Upstream LNG Technology
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Lecture – 28
Tutorial on heat exchanger analysis

Welcome, after learning about the heat exchangers ended analysis, in this particular lecture, we shall be solving a few problems for the application of the LMTD and NTU methods. So, this is a lecture on the tutorial on the heat exchanger analysis.

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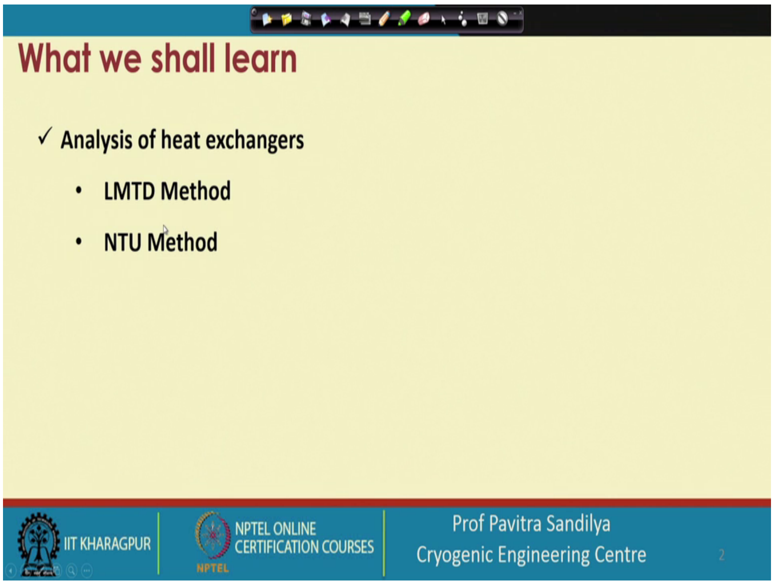

And in this, we shall be learning the applications of the LMTD method and the NTU method.

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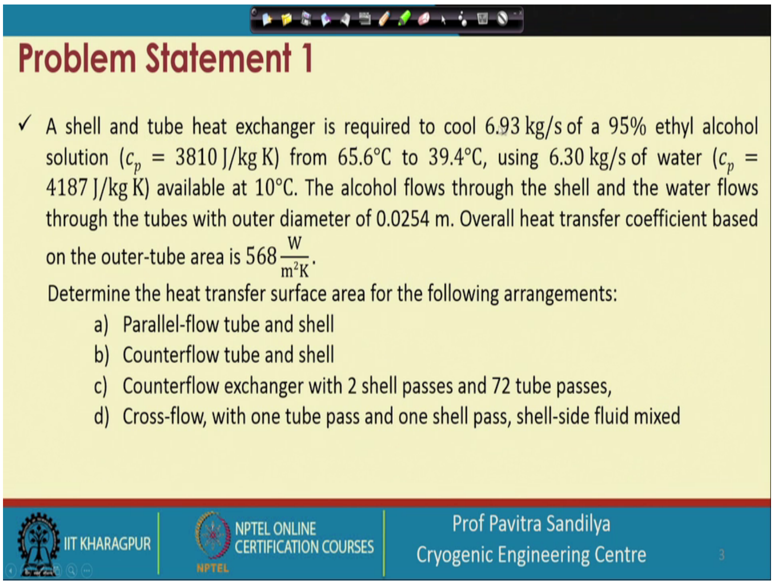

So, let us go to a problem. Statement 1, in this, we have a shell and tube heat exchanger which is cooling a 95 percent ethyl, alcohol solution with a specific heat of this from 65.6 degrees centigrade to 39.4 degree centigrade with a flow rate of 6.93 kg per second and it is being cooled with water with a flow rate of 6.30 kg per second the specific heat is this and the water is available at 10 degree centigrade the alcohol flows through the shell and the water flows through the tubes.

The tubes have outer diameter of this about 2.54 centimeter that is about 1 inch and the overall heat transfer coefficient based on the outer tube area is 568 water watt per meter square per Kelvin and with this given data, we are required to find out the heat transfer surface area for the following arrangements first parallel flow tube and shell then counter flow tube and shell and then counter flow exchanger with 2 shell passes and 72 tube passes and lastly a cross flow with 1 tube pass and 1 shell pass and shell side fluid is mixed.

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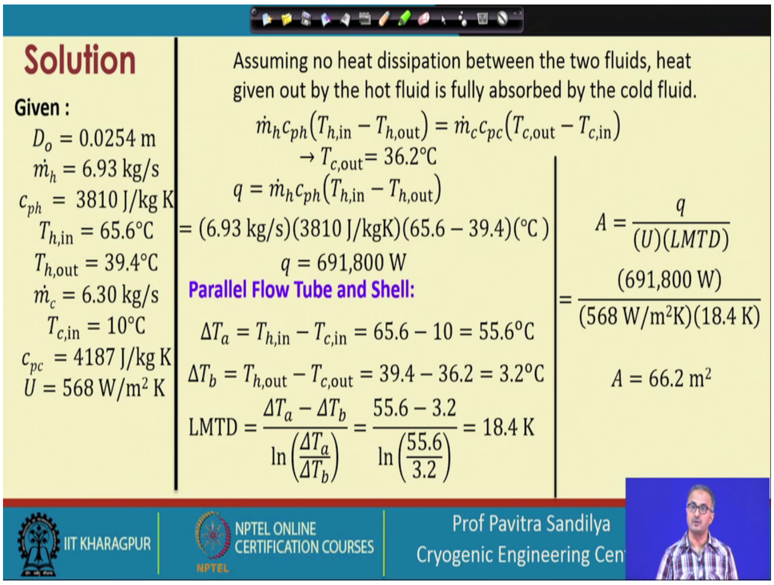

So, now let us go to solution; so, first let us write what all are given to us the outer diameter of the tubes the flow rate of the hot fluids that is oil then the Cp of the oil and these are the outlet and inlet temperature of the oil then this is the water flow rate, this is the water inlet temperature, this is the specific heat and this is the overall heat transfer coefficient.

