Chemical Process Safety
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Lecture 20 - Source Model Problems

So welcome to this module of Source Model and in this module we are going to discuss several problems which are helpful in the entire study.

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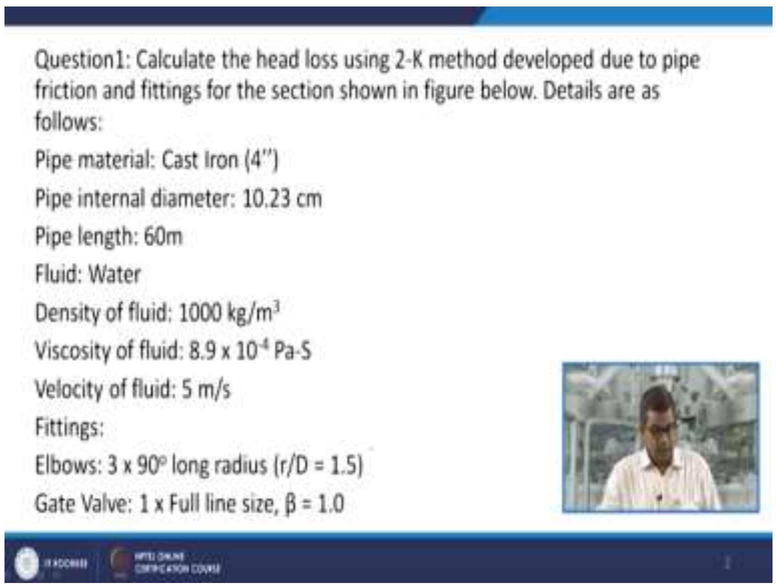

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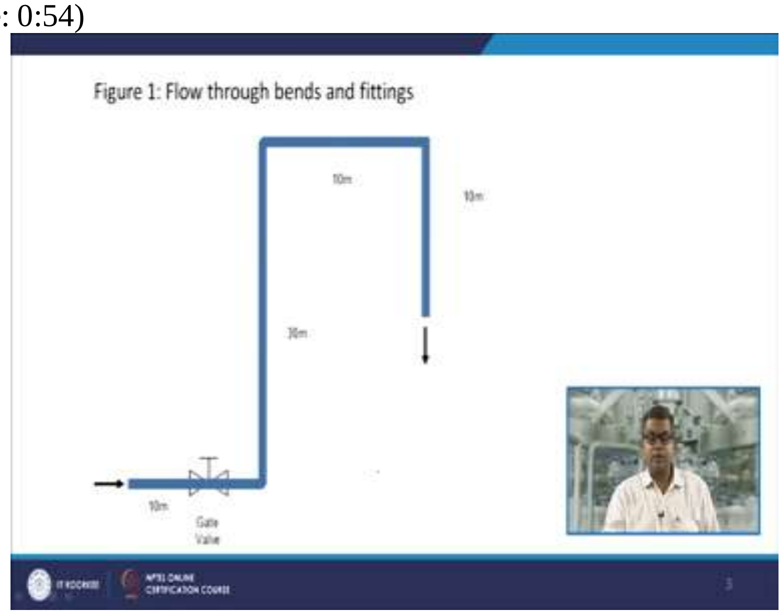

So let us have the first problem. This problem here you need to calculate the head loss using 2-K which we have studied in the previous module, developed in due to pipe friction and fitting for the section as shown in the figure this one, this particular figure and details whatever details are required they are as follows: That pipe material which is having the cast iron 4 inch, the pipe internal diameter is given to you which is 10.23 centimeter, the pipe length is 60 meter. You are using the fluid as water, the density of the fluid is 1000 kg per meter cube.

Viscosity of the fluid is 8.9 into 10 to the power minus 4 Pascal Second, the velocity of the fluid is 5 meter per second. 2 fittings are there, elbow 3 x 90 degree long radius that is r by D is equal to 1.5 and a gate valve 1 into full line size and beta is equal to 1.

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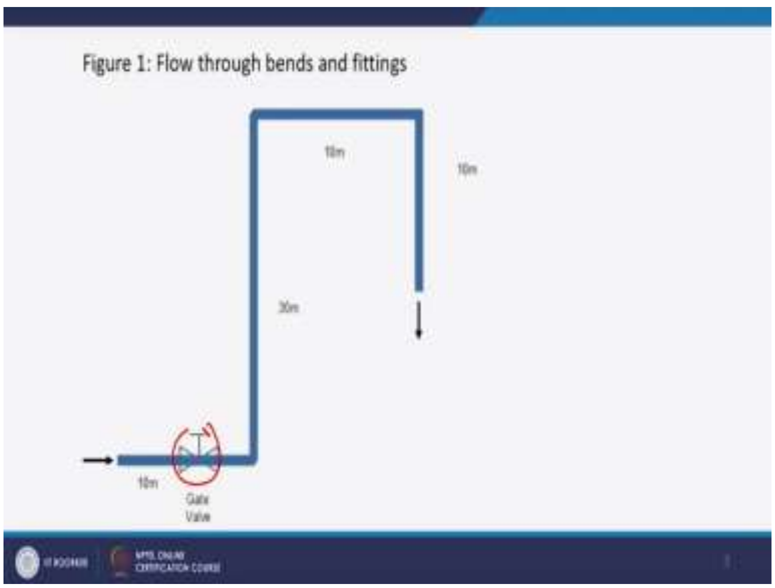

So this is the figure, here this is the 10 meter and then the gate valve is there, the height is 10 meter, then again the length is 10 meter and this 10 meter height. To assist you we are having the Moody's chart with us, so let us start with this particular problem, the solution of this particular problem. The value of K and K_0 we can determine the table which was given earlier.

