INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-09
P-h Charts

with
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Hello I welcome you all in this course on refrigeration in air conditioning today we will discuss the PS charts before we discuss the P-h charts P-h are the P-h stands for pressure and enthalpy the refrigerant property stable then.

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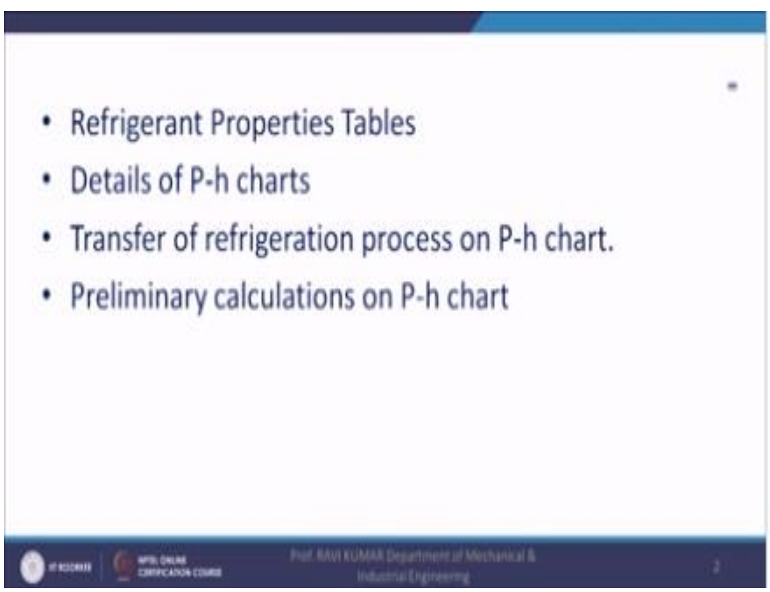

Transfer of reflection process on P-h chart right now we have done reflection processes on temperature entropy diagram we will transfer those processes on P-h charts and some trim Larry calculations like steam tables refrigerant properties stables are also available in market and they are published by different publishers and in these tables you will get thermo physical properties of all refrigerants including the psychometric charge which will be required for air conditioning purpose.

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Now this is one of the sample of thermo physical properties stable of refrigerant r134a i have taken some salient temperatures.

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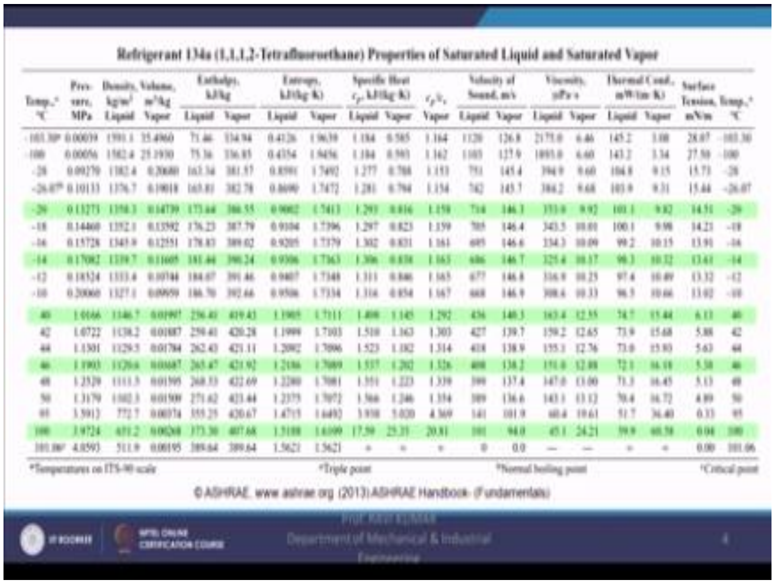

Here in this stable first column is for temperature and they have taken temperature this is chart we have taken from extra handbook of fundamentals 2013 if you do not have access to extra handbook you can purchase any of the chart available in the market and it will be serving the same purpose now here in extra handbook they have taken temperature from - 10 3.30˚C that is triple point temperature of r134a so this chart is for a refrigerant r134a this refrigerant is.