Now, first what we do we make one energy balance in this energy balance, we are assuming that there is no heat leakage. So, that whatever heat is given out by the hot fluid is completely taken by the cold fluid. So, that is why we are writing these are sensible heat given out by the hot fluid and this is a sensible heat taken up by the cold fluid and if we plug in the various values from this data given, then what we find that this is the outlet temperature of the water.

So, water is getting heated from 10 degree centigrade to about 36.2 degree centigrade. After this, we can find out that what is the amount of heat that has been transferred again plugging in the values, we find this is the amount of heat that is about 691.8 kilo watt heat has been transferred during this process.

Now, first let us go to the first configuration that is parallel flow tube and shell and for this we find out the delta T at the 2 ends and this is how we are defining for the parallel flow the delta T are the 2 ends and these are the temperature differences and from this, we can find out the average delta T that is the LMTD from this particular formula, we learnt earlier and we found and find that this is 18.4 K is the log mean temperature difference for this particular configuration.

Now, we know the Q value and in u value from here and put the LMTD from here and plugging in the values, we find this is the area necessary for transfer of the exquisite amount of heat energy.

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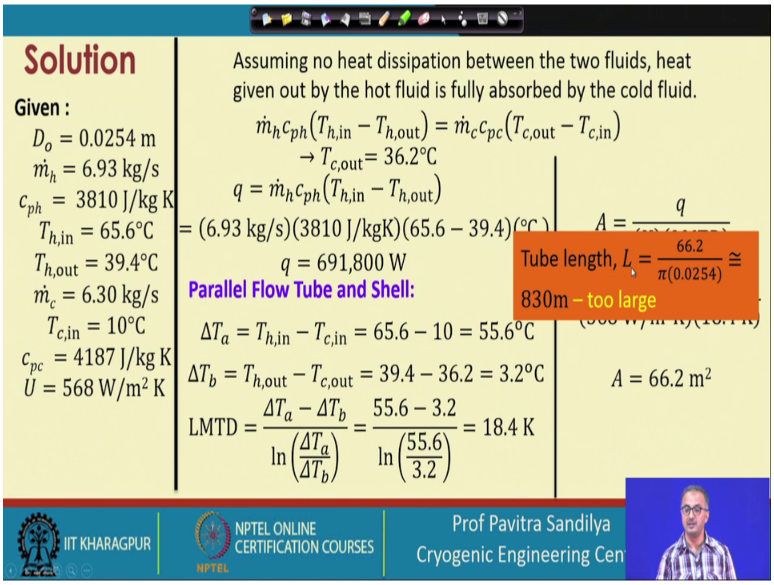

And from this area, if we apply the formula to find out the length of the tubes, we find this is coming about 830 meter, this is way too large for being any of practical use. So, that is how we find that in this way was 1 by 1, we consider different types of arrangements to figure out what is a feasible dimension of the various tubes and shell and the heat exchanger.

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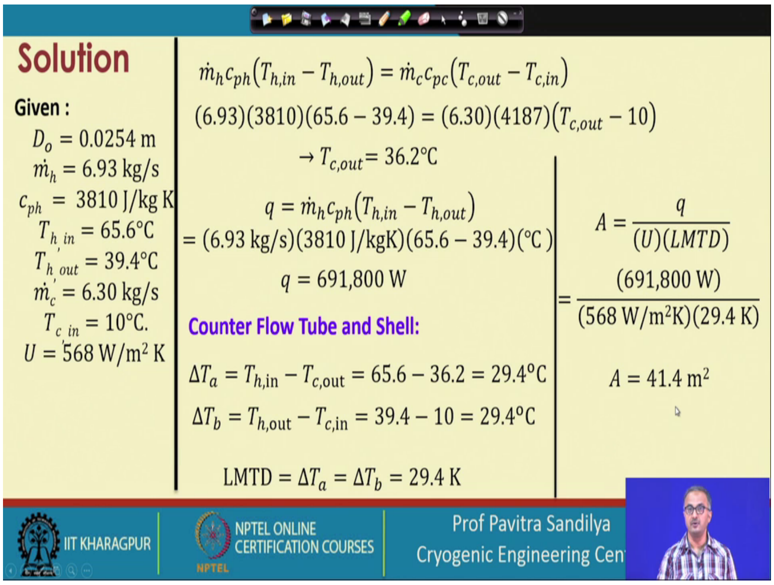

Next, what we do with the same data now we go for the counter flow tube mention in this case, the temperature differences at the two ends are slightly modified, we get this and we find that.

