Upstream LNG Technology

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Lecture – 71
Tutorial on refrigeration – I

Welcome; after learning about the ways of cooling using the expansion valve and all these. We shall do we shall see some problems how to apply those theories. So, in this particular series of the tutorial in this particular one we shall be looking into the T-s diagram.

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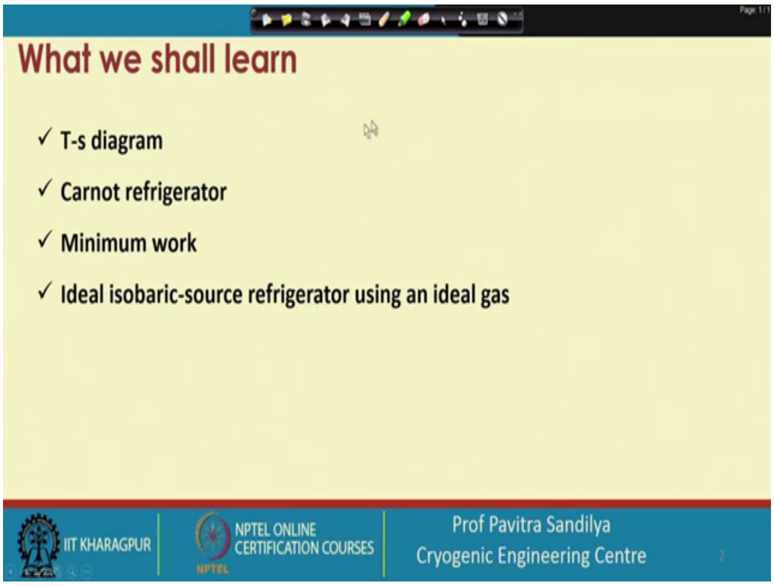

How to see T-s diagram then Carnot refrigerator, the minimum work done and the ideal isobaric source or refrigeration using the ideal gas

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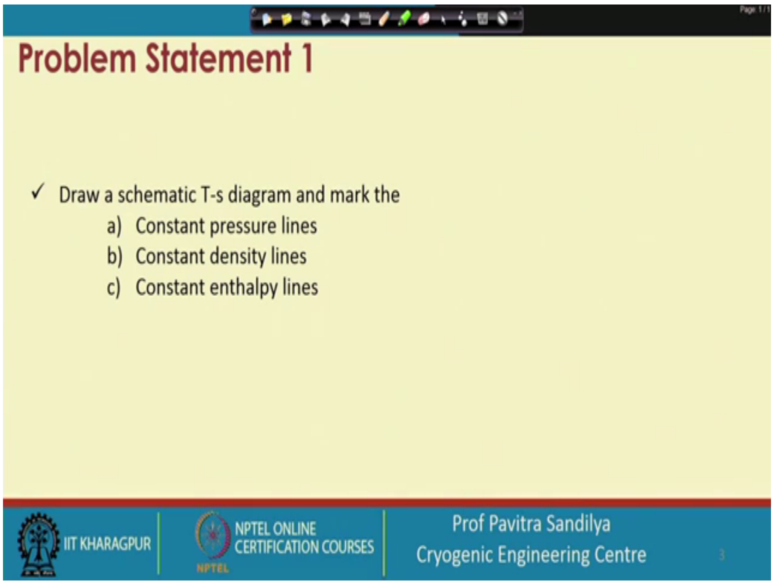

So, first we shall come to see that draw the schematic diagram or T-s diagram and mark the constant pressure lines constant density line and constant enthalpy lines. So, these are the works which are for the basis of the analysis. Because every time you are going to solve analyse the problems you have to see the T-s diagram. So, first let us go to see that how we can read from the T-s diagram.

