Process Equipment Design
Prof. Shabina Khanam
Department of Chemical Engineering
Indian Institute of Technology – Roorkee

Lecture –18
STE Design- Bell's Method-2

Hello everyone. I welcome you all in the third lecture of week 4 of the course Process Equipment Design and here we are continuing the discussion on design of shell and tube heat exchanger using Bell's method. So, if you remember the last lecture there we have started Bell's method and Bell's method is basically initially considers tube bank which is ideal in case.

What is the meaning of that? It means that no other factor is available and heat transfer is occurring over the tube it means at the outer periphery of the tube which will be in shell side of course. So once I am having the ideal case shell side heat transfer coefficient we will further consider different factors. So, we have already covered F n factor which is the factor for tube row correction.

How many tube rows are available between baffle tips that factor we have already considered in the last lecture. So, continuing the Bell's method we will first focus on window correction factor in this factor. So, let us start discussion on F w that is window correction factor. So as you all know that in shell side the window is basically between baffle tip and shell diameter. So that gap which is available after baffle cut that we consider as window correction and its effect is counted is Bell's method through F w factor.

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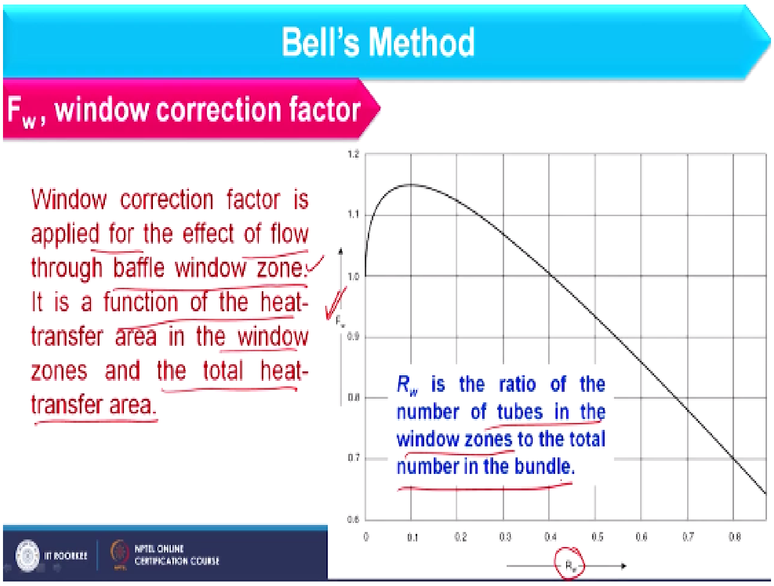

So, window correction factor if I am considering it is applied for the effect of flow through baffle window zone. So, baffle window zone what it is that I have already explained. It is a function of heat transfer area in window zone and total heat transfer area because some section of bundle is available in window zone also. So, how much the area of bundle in window zone to total bundle area.

So, based on that we will consider F w that is window correction factor and that factor you can simply see from this graph. Here, I am having F w on Y axis and in X axis we have R w. So what is this R w? R w is the ratio of number of tubes in window zone to total number of tubes in bundle. So, in this way we first consider R w and then we can find out F w. So, let us see what is R w and how its value can be obtained.

