Upstream LNG Technology
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Lecture – 19
Tutorial on the estimation of thermophysical properties

Welcome. After learning about the various methods to estimate the thermophysical and thermodynamic properties of natural gas, today in this lecture we shall be learning the technique how to estimate these properties by some numerical example. So, in this particular lecture we shall look into the estimation of various types of thermophysical properties.

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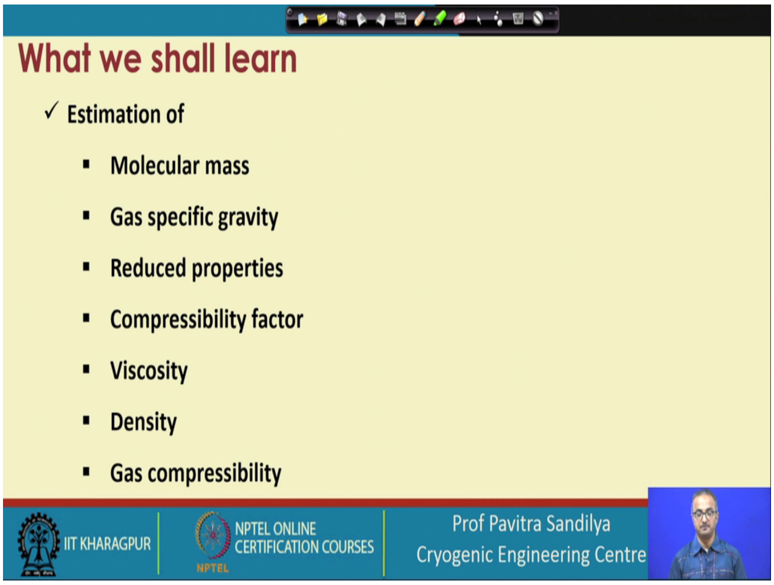

And in that we have the molecular mass of natural gas, gas specific gravity reduced properties, compressibility factor, viscosity density and gas compressibility.

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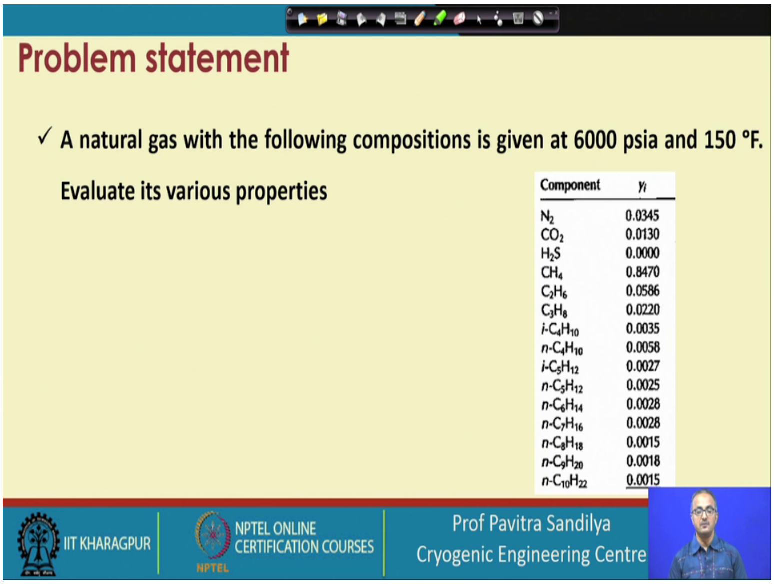

So, let us look at the problem statement, we have a natural gas sample given in this particular table and at a pressure of 6000 psia and a temperature of 150 degree Fahrenheit. And if you look at the table you will find that we had given various types of components nitrogen, carbon dioxide, hydrogen, sulfide methane ethane propane then the C 4 compound, C 5 compounds, C 6, C 7, C 8 and C 10 compounds and in this a second column we have the mole fractions of each of these components. Here we see that we have carbon dioxide about 1.3 percent and we do not have any hydrogen sulfide; that means, this natural gas may be considered to be sweet natural gas.