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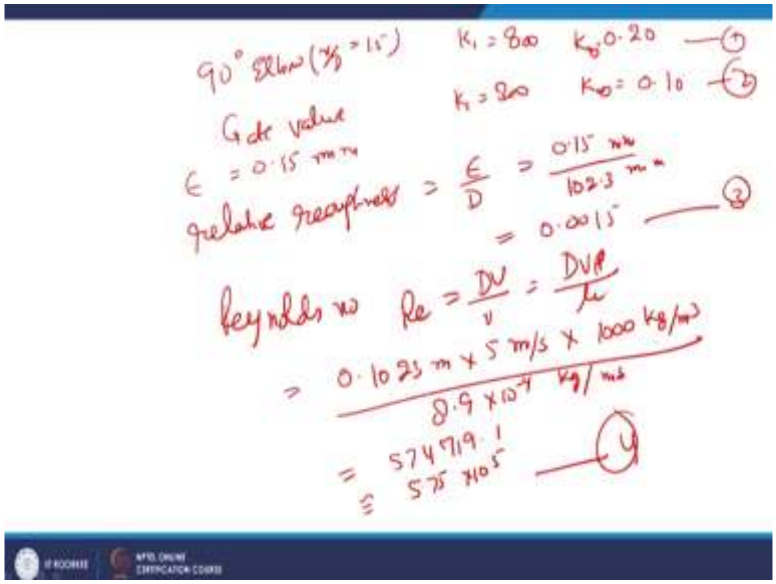

The 90 degree elbow r by D is equal to 1.5, so the K_1 is 800 and K_∞ is 0.2 and gate value, the K_1 is 300 and K_∞ is 0.10. So absolute roughness for cast iron pipe, ε is 0.15 mm and the relative roughness is ε upon D that is 0.15 upon mm, so it comes out to be 0.0015. So it is equation 1, 2 and 3. The Reynolds number Re, DV/ν, $DV\rho/\mu$, it is 0.1023 meter into 5 meter per second into 1000 kilogram per meter cube divided by 8.9 into 10 to the power minus 4 kilogram per, which is (57), 574719.1, nearly you can write 5.75 into 10^5. Now we can determine the value of friction factor using Moody's curve, now here we are having the Moody's curve with us.

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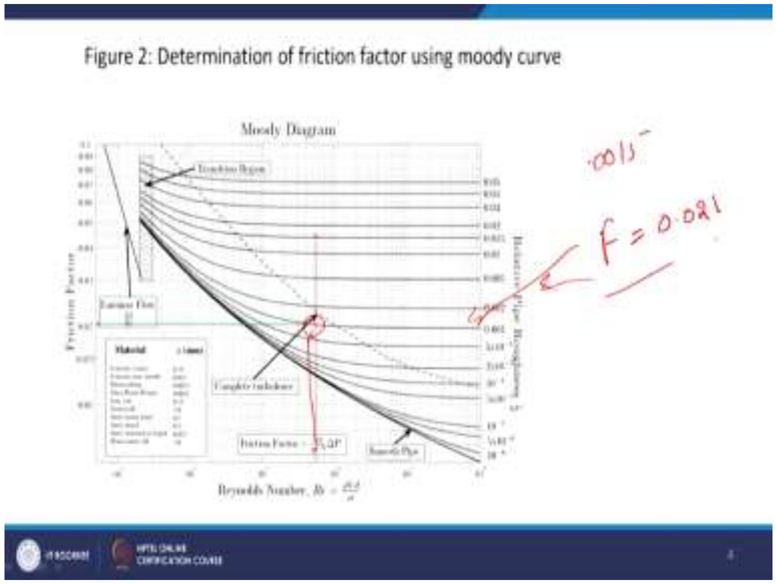

So we can determine the value of friction factor, so if we utilize the values which we have calculated earlier (the) this is your Reynolds number and this is the relative pipe roughness. Now with the help of these 2 factors we can calculate the friction factor. Now, here the relative roughness is 0.0015, so we can calculate from here and the Reynolds number is 5.75 into to the power 5, so the point of cross section is somewhere here and if we extrapolate the things to the friction factor it is coming out to be 0.021, now this is a very useful information through which we can proceed further.