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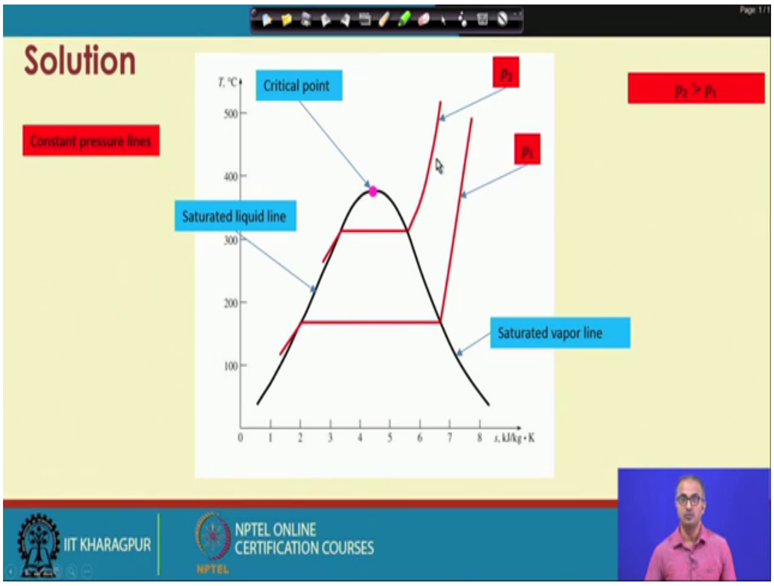

So, here I show that how this T-s diagram is developed. First we draw this T axis and the s axis that is the temperature and the entropy. And you will find these are given in the literature you can find this was a given in some hand books or and you can may be found in the reference book I have specified at the end of the lecture or any other standard thermodynamic books. So, here we are seeing how they look like so with this temperature axis and the entropy axis. And there can be various units of these temperature and the entropy. And first we will find there will be a kind of dome, these dome represents the demarcation between the single phase and two phase regions.

On the left hand side of this particular thing is the sub cooled liquid in between we have the mixture of the vapour and liquid and on the right hand side will be a superheated vapour. And this particular line is the saturated liquid line and this line is the saturated vapour line. So, this is how we represent this particular system on the T-s diagram. Now this particular point is the critical point this critical point means, above which we do not have a demarcation between the liquid and the vapour ok. And we and also we cannot liquefy a gas if we are above the critical point by loading the temperature or increasing the pressure. So, we have v below the critical point to make sure that we can make the phase changes. Now here we find that we shall be having some lines which will be representing constant pressure and these are typical lines you will find on this T-s diagram which will be the constant pressure lines. So, you will find several such lines will be there on the T-s diagram. And how they differ? These pressures will be different.

And we find this is a isobaric line with a pressure of P 1 isobaric line pressure P 2. And how do a pressure are related we find this pressure is more than this P 2 is more than P 1; that means, if we go from the right to left we shall be going to a more and more pressure region and then we shall be having constant density lines.

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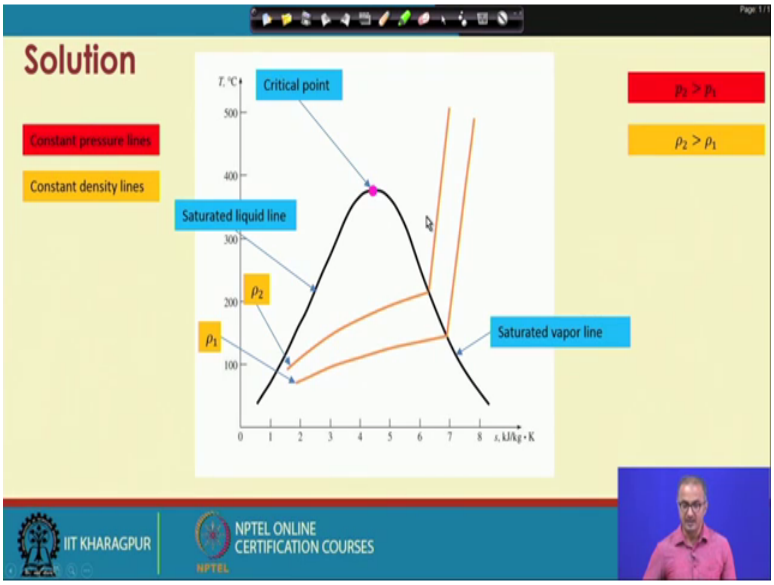

