Upstream LNG Technology
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Lecture – 25
Tutorial on heat transfer in natural gas systems

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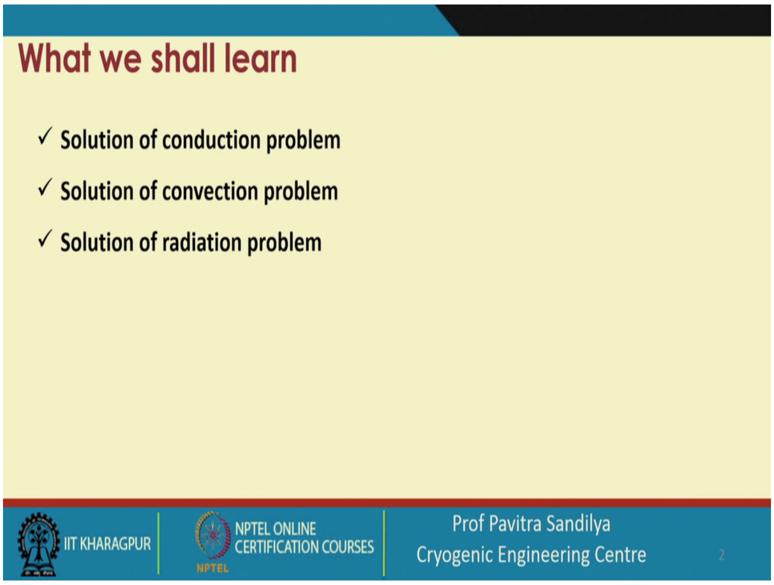

Today, we shall be doing some problems on the heat transfer about which we learnt earlier. Here, we shall be looking into the various types of problems on conductive heat transfer; convective heat transfer and relative heat transfer.

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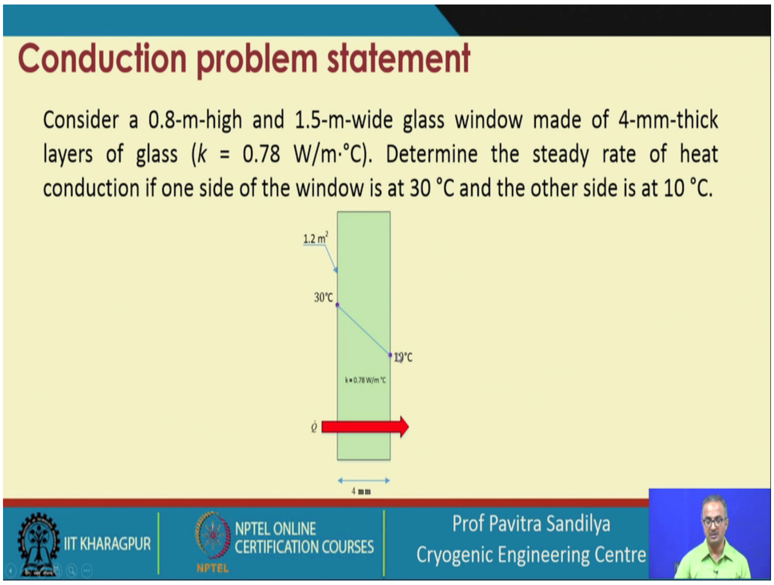

So, first let us take a problem on the conductive heat transfer. Here, we are the problem. The problem statement is that we consider a 0.8 meter high and 1.5 meter wide glass window made of 4 millimeter thick layer of glass.

And the conductivity of glass is given as 0.78 watt per meter per degree centigrade. We have to determine the steady rate of heat conduction, if one side of the window is at 30 degree centigrade and the other side is at about 10 degree centigrade, these are very usual problems, we also encounter in our day to day life. For example, in the summer, we may have very high temperature outside and the room and inside, we may have very low temperature which we can maintain by some air conditioner or some cooler.