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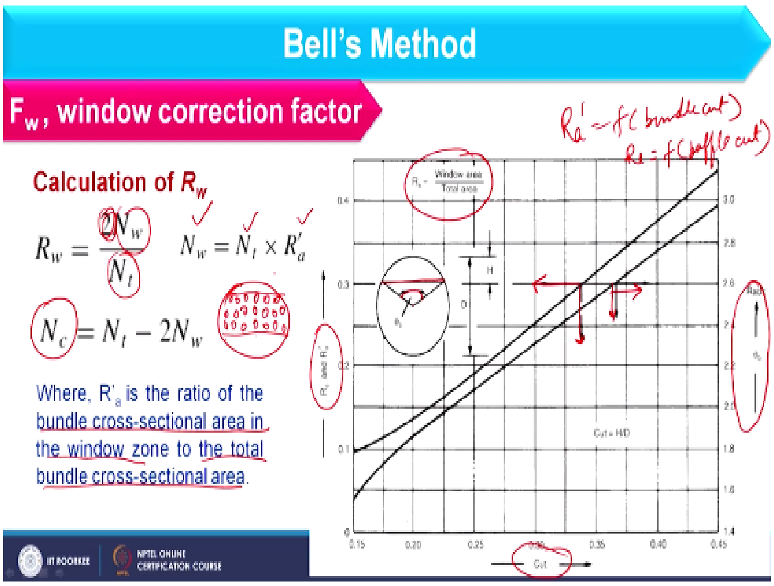

So, let us see the calculation of R w. R w is nothing, but ratio of N w and N t into 2. So, what is N w? N t you know already this we have used in bundle dia calculation that is total number of tubes available in bundle. So, N w is the number of tubes available in window zone and why I have multiplied that by 2 because between two baffle tips we have two window zones. So 2 into N w / N t that is basically the R w.

So, first of all we have to find out N w because N t we already know. So how I can find out N w that will be N t into R a dash. N w is N t into R a dash and what is R a dash? R a dash is the ratio of bundle cross sectional area in window zone to total bundle cross sectional area. So R a dash counts the area of bundle which is available in window zone to total bundle cross sectional area and value of R a dash you can see from this graph.

Now, if you focus on this graph on Y axis we have R a and R a dash and on X axis we have cut and on secondary axis we have theta B and theta B is what? Theta B is the angle at the center of the shell which is made by baffle code. Now, here I am having both parameter R a and R a dash. R a dash you require over here and if you see if you need to use upper graph you have to use this arrow as well as this arrow.

It means upper graph will give the value of R a and R a dash and below graph will give the value of theta B according to the cut. Now, the point is R a dash we have already discussed that the area of bundle which is available in window zone to bundle cross sectional area and if you see the Y axis there we have another factor which is R a. So what is R a? R a is basically window area by total area.

So, window area means that part of bundle as well as the empty area between bundle or the clearance between bundle and shell dia. So R a and R a dash if I am comparing its value we are obtaining from a single graph, but value should be different because one is the part of bundle and another is the part of shell. So how I can differentiate between R a and R a dash. It will depend on what cut I am taking.

So, if I am saying that R a dash is the ratio of bundle cross sectional area which is available in window zone to total bundle cross sectional area. It means it is only counting the bundle. However, R a is basically counting the shell. So, to find out R a dash we have to consider the cut and that cut is basically the bundle cut. How you can find the bundle cut? It is very simple

H b / D b you have to consider bundle cut as H b / D b because H b is the section of bundle which is available in window zone that we have already discussed in F n tube row correction factor so that you can refer.

So here I am having cut which is bundle cut if I am considering R a dash and if I am considering R a the cut is of baffle cut like you have considered 25%, 35% like that. So, based on different cuts you can use this graph. So, you should keep in mind that R a dash is a function of bundle cut and what is bundle cut that I have already explained. R a is basically the function of baffle cut.

So based on that you can find out R a dash and then you can find out N w and so you can find out R w. So here I am having another parameter that is N c. What is N c? N c is basically total number of tubes available in cross flow zone. What is the difference between N cv and N c if I ask you? N cv is basically number of tube rows or we can say number of vertical tube rows in cross flow zone between two baffle tips.

And N c is total number of tubes available in cross flow zone between two baffle tips. So simply you can have this shell where I am having cross flow zone between two baffle tips and these are basically N cv and if I am considering all these values so these are considered as N c. So, you should understand geometrically that what is the difference between N c and N vc.

And I hope you understand the difference between R a dash and R a and how to obtain that. So once you have that R a dash you can find out R w and you can use the previous graph to obtain value of F w that is window correction factor.

