Heat Exchangers: Fundamentals and Design Analysis
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Lecture – 41
Surface Condenser (Contd.)

Hello everyone. So, if you recall we were solving a problem of surface condenser, which is a shell and tube type surface condenser. And this is a very comprehensive problem, because many aspects of condenser design we want to discuss, and we are continuing with the problem for; we are continuing with the problem from the last lecture.

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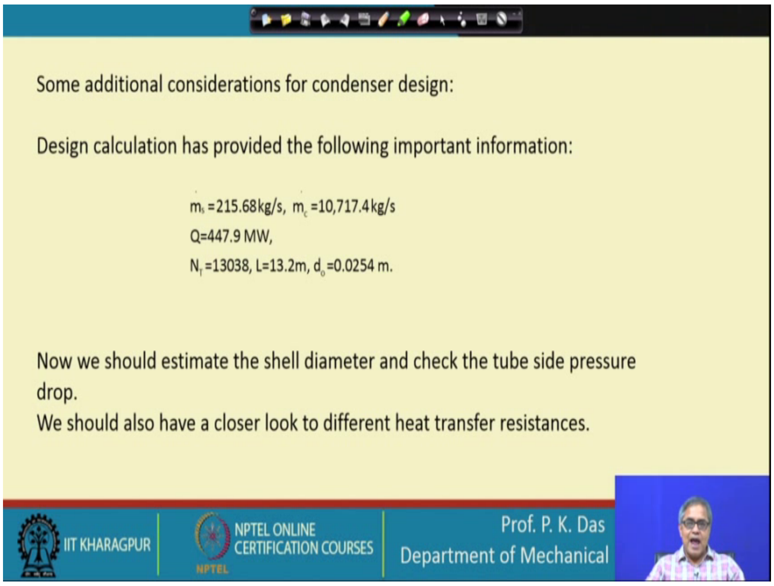

So, if you see or if you recall, we have done this calculations and certain important design quantities we have obtained. We have got the mass flow rate of steam. We have got the mass flow rate of coolant. We have got the total amount of heat transfer. We have got the number of tubes and the length of the tube. This we did not get through calculation, this we have assumed that outside diameter of the tubes that will be 0.0254 meter.

So, this shell and tube heat exchanger yes like to remind you, for recapitulation I like to mention that in these water as coolant is flowing through the tube side and steam is condensing over the tube. And this is a very large condenser and it is for a power plant of high capacity.

Now, we should estimate the shell diameter and check the tube side pressure drop. We should also have a closer look to different heat transfer resistances.

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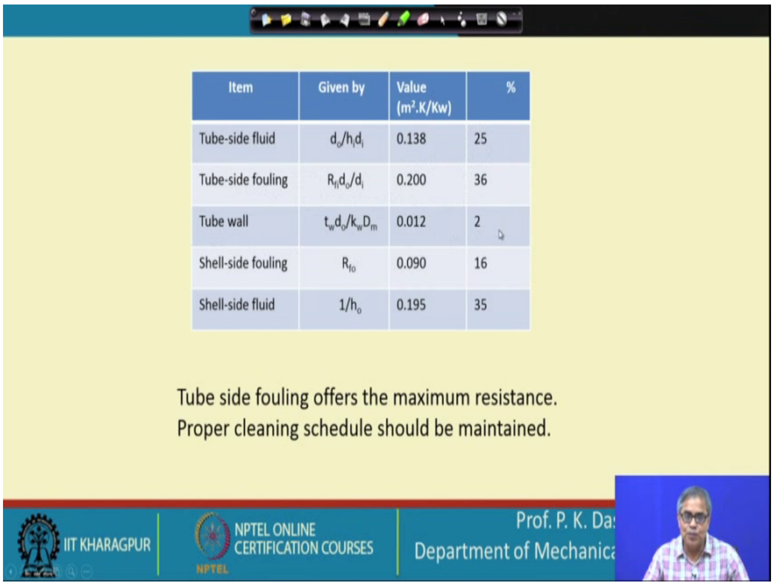

So, now if we go to this slide we can see that there are 5 resistances. Tube- side fluid there is resistance; that means, the water flowing through the tube side there will be some convective resistance; that is,25 percent of the total resistance: tube-side fouling; that is36 percent of the total resistance, tube wall that is only 2 percent. It is heat transferred through metallic surface by conduction and generally it is small.