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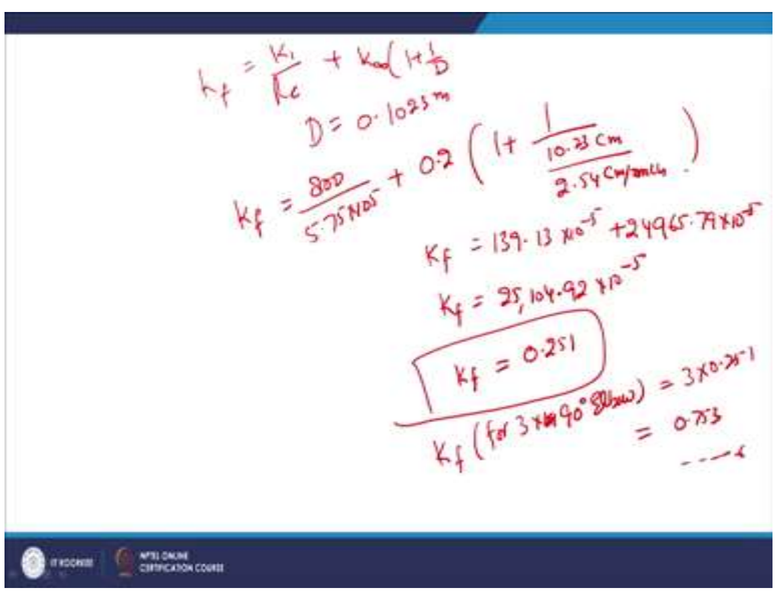

Now, let us calculate the resistance coefficient for 90 degree elbow, the

$$K_f = \frac{K_1}{Re} + (1 + \frac{1}{D})$$

now using K_1 and K_∞ from the previous equation and the Reynolds number from equation number 4 and D is equal to 0.1023 meter, we can calculate the K_f that is 800 divided by 5.75 into 10^5 + 0.2, 2.54 centimeter per inch.

Now always remember to convert the value of D into inch for determining the value of resistance and even in fact all calculation you must be consistent towards the unit.

Now K_f is 139.13 into 10^5 plus 24965.79 x 10^{-5}

So, K_f is coming out to be 25104.92 into 10^{-5}, now K_f is 0.251. Now for elbow of the similar geometry we can directly multiply the value of this particular value with 3, so K_f for 3 x 90 degree elbow which is equal to 3 into 0.251 which is coming out to be 0.753.

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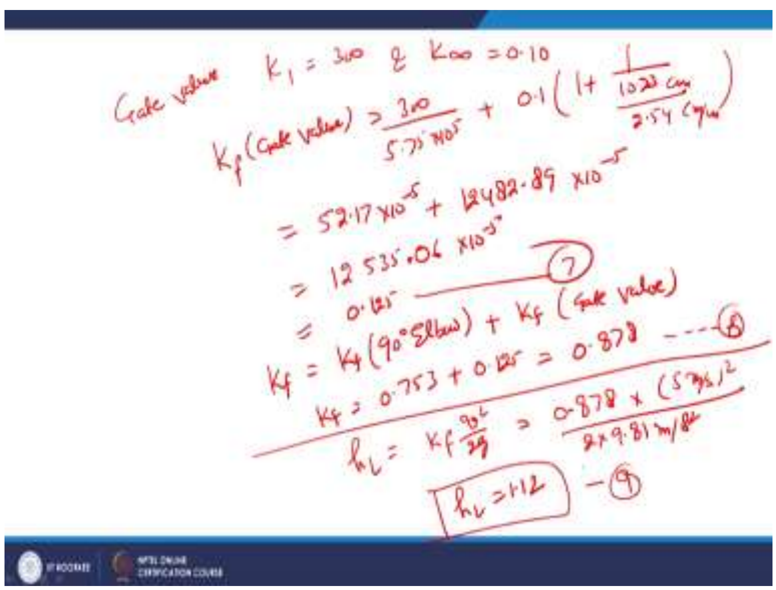

Similarly for gate value K_1 is equal to 300 and K_∞ is 0.10 which is for gate valve, the remaining value will be the same, now K_f for gate value is equal to 300 on 5.75 x 10^{-5} + 0.1, 1 plus 10.23, 2.54 which is 52.17 into 10 to the power minus 5 plus 12482.89 into 10 to power, so 12535.06 into, or nearly 0.125.

So the total resistance coefficient due to the fitting will be K_f is equal to K_f 90 degree elbow plus K_f gate valve that is K_f is equal to 0.753 plus 0.125, 0.878, now total head loss due to fitting can be calculated using this particular equation that is h L is equal to K_f V square upon 2g and this is 0.878 into 5 meter per second square divided by 2 into 9.81 meter per second square, h L is 1.12.