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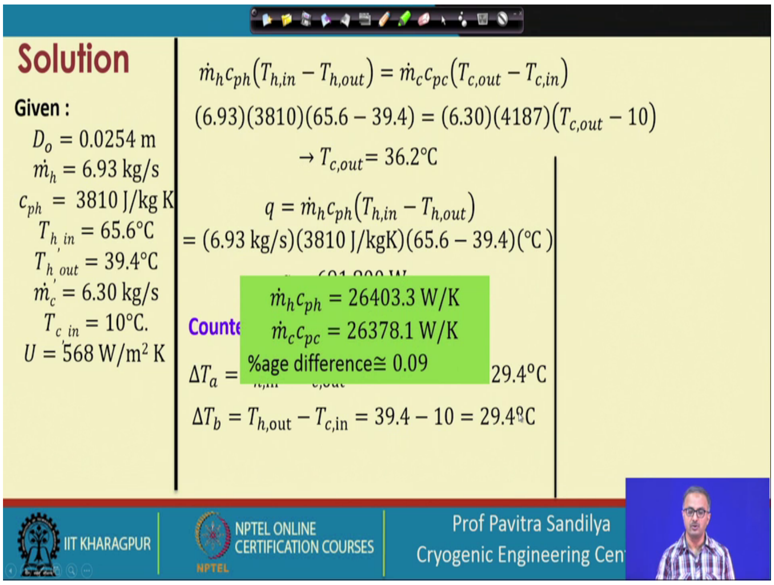

They are coming to be the same. So, naturally when they come to same. So, we find that this is the value of the heat capacities for the cold and hot fluids and there hardly any difference. So, they can be taken to be almost the same because we find that delta T are remaining constant at the two ends of the counter flow and that is what is also expected ideally.

So, this is the value of the LMTD and now we find the surface area required as 41.4 meter square.

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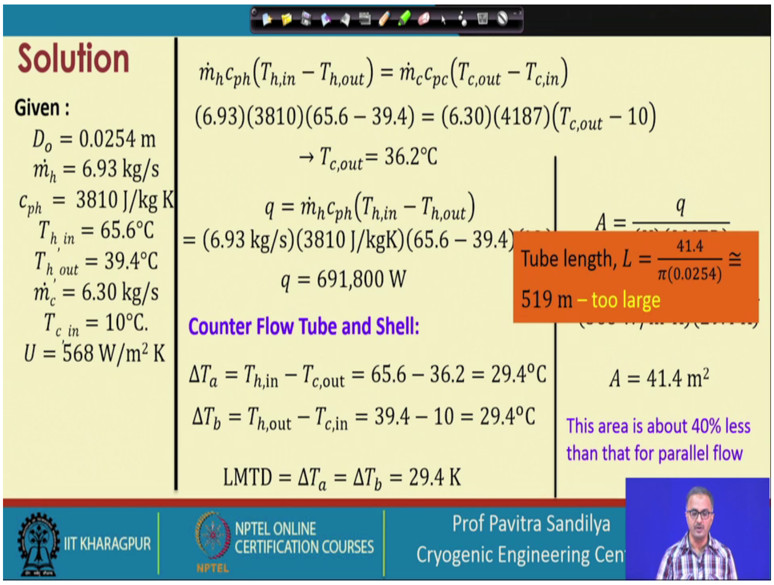

This surface area gives a tube length of 519 meter even though this length is less than what we found for the co current flow, but it is still too high for any practical purposes.

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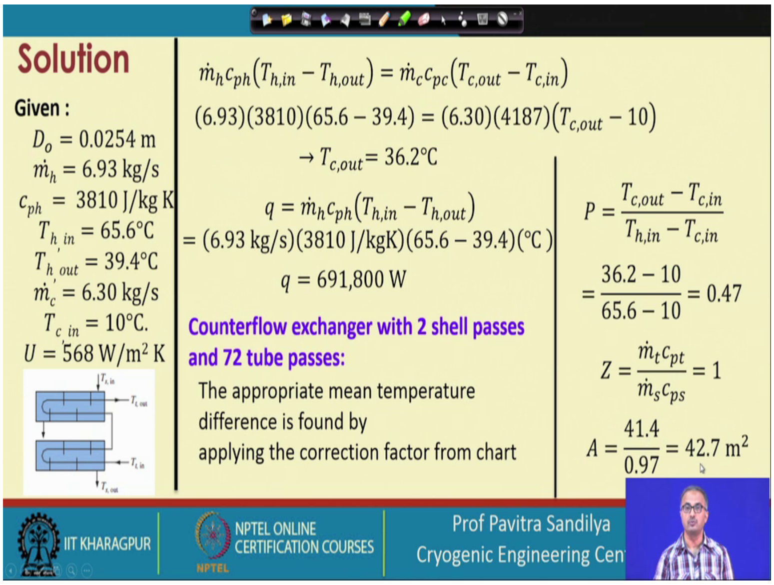

So, next what we do we go for the next arrangement that is counter for exchanger with two shell passes and 72 tube passes, in this case, the we have to take the appropriate temperature difference by using the correction factor chart and which we have shown earlier. Now let us see to use that chart what we do we need to define this P we had find out of P and Z. So, we find the P which is defined like this plug in the values this is the value of P and this is the value of the Z.

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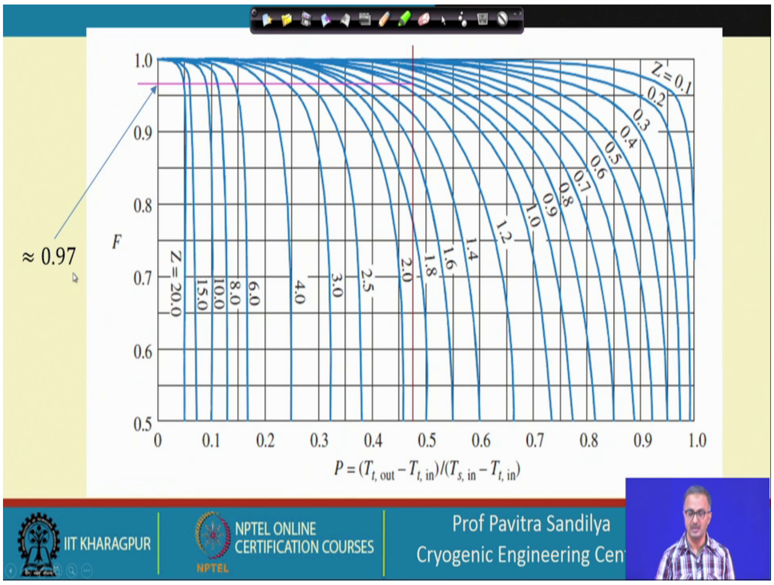