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Used in many of the refrigeration and air conditioning applications now in this chart the first column is for temperature and the triple point temperature of refrigerant r134a is 103.3 temperatures are taken are based on the international temperature scale ITS 90s a is for a triple point of no triple point what is triple point now triple point is a temperature of any substance we are solid liquid vapor phase they coexist if you want to depict this triple point on venture pressure and temperature diagram then this is fusion line this is vaporization line and so this is phases solid liquid and vapor.

So if you keep on reducing the pressure the situation will come that also solid liquid and vapor phase they will coexist at one point this is a single point for water it is for water it is 0.01˚C and pressure at this triple point is 6.611kp similarly because all the most of the fluids they have triple point so here also for r134a the triple point is at – 103.3˚C now other temperature is critical point now after this sorry before critical point there is the normal boiling point so normal boiling point of r134a is – 26.07˚C normal boiling point of any fluid is the boiling point at one atmospheric pressure as you can see in this table at point 10133 that is 0.1013mega Pascal that is 101 33 kilo Pascal.

The boiling point of r134a is – 26.07˚C now critical point critical temperature of this r134a is 101.06˚C now using the turboprop thermo physical properties of r134a from this table we can deal with the problems of refrigeration now the second column stands for saturation pressure the third column is for density of the liquid fourth is density of the vapor at this temperature enthalpy of liquid and enthalpy of vapor at a particular temperature then entropy of liquid and entropy of vapor at particular temperature is specific heats of liquid and vapor at particular temperature.

Ratio of specific heats now in addition to this velocity of sound viscosity thermal conductivity surface tension are also given in this stable though we do not require these properties for the purpose of refrigeration in air-conditioning in most of the cases so our properties of our concern are up to specific heats of liquid and vapor these two left-hand side of these like pressure density volume enthalpy entropy and specific heat these properties are required for calculating for regarding the calculations of refrigeration and air-conditioning I will take one example.

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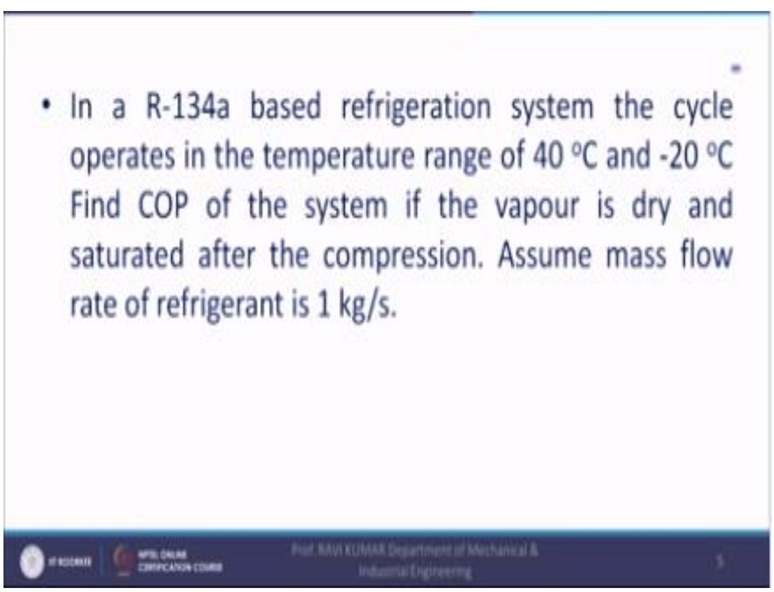

A system is working between.

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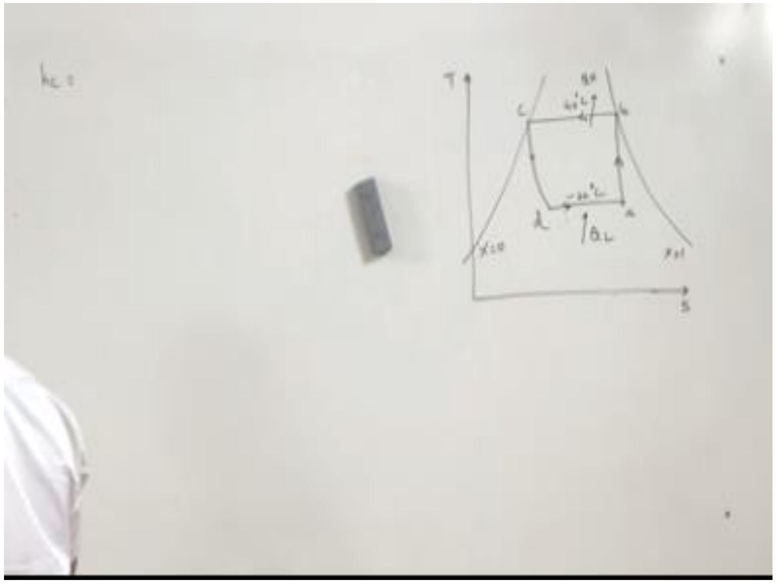