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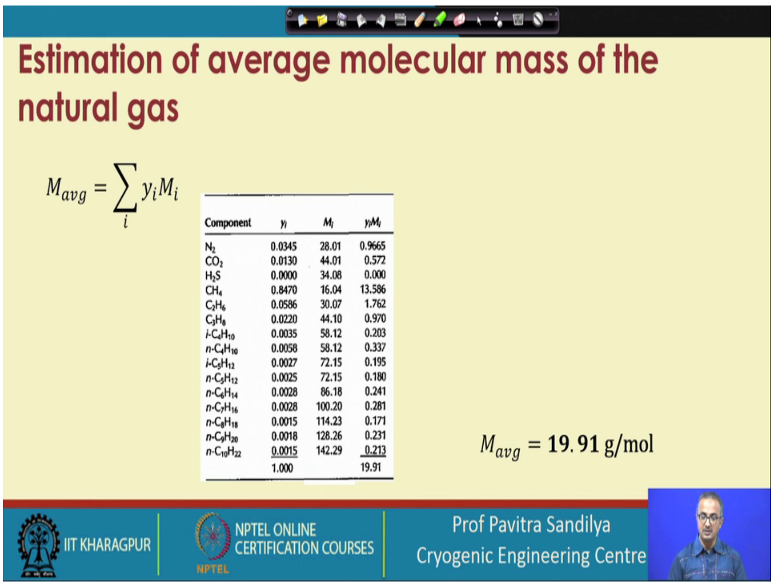

Now, first we go for the estimation of the average molecular mass of the natural gas. So, for this we shall be using this particular formula that is the summation of the product of the mole fractions and the molecular weight. So, what we do now that we have this table in this table, we have given the mole fractions as given in the problem and then corresponding to each of the components, we have the molecular masses of all the components in this particular column.

Now, what we do next is that, we simply multiply the mole fraction with the molecular weight for each of the components and we get the product of the mole fraction and molecular weight in the third column. And after doing this product then we sum it sum it up and we get this value, and these value is the average molecular weight of the natural gas. So, this is quite straightforward only we have used the molecular weight and with the given data of the mole fractions, we got the average molecular weight of the natural gas.

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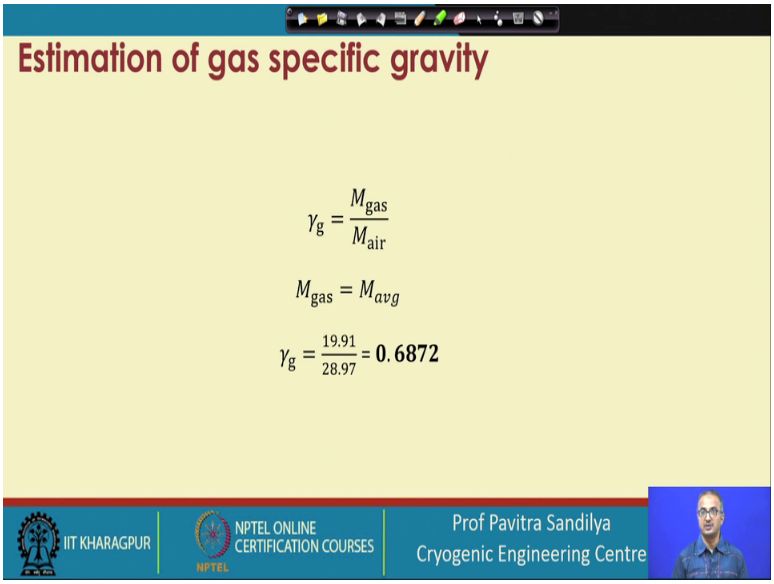

Next we come to the gas specific gravity for this we use this formula that the ratio of the molecular mass of the gas and the, to the mass of air. So, mass of air is taken to be about 28.97 and the molecular mass of the gas is the nothing, but the average molecular weight of the natural gas. We put this value here and we find that it is 0.6872, it means that this natural gas is lighter than air; that means, if there is any kind of leakage happening in the system for this natural gas, it is going to rise up and it is going to get dispersed. So, this particular problem is saying that the natural gas is lighter than air.