Now with this value of P and Z, we make use of this chart, we first what we do on this from the x axis, we locate the P value and make a vertical and then the Z value, we know it is 1. So, from this we find that here, this have 1 Z; so, here where it intersects here from that we go horizontally on the y axis to find out the value of f and it is coming around 0.97.

So, with this f value, what we now do we use this expression for the a and we find this the a is coming to be 48 point 42.7 which is a bit more than what we obtained for the pure counter flow without any tube passes.

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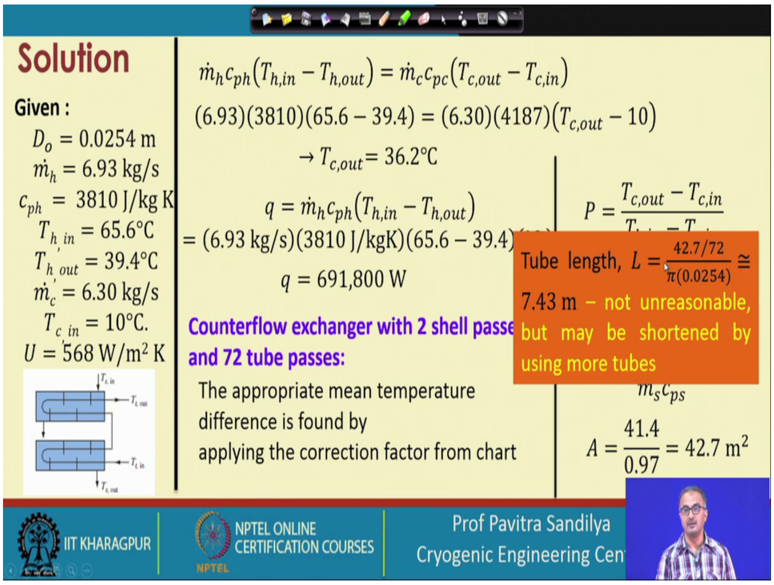

And now we find because there are seventy two tubes, we find that the tube length is coming to 7.43 meter, even though it is not really unreasonable, but it is still quite a large value that it shows that we need to have more number of tubes, if we want to reduce the length of the tubes.

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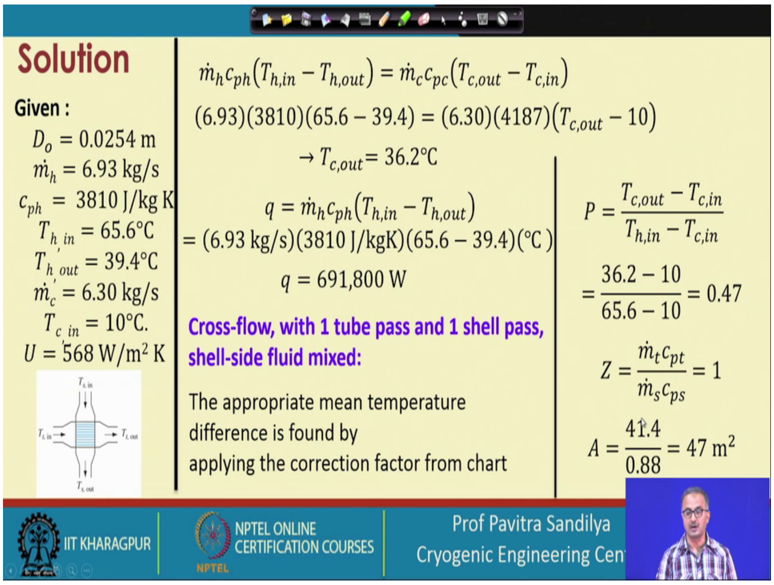

Next, we come to the another configuration in this we have cross flow with the shell side tube fluid mixed and we have now one tube pass and one shell pass again this is the particular thing, we can see from this figure how the cross flow configuration looks like and again, we have to use that particular chart in this case, we define the P and Z like this we find the value of P as point four seven and the Z as 1.

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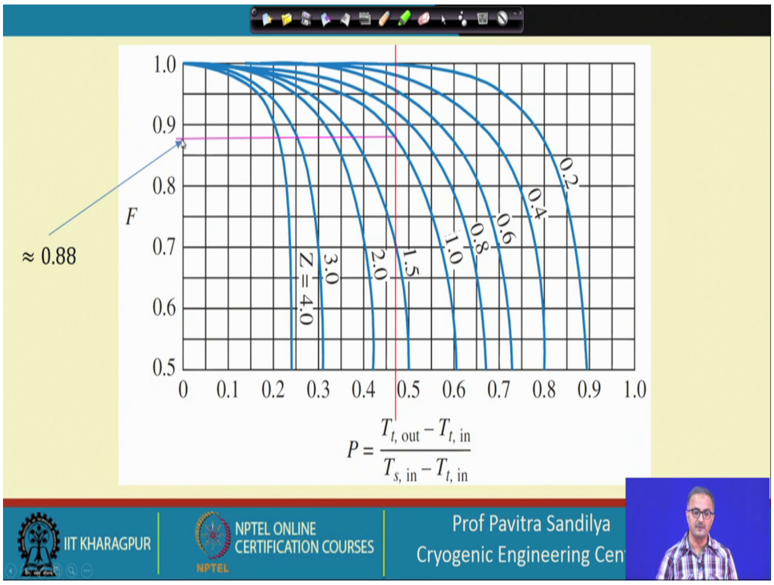

We go to this chart again, we locate the point four seven from the x axis and wherever, it intersects with the value of Z equal to 1 from here. So, from here we make a horizontal line on the y axis to read the value of the f as 0.88, we take this value of the 80 and we will modify the area from the counter current heat exchanger to get the value as 47 meter square.