So, in many heat exchanger calculation at the first-round people may neglect this one, because this is generally small. Then, shell-side fouling that is 16 percent and shell-side resistance that is 35 percent. So, out of all these thing the 36 percent is the tube-side fouling and that is quite large. Shell-side heat transfer coefficient: that is condensation heat transfer coefficient that should be low, but, what happens due to the effect of inundation etcetera, the average heat transfer coefficient falls. Unless we make some method to take care of this, so the average heat transfer coefficient that falls.

But what is to be noted that tube side fouling is quite high, 36 percent. So, there should be in shell-side fouling is also not negligible. So, there should be some method in heat exchanger to take care of the fouling; that means, time to time the heat exchanger both the tube side and the shell side needs to be cleaned. And particularly tube-side fouling is very high. So, tube-side fouling offers the maximum resistance and there could be different schemes of cleaning.

One scheme of cleaning could be chemical cleaning and another scheme which is also very widely used that people use; people circulate metallic balls of suitable size through these tubes. And then, due to this circulation these metallic ball they help in dislodging the fouling layer and then it has to be cleaned.

So, this is one aspect of it.

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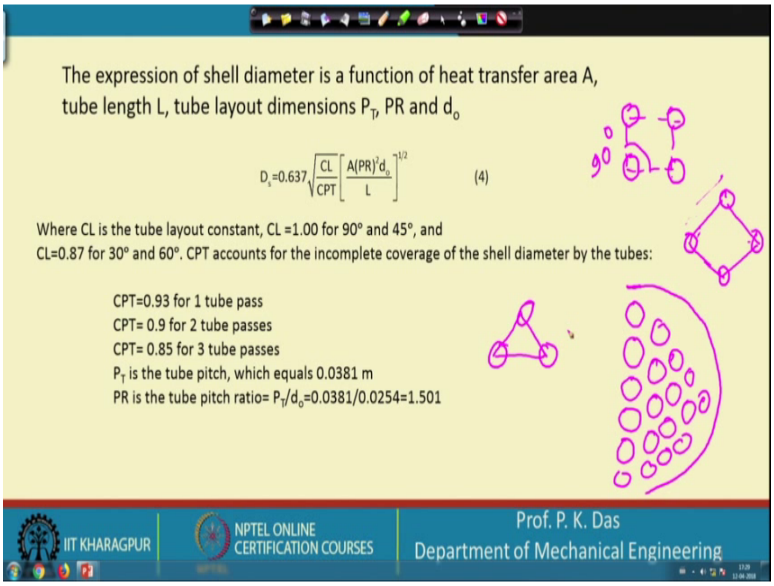

Now so far, we have not got the shell diameter. Shell length we have got some idea, that tube length is around 15 meter I believe. That is what we have calculated. So, of that order the shell length should also be of that order. The expression of shell diameter is a function of heat transfer area A, and tube length L, tube layout parameter P T PR and obviously, the outside diameter of the tube that is d o.

So, there is some sort of a formula which is actually, basically some empirical formula with that, D s or shell diameter can be found out. So, if we look into the how it is done. So, it is like this the tubes are lay out laid like this. Let us say, the tubes are laid like this. So, I have taken just is some example something like this. So, now the shell diameter has to be provided to encompass all the tubes.

So, actually what will be the tube layout that one has to first identify. And then, based on the tube layout one has to first identify what will be the tube layout, and then based on the tube layout one has to select the shell diameter. Some sort of a clearance has to be kept and there are certain recommendation. And it will depend on the outer diameter of the tube plus the tube pitch. So, that will also come. So, let us see what are the things here.