40˚C and - 20˚C a system is working between 40˚C and -20˚C 40˚C is the temperature of condenser and - 20˚C is the temperature of evaporator and the vapour is dry and saturated after the compression it means at the entry of the compressor vapour is such has quality less than 1 and this is - 20˚C this is temperature entropy quality 0 quality 1now we will give the nature also AB C D so process A 2 B is a constant entropy process B to C is translation of vapour C to D is constant enthalpy expansion and D to a is evaporation of evaporation process or it takes the refrigerant takes heat from the surroundings.

And here the heat is reacted now the properties of refrigerant at these salient points can be directly taken from the table itself so the enthalpy at C enthalpy at C and enthalpy at C is the liquid enthalpy.

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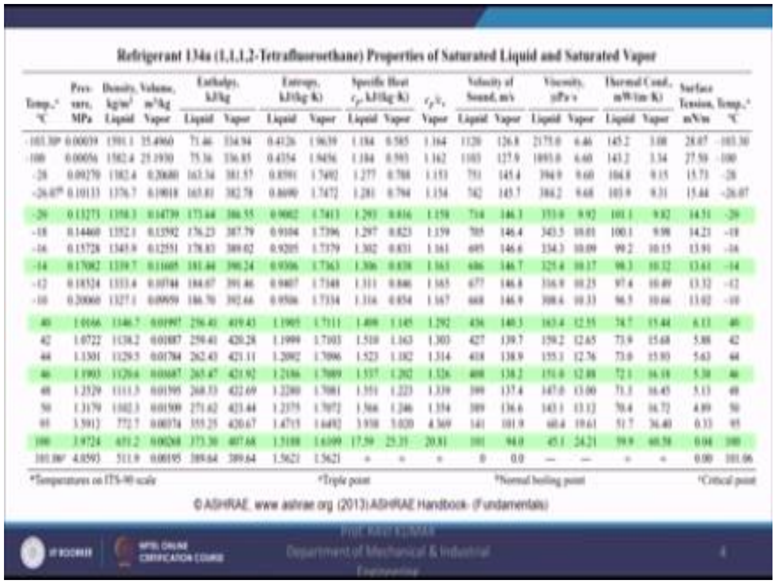

Enthalpy at C is liquid enthalpy at 40˚C so here the 40˚C the liquid enthalpy 256.41 so 256 by 41 is.

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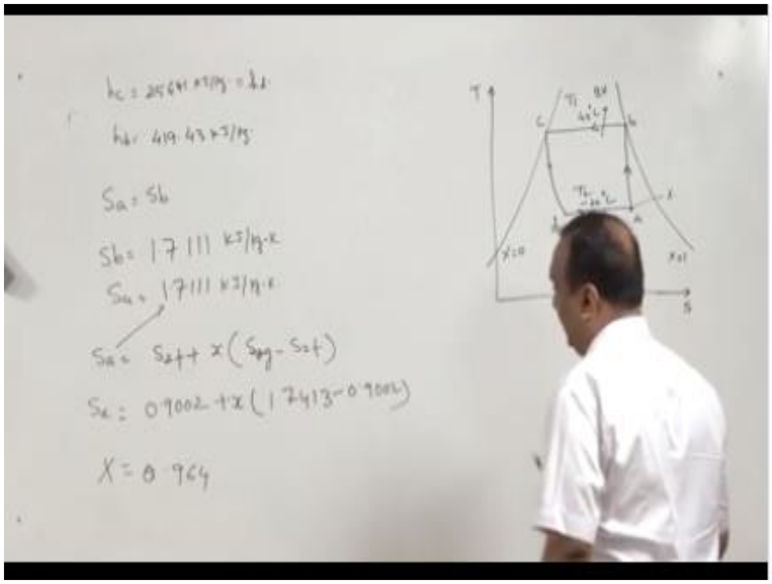