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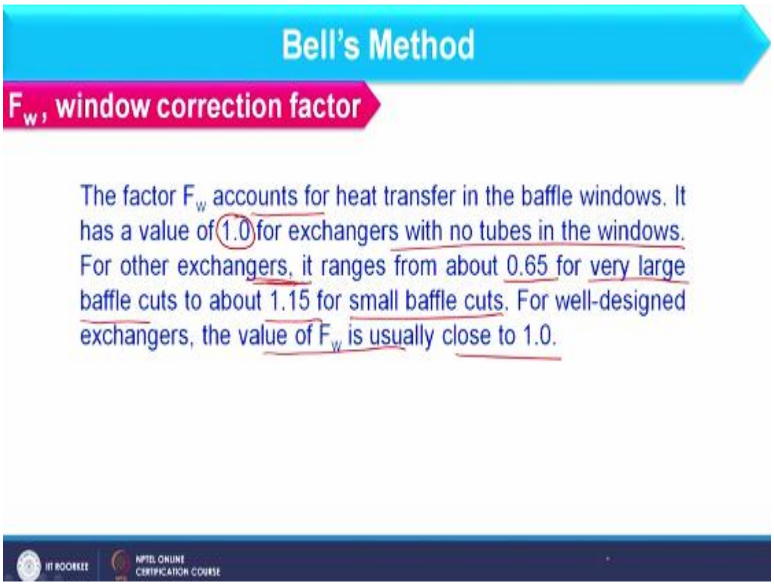

So as far as window correction factor is concerned it is basically accounted for heat transfer in baffle window. So, its value is 1 for exchanger with no tubes in window. Sometime window zone does not include any tube and such type of baffles we have already discussed when we were discussing the constructional details of exchanger with shells. So, there you can find the baffles of such type.

For other exchanger it various from 0.65 to 1.15. 0.65 for very large baffle cut and 1.15 for small baffle cut. For well designed exchanger value of F w is usually close to 1. So, that value you can obtain from the graph we have already discussed and accordingly you can consider window correction factor. Now, next factor is very important that is bypass correction factor. Now here we are considering basically stream C if you remember different streams we have discussed in last lecture.

So F b basically counts stream C. So, first of all we will see what is bypass and how its effects can be reduced.

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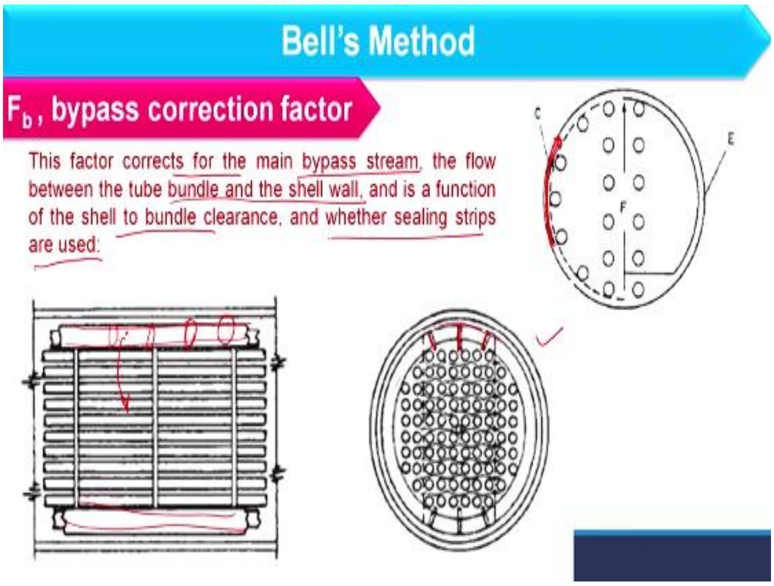

So you can see this is basically the bypass streams which we name as stream C also and this bypass correction factor it corrects for main bypass streams. The flow between tube bundle and shell wall and is a function of shell to bundle clearance and whether sealing strips are used or not. So what is sealing strip? Now what will happen when I am having the bypass zone there liquid will remain stagnant and liquid will not participate in heat transfer.

