the disadvantage with this particular type of heat exchanger.

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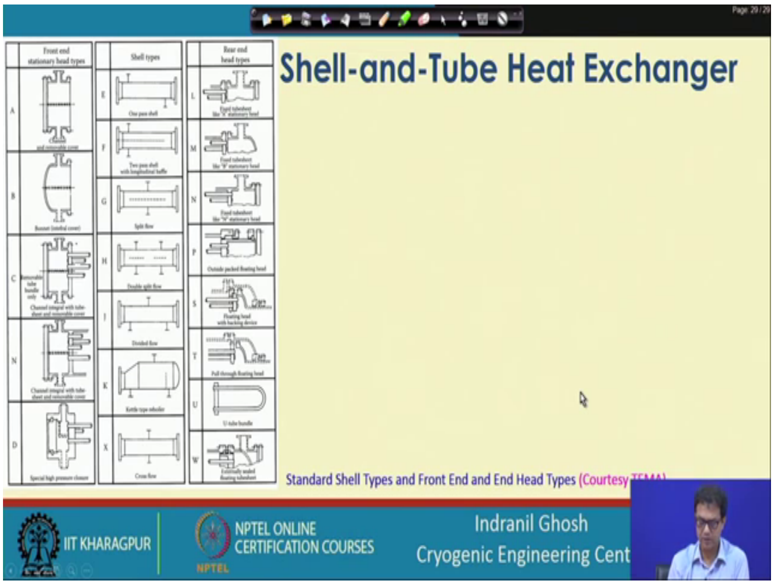

So now, if we go to the other type you will find that, this standard shell, and type of the front and head types and is already specified as I have told that the tubular exchanger manufacturers association or TEMA has given so many standards. And that according to that standard we have a different type of front stationary heads. And then we have the rear stationary heads and the shell type.

So, as you have seen in the previous I mean previous slides, that we have one entry side one exit side or the rear side. And then we have the different type of shell sides. So, these are different it is as per the specification or the standards. We cannot just like that and design any type of shell or choose any type of shell. And there numbered alphabetically. So, this is an e type of shell for example. So, if you look at this is e and this one pass shell; that means, this will come here and move out like this. This is a 2 pass. So, it will come like this and it will be coming like this. Here this is speed split flow and that is coming inside getting distributed and then rejoining and coming out like that.

So, similarly you have double speed, do we have the divided flow we have the kettle type and we have the cross flow. So, instead of naming them by individually double spread flow or divided flow we use these numbers h j k like that x. These are the type of the shells which are in use. Similarly, as we have seen that we have the channel and recoverable cover removable cover. So, this is for the entry and you see this is named as

a. Similarly we have other configurations like a b c n d and on the side l m n p like that we have different type of configuration specified by the TEMA.

So, while designing the heat exchangers or using a particular type of while solving a particular type of exchangers, we had to look for this defined type of nomenclature that has been given by the suggested by the TEMA.

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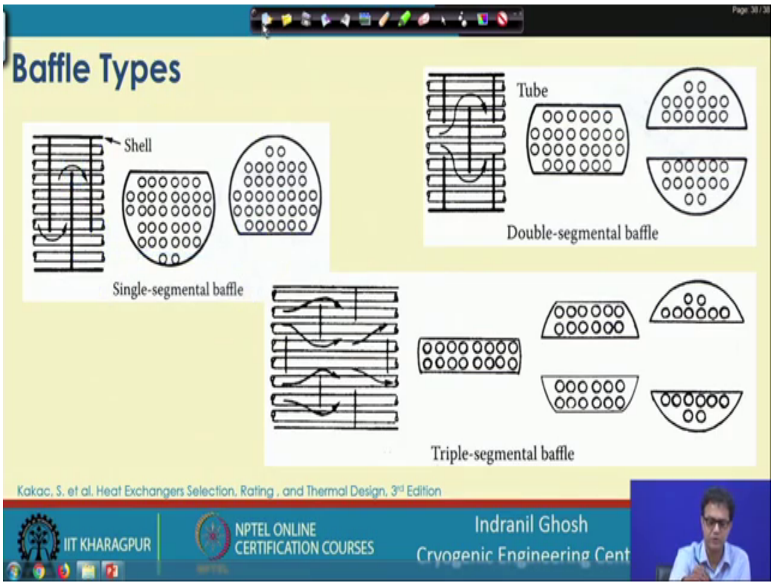