So, this is a very common problem and here we want to find out that how much heat will be passing through the glass window. So, it here we have shown by the figure that here, we this is represents the glass window and the; this is the area through which the heat transfer is occurring. So, suppose on a left hand side, we have the high temperature of 30 degree centigrade and on the right hand side, we have the surface which is at 10 degree centigrade and the thermal conductivity is given as 0.78 watt per meter degree centigrade and we have to find out the value of the Q and the thickness of the glass window is given as 4 millimeter.

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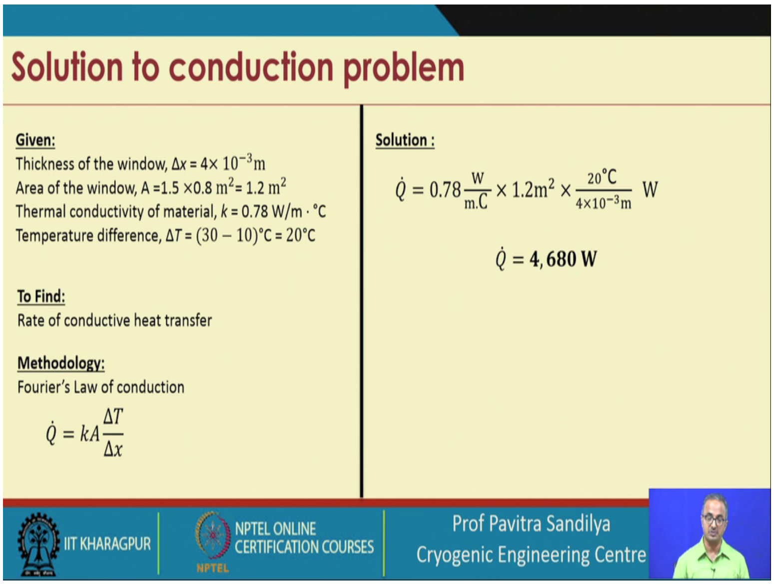

So, because this area of heat transfer that we have to first figure out that thickness; here, we are the these are the thing which are given and the temperature difference is 30 minus 10 is equal to 20 degree centigrade and we have to find out the conductive rate of heat transfer and for this we shall be using the Fourier's law of heat conduction which is given like this. Here, we have the formula.

Now here we have just plugging the value of k that is 0.78 watt per meter per degree centigrade, then we have the area that is area is 0.8 into 1.5 that is 1.2 meter square and then we have the temperature difference that is 20 degree centigrade and the thickness of the material is 4 mm that is 4 into 10 to the power minus 3 meter.

So, we have put all the units in the SI unit. So, that if we cancel out the units if these end up with the watt. So, we have this Q as 4680 watt or 4.68 kilowatt. So, this is the kind of heat that will be coming through the glass window with a thickness of 4 mm. So, that is how see you can see that 4.68 kilowatt, you can approximately see that what kind of voltage, we are using at your home. We are using say 20 volt bulb, 60 volt bulb, but in that respect this, you can see this kind of heat transfer which is occurring through the window is quite high.

So, that is why in sometimes, we put some kind of curtains over the glass window to prevent the heat to move from the outside to inside for our during the summer.

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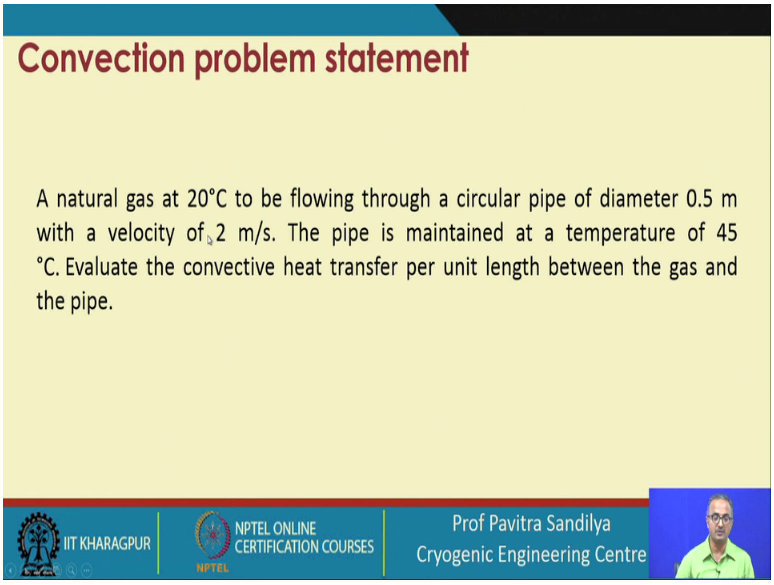