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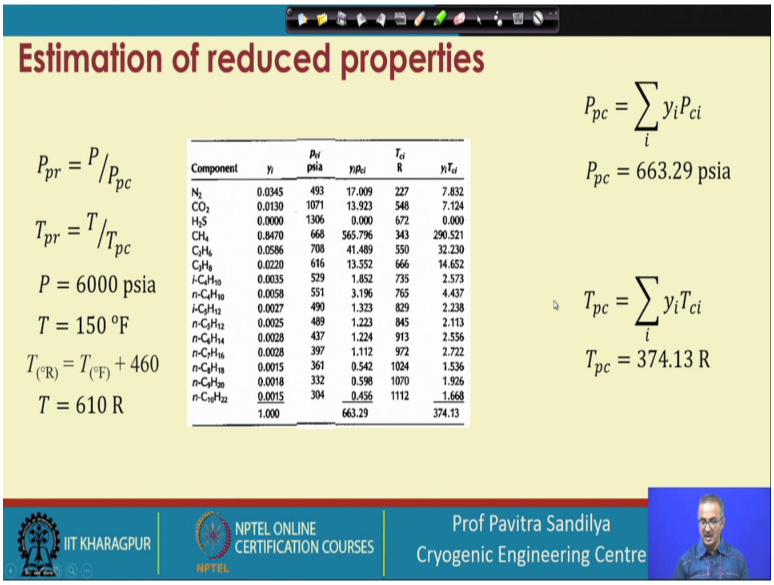

Next we come to the estimation of the reduced properties, in this we shall be looking into the reduced pressure and the reduced temperature. First we shall look into the reduced pressure formula that is P pr that is a pseudo reduced pressure, pseudo because as you know that this is having various components together. So, we shall be taking the natural gas to be like a pure component with some pseudo properties. So, we have the pseudo reduced pressure which is the ratio of the actual pressure to the pseudo critical pressure. So, pc is the pseudo critical pressure, similarly we have the pseudo reduce temperature which is the ratio of the actual temperature to the pseudo critical temperature. The pressure is given to be 6000 psia temperature is 150 degree Fahrenheit.

So, first what we do, that we convert the temperature from the Fahrenheit to absolute scale that is the Rankine scale by adding 460 and we get this as the absolute temperature that is 610 Rankine. After this we again consider the distribution of the natural gas composition of natural gas, and here we have the formula for the pseudo critical pressure and this is again from the case rule, we find that the summation of the product of the mole fraction and the critical pressure of each of the components.

So, now what we do again we find out the critical component of the pressure from the literature and these are the critical pressure of all the components given here and next what we do? We multiply the mole fraction with the critical pressure for each of the components and then sum it up. Now, this summation is the is the critical pressure of the natural gas; next we come to the pseudo critical temperature of the natural gas again; we use this particular formula summation of the product of the mole fraction and the critical temperature of each of the components. Again we go to this table we write the critical temperature in terms of Rankine and we get these critical temperatures for all the components. And then we take the product of the critical temperature with the mole fraction and the sum it up, after this we get the pseudo critical temperature of the natural gas.

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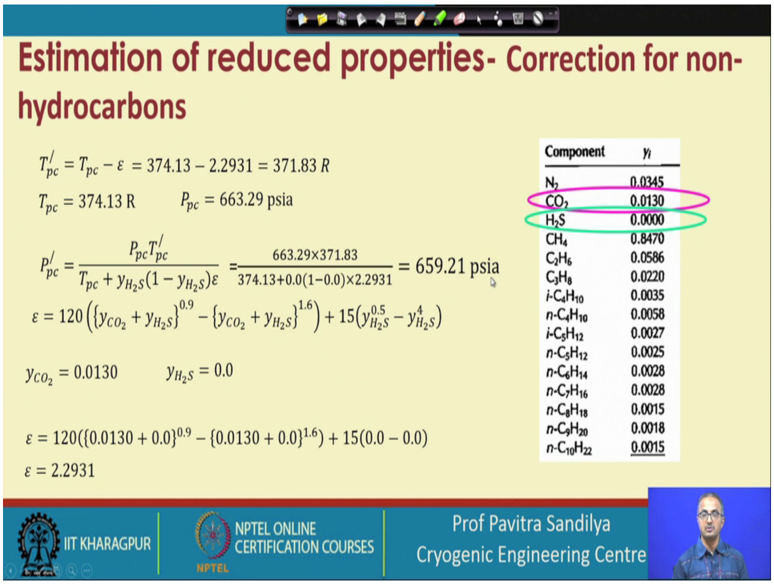