kilo joules per kg is the liquid enthalpy at Point C and that is also enthalpy at point D because this is a constant enthalpy process enthalpy at P is equal to you can see from here at 40˚C it is 419.43 kilo joules per kg that is enthalpy at B but we do not know enthalpy at A this has to be found out using these properties as we know then entropy at a is equal to entropy at B because this is a constant entropy process entropy at B is known to use entropy at B that is 40˚C entropy of vapor at 40˚C so entropy at A is equal to entropy at B now entropy at B is a entropy of saturated liquid refrigerant at 40˚C.

And entropy at B is 1.711 kilo joules per kg Kelvin this can be seen from here itself and now for Sa is not known to essays also then 1.711kilo joules per kg Kelvin we do not know the quality of vapour at state A if you know the quality of vapor at state A we can easily find the enthalpy of vaporization at A in order to find the quality at state A we will use the relation Sa is equal to S2f+xs2 g - s to f that is at - 20˚C entropy of saturated liquid change in entropy during vaporization from saturated liquid to saturated vapour multiplied by the quality of vapour.

And that is going to be equal to 0.9002 Sf2 we can always comfortably take from here it is - 20˚C entropy of liquid that is 0.90 0 2 + X Sg2 is 1.7413 – 0.9002 so entropy at this point -

entropy at this point and Sa is the value of Sa is with us so we can find the value of x here and the value of x here is 0.964 that is the quality of vapor at state A, now once we have the quality of vapor at state A we can find the enthalpy of vapour at state A.

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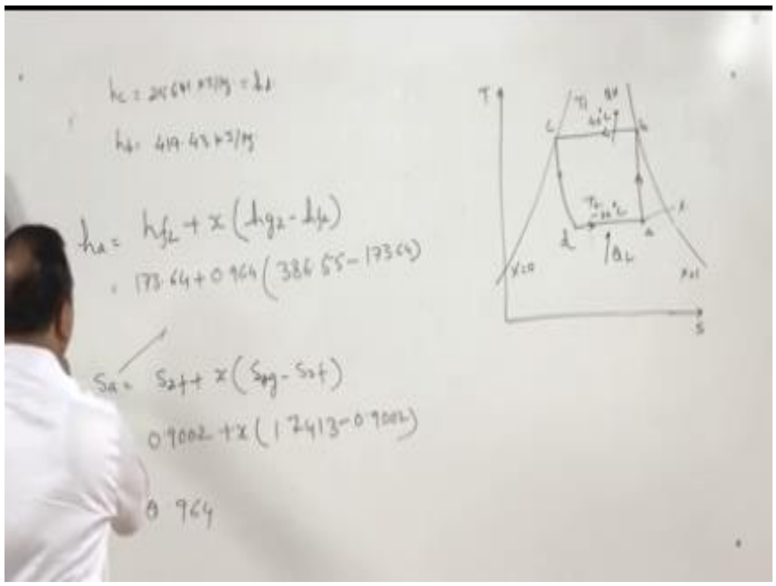

Now in order to find enthalpy at A we can make use of this stable now enthalpy at A is equal to enthalpy of liquid at - 20˚C plus quality of vapour at A multiplied by enthalpy of gas at - 20˚C and enthalpy of liquid at - 20˚C or change in enthalpy for the conversion from saturated liquid to saturated vapor at - 20˚C now here we can put the values Hf2 is 173 0.6 4+ x we can take from here 0.964 multiplied by hg2 that is 386.55 kilo joules per kg and 173 0.64 kilo joules per kg.