And how they look their looking is similar to the constant pressure lines, only thing is that there is a this kind of deflections are coming in this. And we find there will be several of this constant density lines. And we will find this will be having different densities and these densities are related as the density as we move from right to left the density will be increasing. And next we shall be having the constant enthalpy lines or the isenthalpic lines.

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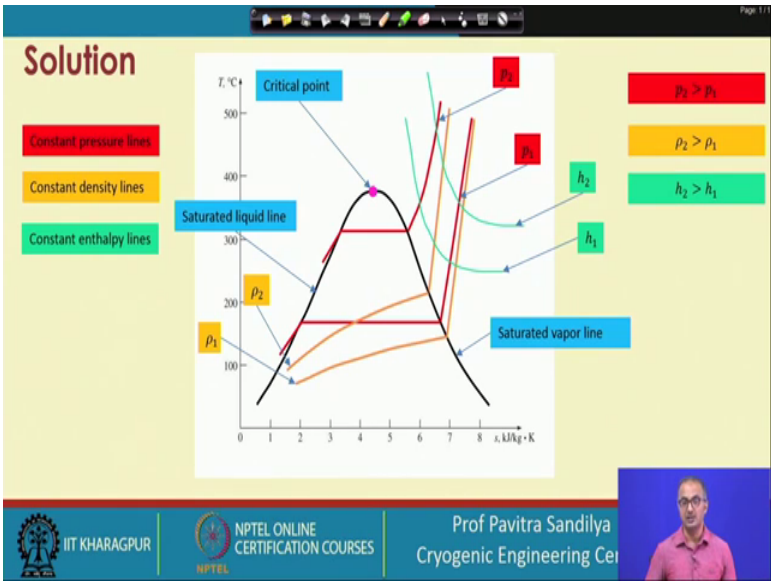

And in this we will find we had such kind of lines will be there on the system. And these each of these lines we will have the two different enthalpies. And this is enthalpy 1, enthalpy 2 and we will find that enthalpy 2 is more than enthalpy 1. That means if we move vertically down we will find the enthalpy is decreasing.

So, in case of pressure and the density the depth the value decreases as we move from right to left where as in case of the enthalpy the value decreases if I move from top to bottom. So, this is how we find these things are arranged in a typical T-s diagram. So, putting everything together will find there are several lines will be there in the T-s diagram. And when we go for the solution of problems we will find the actual ones.

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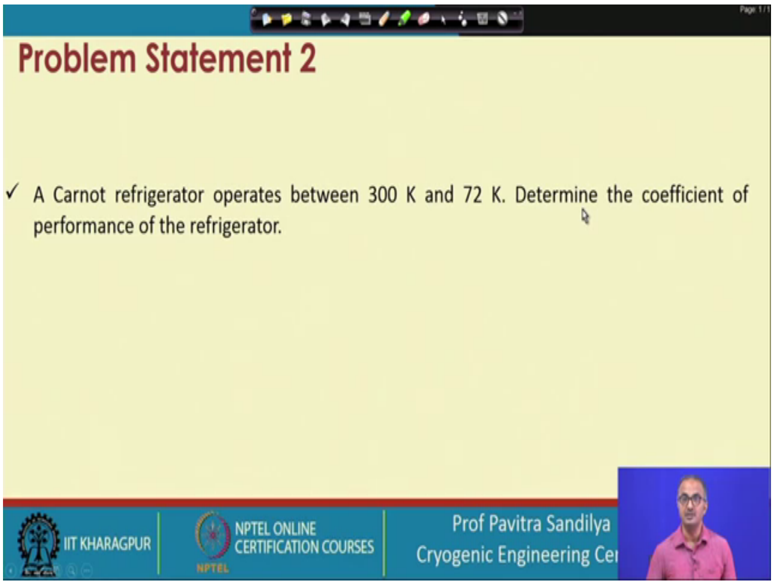

Now let us come to this another problem; in this problem we are given a Carnot refrigerator which is operating between 300 Kelvin and 72 Kelvin and we have been asked to determine the coefficient of performance of the refrigerator.