And therefore, we avoid such accumulation of the fluid inside the exchanger because exchanger is used to transfer the heat and if stream is not participating in heat transfer we have to make such arrangement so that it should come to the main zone and main zone is the cross flow zone. So what we have to do? We have to bring the liquid which is available in bypass zone to the cross flow zone.

So, first of all you see this schematic where at the top we have this strip and this is basically covering the bundle and if this is the shell and this is bundle this basically covers this gap and distribute liquid from this clearance to main cross flow zone and in this schematic cross sectional view is shown where you have this bundle and this is the shell and here I am having the sealing strips.

So sealing strips are nothing, but the metal strips which is inserted in baffles to distribute the liquid which is available in bypass zone.

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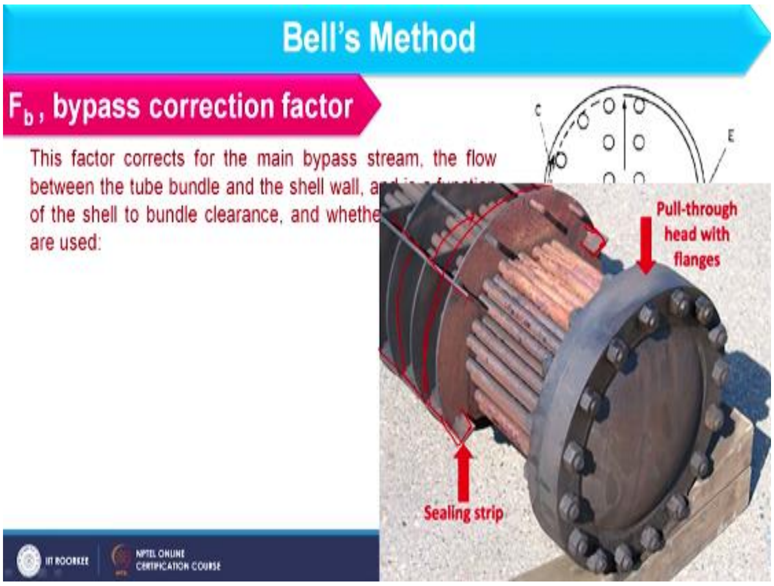

In this image you can see the sealing strips, this is basically the sealing strips, this is also a sealing strip. So, sealing strips are basically inserted in the baffle and this basically reduces this section. If I am not putting any sealing strip then what will happen this complete section remains available for liquid where liquid can be accumulated. So, if I am using these sealing strips it distributes the liquid when sealing strips will be there because the hurdle in the flow liquid will be distributed and it will reach to the cross flow section.

So in this way we are using the sealing strips and where sealing strips are most important to place when I am dealing with internal floating head heat exchanger because that is the only heat exchanger where clearance is maximum if you remember the clearance graph. So, in that case we should definitely use sealing strips however first of all we should check that whether sealing strips are required or not for that also we have some criteria. So, let us discuss that.

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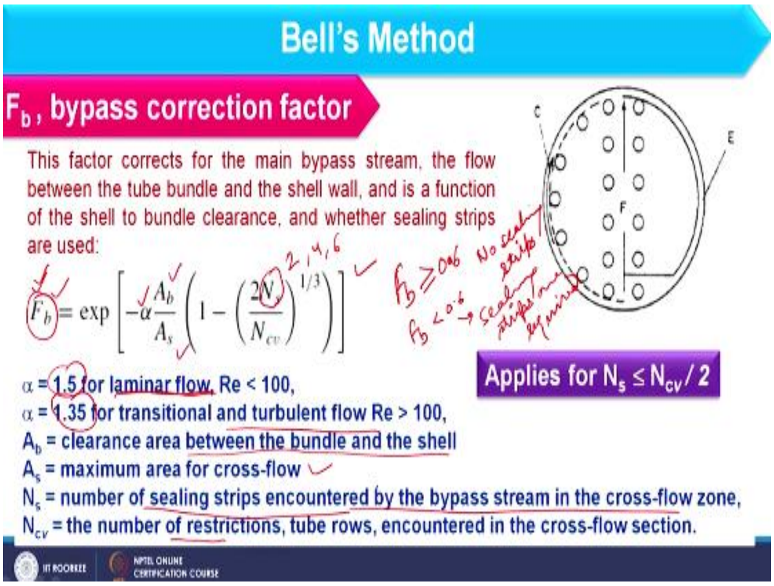