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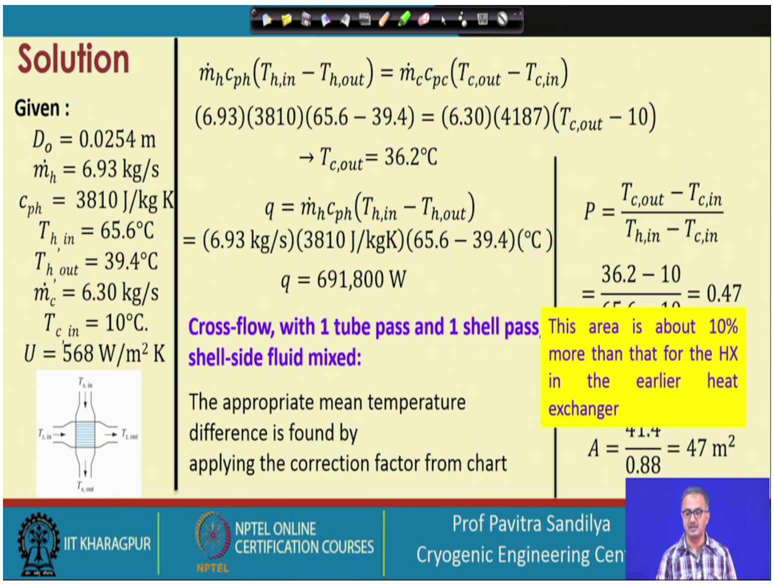

Now, this area is about 10 percent more than that for the heat exchanger in the earlier what we found earlier ok.

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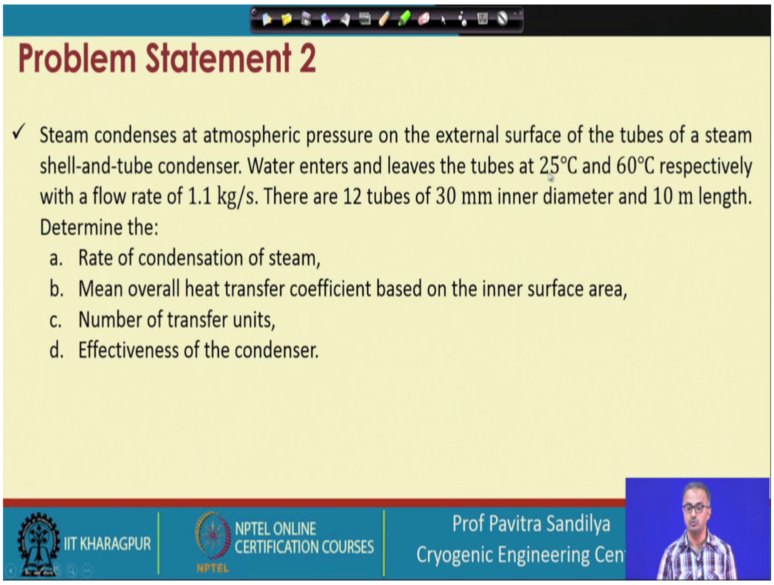

So, this is how we learned that how to find out the surface area for heat transfer for different types of configurations. Next, we come to another problem in this problem, we have steam condensing at atmospheric pressure on an external surface of tubes of a steam shell and tube condenser water enters and leaves the tubes from at 25 degree centigrade and 60 degree centigrade respectively.

And the flow rate of water is 1.1 kg per second, we have 12 tubes of 30 mm inner diameter and 10 meter length; what we need to determine are the rate of condensation of the steam, the mean overall heat transfer coefficient based on the inner surface area number of transfer units and the effectiveness of the condenser.

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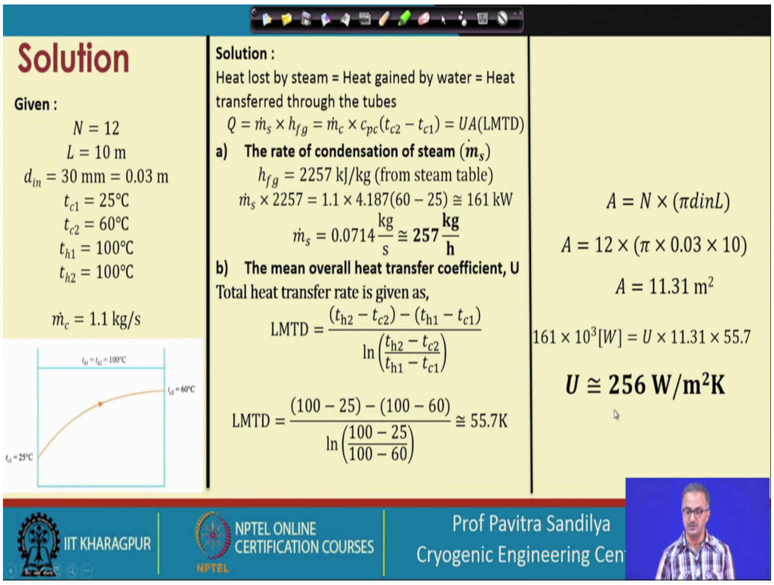

So, here first we write water the given values to us. So, these are various values given to us and now, we draw the particular graphical form of this we have here this particular orange line is showing how the water temperature is increasing and this blue line is showing the steam temperature the steam temperature is remaining constant, if we assume that it is only a phase change which occurs at a constant temperature at a given pressure and if there is no sub cooling. So, assuming that we are saying the steam temperature remains constant throughout the heat exchanger whereas, water temperature increases from 25 degree centigrade to 60 degree centigrade.