Here we have a problem on the convective heat transfer. So, the problem says that we have a natural gas at 20 degree centigrade. And it is flowing through a circular pipe of diameter 0.5 meter at a velocity of 2 meter per second the pipe wall is maintained at a temperature of 45 degree centigrade. So, we have to figure out; what is the convective rate of heat transfer per unit length of the pipe between the gas and gas and the pipe. So, because of pipe is at a higher temperature than the gas. So, what will happen during the natural gas flow a natural gas will tend to heat up?

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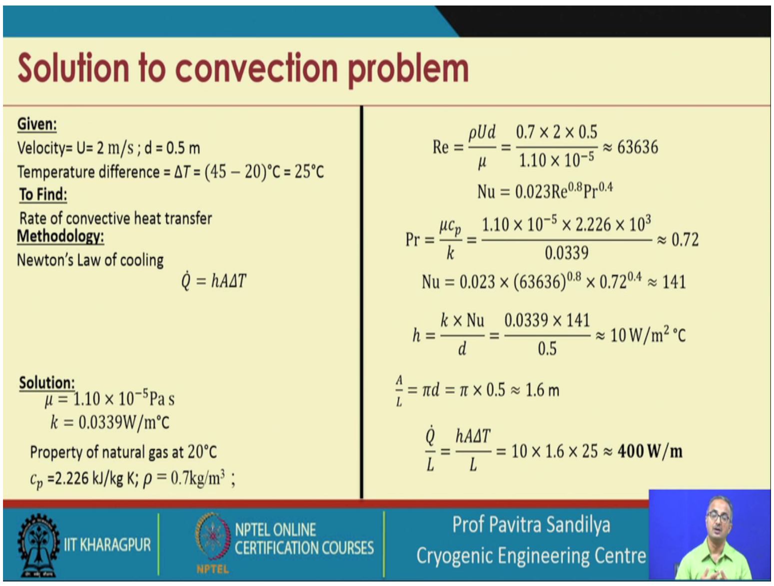

So, for this, we use the Newton's law of heating, first, we put whatever is given to a that is the velocity of the gas the diameter of the pipe line and the temperature difference as 25 degree centigrade. And with this we will be using the Newton's law of cooling or heating to find it out at we are finding that this is the ha delta T and here the question comes how to find out the value of the h.

Now, this is for thing is you have to keep in mind that this is a closed tube circular tube. So, we have to figure out various types of correlations which pertain to the circular tubes and then we have to figure out what kind what a because it is a case of post convection. So, we have to find out the various types of correlations which are proposed in the literature on the post convection and some of which I showed you in my previous lecture and for to choose the appropriate correlation in the post convection mode, we have to find out the value of the Reynolds number.

So, here we have the Reynolds number as 636,036. So, sorry 63,636; ao, this very very high Reynolds number and it is much more than 2000; such a critical Reynolds number in a circular tube for giving us the turbulent flow. So, in the turbulent regime, we use this particular equation that is also called Detres Boelter equation and in this because this is a case of heat and of the natural gas. So, we are using the power of the planetary number as 0.4.

So, we are using this particular equation and in this we shall be plugging in the values of the Reynolds number and the planetary number is given by this equation nu Cp by K and here we plugging the value of the various properties and we get the planetary number as about 0.72, we put the 0.72; in this equation and this 63,636 in this equation and then we get the value of the Nusselt number as 141 and the Nusselt number is the hk by some characteristic length, in this case, the characteristic length has been taken to be the diameter of the tube.

So, with the Nusselt number with the thermal conductivity of the fluid and the diameter of the tube, we can find the value of the heat transfer coefficient and once we know the value of the heat transfer coefficient, we can again go back to this particular equation, here this case, we find the area through which the heat transfer is taken place is pi d into l. So, this pi d L, we put and then we put a by L that is the pi d and this pi d value is 1.6.