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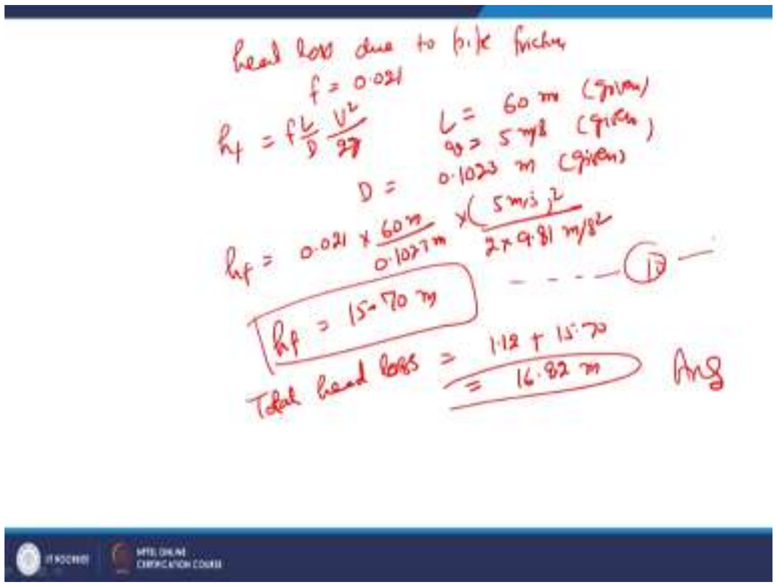

Now calculation for the head loss due to pipe friction, so f is equal to 0.021, h_f is f LD, V square upon 2g. L is 60 meter that is given, V is 5 meter per second again given, D is 0.1023 meter that is given, so h_f is equal to 0.021 into 60 and 0.1023 into 5, 9.81 meter per second square, so h_f is 15.70 meter.

So total head loss, 1.12 plus 15.70 which is 16.82 meter, now it is to be noted from the equation number 10 and 9 that the loss due to fitting is comparatively very less than the losses due to friction pipeline of 60 meter. So therefore for a large pipeline such as the crude oil pipeline which usually flows from countries to countries in several kilometers we can neglect the frictional loss due to fitting whereas for safety calculation these values are extremely important.

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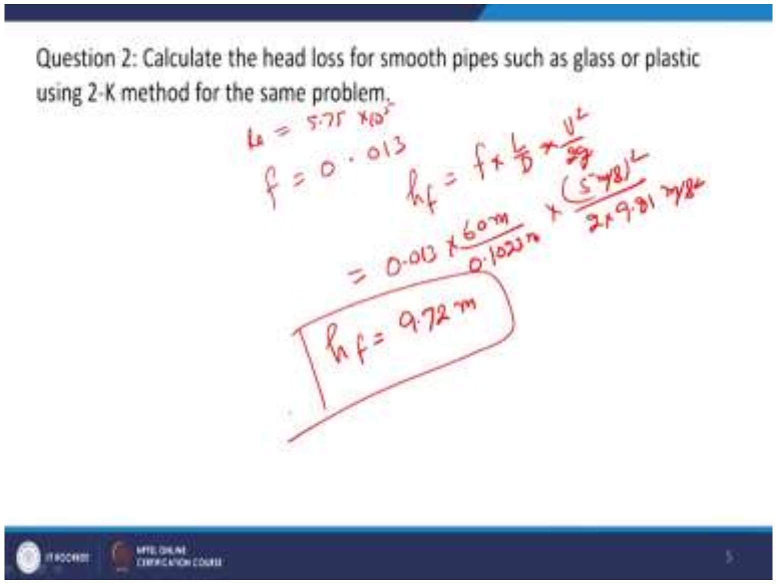

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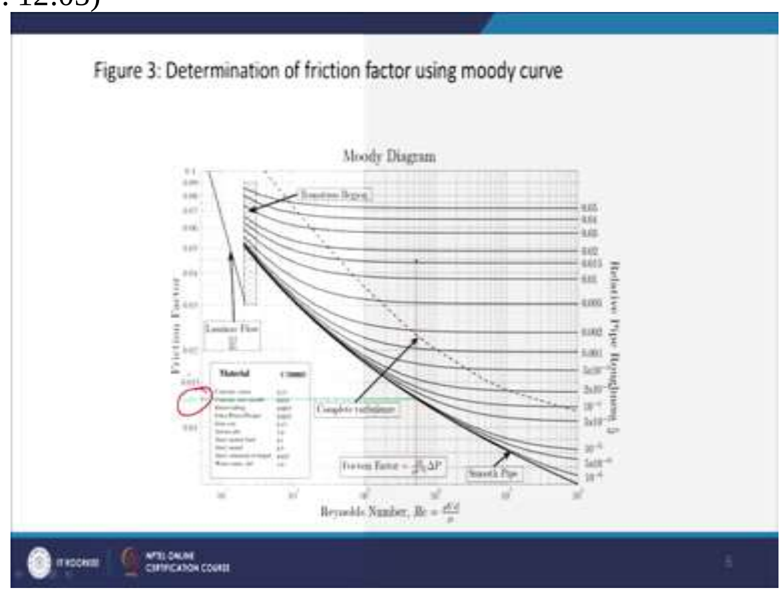

Now, let us take the second problem that is you need to calculate the head loss for the smooth pipe such as glass or plastic using the 2K method for the same problem which we have discussed in the previous problem, so as all conditions are same for this problem except the pipe material low and hence the relative roughness, so we can directly calculate the value of the friction factor, now from Re which we have calculated in the previous equation Re is equal to 5.75 into 10^5.