This is kind of a formula which is bit empirical, with this we can calculate the shell diameter. Where CL is the tube layout constant, CL is 1 for 90 degree and 45 degree. So, 90 degree and 45 degree what are 90 degree and 45 degree? Suppose this is the tube layout; that means, they are laid or arranged in square array. So, this included angle is 90 degree. So, this is your 90-degree layout. And if we rotate this then if we rotate this. So, we will get some sort of a 45 degree kind of a arrangement. And if they are staggered then one can get this 30 degree or 60 degree depending on how the tubes are rotated.

So, depending on this kind of things something has been discussed in case of; earlier also I have discussed this thing and in case of sullen tube heat exchanger these things I have discussed. So, I will not spend much time on this. What we like to say that, the CL can be taken depending on the tube layout and CL is equal to 1 for 90 degree and 45 degree, let us take that. And CPT accounts for the incomplete coverage of the shell diameter by tubes.

See what is happening that actually we cannot bring a tube very close to the shell, so that is why sometimes though half a tube will come. So, we avoid to have any tube there. So, how can I explain it?

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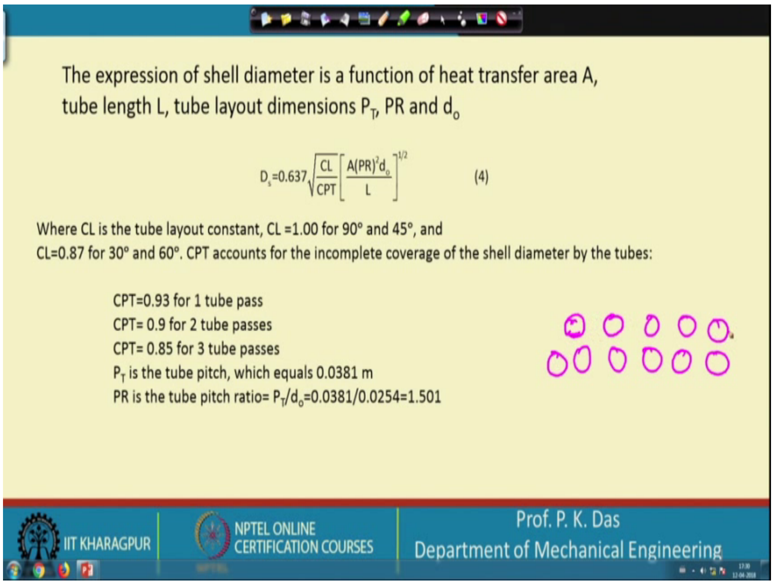

It is like this let us say one row of tube is something like this, another row of tube is. So, probably here one tube we do not give at the end we do not give. So, towards the end generally it happens.

So, the CPT accounts for the incomplete coverage of the shell diameter by the tube and then CPT is equal to.93 for 1 tube pass more number of tube passes, the value of CPT will be lower. And CPT is equal to.9 for 2 tube passes etcetera. P T is the tube pitch which is equals to.381 meter. This is a given number for this particular design. And PR is the tube pitch ratio P T by d 0; so that we can calculate.

So, P T has been given. As you can remember the inner tube diameter and outer tube diameter were supplied in this problem. So, similarly P T has been given. So now, this I have told how to select the; or what could be the guideline for selecting the inner diameter and outer diameter.

Similarly, there is some sort of a judgment to be taken how you can calculate or how you can select the pitch. See, you make the tubes more close then, there will be very less path of steam flow, obviously that is not very good. And if you make it more sparse the tubes if you make more sparse then what will happen then your shell diameter will increase, the heat exchanger size will increase.

So, one has to make a compromise from experience from again from hand book etcetera one can take some sort of a hints and then one can select the P T. So, all these things have been calculated.