So here I am having the expression to consider bypass correction factor which is the function of A b and A s N s and N cv and alpha also. So, all these parameters you can see below alpha is basically the factor which is counting the flow. If laminar flow is there, we can have different value of alpha for turbulent and transition we have different value of alpha so whatever would be the region that you can consider through Reynolds number you can choose alpha value accordingly.

And A b is basically the clearance area between bundle and shell. So, A b basically counts where stream C will lie so we will calculate that area then only you can understand the necessity of sealing strip. A s is the maximum area for cross flow because this is at the bundle equator so that is the maximum cross flow area as we have discussed in Kern's method. So, this A s you have to take directly from the Kern's method.

Now why I am considering A b and A s? A b is the area which is available between bundle and shell and fluid or stream C is available there only. However, cross flow area why I am taking because I am bringing stream C to cross flow area so that it can participate in heat transfer and should not remain at dead zone and N s is basically number of sealing strips which will depend on the clearance.

And finally we have N cv which is basically the vertical tube row restriction that we have already discussed in F n correction factor. So, here we have the expression like F b is a function of areas as well as sealing strips. So, these sealing strips must have some maximum value. What is the maximum value? The maximum value of sealing strip should be equal to or less than N cv / 2 because we are bringing the fluid to cross flow zone.

So we have to consider restrictions available in cross flow zone and that is N cv. Let us say if your N cv is coming like 15 so you can consider maximum 7 sealing strips and usually sealing strips are even number. If you are putting one sealing strip at top or the upper clearance you have to put another sealing strip at bottom clearance also. So, N s should be even number and that should be equal to or less than N cv / 2.

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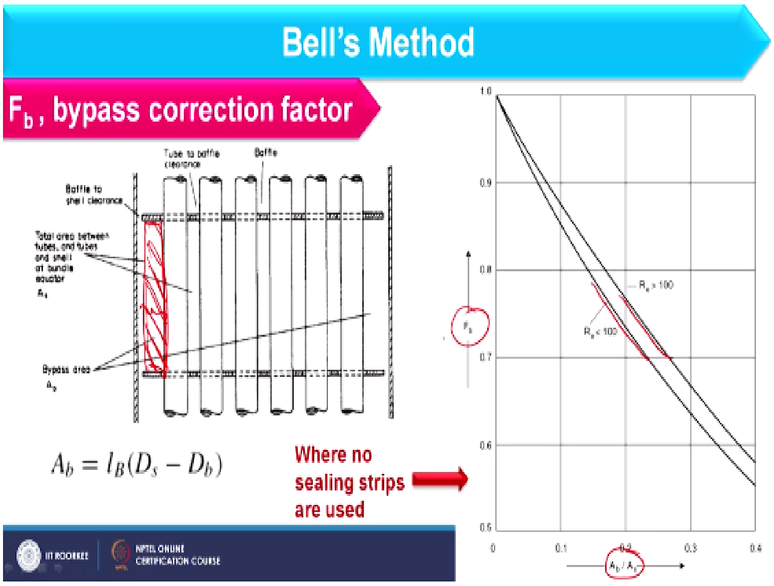

So here you can see this schematic so A b is basically this area between two baffle and it will depend on the clearance. So, we can find out A b like l B that is the baffle spacing D s – D b so you can simply find out this section area. So you can simply find out this section area as A b A s you know already so I am not going to explain that further. Now what you have to do? First of all you have to consider whether sealing strips are required or not for that what you should do?