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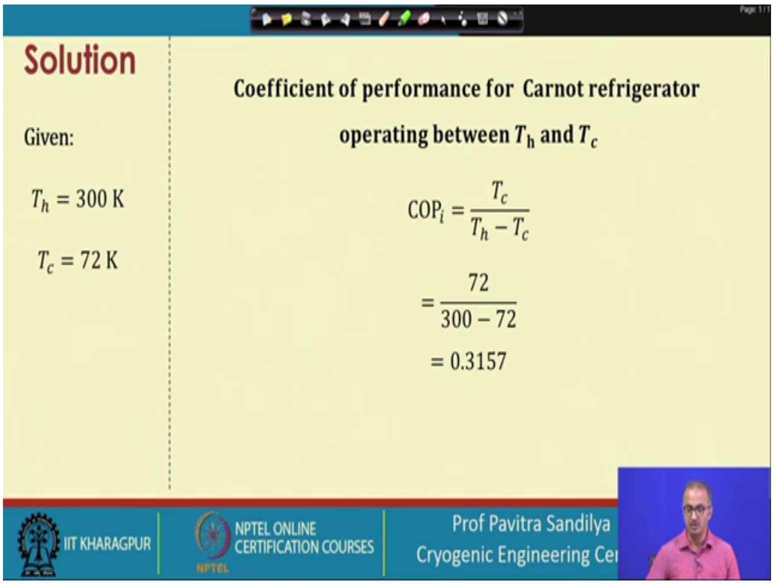

So, in this first we write whatever information is given to us and we put the proper symbol to them. This T h is equal to 300K that is the hot temperature and the cold temperature. And for this we are using this particular formula to find out the COP and this is in this just we plug in the values of the various temperatures so that we get the COP as this value. So, this represents where by knowing the high temperature and low temperature we can find out the COP of a Carnot refrigerator.

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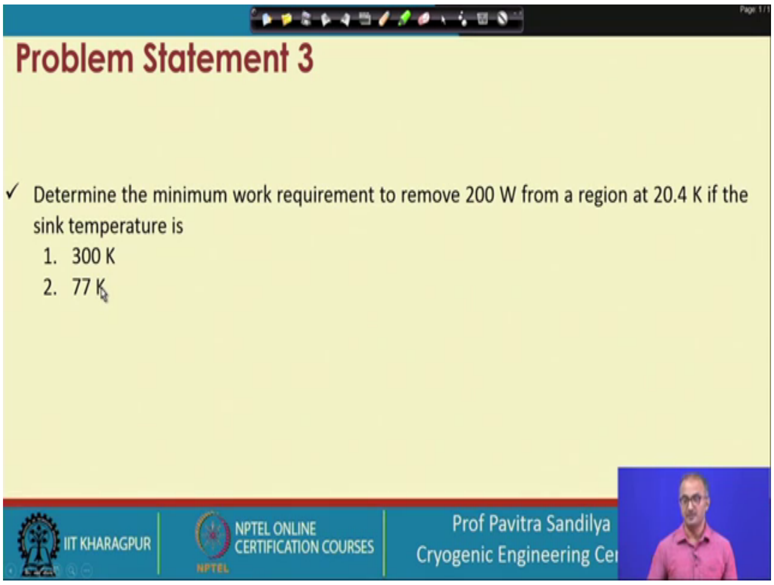

And now next we come to another problem; in this we have to determine the work required where to remove this amount. This amount 200 Watt of the power from a region, from this 200 20.4 K and we are given two different temperatures. So, if you want to remove the work to absorb because we are trying to cool it down from here to take out; we have to do some work of the system ok. So, once is this sink temperatures in if it is 300 K, this is 77 K. So, 300 K you can imagine as if we are throwing the work to the ambient and this is some other liquid at room temperature. So, we will find that depending on these two sink temperatures our work requirement will also change.