So, here are the various data which have been plotted on this particular graph. So, after plotting these graphs, what we do that they told you, there is no sub cooling. So, we go for the solution again we make the energy balance like this that for the steam, we find that it is the amount of steam that is condensed into the latent heat of vaporization for the water; water is getting heated up. So, that is sensible heat transferred from the steam to the water and this is equal to the whatever heat is getting transferred between the steam and the water to the tubes and that is coming through UA LMTD.

So, we shall be using one by one all these expressions to find the rate of steam condensation we knew we want to know the value of the HFG which is obtained from the steam table and this is the formula, we use in this particular equation, we take the formula and we find that this is the amount of the heat that is being transferred and once we know the heat transferred, we divide by this HFG and we find this is the rate at which steam heat condensing.

Now, next we come to find out the overall heat transfer coefficient for this we first define the LMTD like this for this kind of flow and then we find the LMTD coming out to be 55.7 K and once we know this we find the area that is number of tubes into the inner diameter this in should be subscript. So, this inner diameter and the length of the tubes of PIDL and with this we find the total area offered by all the tubes coming out to be 11.31 meter square once we know this area we go back to this formula we plug in the value of a plug in the value of LMTD, we know the value of q. Now it is easy to find out the value of u from this particular formula and this we find this coming out to be 256 watt per square meter per Kelvin.

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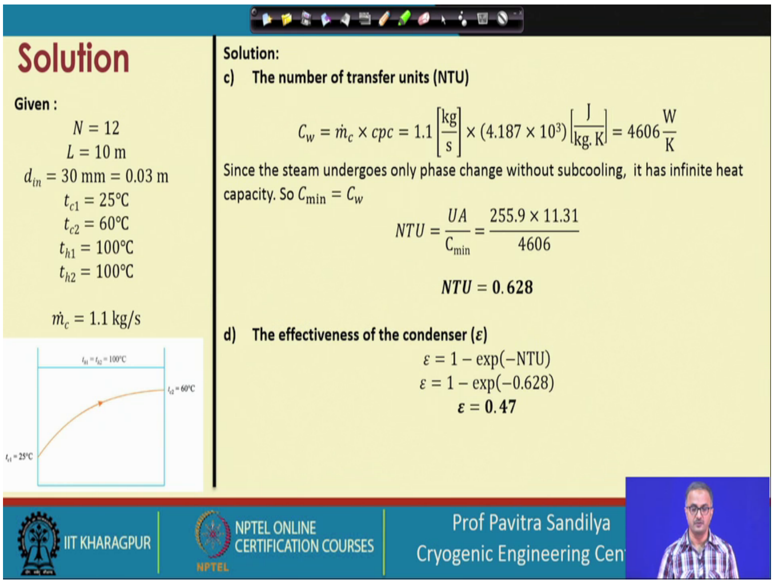

For the third part to find out the transfer units, what we do that we use this formula that first, we have to understand the heat capacities on the two sides this for water side that is m into Cp, then with and because steam undergoes only phase change without sub cooling. So, it has infinite capacity. So, the C min will be the same as the Cw and from this NTU formula, we know that NTU equal to UA by C min, U value we know a value, we know put the value of C min and we get the value of NTU as 0.268.

Now, once we know the NTU value, we use this formula to find out the effectiveness of the condenser and plugging in the values, we find the condenser is about 47 percent effective. So, it is not a very effective condenser, but this is how we solve this set of equations.

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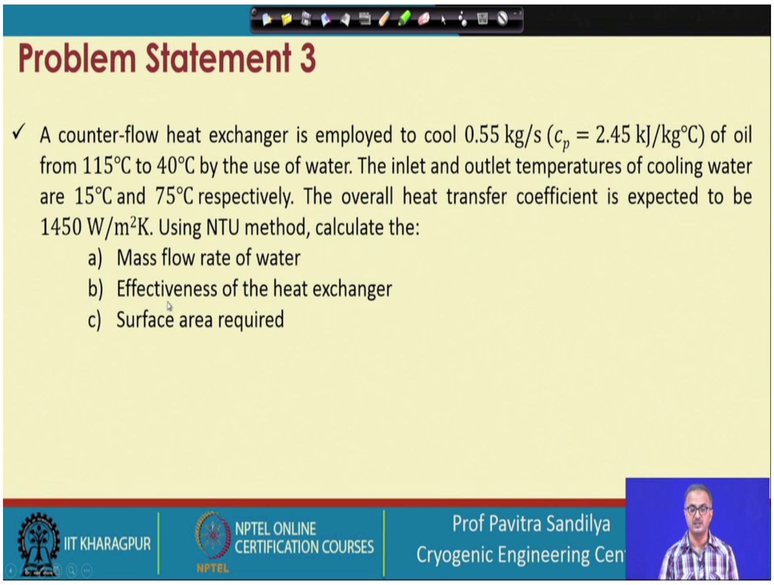

Next come to the another problem, this problem is on a counter flow heat exchanger that is employed to cool this amount of oil by use of water and we have inlet outlet temperature of cooling water has 15 degree centigrade and 75 degree centigrade respectively. The oil is to be cooled from 115 degree centigrade to 40 degree centigrade and the overall heat transfer coefficient is this value the using the NTU method, we have to find out the mass flow rate of water effectiveness of the heat exchanger and area required for the heat exchange.

