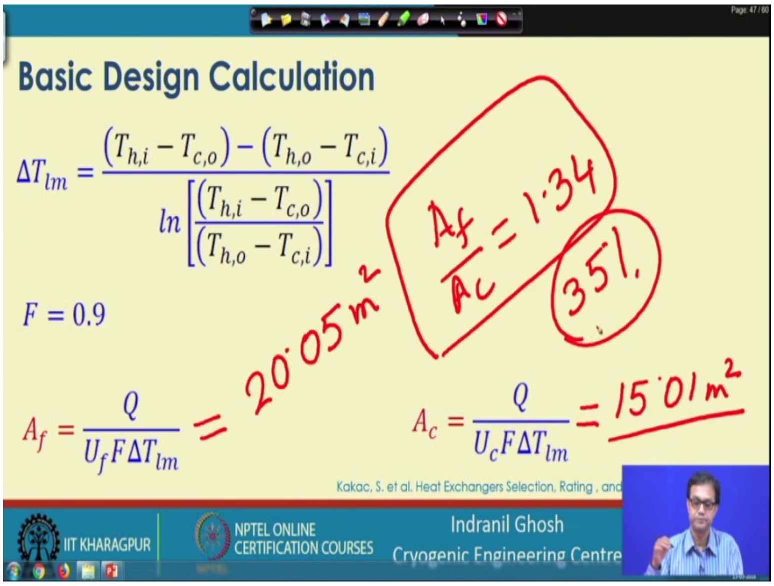
Heat Exchangers Fundamentals and Design Analysis
Prof. Indranil Ghosh
Department of Mechanical Engineering
Cryogenic Engineering Center
Indian Institute of Technology, Kharagpur

Lecture – 15
Tubular Heat Exchanger: Shell and Tube Design (Contd.)

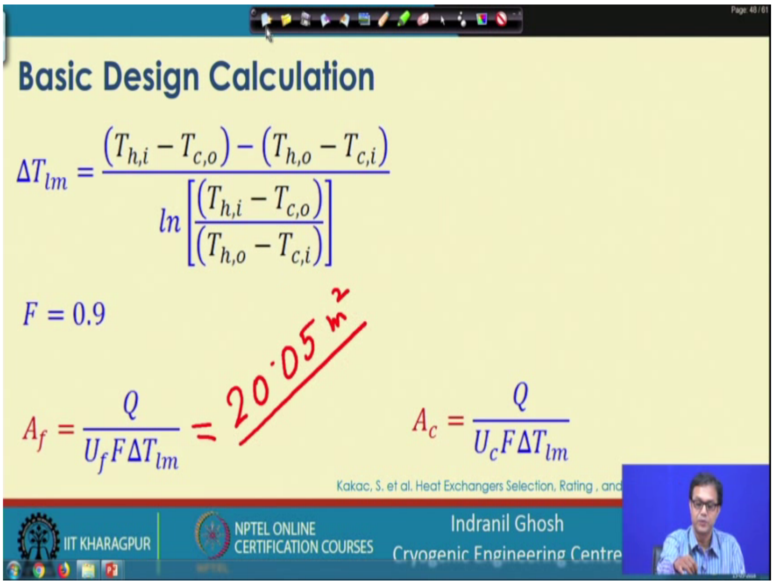
Welcome to this lecture. This is in continuation to our earlier discussion where we were trying to design the Shell and Tube heat exchanger, where we have been asked to design the shell and tube heat exchanger for heating up the raw water with the condensed water. And we were trying to design it and we have estimated the overall heat transfer.

(Refer Slide Time: 00:37)