Now, here we now go for the some correction factors because whenever we have some non hydrocarbons as we learnt earlier, that we have to apply some corrections for the presence of the non hydrocarbon gases. So, in these cases we have the corrections for the H 2 S, and here we have the we shall be applying the correction factor like this that T prime represent the corrected critical pseudo critical temperature which is given as the act the pseudo critical temperature minus epsilon. And we shall see how to find epsilon, and this Tpc is given here and Ppc we know, and this is the correct pseudo corrected pseudo critical pressure, which is again given in terms of the pseudo critical temperature corrected and the without correction and this is the amount of the H2S.

So, in this particular formula we have epsilon in the corrected pseudo critical temperature and pseudo critical pressure, and this epsilon is found from this formula. Here we find that we have the mole fraction of carbon dioxide and the mole fraction of hydrogen sulfide gasses. So, when we incorporate from this particular table, the carbon dioxide mole fraction is 0.0130 and the H2S is there is no H2O that 0.000. So, with these equal values we find the value of epsilon as 2.2931. Once we found the value of epsilon, then we can correct our pseudo critical temperature and the pseudo critical pressure like this. So, these are the corrected pseudo critical temperature and pseudo critical pressure.

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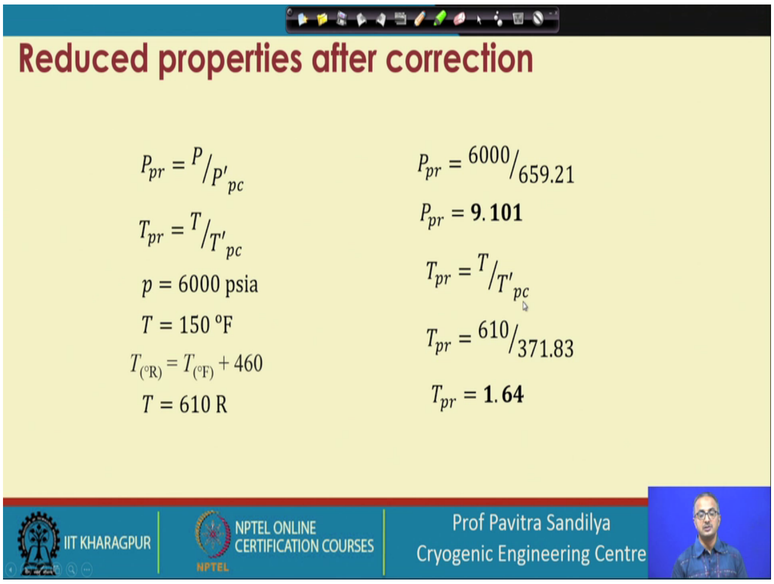

After getting these corrected values, now we go to find out the pseudo reduced pressure and pseudo reduced temperature from this formulae. And here we just plug in the values of the given pressure and the corrected pseudo critical pressure to obtain the pseudo reduced pressure like this. Similarly if plug in the value of the given temperature and the pseudo critical corrected temperature here. So, we get the value of the pseudo reduced temperature.