So, we with this, we what we do we put these value in this equation and we get the value of the heat transfer by convection per unit length of the pi is 400 watt per meter; that means, for a pipe length of 1 meter 400 watt of the heat will be coming from a wall at 45 degree centigrade to a natural gas at about 20 degree centigrade.

Now, please understand that this is the many assumptions in solving these problems because as natural gas moves inside it gets heated up. So, naturally the driving force keeps coming down as the gas moves through the pipe line. So, the heat flux will also start reducing as the gas is going ahead.

So, in this particular problem, we have just taken you can say that we have taken a small section over which we are assuming that the natural gas temperature is remaining constant at about 20 degree centigrade; however, in a real situation this temperature will keep on increasing and that is how it will keep on reducing the convective heat flux during the journey of the natural gas through the pipe line.

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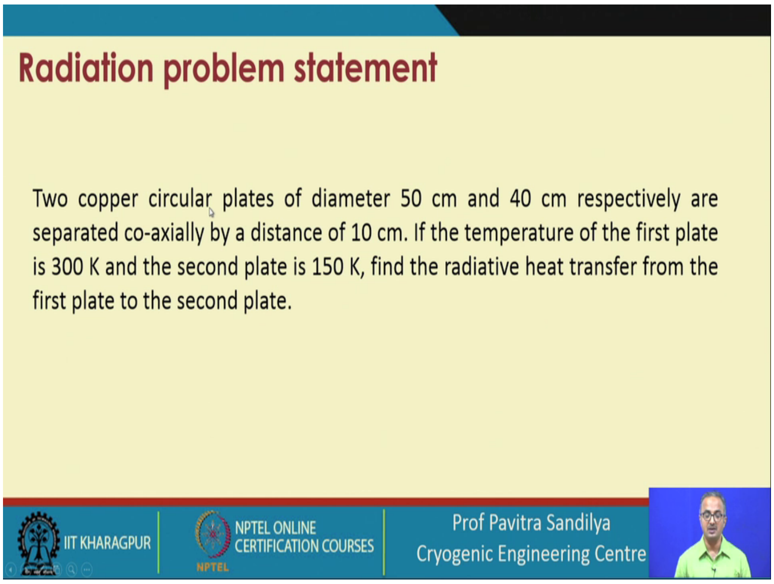

Lastly, we come to a problem on radiation heat transfer here, we have 2 copper circular plates of diameter 50 centimeter and 40 centimeter respectively.

Now, please note the geometry of the surface is very important here, we are talking about the circular plates and we shall see how this matters in the evaluation of the radiative heat transfer and these 2 circular plates are separated co axially that is they have the same axis they are standing 1 over the other with the same axis. So, the co axially, they are separated by a distance of about 10 centimeter, if the temperature of the first plate is 300 K and other is 150 K; the temperature difference is about 150 K.

Now, please understand 300 K is about 27 degree centigrade; whereas, 150 K is much below the 0 degree centigrade. So, it is negative temperature negative in centigrade scale. So, such a large temperature difference, they are existing. So, there will be some kind of a relative heat transfer between the surfaces, here we are neglecting any kind of convective heat transfer, then by neglecting the presence of any medium that is we are not considering the presence of any gas between the 2 circular plates.

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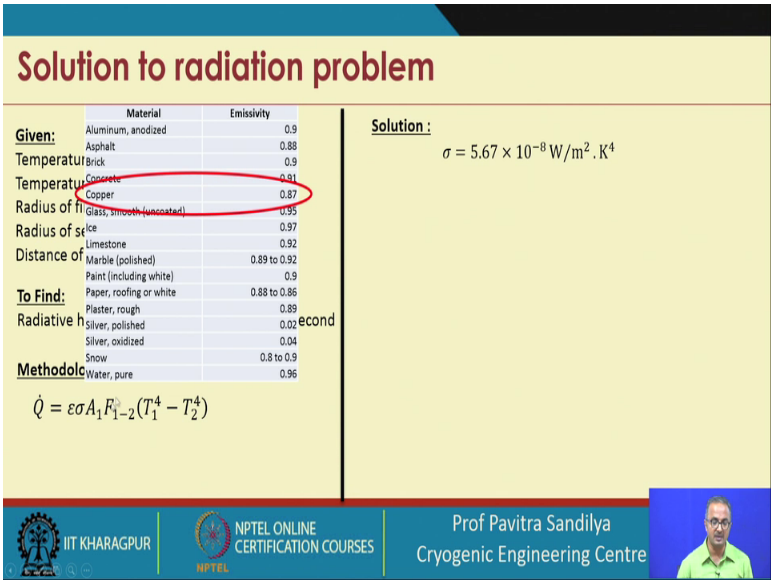