So now if we look into the different type of battles, we have several type of baffles that is possible. So, the baffles are basically providing are giving 2 type of advantages. One is first of all it gives the mechanical stability to the tubes. That means, that if a long tube is there I am sorry, if a long tube is there and to there is no support for that one there is the possibility that tube will be having sagging at the middle or at the at different points.

So, that gives a some kind of mechanical support to this. And not only that it also allows a longer or diverts the fluid from one to the other end. And thereby enhances the heat transfer coefficient, but at the cost of course, the pressure drop. So, as I was telling that there are different type of baffles are possible. We have the single segment baffle. So, it is only one segment. Then we have the other segment and if it is you know it if this is the one corresponding to this the other one corresponds to that.

So, we have about 30 to 35 percent or percentage up it is cut. And that cut portion is if it is on this side, the other one in the next immediate successive one will be on the opposite end of it. So, that is how this is the single segmented baffle is used. Whereas in case of double segment, as you can understand that we have this part for one end and the other part is at the middle which is like this. So, this is the one which corresponds to this one, but corresponding to this part, this part, and this part we have this end and this end. So, like that they are arranged in the double segmented baffle.

Similarly, we have here the triple segment battle so; that means, this one, this 2 and this 2 this 3 constitute a single unit for the baffle. So, first of all this is one part. Then we have this part and then we have this part. At this end this will come here, this will come here. So, like that they are arranged in sequence.

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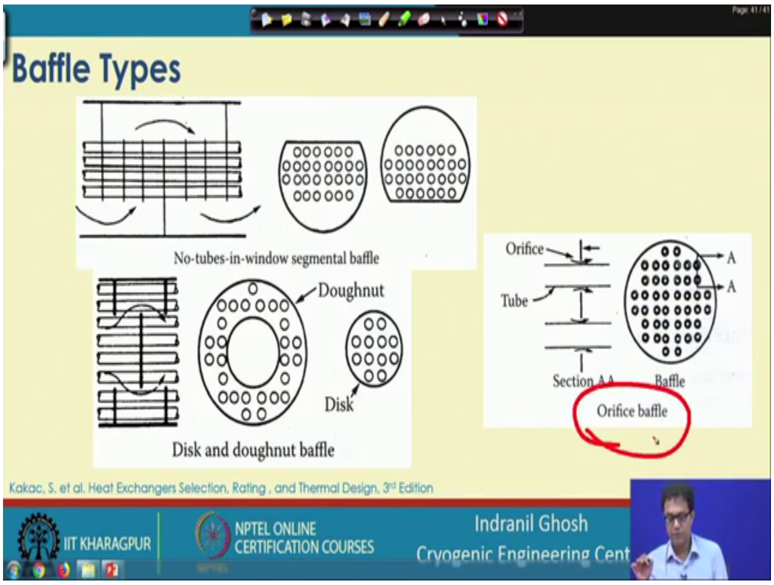

And then we have other type of baffles also. Where this particular is baffle is no tube in the window segment so that means we have baffles here. And finally, on this part you see there is no baffle in this particular segment. So, this is back end. So, like this is flowing, and we have on this part again we have no baffle or I mean no tube in the window segment this is another type baffle. Then we have the disc and the doughnut shell. So, this is the disc and doughnut shell. This is the disc part and this is the doughnut. And if you look at the doughnut part is placed over here and the disc part is placed at the center of the tube.

So, this is another type of the baffle. This is called the orifice baffle, where we will find that I mean tubes are fitted like this, this is a tube and we are connecting or we have the baffle like we put it the baffle like this. So, if the baffle is like this, what will happen the fluid will be flowing like it is coming over here? And it is passing through this it is passing through this end we have. So, this is on the shell side fluid one fluid is. Obviously, going through this as usual I am sorry this is a this fluid is passing this is the tube side fluid, this is the shell side fluid and we have this is baffle.