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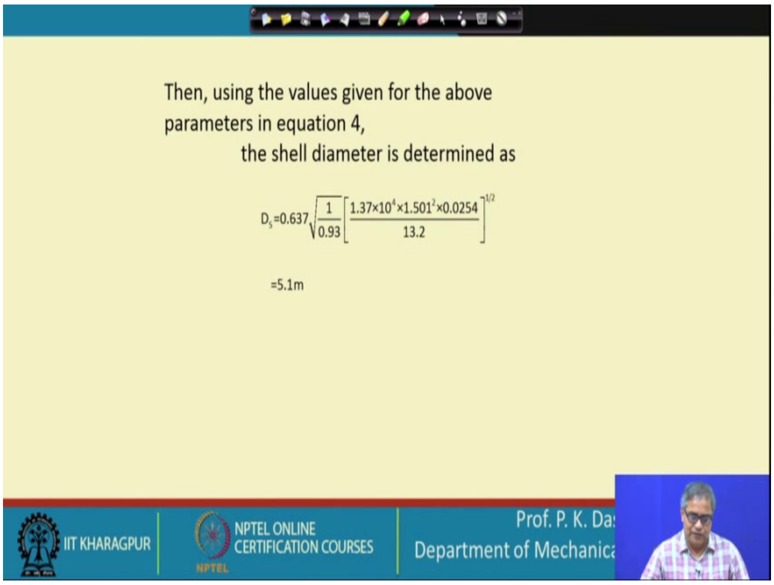

Next slide if we move then from there we can calculate the shell diameter which is 5.1 meter. This is the shell diameter. So, more or less the geometrical parameters we have got. Sometimes after this, again the geometrical parameters are to be reached by modifying certain other quantities which we will see. Sometimes during the mechanical design itself the geometrical parameters are changed while doing the mechanical design. But, as I have told in this course we are focusing on only thermo hydraulic design and design analysis.

So, we will be satisfied with this shell diameter. We know how to arrive at the shell diameter. But, in many cases it has to be checked and rechecked and sometimes it needs to be modified.

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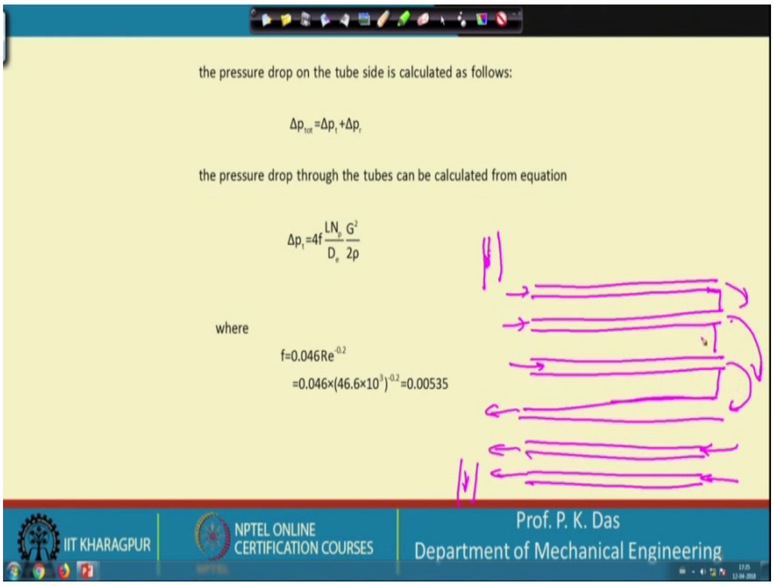

Now, we go for the pressure drop calculation in the tube side. See, the tube side pressure drop calculation is very crucial not on the shell side, because you see for shell side your steam is flowing and the motive power for the steam or the capability for steam movement that comes from the turbine itself. So, turbine is releasing this steam at certain velocity and pressure. So, this will give the steam ability to move through all the tubes of the tube bags. Still it is condensed.

So, the tube side pressure drop again there are certain things, let us try to understand what it is.