So, here if the solution that we are given of this values the t one is given 300 K T 2 has 150 K, then radius of first plate r 1 that is 25 centimeter radius of second plate r 2, this is r 2 not r 1 that is 20 centimeter and a distance of separation is 10 centimeter and we have to find out the radiative heat transfer rate. So, we are using this equation and in this equation, first we figure out the value of the emissivity and for because is copper. So, we find the emissivity of copper as 0.87.

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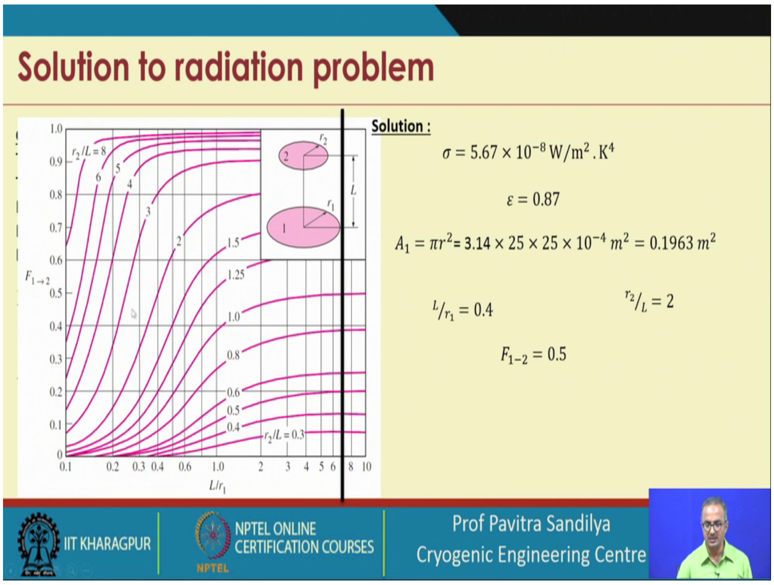

Next, we find out the area over which this is taking place this is pi r 1 square because it is from the surface 1, we are talking about. So, pi r 1 square, it will be. So, it is we are putting the value of r 1 has 25 centimeter and we are getting this particular 0.1963 meter square, after the unit conversion and then we are finding the value of L by r 1 and r 2 by L and these things are coming because the figures for the this shape factor is given in terms of the L by r 1 and as r 2 by L as the parameter.

So, what we do? We find the L by r 1.4 which we locate here on this axis 0.4 and we move straight up and then wherever the r 2 by L is 2 that is at this position. So, we move ahead move straight away, then we go to this value of r 2 by L as 2 and wherever it intersects, then we read out the value of the shape factor from the y axis. So, these value we read out it is about 0.5.