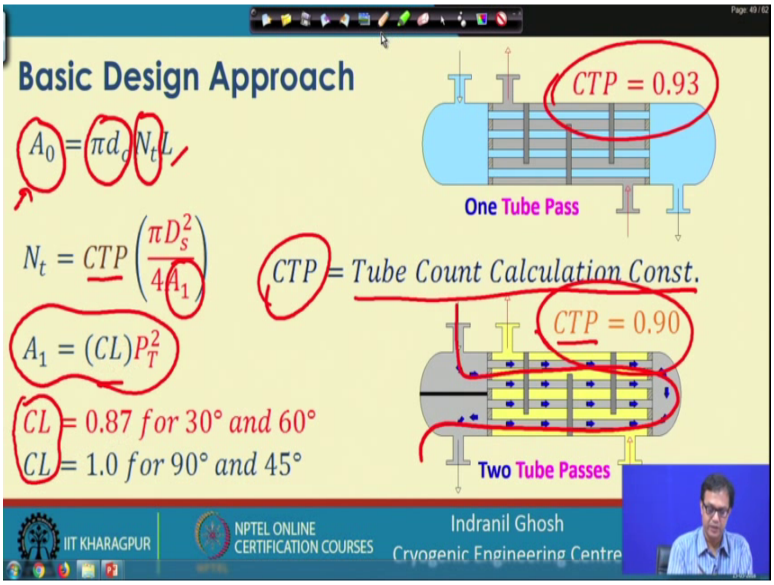
There we found that this heat transfer area corresponding to this is 20.05-meter square, and this is 15.01-meter square. So, that means, this ratio A f by A c was 1.34 and this design is within our limit where it was expected that oversized design should be less than 35 percent.

(Refer Slide Time: 01:24)



So, based on this surface area as we have said that we will be working with this 20.25-meter square heat transfer surface area. Now what we need to design is how many number of tubes will be able to provide this kind of heat transfer surface area. So, for that we now go to the next slide.

(Refer Slide Time: 01:41)

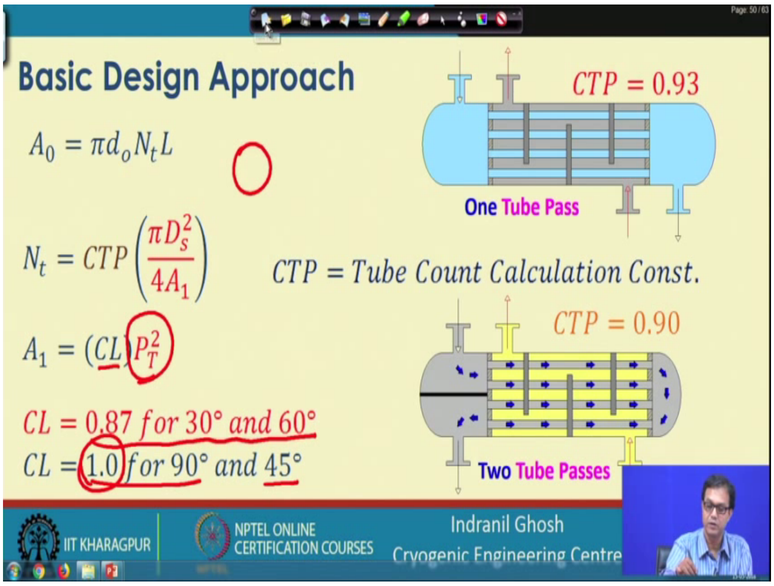


Where this surface area as you have as you can understand that we have estimated this external heat transfer surface area and imagine that we have N t number of tubes each of length L and each one is having a surface area external surface area of pi D 0.

So, N t number of tubes each of length L, each of surface area pi D 0. So, that gives you the total number of heat transfer surface area as A 0. But it is not all because this N t from here you will find that this pi D square by 4 A 1 and CTP, that CTP is basically the tube count calculation constant as we have discussed in the earlier class, that the tube count constant calculation constant takes care of the extra area that we have to provide to house all these tubes inside the cell. And CTP for a single pass one tube pass is 0.93 and CTP for double pass, double tube pass. Double tube passes basically the fluid is entering here coming like this and going out like this.

So, that is how it is the double pass. So, in case of double pass this CTP or tube count calculation constant is 0.90 and for other I mean if it is a 3 tube passes, then it will be having 0.83 value. So now, we also have this A 1 area given by CL into P T square this is you can understand that this is because of the; it depends also on the arrangement of the tubes whether we are arranging them in square pitch, whether we are arranging them in the triangular pitch with 45 degree or 60 degree or 30 degree. So, accordingly this will change this CL will also vary. And this is basically nothing but the layout constant.