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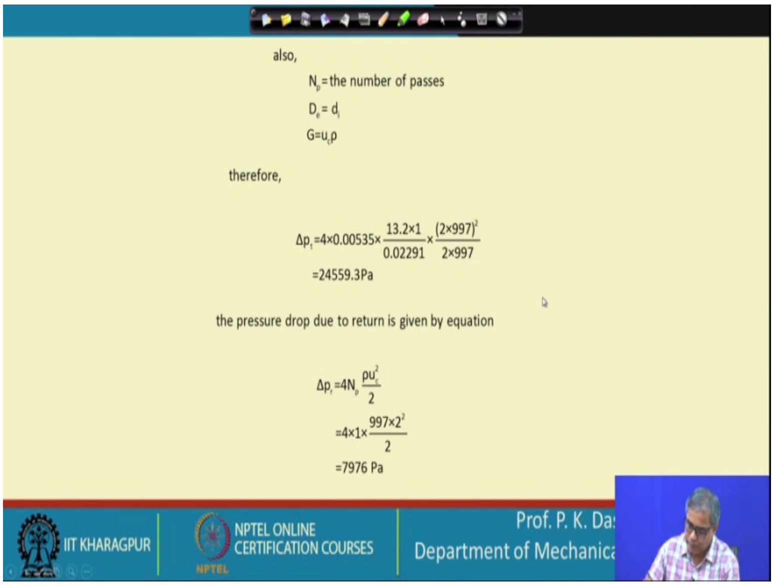

You see the tubes are; sorry, tubes are laid like this, this is a tube, this is the second tube. So, tubes are laid like this and through this tube when fluid flows there will be a pressure drop. But sometimes what happens there are tube passes etcetera. Let us say this is another pass of the tube, so up to this goes gose gose. And then there are three more tube through this the fluid comes back. Okay? And then, it is like this and this side the fluid comes out.

So, for the tube side fluid this could be the inlet, and this could be the outlet. So, this kinds of configurations are possible. And if this kind of configurations are there obviously you can understand there will be some sort of a pressure drop. When it is passing through the tube, when it is passing when the fluid is passing through the tube there will be some pressure drop. And, when it is taking a turn returning then, there will be some additional pressure drop. And both one has to take care of.

The pressure drop on the tube side is calculated as follows. Delta p total is equal to delta pt, tube inside the tube and delta pr for returning. The pressure drop through the tubes can be calculated from this. This is very easy you can understand there is a friction factor and the length of the tube. Then there is some sort of a mass flow rate through the tube. So, simple pressure drop formula one can use. And this kind of co relation has been suggested. So, with this one can calculate what is the pressure drop through the tube.

So, you see friction factor we are getting and from friction factor this is your Reynolds number. So, this gives the friction factor; f is the friction factor. Now, if we go to the next slide. So, N p is the number of passes here it is only one pass. So, number of passes is important because that gives the total if there is if the length of the tube is 2; sorry if the length of the tube is L and if there is 2 number of passes then, the total length of the tube which the fluid has to pass through will be 2L. So, in this case it is one. So, diameter we have got, and G is the related to the mass flow rate, so mass flow rate we have got and therefore we have got what is the pressure drop through the tube.

Pressure drop through the tube, and then what is pressure drop due to return is given by this equation and here there is only 1 pass so you will get this kind of an equation. So, basically this pressure drop through the tube and pressure drop through the return that can be combined together to get the total pressure drop. Total pressure drop we have got.

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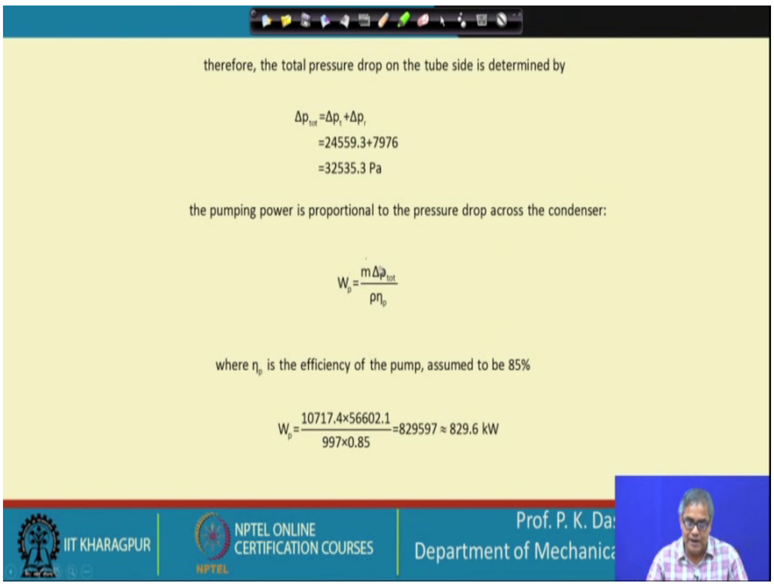