This is the baffle and baffle between the baffle and the tube we have a small gap through which we allow the shell side fluid to pass through. So, that is what is you see here this is; it is forming a kind of orifice, at between the baffle and the tube. And that is why you know the fluid will be passing through. Obviously, you can understand that it will give you a very large I mean kind of heat transfer.

I am sorry heat transferred, but at the same time there would be large amount of pressure drop also.

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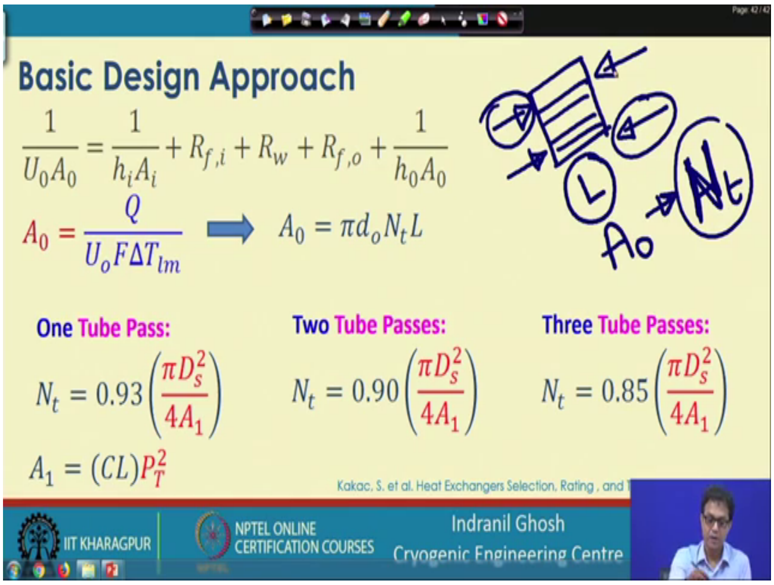

So now, we go to the basic design approach quickly, and we will you have already learned about it to some extent, but as you can understand from the geometry of this particular heat exchanger. That you know any kind of thermal design will be I mean quite complicated, if we have to really look into it is geometry.

So now here what we do first we know the heat exchanger geometry and in a. In a basic design approach what we. Firstly, do is we try to calculate or we try to first estimate a kind of design or the heat exchanger. And then we go for the rating; that means, we know first of all we have been given the inlet condition of the fluid. And we know the both the fluid streams both the fluid streams inlet fluid exit temperatures are known. What it is not known is the overall length of the exchanger and other details how many tubes how many number of tubes what is the diameter what is the shell diameter de cetera etcetera.

So, what we first try to do we make a rough estimate of the overall length and the heat transfer area. Then we make an estimate off this heat transfer surface area and then we try to figure out the actual number of the tubes n t we will the number of tubes we will be trying to find out. And from there when we have some kind of geometry known to us then we go for the rating problem, as if we have finalized the heat exchanger. And we have the inlet temperature known to us and then we try to calculate the exit temperature. So, basically it is a kind of trial and error method, but slightly better than the trial and error.

So, if we have the heat transfer known what is the heat duty that is known, we have the delta t l n known, because we know in a design problem all the exit temperatures. This f factor generally we assume it to be 0.9 or around. Because in a counter current exchanger it is one, but it is not really a counter current exchanger and actual value of the f finally, when we go for the rating problem we have to get that value. And this U 0 now we have to make an estimate. So, we have a certain known value it is already also given in this particular book, one can refer to this book while designing such kind of exchanger. And from there we get the value of U and from there we can try to estimate the A 0. Once we know the A 0 we try to find out the number of tubes in terms of the pi d 0 and the length is already known.

And then for one pass tube, we have this is the kind of n t I mean number of tubes and we have this constants. We will talk about this particular type of constant why it is coming like this. And finally, we have these relations by which we can try to estimate the number of tubes for different number of passes.