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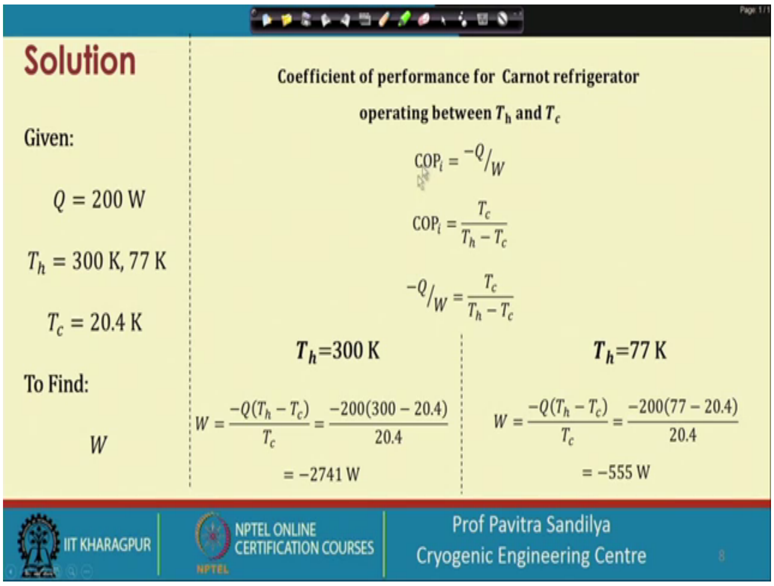

So, we just put the all input information here. So, we have to work with once with 300 K and then with 77 K and this lower temperature available. And this is the work requirement so what have to do that we write the COP value for the ideal system. And this is how we write the system and we find that if we plug in the values of these various temperatures, we find this is the work requirement.

So, we go this is the work requirement if you are going for 300K. And if you are going for 77K we find this is the work requirement. So, you can see easily that more the temperature sink the more is the work requirement for a given Q ok. And for a given Q and the for a given T c when T h is changing. So, we are going with the basic definition of the COP and to get the work requirement.

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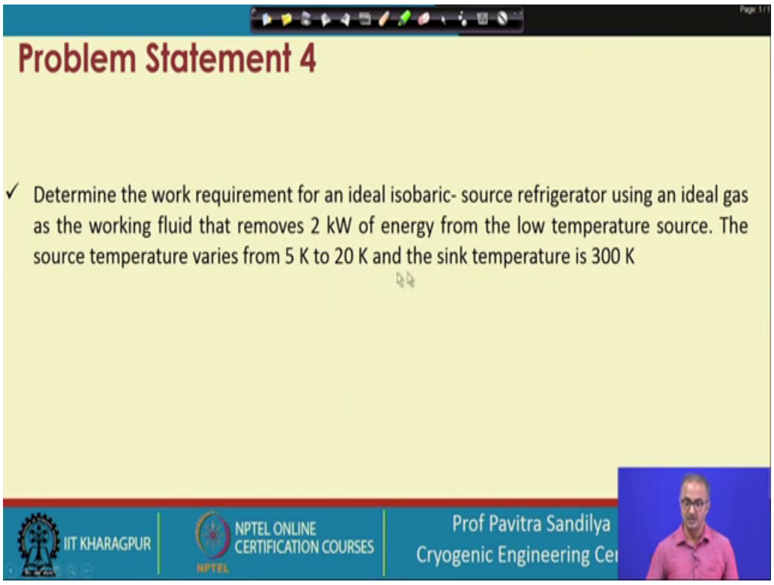

Now, going to the next problem, so here we are asked to find out the work again required for an ideal isobaric source and we are going to assign isothermal source. The isobaric source using the ideal gas as the working fluid that removes 2 kilowatt of energy from the low temperature source and the temperature varies from 5K to 20K at the lower range and the sink temperature is constant at 300 Kelvin.