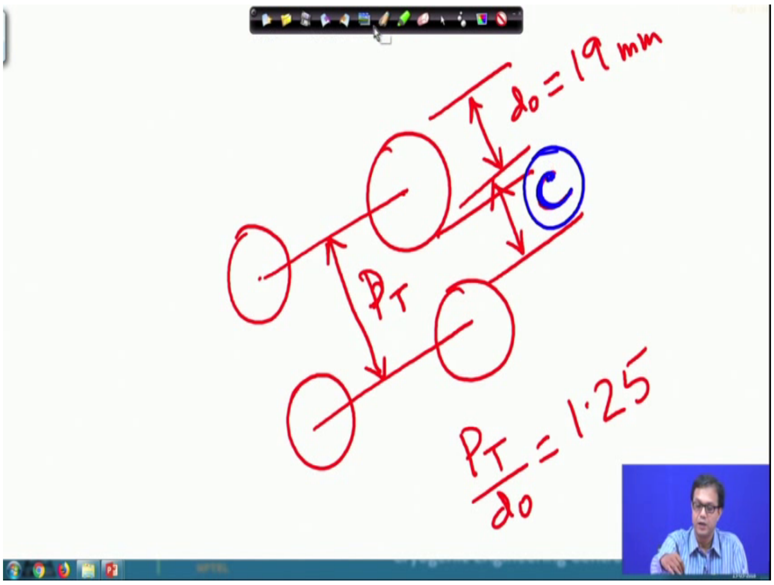
(Refer Slide Time: 04:29)



So, we have the CL 0.87 for 30 degree and 60 degree. But here this is one for 90 degree and 45-degree as you can understand that we have been asked to look for a square peach. So, for us this number is one.

So, we have to assume this CL is equals to 1, and P T is already given P T that is basically it is like this, if we look into it is like this.

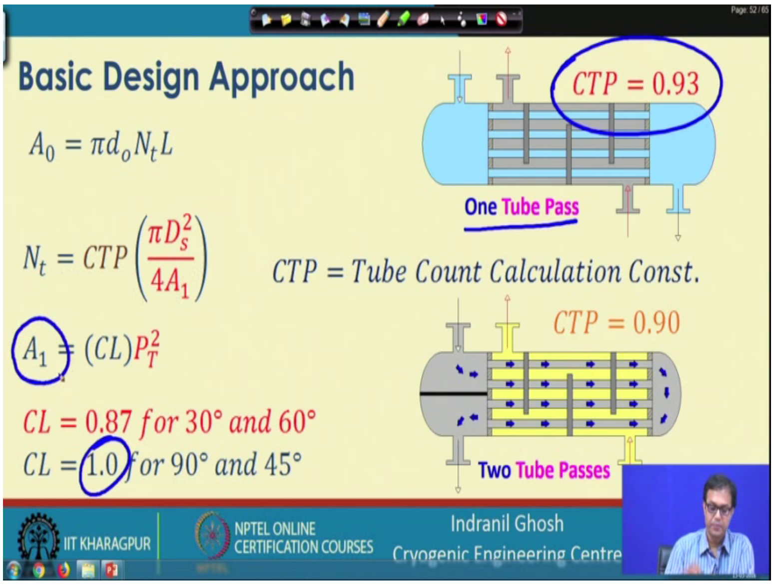
(Refer Slide Time: 05:05)



We have 4 such tubes, the OD of each tube is d 0 given by 19 mm, and this between this 2 this is the pitch P T, rather P T and P T by d 0. This is given as 1.25. Here we have the clearance, this is nothing but clear and c, you will be using this term later on this will also be necessary how the clearances you know. So, this is what we have been given and now I am sorry, so.

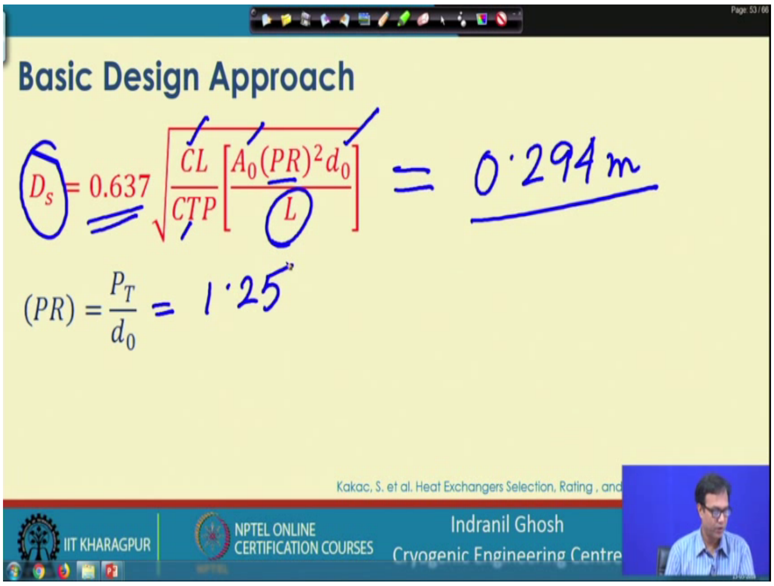
So, based on that this information since we have a single tube pass tube single tube pass, and we have a square pitch we have 1 and we have 0.93 value.