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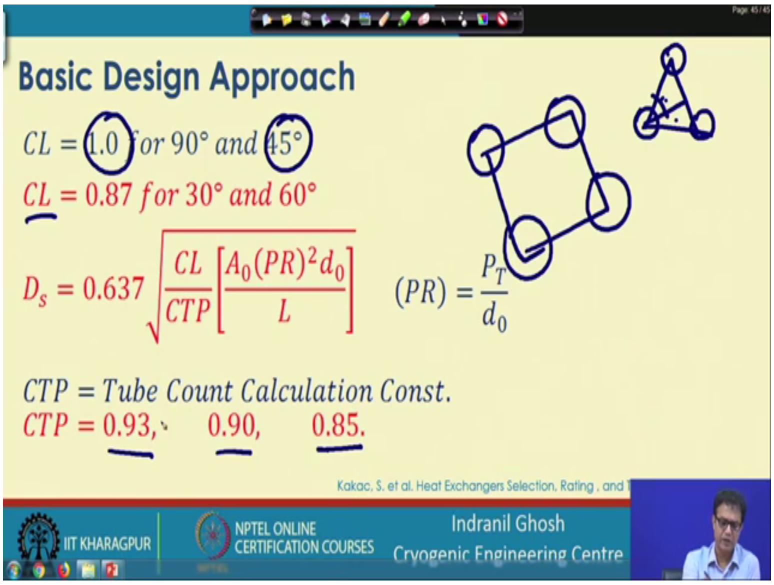

We have this CL equals to 1 for 90 degree. And this is for 45 degree that is the tube arrangement this depends on the type of tube arrangements we are following. If it is like this way I mean they are 40 I mean they are at 90 degree or in line configuration, then it becomes 1. Or if it is 45-degree then this is also this is also 45 degree corresponding to that CL equals to if it is 45 then it is 1.

Whereas for 30 and 60-degree angle if it is 30 degree it is point 8 7 if it is 60 degree also it is CL comes out to be 0.87. And that 0.9 and 0.93 and 0.85 all this tube constant calculation comes tube count cons a calculation constants. That we have I mean used in the earlier I mean relation in the previous in the previous slide, if you look at we have used that relation. And based on that we would be able to calculate the diameter of the shell side

So, we will try to look this one in details in a later on and finally.

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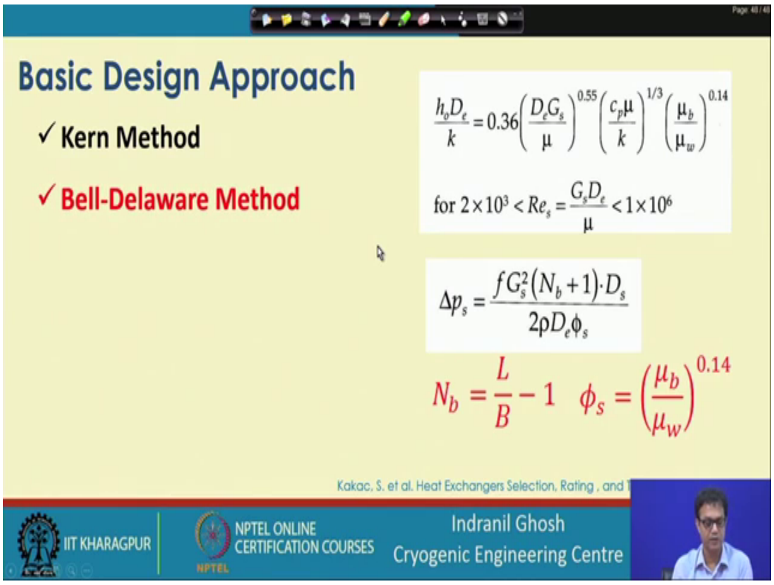

You will get once we have this known to us. Then we can go for either of these 2 types either we use the Kern method or we use the Bell-Delaware method to calculate the actual heat transfers. So, that is all.

Thank you.