You have this expression of F b in this case you will put N s as equal to 0 initially you will put N s = 0 while putting N s = 0 you can find out F b value. If F b value is greater than 0.6 we consider that no sealing strips are required and at N s = 0 if F b value is coming less than 0.6 here we should equate also and if it is coming less than 0.6 it means sealing strips are required.

So we have two cases first is you do not need sealing strip and second is you need sealing strips. So, if you do not need sealing strips if sealing strips are not used you should use this graph to see the value of F b. So, here I am having A b / A s depending upon the Reynolds number you can find out F b value from this graph. Now what will happen if I need sealing strip?

In that case you will consider different N s values and as I have told you that N s value should be even so we have to first check with 2 N s stream, 4 N s streams and 6 N s value. So, if 2 sealing strips I am considering we have to find out F b at N s = 2 and that F b value should be more than 0.85. Now why 0.6 and why 0.85? This is basically the range which we are considering that F b should be in feasible range so that point we will further discuss.

So, first of all you have to put N s = 2 and calculate F b value and you should keep on increasing the N s value in even number till F b becomes greater than 0.85. If you keep on increasing N s value where you have to stop? You have to stop when N s should be equal to less than or equal to N cv / 2 and that value should be even. So, you have to stop when F b value you can obtain as 0.85. So, first you have to check whether sealing strips are required or not and then you have to obtain F b value accordingly.

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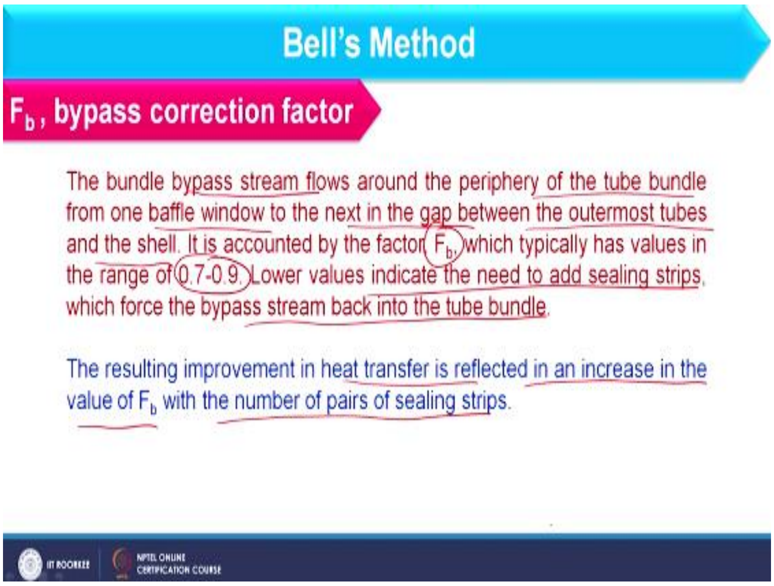

So, here I am having bypass correction factor so the bundle bypass streams around the periphery of tube bundle from one baffle window to the next gap between outermost tube and the shell. It is accounted by the factor F b we have already discussed and its value vary from

0.7 to 0.9 therefore I have chosen a range 0.62 to 0.85. So lower value indicates the need to add sealing strips which force bypass streams back to the tube bundle.

And therefore, we are considering the gap between bundle and shell and the cross flow area. So resulting improvement in heat transfer is reflected in an increase in value of F b with the number of pairs of sealing strips. So, therefore I have told you number of sealing strips should be even in number, but because that should be installed in pair.