Now with the help of Moody's chart which is given over here we can calculate because the relative pipe roughness is will be different because we have changed the configuration and Reynolds number is same. So we can, if we extrapolate then we can have this value of f that is f is equal to 0.013, so hence losses due to the fitting will remain same. Only losses due to the friction pipe will reduce and can be determined with the help of this equation that is f into L upon D into V square upon 2g, so this is comes out to be 0.13 into 60, 0.1023 meter into 5 meter per, into 2, into 9.81 meter per square, so h f is 9.72 meter.

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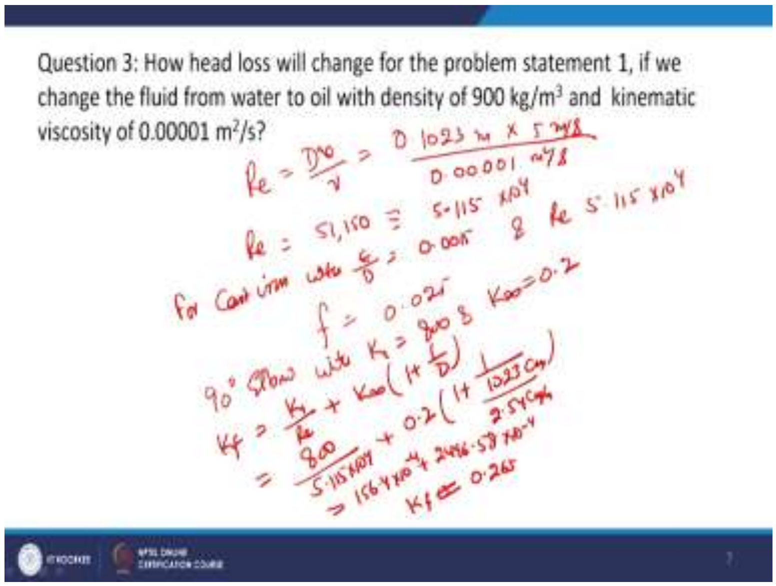

Now, let us have another problem, the problem number 3, the problem says that, "How head loss will change for the problem number 1, if we change the fluid from water to oil which is having the density of 900 kilogram meter cube and kinematic viscosity of 0.00001 meter square per second?" So now we have changed the fluid, so as a Reynolds number depends upon the density and viscosity of the fluid, so it will be changed and hence all the calculation will be changed accordingly.

So let us see that how Reynolds number is having its value 0.1023, we have taken it from problem number 1, 5 meter per second, 0.00001 meter square per second, so Reynolds number is coming out to be 51150 that is roughly 5.15 into 10 to the power 4, now for cast iron with ε upon D is equal to 0.0015 and Reynolds number 5.115 into 10 to the power 4, now we have calculated the Reynolds number, so now next aspect is to calculate, to find out the Moody's chart.

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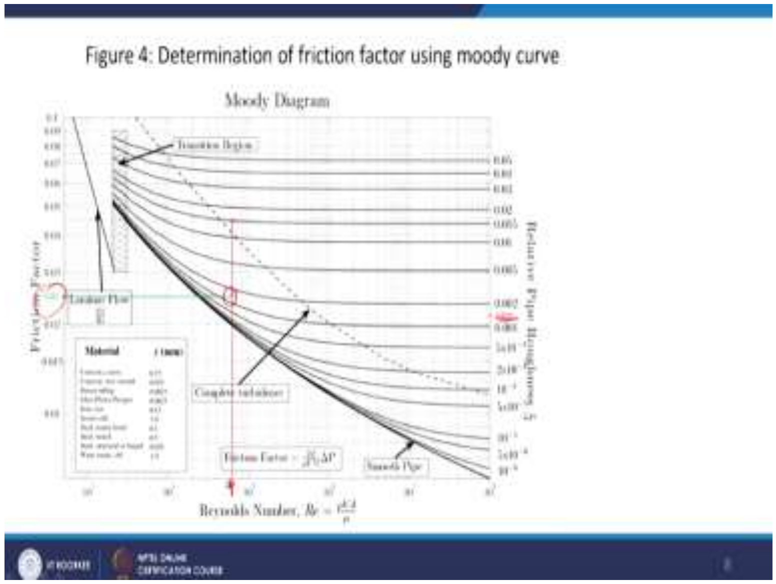

Now this is our Moody's chart, from here we can calculate because we know the roughness (fact) relative pipe roughness which is point 0.0015, here you can see this one and Reynolds number is somewhere in the zone of this one, so the cross section is this one and if we extrapolate the things and it is comes out to be 0.25. So if that is the friction factor is 0.25, now calculation for determining the resistance coefficient for 90 degree elbow with K 1 is equal to 800 and K infinity is equal to 0.2.

So K_f is equal to K_1 upon Re plus 1 plus 1 upon D which is 800 upon 5.115 into 10 to the power 4 plus 0.21 plus 1 upon and 10.23 centimeter upon 2.54 cm. This is 156.4 into 10^{-4} plus 2496.58 x 10^{-4}, so K_f is 0.265.