(Refer Slide Time: 06:05)



So, accordingly if we put this one and the value of A 1 also, accordingly we will be able to estimate the diameter of the shell.

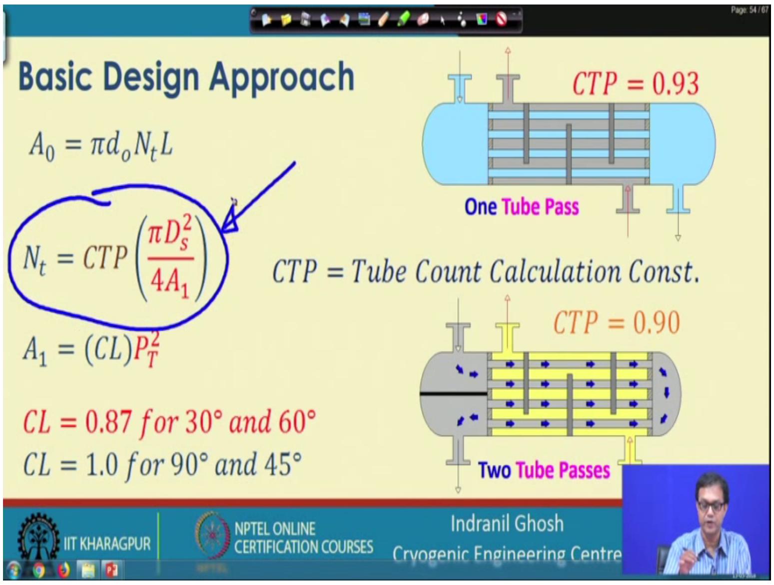
(Refer Slide Time: 06:27)



So, this is this gives you the diameter if we put all these values we will find that this constant 0.637 is coming. And this we will be able to find out, because this CL is known, CTP is known, A 0 already we have estimated it to be 20.05. The pitch ratio is also know, d 0 is also known L is known. So, this the diameter of the shell can be estimated.

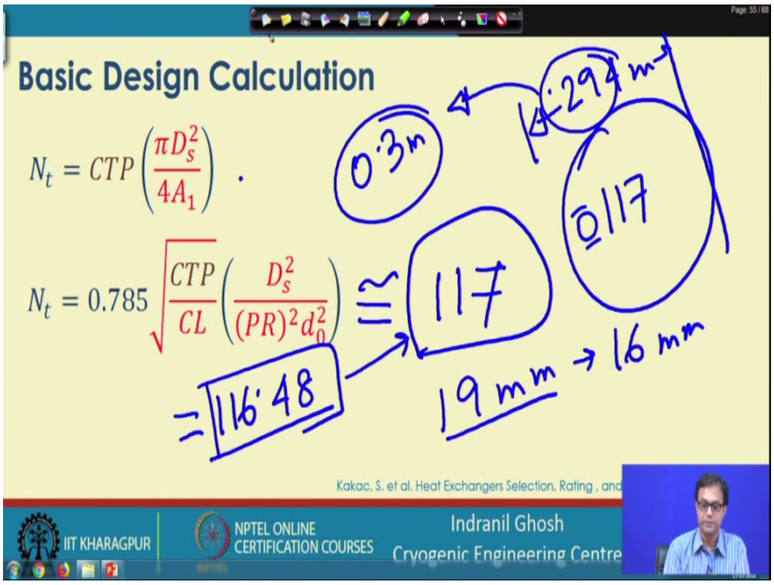
So, this diameter of the shell is coming to be 0.294 if we put all the values. So now, we know the diameter of the shell. So, this is also it is known already it is 1.25, we already we have said about it. Now if we look into the previous equation we find that we also try to find out what is that N t.

(Refer Slide Time: 07:39)



Because this is of our target, I mean, how many number of tubes finally, we have to decide. So, if we do that now we will try to calculate, what is the number of tubes.