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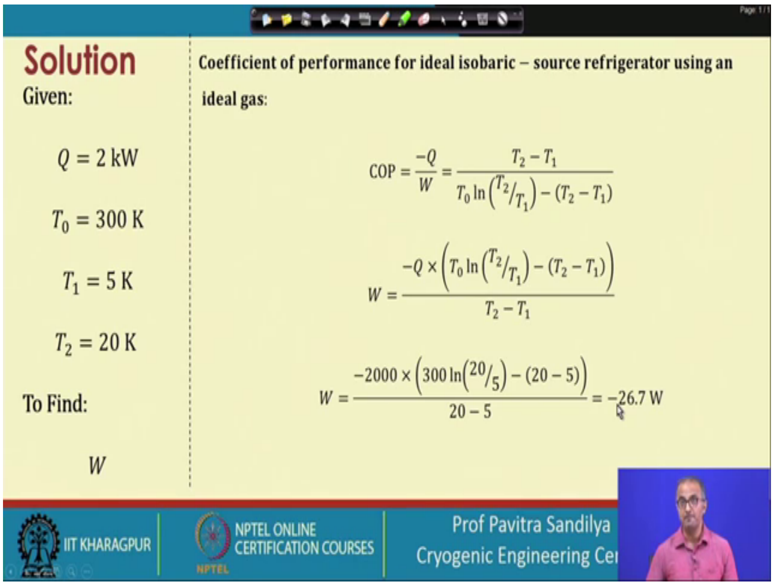

So, we again we put all the data given to us and you have to find out the work. So, what we do that as we have learnt earlier this is the COP equation, for the isobaric refrigerator.

And here again this is the amount of heat that is to be removed that is a work done. And here we found for the ideal gas this is the expression we saw in our lecture.

And we the plug in the values these things and we find that here we have the work done for the given value of the Q and we plug in all the values here we get the work done. So, here the sink temperature and these are temperature within which the source temperature is varying. So, we find this is the work done and negative sign shows that we are work doing work on the system; so this a negative sign.

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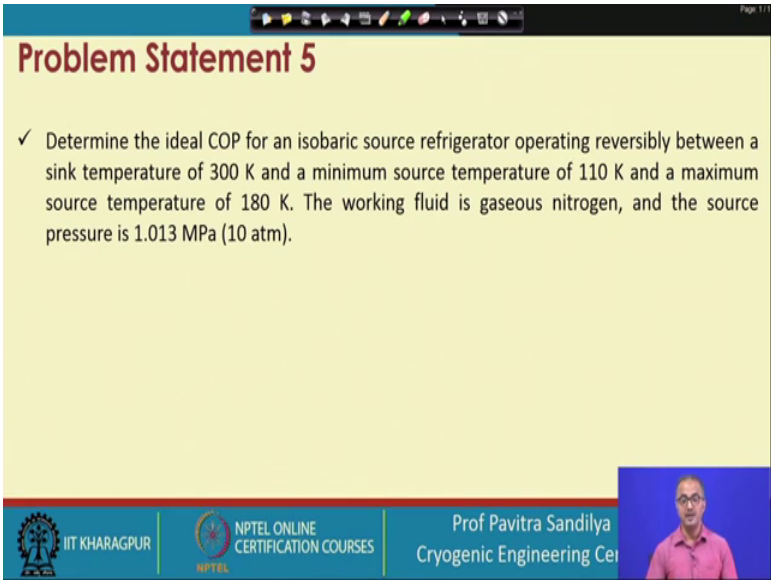

Next problem we have to find the ideal COP that is the quotient performance for again for isobaric source refrigerator and which is operating reversibly between a sink temperature of 200- 300K and the minimum source temperature of 110K and maximum is 180K. And in this case the working fluid is the gaseous nitrogen whereas the pressure is the about 10 atmosphere.