And then, from the total pressure drop the pumping power can be determined; that m into delta p total divided by rho and efficiency of the pump. Efficiency of the pump, this pumps are big pumps so one can take as the efficiency to be high like 85 percent or so. And with that we have got that the pump power will be 829, almost 830, 830 kilo watt. So, you can understand this is a big pump, this is basically the speed water pump of the power plant and it should be quite large for such a capacity of the power plant and we are getting 829 or 830 kilo watt, around 830 kilo watt the pumping power we are getting.

So, what did we get from this calculation. We got several things. We got the length of the tube. We got the shell diameter. So, the overall less the size of the heat exchanger is known. And then we have got the number of the tubes, that is also very important how many tubes are there. Then what will be the pressure drop. So pumping power, how much pumping power is needed for this condenser that we could get for only for the condenser. Now, you see there will be other requirement. So, only for the tube side resistance of the condenser we have got the pumping power should. One should not take that this is the total pumping power for the power plant.

Now, let us go to the next slide; next slide certain analysis has been given.

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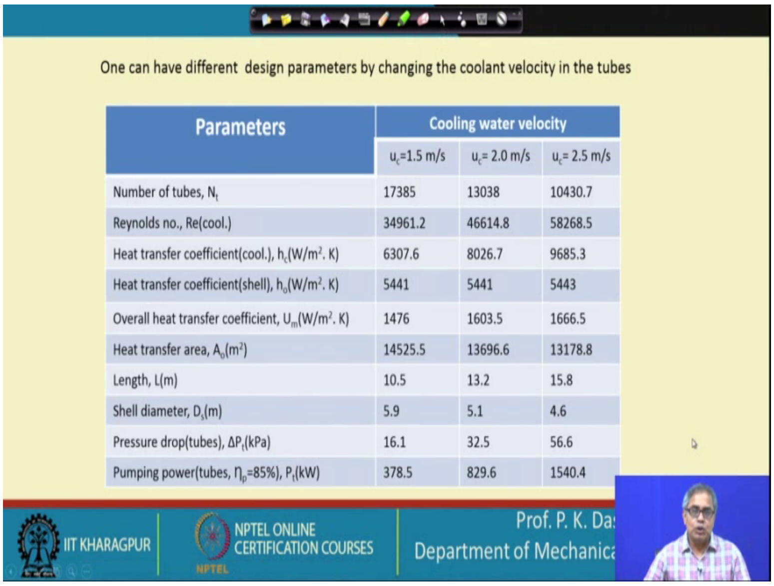

So, you see what we have done at the beginning of the calculation. Tube side velocity we have assumed; that is 2 meter per second. So now, let us say this velocity will vary little bit. We have got for we have got the calculation for 3 different values. One is 1.5 meter per second, one is 2 meter per second for which the calculation has been presented over here and another is 2.5 meter per second

We have calculated the number of tubes and you see as the velocity increases obviously the total amount of flow rate is same water flow rate, so number of tubes will reduce. Then, Reynolds number there will be certain change in Reynolds number. Heat transfer coefficient: heat transfer coefficient will increase as we are increasing the; that is of course, coolant side heat transfer coefficient will increase as we are increasing the number of tubes. As you can see that the Reynolds number is increasing, so we will have an increase in the heat transfer coefficient; Reynolds number is increasing, so heat transfer co efficient will also increase.

Outside heat transfer coefficient there is not much of a change. Not much of a change in the outside heat transfer coefficient, it will remain in the same range. But, this is low because as I have told that it is the average heat transfer coefficient and there is a large effect of inundation.

Overall heat transfer coefficient there is a small change. Then, heat transfer area will change. Length of the tube will change. We have got 13.2 meter for the current design, it should be small for your, this one low velocity of water and it will be large for higher velocity of water.