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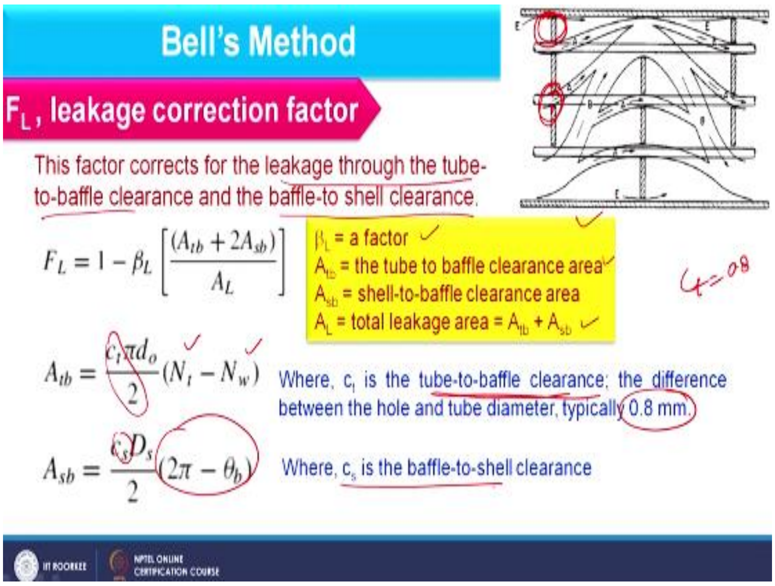

Next factor I am having is the leakage correction factor. So, this factor considers the leakage through tube to baffle clearance and baffle to shell clearance. So, if you see this schematic leakage correction factor basically counts stream A and E. So, we have this correlation for leakage correction factor which is basically function of beta L A tb A sb and A L. So, beta L is a factor A tb is the tube to baffle clearance area that is this section only.

A sb is the shell to baffle clearance area and A L is basically total leakage area where addition of A tb and A sb is done. So, A tb is basically c t pi d 0 / 2 into N t – N w. So you see as far as c t is concerned that is basically tube to baffle clearance and this difference or this gap is always 0.8 mm. So, c t value is equal to 0.8 always so here I am considering c t / 2 because I have to consider this gap only and pi d 0 that is the outer periphery of the tube.

So pi d 0 into c t / 2 is basically the open section or the open periphery over the tube and between baffle hole. So that should be multiplied by N t – N w. N w is basically number of tubes in window zone and this A tb basically counts tubes which are inserted in baffles. So N t – N w would be the total number of tubes which are inserted in baffles. So c t will be applicable there and value of ct should be equal to 0.8 always.

And now we have A sb where C s D s into 2 pi – theta b is considered and that should be divided by 2 and what is C s? C s is basically baffle to shell clearance.

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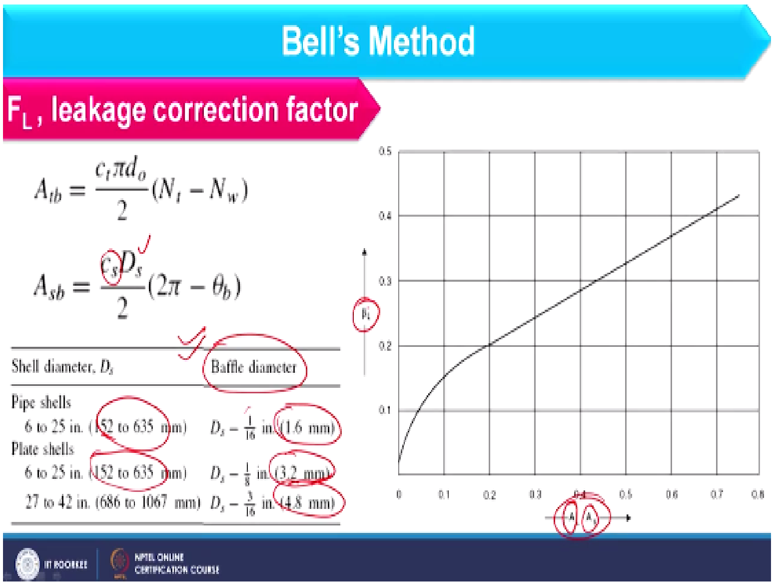

Now how I should find out the C s value? C s value will depend on shell dia. So you can use this table where pipe shells and plate shells are given and you can have another factor that is baffle diameter. Baffle diameter is what? Shell diameter – some clearance so that clearance is basically 1 / 16 inches in pipe shell where diameter is in this range. So 1 / 16 inches when you convert it gives 1.6 mm.