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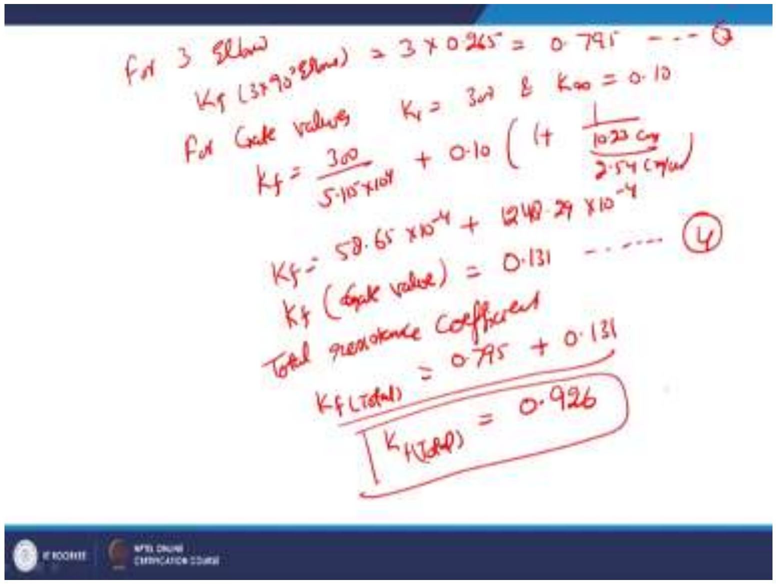

Now for 3 elbow, the K_f 3 into 90 degree elbow which is 3 into 0.265, 0.795. For gate valve K_1 is equal to 300 and K_∞ is 0.10. Now K_f is 300 upon 5.115 into 10 to the power 4 plus 0.10, 1 plus 1 upon 10.23 centimeter, 2.54. Now K_f is 58.65 into 10 to the power minus 4 plus 1248.29 into 10 to the power minus 4, so K_f that is gate valve 0.131.

So the total resistance coefficient K_f total is 0.795 plus 0.131 which is 0.926.

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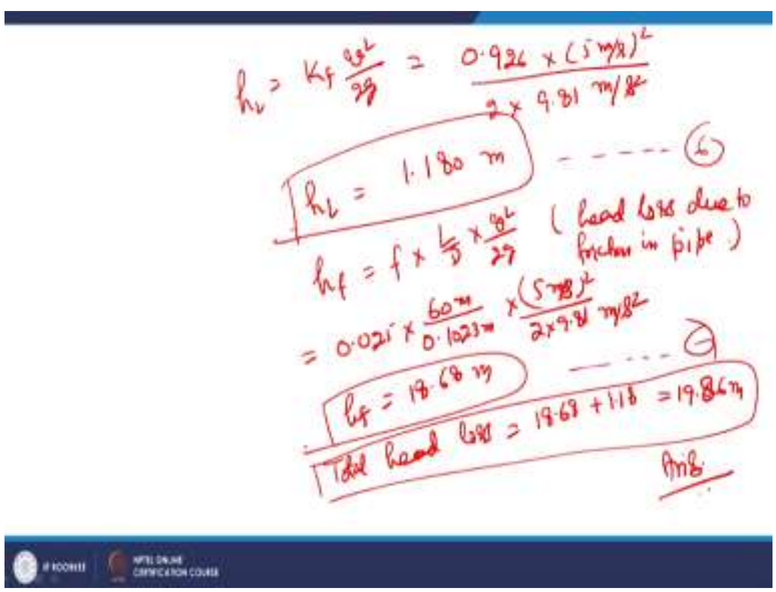

Now the head loss due to the fitting can be calculated as h L is equal to K_f V square upon 2g, this is 0.926 we have calculated earlier into 5 divided by 2 into 9.81 meter per second square, so that is h L is equal to 1.180 meter.

Now head loss due to friction in pipe can be calculated as h_f is equal to f into L upon D into V square upon 2g, this is the head loss due to friction in pipe which is 0.025 into 60 meter upon 0.1023 meter into 5 meter per second square upon 2 into 9.81 meter per second square.

So h f is 18.68 meter, so that total head loss is 18.68 plus 1.18 is equal to 19.86 meter, this is what we required. Now it is to be noted that in above mentioned 3 problems if we did not consider the loss of head due to the kinetic energy change, so try to calculate the head loss for the problem number 3 using the case for a smooth pipe.