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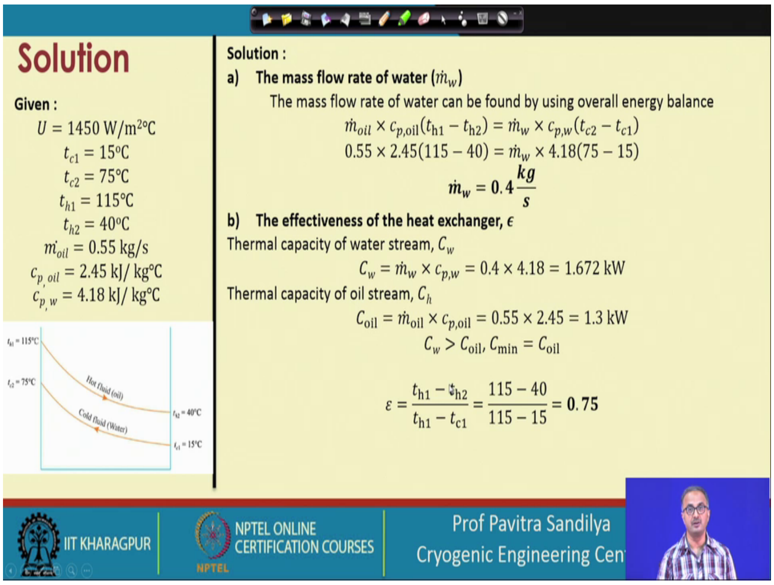

So, first we write down all the data given to us and then this is the way the configuration is that there is a counter current flow because of this we find the temperature difference that is the driving force for the heat transfer is remaining almost constant because they are almost parallel we are assuming that they are almost parallel. So, this is how we are locating all the temperatures on the graph and now become the solution first to find out the mass flow rate of water and again, we are writing the energy balance assuming there is no heat in leak and putting in the various values given in the data we get the flow rate of water as this.

Next, we come to find the effectiveness of the heat exchanger for this we find out the thermal capacity of water and the oil like this and we find that the thermal capacity of water is more than oil; so, C min equal to C oil. So, we shall be basing our calculation C min and this is the way we are defining epsilon when C min is equal to the C of the hotter fluid. So, this is how we define the epsilon for that and we find this is coming to 0.75 or 75 percent.

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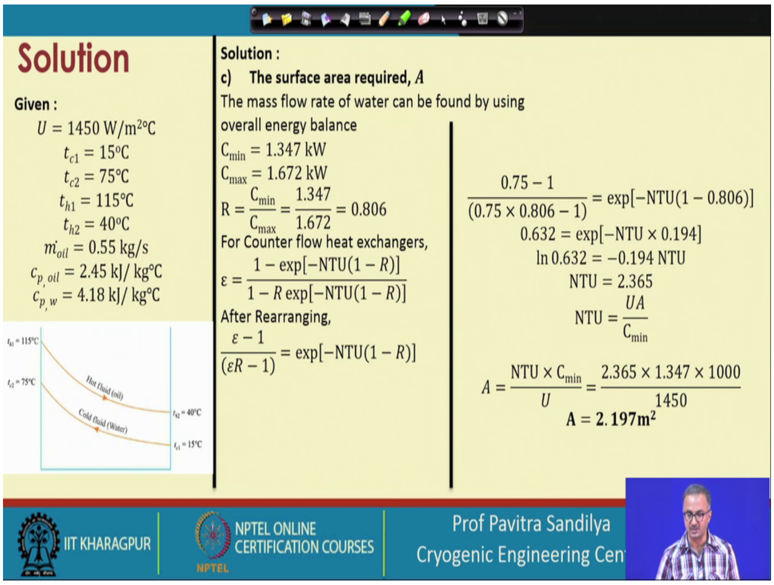

Now, again for the surface area required what we do is that first we note that these are C min values these are C max value and this is the ratio of the C min to C max and for counter for heat exchangers, we use the formula of the effectiveness factor for with this and plugging in the values we can find out the value of the NTU coming to be like this. So, this NTU is UA by C min and we know the values of everything now putting all the values we find the required area is coming out to be two point one nine seven meter square.

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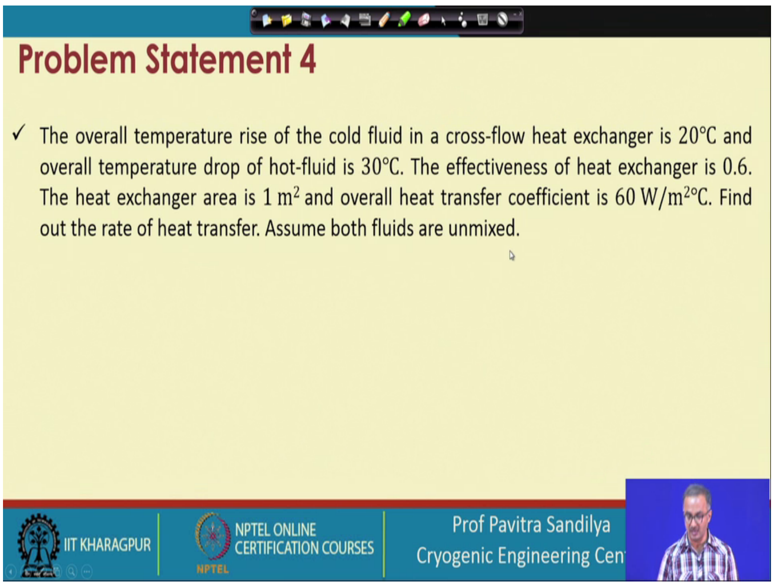