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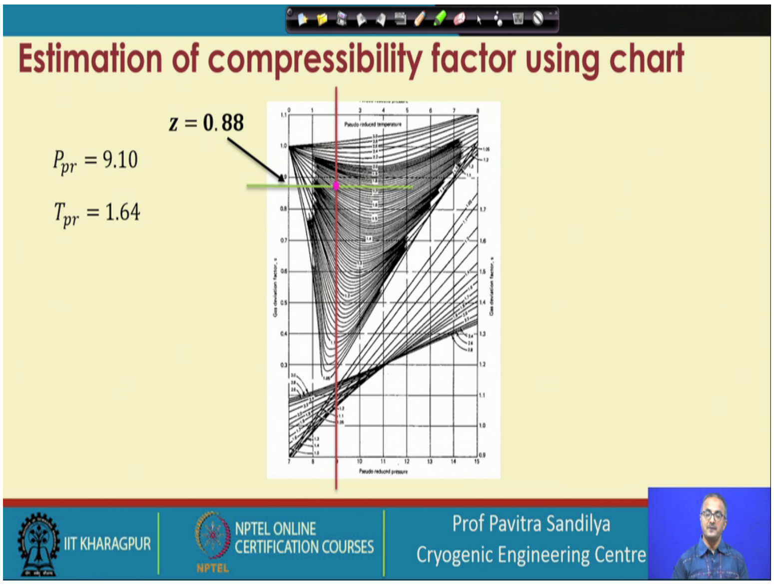

Now, we shall be using these pseudo reduced values to find out the compressibility factor from this particular chart, which we have shown in our lecture. Here we have on the y x axis the pseudo reduced pressure and pseudo reduced temperature is given in this particular these curves. So, we first locate the pseudo reduced pressure from the x axis from the vertical line and then we locate the pseudo reduced temperature from the horizontal line, and here we read out for sake of explanation I have used a very big dots.

But in actual case what you have to do that you have to take a very sharp pencil and with that you have to go to this particular graph and find out the exact location of the point of intersection of this vertical and the horizontal lines to get the value of the compressibility factor. So, this value is coming out to be about 0.88. So, this is we are using the compressibility chart to get the value of the compressibility factor.

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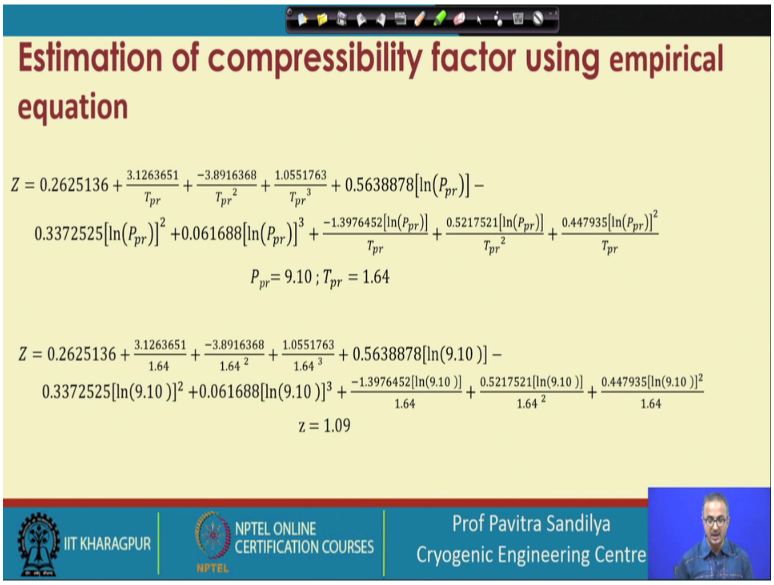

As we learnt in our lecture that there are various ways of finding the compressibility factor another way is to using some empirical equation and this is one of the empirical equations, which we considered in our lecture there are various empirical relations possible. So, in this equation we have the values of the pseudo reduced temperature and the pseudo reduced pressure and we plug in the values of these pseudo reduced temperature and pseudo pressure and the pressure and to get that we get the value of the z as 1.09.

Here we find there is certain discrepancy between what we have obtained from the chart and what we get from the particular correlation. This is not surprising because whenever these kind of correlations or the charts are developed they are developed considering some particular samples of natural gas, and it may be possible that the kind of natural gas we are handling may not be having the kind of compositions with which these charts and the correlations were developed.