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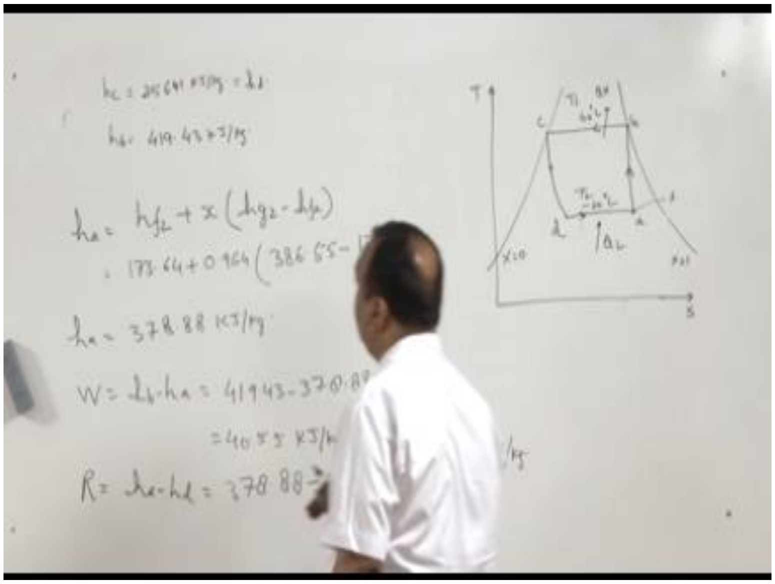

The final expression for ha will be 378.88 kilojoules per kg now we have enthalpy at state one and enthalpy eight is sorry state a and enthalpy at state B now difference of these two enthalpies will give the work of compression so work of compression is hb by this ha that is 419.43 – 378.88 so difference of these two will give 40.55 kilo joules per kg now refrigerating effect R can be calculated as ha - hd itself is equal to hc so these properties are available with us so we will be getting here 378.88 – hc and sc is 256.41 and this will give the refrigerating effect equivalent 2122.47 kilo joules per kg.

Since the mass flow-rate mass flow rate of refrigerant in the system is 1 kg per second so if you multiply this 1/1kg per second.

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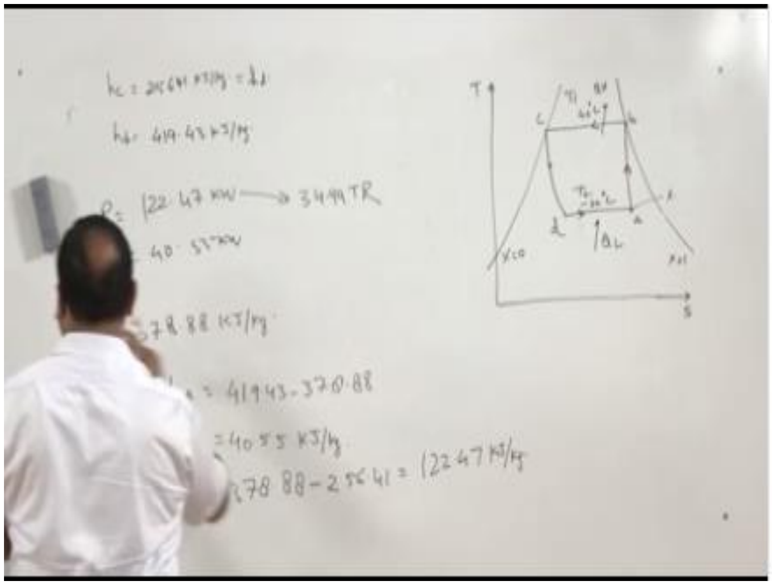

Will be getting refrigerating effect as 122.47 kilowatt and same manner the work consumed by the compressor will also be 40.55kw now if you want to convert this into tons of refrigeration then it is going to be 34.99 tons of refrigeration that is.