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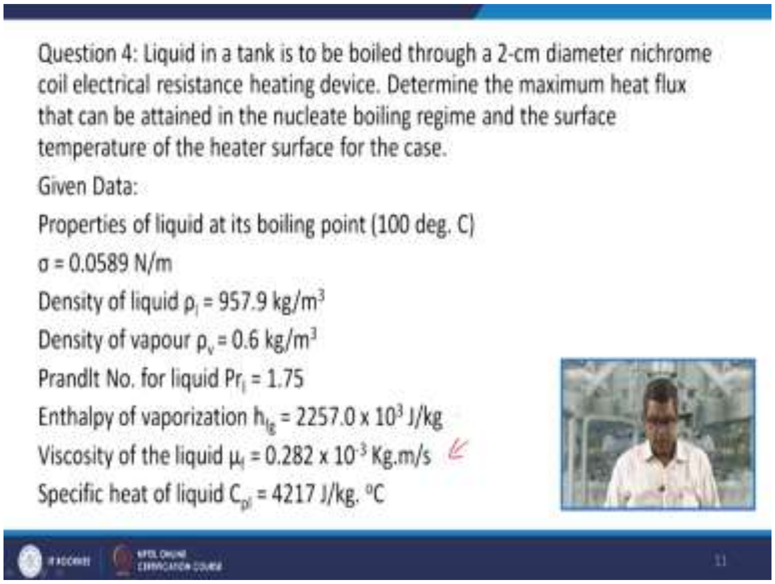

So the next problem is related to the pool boiling, now here is the problem that a liquid in a tank is to be boiled through a 2 centimeter diameter nichrome coil electrical resistance heating device. Now you need to determine the maximum heat flux that can be attained in the nucleate boiling regime and the surface temperature of the heater surface for the case. Now there are sufficient data given that is the properties of the liquid at its boiling point 100 degree Celsius.

Small sigma is equal to 0.0589 Newton per meter, density of the liquid ρ_l is 957.9 kilogram per meter cube, density of the vapor P V is equal to 0.6 kilogram per meter cube, Prandlt number for liquid Pr_l l is 1.75, enthalpy of vaporization h_fg is 2257.1 into 10 to the power 3 joule per kilogram, viscosity of the liquid mu f is 0.282 into 10 the power minus 3 kilogram meter per second, the specific heat of the liquid C_{pl} is 4217 joule per kilogram degree Celsius.

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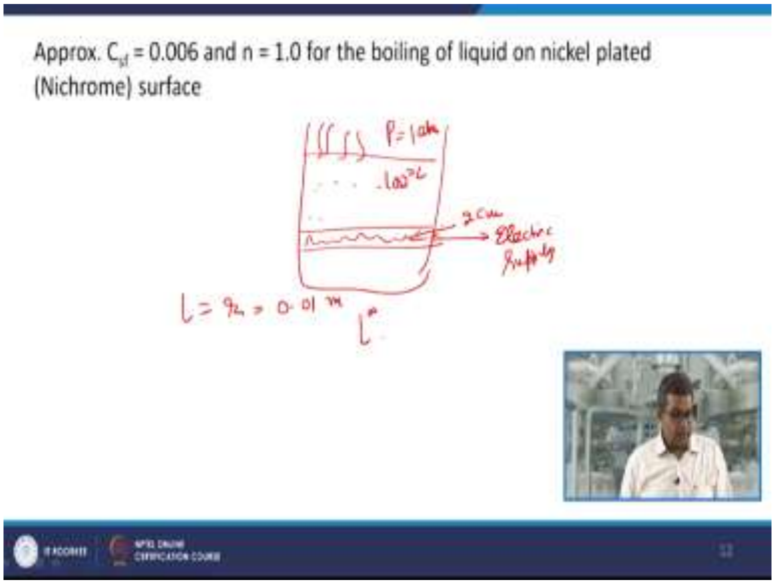

And approximately C_{sf} is 0.006 and n is equal to 1.0 for the boiling of the liquid on nickel plated nichrome surface, so let us take the problem. This is the figure of the pool boiling here, this is the 2 centimeter electric supply, this is the supplied electric supply, 100 degree Celsius, now P is 1 atmosphere. Now the heating element in the case can be considered to be the short cylinder whose characteristic dimensions in its radius that is L is equal to r is equal to 0.01meter. The dimensionless radius L star and the constants here can be determined from the table which I am going to draw.

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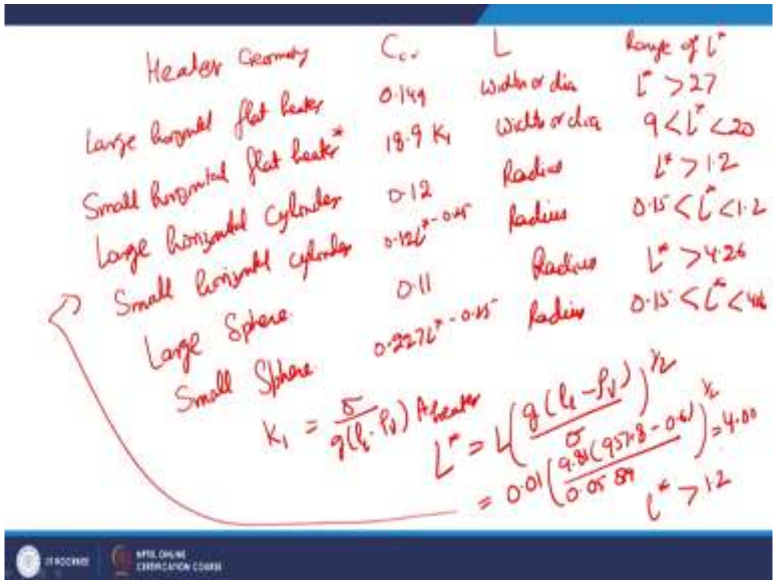

Now here the heating, this is very important table, heater geometry L, range of L star, now here the large horizontal flat heater 0.149, or dia, small horizontal flat heater which is our case 18.9, large horizontal cylinder 0.12, in this case we will consider radius. This L star is greater than 1.2. Small horizontal cylinder 0.12 L star, radius 0.15, L star 1.2. Large sphere 0.11, 4.26 L star is greater than 4.26. Small 0.227 LS star, fine less than 4.2 size. So if we calculate the K1 which is g P minus P L minus P V, A of heater. L star is L g P L minus P V, half which is 0.01, 9.81, 0.6 going to the power half which is, now if we compare with this table the L star is coming out to be the greater than 1.2.