So, these whether we are using chart or any kind of correlation it might happen that, there might be some discrepancies and in this case we find the discrepancy is about 15 to 20 percent. So, these kind of things are very much expected in this natural gas literature because of the variations in the natural gas compositions. So, this just here we just see that how we can estimate the values of this compressibility factor using some chart and using some correlations. And when you are going for filled things, there you have to figure out that what is the appropriate correlation that can be used for the particular case.

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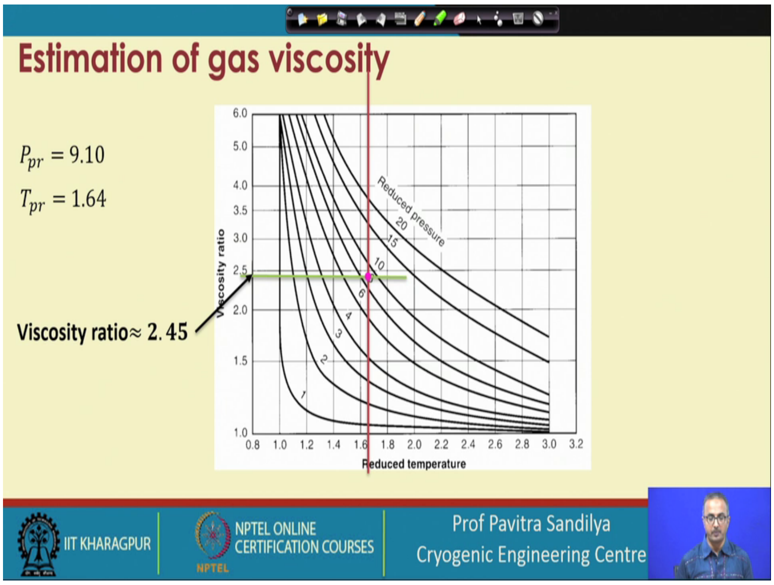

Next we come to the estimation of the gas viscosity. Here we have the viscosity ratio here we find that the on the x axis we have the reduced temperature and we have the various curves for different types of reduced pressure. So, what we do that we first locate the reduced temperature as 1.64 and then we locate the horizontal for this reduced pressure and from here from the point of intersection, we note down the viscosity ratio to be about 2.45.

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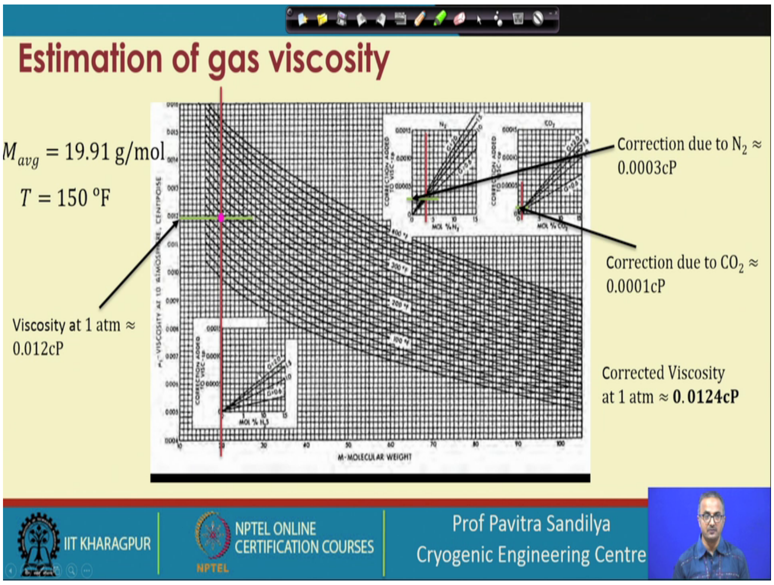

Now, with this value what we do, we now go for some corrections for nitrogen carbon dioxide and hydrogen sulfide. So, for we have to corrections and we take here these values of the molecular weight that is 19.91, on the x axis here the molecular weight. So, we take that value and then we locate the temperature for the, from these curves in Fahrenheit and then we find read out the value of the viscosity from the y axis.