(Refer Slide Time: 07:52)

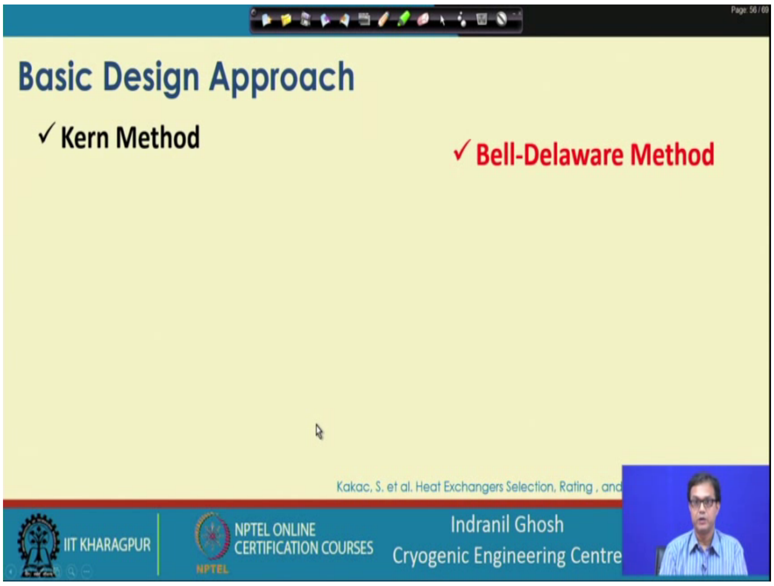


So, already we have decided the D s. So, you will also find that this N t is related to the D s, and if we calculate this one, we will find if we put all the values here. We will find that it is coming approximately 117 numbers. So, we have to take a round off value, because it is calculation will come as 116.48, but we cannot have a fractional number of tubes. So, we will be taking the next higher value as 117.

So, as we can understand that, we should have a diameter of typically of 0.294 meter. And we have to accommodate something like 117 number of such tubes. So, this is a summary of a the rough estimate that we have obtained for this heat exchanger. We have say 0.294; we will not go we will go for nearly about 0.3-meter diameter of the shell. And the tube length is already known it is 5 meter. And the OD of the tube already it has been specified to be 19 meter for the tube. And it is id is 16 meter, 16 sorry, 16 mm. And we have also been told about the baffle spacing and already we know about the square pitch.

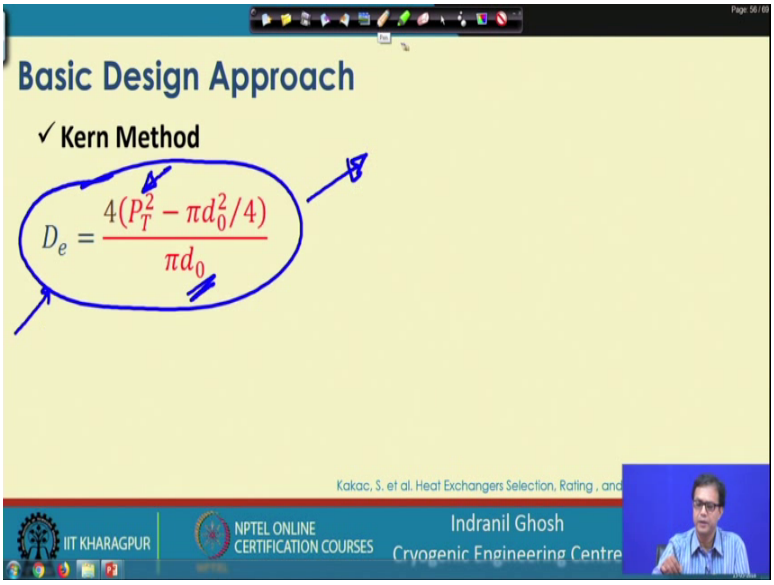
So, based on this rough estimation, we can now try to find out, we can now try to find out what would be the actual dimension of the heat exchanger. So, for that what we need to do is that we are having 2 different techniques.

(Refer Slide Time: 10:10)



One is the current method, popularly known. And another one is the Bell Delaware method. So, we will not talk about this method in this class or in this lecture, and we will just briefly talk about the current method.