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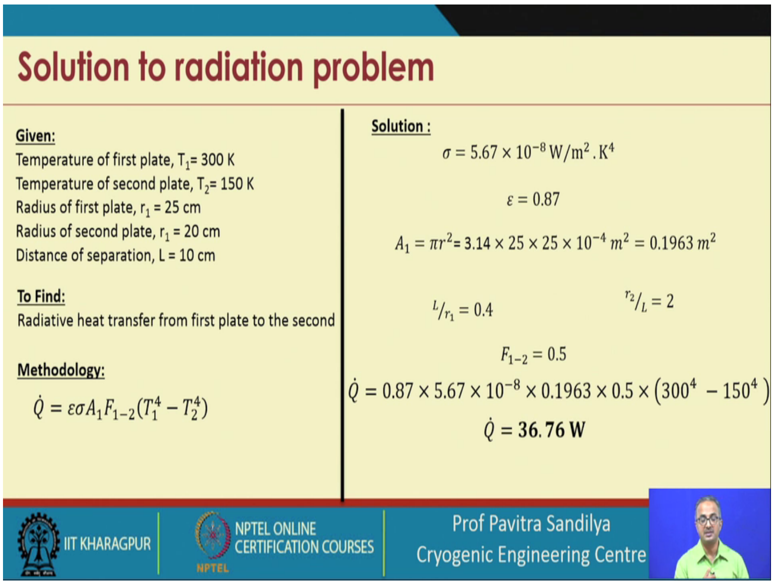

And now with this values various values we obtain; what we do? Now we plug in these values in this particular formula to get the radiative heat flux value please mind it that in this case radiative heat transfer the the driving force is not simply temperature difference, but it is the force power the temperature raise to force power is the which is giving the driving force and with this we obtain the radiative heat flux as 30 about 37 watt.

So, about 37 watt heat transfer is happening due to radiation between 2 plates at 300 K and 150 K, but please mind it that depending on the type of material we use the emissive will keep on changing and also the way that 2 plates are oriented the shape of the plates will dictate the value of the shape factor and also the dimension of the plate will dictate the area of the of the particular geometry.

So, all this things will matter in deciding the radiative heat transfer, here, we try to see that how much heat transfer is taking from plate 1 to plate 2 in other way round, if I we can also find out what is happening from plate 2 to plate, 1 in that case, we can simply replace A 1 by A 2 and if we put other things same, we will find we will get the whatever the radiative heat transfer taking place from A 2 to A 1.

So, depending on what we put whether A 1 or A 2 depending on that and also the shape factor will also change because the r 1 r 2 will also be defined interchangeably for the 2 plates. So, depending on whether it is coming from a bigger plate to smaller plate or a smaller to bigger plate the amount of heat transfer will be different and as we know that if is from smaller to bigger we can say that almost all the radiative; heat radiative waves will be going to the bigger plate, but when it go from bigger to the smaller some of these waves are lost and which could do not reach the smaller plate.

So, because of this we find that the radiative heat transfer will be changing whether it is a between the bigger one and the smaller one or from the smaller one to the bigger one or the bigger one to the smaller one for the same system. So, here we have found out the case where the heat transfer is taking place from a bigger geometry to a smaller geometry.

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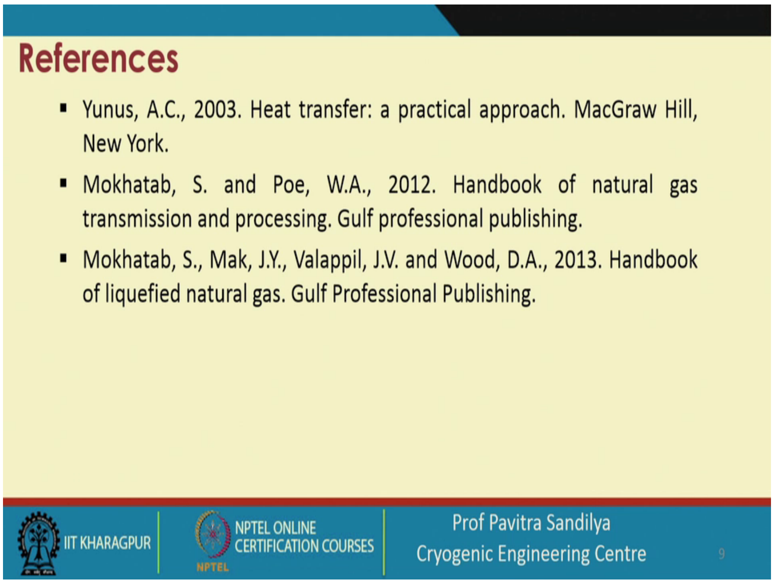

And these are the some of the references, you can see for more on this kind of problems.

Thank you.