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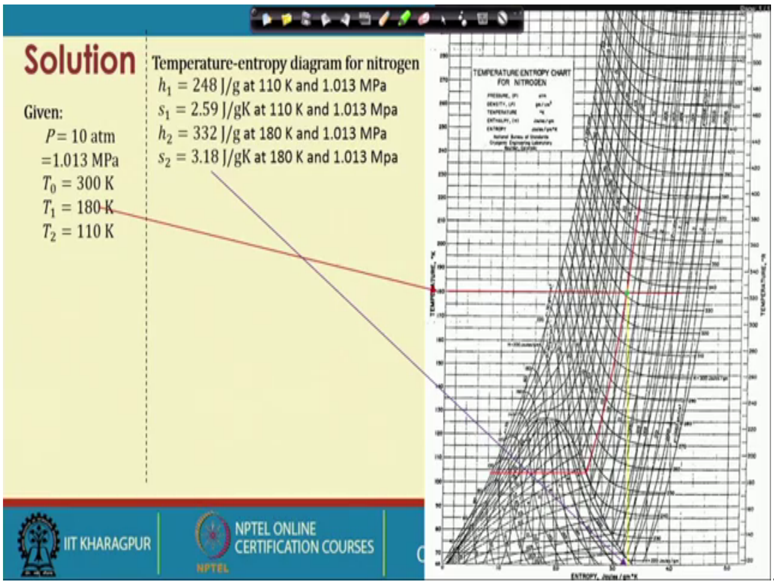

So, with this information we have to find out that from the temperature entropy diagram and please understand we here we are not assuming any ideality. So, that is why we are not going to use the expression we have just used for the previous problem which was in terms of only the temperatures.

So, here in this case we have to use the actual T-s diagram for the working fluid. And we are choosing in this case for the nitrogen so, whenever you are following this problem, but keep in mind that whether you are going to assume ideal gas or not.

And depending on the condition given to you should be very careful in selecting that thing ideal or not. And in this particular problem the pressure is high the temperature is low so both these things are indicating that it will be wrong to assume an ideal gas ok.

So, that is why we have to go for the actual T-s behaviour and it is very simple you see that only thing is that we have to locate from this thing there are many isobaric lines here. So, we have to locate properly this we have to see that it is 10 here. So, we are locating this particular isobaric line at 10 atmosphere and whatever earlier other things are done we are now we shall just locating the various temperature.

So, the T 2 is 110 K so we are locating this value and we take a horizontal line over here and this is the point of intersection of the isobaric line and the isothermal line and at this point we have to read out whatever other things we need whether it is density whether it is enthalpy or the entropy all these things we have to read out at this particular point.

And to know these values we have to also do some kind of interpolation between the two values. So, we have to also know that interpolation techniques to get the values at this point of the various other thermodynamic properties. So, from this thing we are finding the h 1 to be above these value ok. And then we are taking the other that is h 1, s 1 are here which will be needed to find out the work done.

And then we take another temperature T 1 again we are locating the isothermal thing and we are finding the intersection at this point with this 10 atmosphere isobaric line. And again at this point we are reading the value of the s from this axis where as enthalpy is read from these in isenthalpic lines we will find that this particular point is not exactly falling on this isenthalpic line. So, what we need to do we have to find the interpolate the enthalpy at this point between these two enthalpies and then we are going for these values for enthalpy at 0.2.