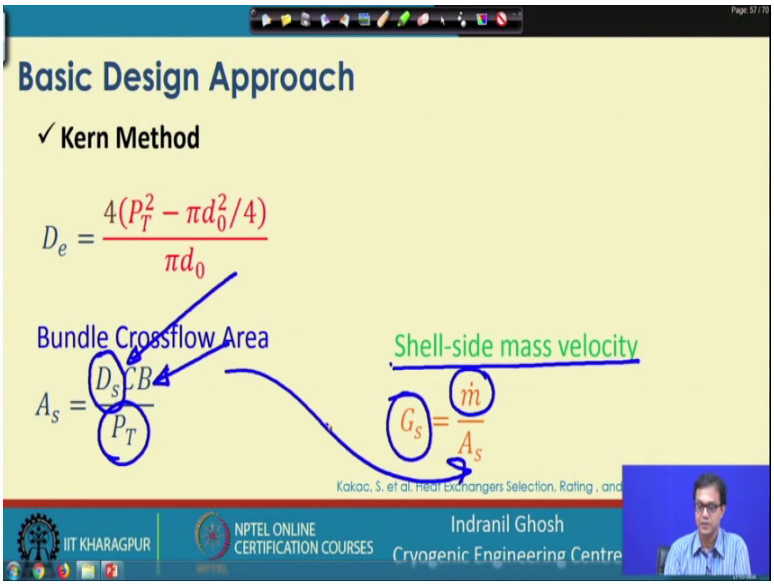
(Refer Slide Time: 10:28)



Where it will be this is the estimations are based upon the equivalent diameter, where we can find this equivalent diameter this is for the square pitch. And we find this is depending on the pitch dam, a pitch ratio P T square and then pi. And this is the d 0 the external diameter of the tube.

So, we can estimate this equivalent diameter. Please, mind that this is not the hydraulic diameter. This is we have talked in the earlier class; this is based upon the heat transfer perimeter. I mean wetted perimeter of the heat transfer area.

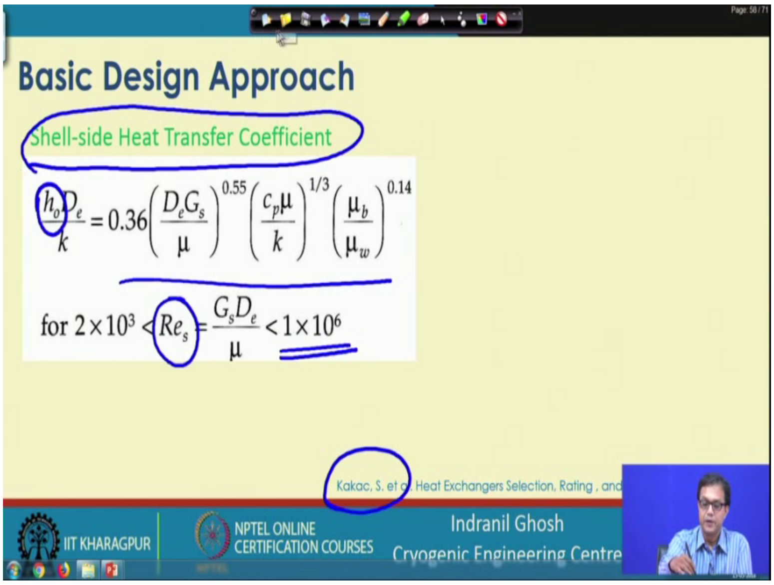
(Refer Slide Time: 11:27)



So, now if we look into the, this is the bundle cross flow area, and this is the shell side mass flow velocity, this will also appear in our calculation. So, this is how we calculate I am sorry, this is previous, ok. So, here this D s is the shell diameter. This c as I told you earlier, that this is the clearance this is the baffle spacing and P T is the pitch dia I mean pitch. So, the transverse pitch and the shell side mass velocity this is the mass flow rate divided by the bundle cross flow area, s from here we have to put this value to get the mass flow rate, mass velocity on the shell side.

So, let us try to get those values. Once we are able to get those values we will be able to estimate the overall heat transfer coefficient.