So, with this viscosity value that it is coming out to be about 0.12 centipoise this is at one atmosphere pressure, and then we apply from this chart we apply the correction for the nitrogen. Here we again take the mole fraction of nitrogen and we get the g value and we find the value of the correction factor here. Similarly we can go for the correction for the carbon dioxide and these are the various correction factors we are finding and ultimately we get the corrected viscosity as this.

Now, we see that because there is no H2S. So, there we need not apply this particular curve for our case. So, we are only with nitrogen and carbon dioxide.

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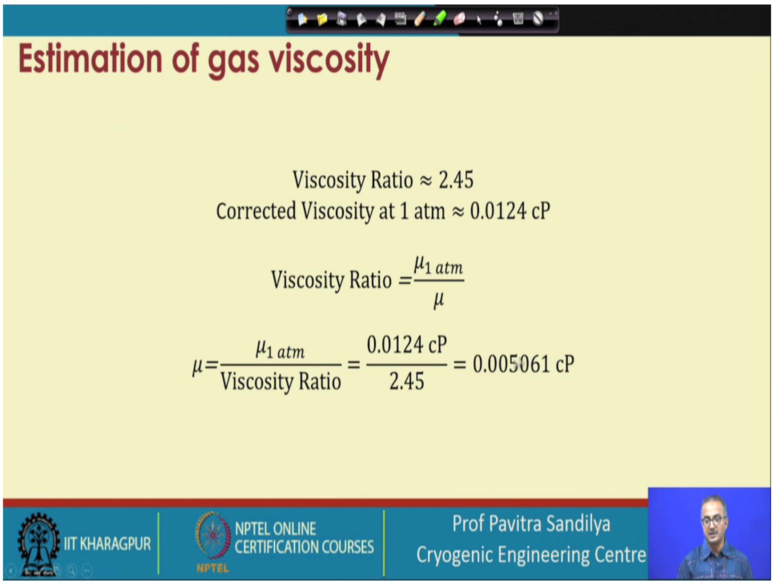

After this we go for the actual viscosity, because we have found the viscosity at one atmosphere now we shall be using the viscosity ratio to find out the viscosity for the given pressure that is 6000 psia. So, this is how we find out that viscosity ratio is defined as the viscosity at one atmosphere that is 14.7 psia to the viscosity at the given pressure.

So, so the actual viscosity is this that the viscosity at one atmosphere to the viscous ratio and we give this value. So, what we find that the, with the increase in the pressure the viscosity has reduced.

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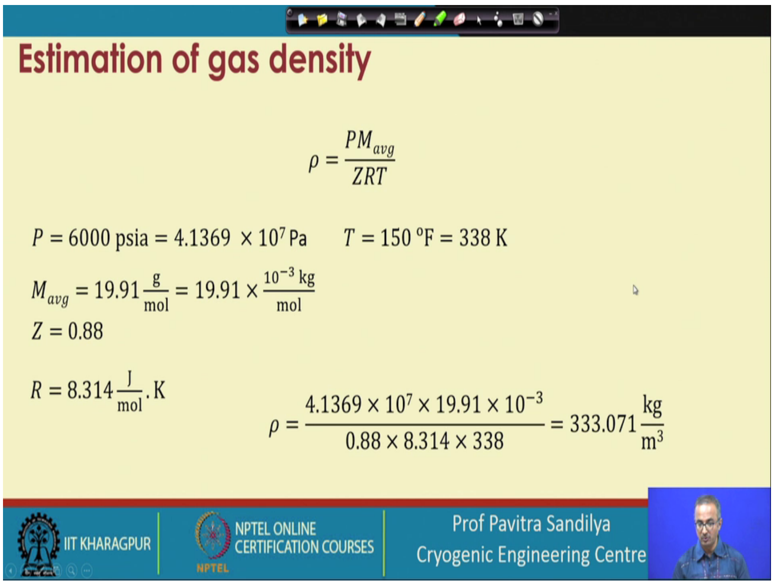

Next we go to the estimation of the gas density for this we use the equation of state, and in this case we are using the compressibility factors Z for the real gas and we have this value has 0.88, the deviation from unity division of Z values from unity tells us that the gas cannot be considered to be ideal. So, we are using the non ideal equation of state by incorporating the Z value and we put the other rest of the values, and we find that the density is about 333.071 kg per meter cube.