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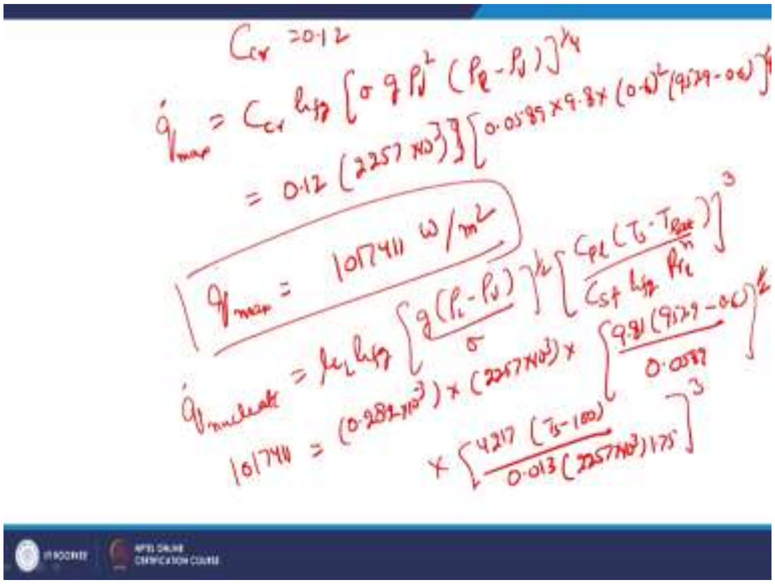

Now which corresponds to C r is equal to 1.2, then the maximum or critical heat flux is you can determine from the equation which we have discussed previously h fg, g P V square P L minus P V to the power 1 by 4 which is 0.12, 2257 into 10 to the power 3, 0.0589 into 9.8 into 0.6 square into 957.9, 0.6 to the power 1 by 4. So Q maximum is 1017411, so once our radiation which gives the nuclear boiling heat flux for a specified surface temperature can also be used to determine the surface temperature when the heat flux is given.

Now if you substitute the maximum heat flux into the following equation that is this one, ρ V, T S minus T and to the power 3, so it is 1017411 is equal to 0.282 into 10 to the power minus 3 into 2257 into 10 to the power 3 into 9.81, 957.9 minus 0.0589 to 1 by 2, multiplied by 4217 T S minus 100 upon 0.013 into 2257 into 10 to the power 3, 1.75 whole cube.

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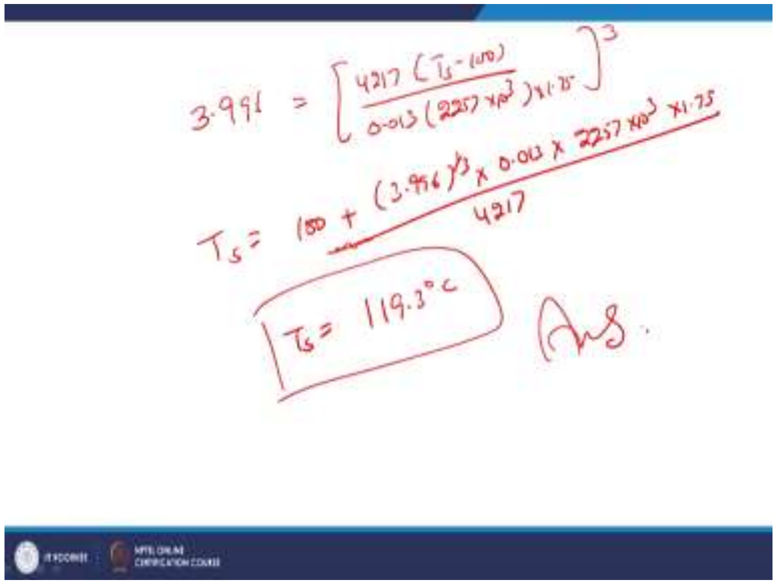

So this is 3.996, 4217 T S minus 100, 0.013 2257 into 10 to the power 3 into 1.75 whole cube, so T S is equal to 100 plus 3.996 into 0.013 into 2257 into 10 to the power 3 into 1.75, 4217, so T S is coming out degree Celsius this is the desired result. So, by this way we have discussed 4 different problems related to the source model and I hope that these problems, because these problems are very elaborative I hope that these problems are helpful for understanding of this particular chapter. Thank you very much.