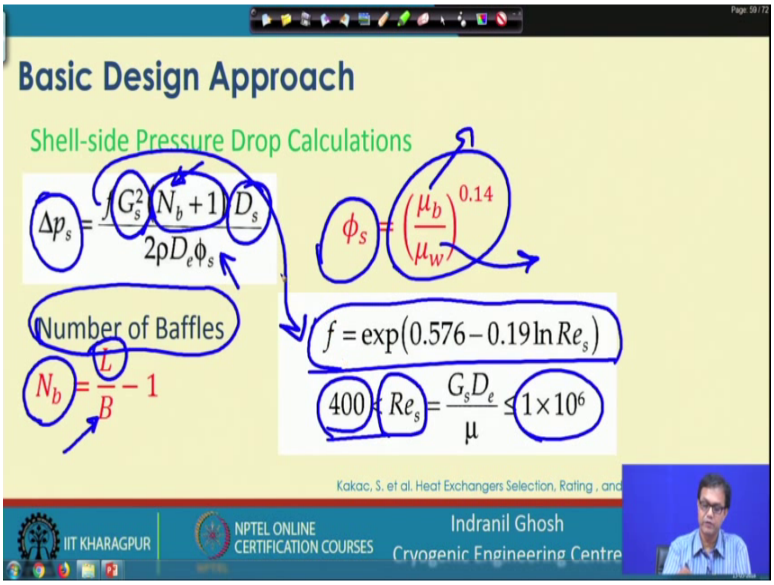
(Refer Slide Time: 12:27)



I am sorry, the heat transfer shell side heat transfer coefficient, and this will be related to this correlation. And this has been taken from Kakac s book. And this is for the Reynolds number range, 2 into 10 to the power 3 and within less than one into 10 to the power 6. So, for this shell side I mean for this range of Reynolds number. We can try to estimate the shell side heat transfer coefficient.

So, then we should also look for this is about the heat transfer coefficient.

(Refer Slide Time: 13:13)

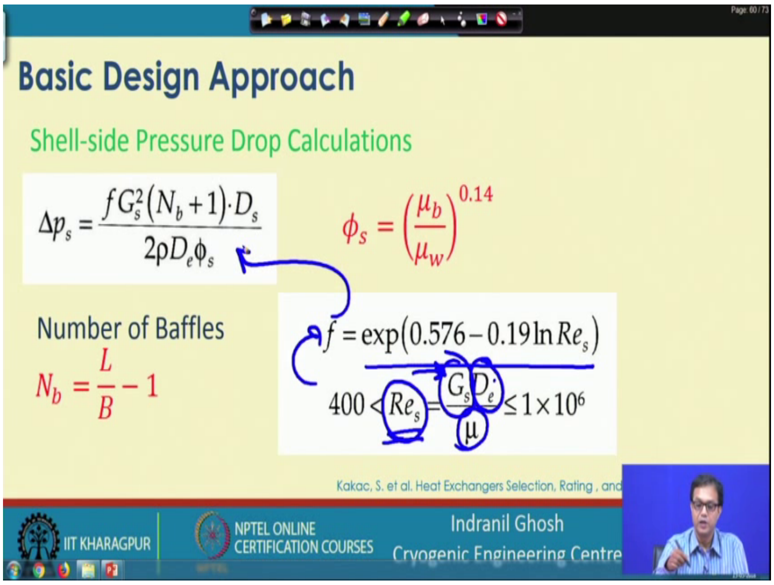


We also need for the pressure drop calculation and this will depend on that mass velocity of the shell side. And also it will depend on N b, the number of baffles which will be used. So, this is the baffle spacing, this is the length. And N b is L by B minus 1. And here if you can look into it, I mean, look in this expression for the pressure drop on the shell side this will be N b plus 1 so that if we have N b number of baffles, the fluid will be passing N b plus 1 number of times over the tubes tube banks.

And we get the pressure drop related to that this way. And also we have this phi s as a ratio of the bulk. This is evaluated at the bulk and this is that the fill an average temperature. And this will come over here; this D s is basically the shell side diameter.

And the friction factor so, it will be an expression like this, for this is valid for the Reynolds number in the range of 400 into 1 into 10 to the power 6. And as you can understand that this is not very I mean this takes care of the number of baffles in it, and we have to use a slightly different kind of correlation, I mean, for the shell side. So, this is how we will get the friction factor and evaluate, we can evaluate the friction factor.