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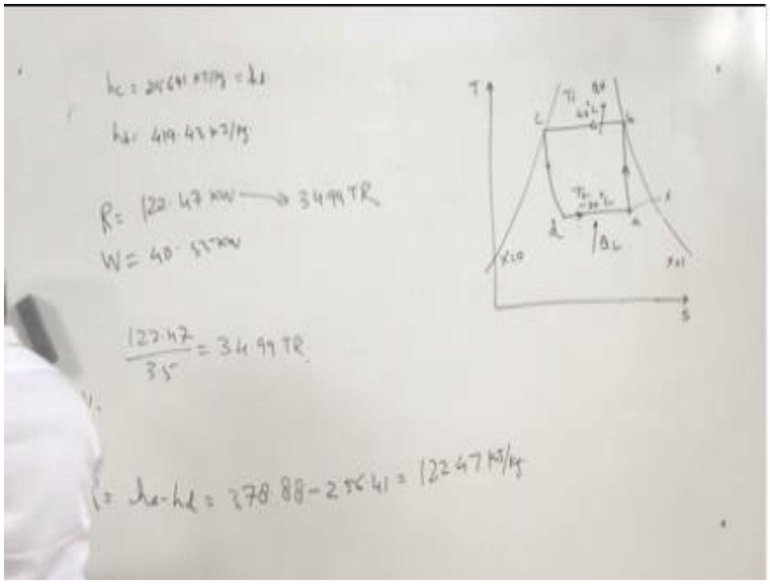

If we divide 122.47/3.5 will give us tons of refrigeration and that is going to be equal to 3.99 tons of refrigeration now if I want to transfer because in this process as a practicing engineer I will have to make elaborate calculations so in order to facilitate the practicing ingenious P-h charts.

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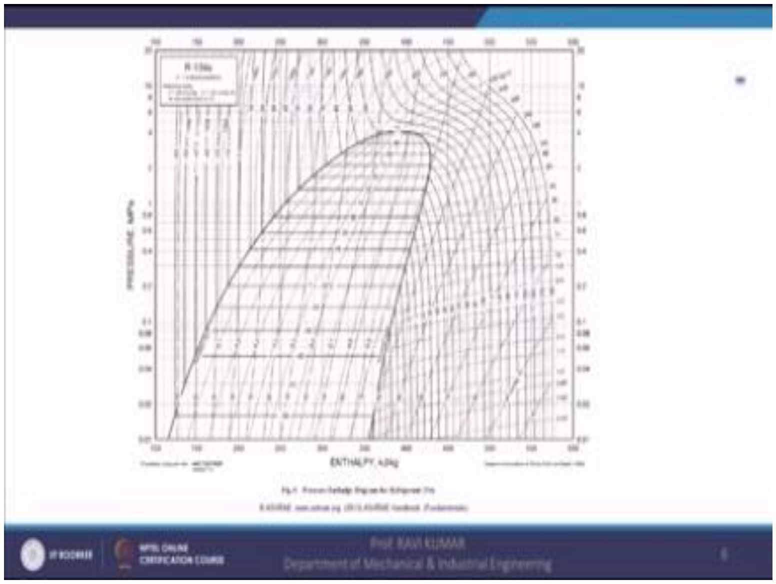

Have been evolved now in these P-h charts this is the P-h charts of or for R-134a and every refrigerant has got its you know unique P-h chart this child is prepared is we have already taken from ASHRAE, ASHRAE handbook for fundamentals 2013 but if you purchase the this thermo physical properties booklet for refrigerants.

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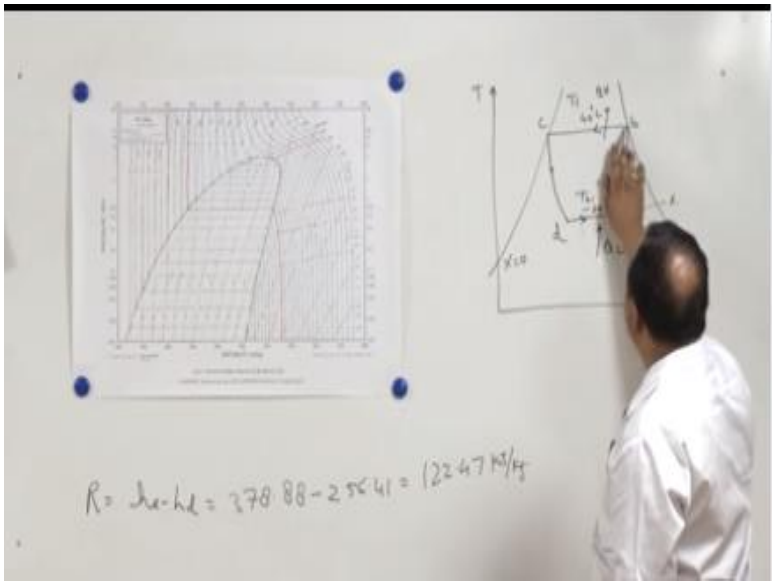

In that booklet also you will get these charts for most of the refrigerants which are being used in the market now if I want to transfer these processes into this P-h chart now the beauty of the P-h chart is you have to do minimum of the calculations because it is between pressure and enthalpy and enthalpies instead of taking from the table and then doing the calculations especially for the wet vapor or superheated vapor here directly you can take the values of enthalpy from the chart now this chart consists of it is between pressure and enthalpy pressure is on a log scale enthalpy is on a linear scale the thick line.