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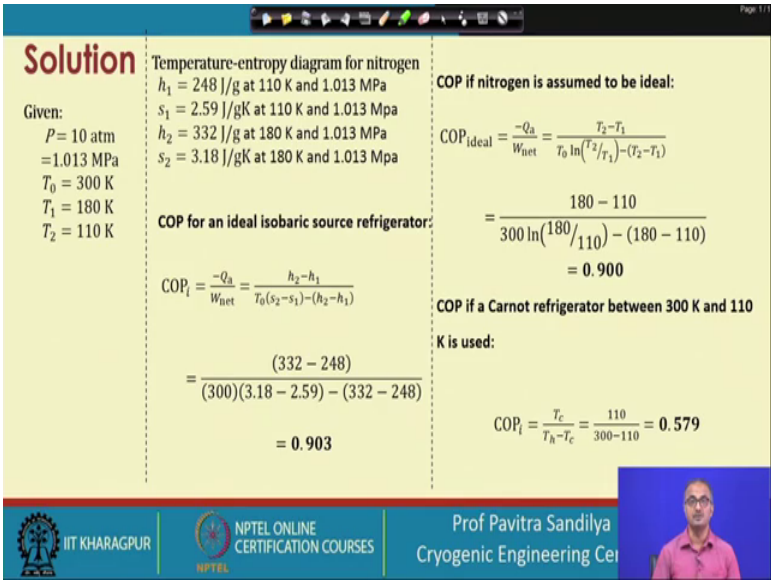

Then what we do that we are finding this COP and this is the expression given for the COP for the actual gas that the real gas and again for the ideal similar thing. And we are just plugging the values of all these enthalpies and entropies which we have found out from the T-s diagram and we find that this is the value of the ideal COP. And if suppose somebody may assumes that what would be the COP if somebody assumes nitrogen to be ideal at this conditions that is that I was telling that be careful in choosing the or assuming the ideality. So, let us see if somebody does it what happens now if we again use this expression and we plug in the values only the temperatures and what we find we get a value of 0.9.

So, in this case we find that there is a slight difference between the two COP's. So, this shows that depending on the condition the whether this application of the ideal or ideal real thing will be working out or not. So, if the COP of a Carnot is found out then we find out this is the Carnot COP ok.

So, we are finding that the Carnot COP between this 300K and 100K that is if we are assuming an isothermal source at 110K ok. So, we are finding that certainly there is a big difference between the values of the COP of the ideal COP or the Carnot COP depending on whether we have an isothermal source or a variable temperature isobaric source

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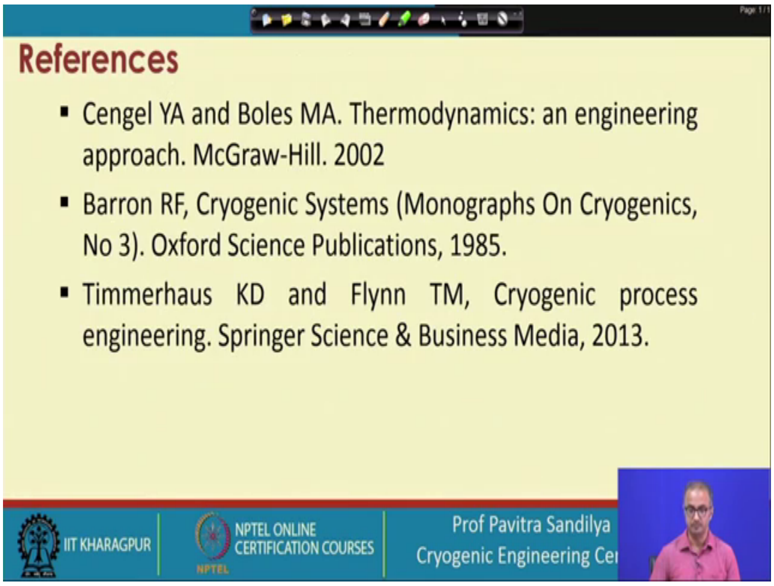

And these are the various books which you can refer to for further details and explanation of this theories.

Thank you.