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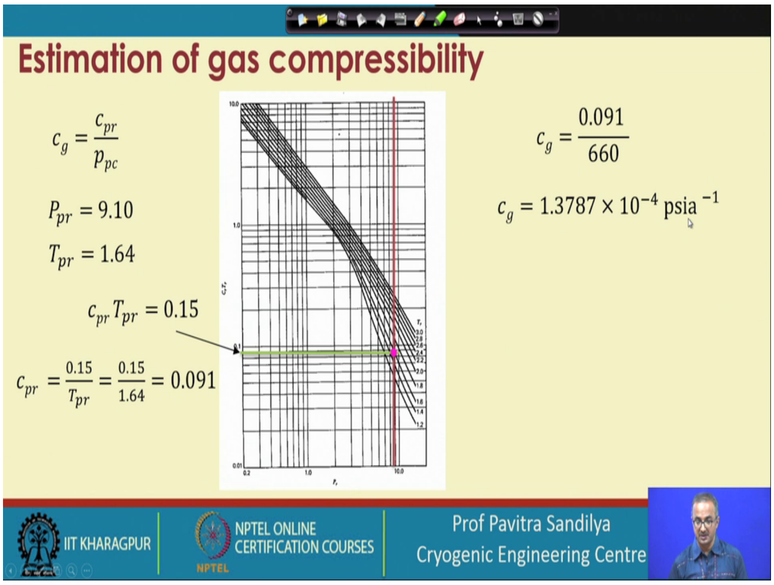

Next we go to the estimation of the gas compressibility; here we again find out these various factors Cg P pr T pr now here we see that from this particular curve we showed in our lecture. On the x axis we have the reduced pressure and these curves are for different reduced temperature. So, what we do again we locate this 9.10 from the x axis and then we locate is 1.64 on these particular curves. Please see that we may not be having the exact value of tr in that case we need to interpolate between the various curves.

So, somehow we here we are putting the point to indicate that the 1.6 are for the reduced temperature and corresponding to this we find the value of this cr tr then this is nothing, but this coming up at 0.15. So, after finding this value we find the value of Cp rs 0.15 divided by T pr and this is coming out to be this and this C pr will be used in this particular formula. Next we find the value of Cg from this expression from the C pr divided by the 660 and here we get the value of as this much per unit pressure per unit pressure.

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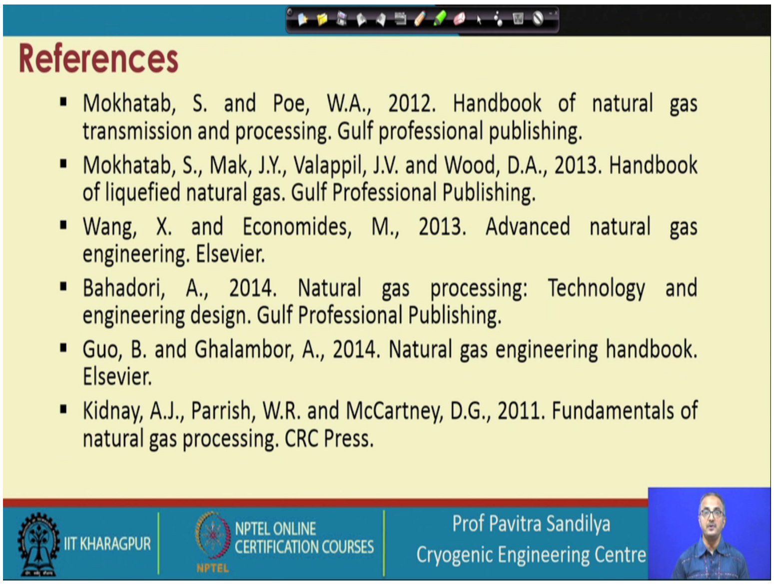

Now, this is how we find the value of the compressibility factor, here we have the references from which you can learn more about these estimation methods.

Thank you.