(Refer Slide Time: 15:07)



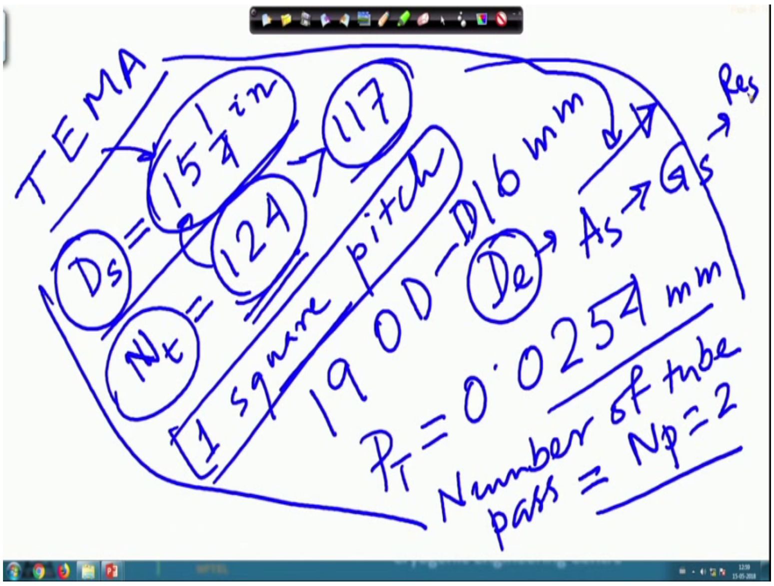
First of all, we have to calculate the Reynolds number. This Reynolds number is gib depending on the G s D e and mu. So, already we have talked about how to evaluate the G s. We have already given the expression for the equivalent diameter, and this is the fluid property. So, once we know the R e s the shell side, then we can calculate the friction factor. Then we can try to calculate the pressure drop on the shell side and we have to see whether it is within the allowable limit.

So now we can get back to our original discussion. So, I am sorry, previous so now, if we are able to get all this information, I mean, the we have some rough calculation of the shell and the tube. And now we have to rectify or rather we have to go for the rating problem as you can understand that we have done a rough estimation of the heat exchanger. Now we have to apply the current method or I mean, where we have been told about the heat transfer coefficients and the pressure drop correlations has already been given. And now we have to select some kind of heat exchanger or there is a guideline by the tubular exchanger manufacturing, manufacturers association that is TEMA.

So, there you will find that for accommodating 117 number of tubes, as that that is the number of tubes we have estimated. So, we have to get a guideline from TEMA to accommodate that number of tubes of 117; obviously, you will find that exact number of 117 number of tubes will not be available. So, the nearest possible number of tubes which is close to 117, but it should be more than 117. So, accordingly we will find that there is a guideline and for such design, we find that the shell diameter and since we, it is it is given in terms of single pass double pass or triple pass and so on.

So, here in this case since it was optional, that we can choose a single shell or double shell also I mean double shell and double tube type.

(Refer Slide Time: 18:20)



So, 2 tube pass we can think of a, something I mean this is pre dictated by the TEMA. And you can look into it that this is 15, and one 4th inch diameter of this D s. And the number of tubes now according to this, this is 124. So, this is more than the 117. So, corresponding to this value, I mean, corresponding to this one we find that this is the nearest possible one, where we can accommodate that number of tubes this has already been, I mean, standardized by TEMA standard.

So, according to that one we find that 15 1 4th inch number of I mean diameter shell, will be able to accommodate 124 number of tubes in one square pitch. This is the pitch that is also defined by them. And here the baffle spacing and we have also been specified about the tube OD, that is 19 and the 16 mm is the id of the tube.

So, and the baffle spacing is remaining the same pitch, P T it is now slightly changing to 0.0254 mm. And the number of tube passes that is, earlier we were using number of tube passes, where tube passes was single, but now we will have number of tube passes Np equals to 2.

So, accordingly this is based upon the preliminary design calculation that we have done. Now we have gone to the TEMA standard to rectify our design. And now we have come to this conclusion that we will be using something like N t equals to 124 in a square pitch 1 mm sorry, 1-inch square pitch. And the number of passes of course are 2.

So, accordingly we would be able to calculate all the pressure drop and the heat transfer coefficient, as we have suggested in the previous slides that, how to estimate the heat transfer coefficient depending on the D e value. We have to estimate the D e value again. We have to estimate the A s, then we have to estimate the G s from there we will be able to calculate the R e s. And from there we should estimate the overall heat transfer coefficient, and the pressure drop coefficient. And then we will be able to justify whether the required pressure drop and the heat transfer is achieved or not.

And then we will find that if it is within the allowable limit, we will conclude that the design is perfect, otherwise we have to again choose a different configuration form the standard TEMA standard and do the calculation again.

Thank you.