Shell diameter: shell diameter will also change. Shell diameter will reduce if we are increasing the velocity of the coolant. So, that is another point. and then the pressure drop per tube or other the pressure drop: Pressure drop we can see that there is a large change. Smaller tube smaller velocity we will have lower pressure drop. And as we go on increasing the velocity, the pressure drop will be higher and higher. And similarly, the pumping power that will also increase because of the change in the pressure drop.

Actually, the middle column only we have done the calculation. We have done the calculation for this, for the left hand side column and the right-hand side column we have not done any calculation, but the values have been given. So, it is a good opportunity that you can repeat this problem which is a very comprehensive problem for different water velocity through the coolant tube and check whether you are getting this figures or not. So, this will give you a good practice. Keeping that in mind I have selected this problem, so that you can go for this.

Now, what generally is left for the; let us go to the this is of course last slide, but, let us discuss what design we have what design features we have got and then what is left. Quite a few things are left. The heat exchanger design is not complete, quite a few things are left.

The tubes are quite large, sorry the tubes are quite lengthy. By our calculation we have got around 13 meter and if we go on increasing the water velocity the tube length will increase further and you can get even 15-meter length of tube. So, obviously such along tube cannot be rested on two tube seats at the ends of the heat exchanger. So, we should have arrangement for supporting the tube in between. So, this is one thing one has to think of.

And, this support generally comes in the form of baffles. And when the baffles are there they will also help to have the cross flow of the shell side fluid. In this case which is your vapor, which is the vapor of or steam which is flowing through the condenser.

So, this is one thing. Let me go to certain other features of the heat exchanger which has to be taken care of.

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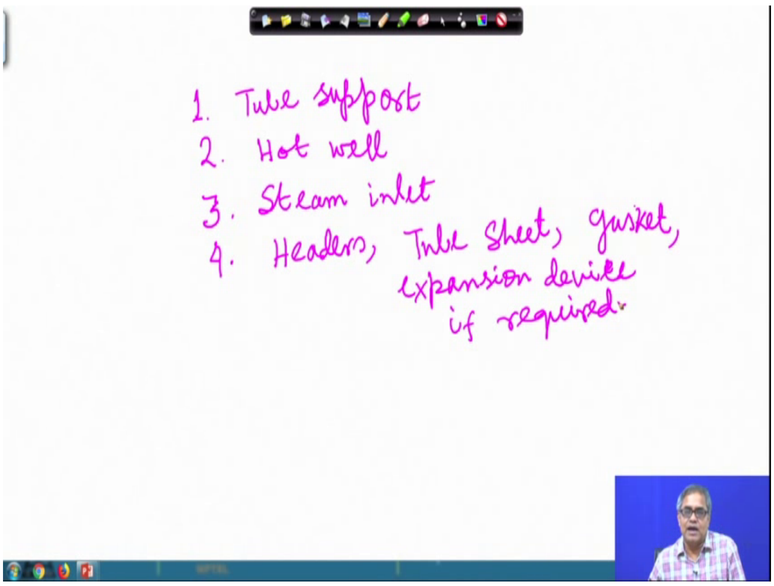

So, first thing is these are the things one has to take care of: tube support, which is very obvious because the tubes are very long. Then, second thing that condenser should collect at the bottom of the condenser surface condenser and then from there it has to be taken out of the condenser.

So, there is something called hot well in surface condenser. So, there is something called as hot well. So, the hot well design is also to be done when we are designing the surface condenser. Then, steam inlet. This also needs to be designed. Then of course, the headers of the shell: headers, tube sheet, gasket, expansion device; if required.

So, all these things, there are many other things in the heat exchanger. All these things our thermal hydraulic design has not taken care of and obviously the shell thickness etcetera those are also points to be looked into. So, all these things are to be taken care of.

So, with these I think I can go back to the last slide. So, thank you for joining. And you see, last 2, 3 lecture we are continuing a problem, because of its comprehensiveness and I think we are at the end so you can recapitulate it. And you can also should do the problem by changing some parameter.1 parameter change I have shown; that is the velocity of coolant or liquid water through the tubes. So, you can check the design; the design principle.

Thank you.