Next, we go to our fourth problem in this problem what we have we have the overall a temperature rise of the cold fluid in a cross flow heat exchanger is 20 degree centigrade; that means, we are given the delta T and the overall temperature drop of the hot fluid is thirty degree centigrade. So, we are not given the inlet outer temperatures, but instead, we are given the temperature differences that are obtained for the hot fluid and the cold fluid.

The heat exchanger effectiveness is 0.6, this is the area of the heat exchanger for surface and this is the overall heat transfer coefficient with these data we have to find out the rate of heat transfer and it is assumed that both the fluids are unmixed.

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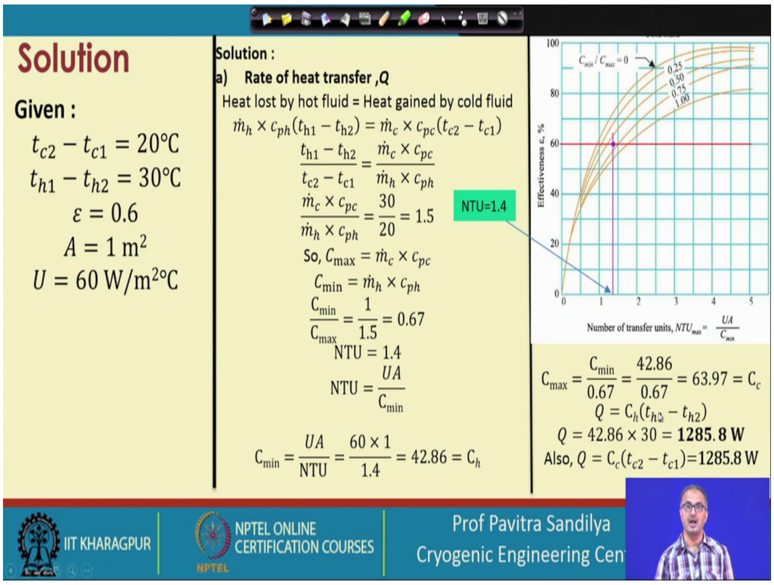

So, we write all this data given to us after this we go for the solution. So, the rate of heat transfer is the first before that; we make the energy balance like this. And we put the respective values we just rearranged this energy balance equation and put in this fashion and we find that these values these thermal capacities are coming like this. And because it is more than 1, we find that that for the thermal capacity of the hot fluid is less than that for the cold fluid so; that means, in this case, the C min will be based on the hot fluid.

So, we can find this C min C max and this is the ratio of the C min C max which is and we can find easily from this particular graph they C me the effectiveness and all these C min C max; what we do that first we the effectiveness get 0.6. So, 0.6; we find from here horizontal line and C min by C max is 0.67. So, it will be somewhere between 0.5 and 0.75. So, that we locate somewhere here and now we drop down a line to the x axis to read the value of the NTU max and that is nothing, but you a by C min. So, we read the value of NTU as 0.4.

Now, after this we use this formula and we find that the C min is coming to 42.86 and that is nothing as I told you that is the value also of the C of the hotter fluid, using this, we can find the value of C max C max is nothing, but the C of the colder fluid and now, we can find the value of Q either using C max or C min.

So, suppose we are using C min then we find out the Q coming out to be this the same value may be obtained if any of you want to use the value of the C max, but just you have to keep in mind that you have to take the appropriate the temperature difference to evaluate the value of the heat transfer.

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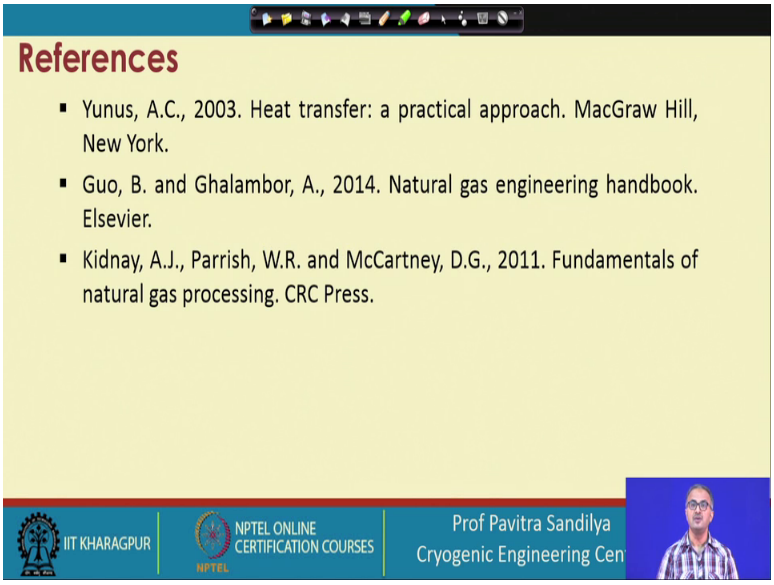

These are the various references you may look into for further details and explanations.

Thank you.