Similarly, for plate shell we can have same range of diameter, but clearance is more because plate shells are usually prepared with the rolling so some deformity may occur while rolling and therefore smooth insertion of bundle with baffle needs more space. So, in that case plate shell will have more clearance in comparison to pipe shell. So, the bracket which is available in this table that you can consider as C s value.

So C s value / 2 because you have to consider the gap between baffle and shell and D s is the shell dia so 2 pi / theta b. 2 pi / theta b is what? Theta b is basically the angle which is made by the code of baffle to the center of the shell so that theta b you can obtain from this graph here I am having the cut and here you can see the theta b value and in that case this cut will be baffle cut.

So you should keep in mind at which condition you have to use bundle cut and at what condition you should use baffle cut. So, theta b will depend on the baffle cut. So 2 pi that is the complete periphery – theta b so it will basically give this section only into D s. So in this way you can find out A tb and A sb and once you know A tb and A sb A L is the addition of A tb and A sb A s is the cross flow area that we have already calculated in Kern's method.

So based on these factors you can find beta L which is a design factor so considering all these parameters you can find out leakage correction factor that is F L.

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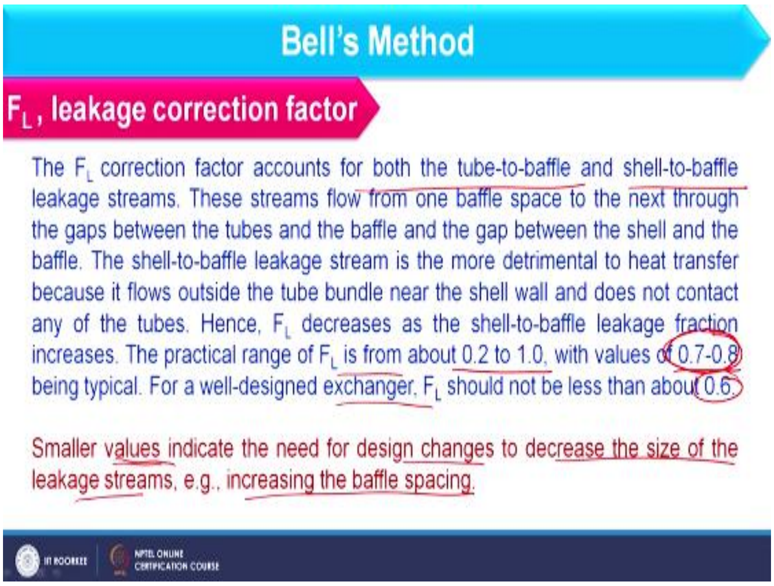

So as far as leakage correction factor is concerned it counts for both baffle to tube and shell to baffle leakage streams and as far as its range is concerned the practical range of F L is about 0.221 with value 0.7 to 0.8 being typical. So, we should consider that value should lie between this. However, for well design exchanger F L should not be less than 0.6. So, if we are finding F L less than 0.6 we should change A sb, A tb or beta L value.

So you should see what parameters will be affected when you have to increase F L or leakage correction factor. Further, the smaller values indicate the need for design changes to decrease the size of the leakage streams that is increasing the baffle spacing. So in this way you can consider F L factor and you can improve the value of F L and here I am stopping this lecture. In the next lecture, I am continuing the design of shell and tube heat exchanger using Bell's method. So that is all for now. Thank you.