You are seeing here is a saturation line below this line on this side of this line that is a saturated liquid on this side of this line is saturated vapor this is critical point beyond critical point the vapor phase does not exist now this chart is prepared for it is on the y-axis the pressure is given in mega Pascal is starting from 0.01mega Pascal to 20 mega Pascal on the x-axis enthalpy is given from C 100kilojoules per kg to 600 kilo joules per kg properties are computed with the help of NST ref pro version 7.0 now in this chart there are constant temperature lines if you look at the constant temperature lines.

They start let us say follow the constant temperature line of 30˚C so it starts from here then it goes in a horizontal direction because there is a phase change from liquid to vapor and then there is a curve following this is the constant temperature line for 30˚C temperature it also has constant density lines now constant density lines you can see here the vapour constant as they are dotted lines they are shown here at different values say starting from 0.4 kg pm^3 it goes up to 600 kg per meter cube they are all constant density lines horizontal lines are of course constant pressure lines.

Vertical lines are constant enthalpy lines it has constant quality lines also they are shown here constant quality lines this is 0.1 0.20.3 0.4 and so on up to 1 now if I want to transfer this process of temperature entropy diagram to this P-h diagram in that case process we will start with the bc process bc 40˚C so at 40˚C.

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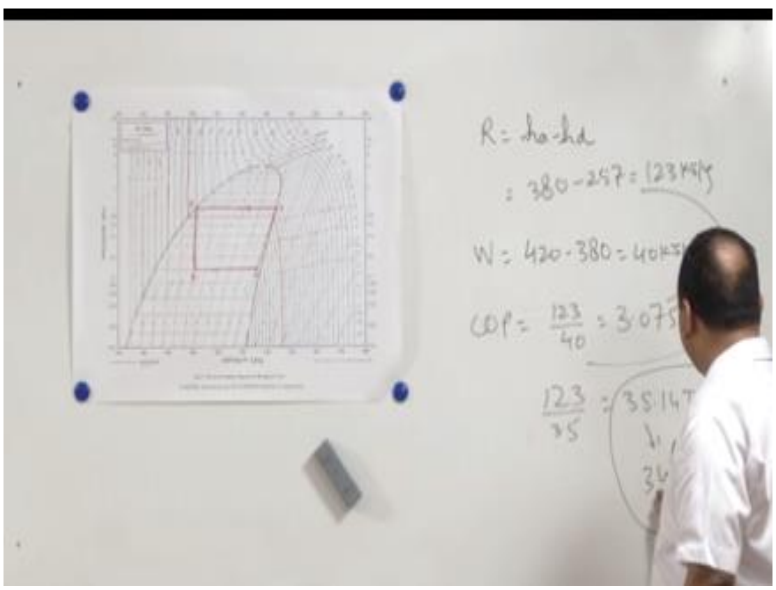

Temperature this is process by taking condensation of vapour so heat transfer during condensation of vapour you can directly read from here enthalpy 8b minus enthalpy at C so you do not have to make elaborate calculations all the values are available here now CD is a constant enthalpy process so this is a constant temperature line minus 20 degree centigrade line so if we draw a vertical line from C vertical line of C this will give the state D both the states are having the same order of enthalpy from D to a is evaporation at a the qualities 0.96 for so point if we look at the 0.96 for it will come somewhere here.

And at the end of the compression it is saturated and this is a constant as one line I forgot to tell you this chart has constant entropy lines also they are very important these in tulane lines are constant entropy lines so we will follow a line parallel to the constant entropy line and it will come somewhere here so this is state a now from this p-h diagram suppose I want to kill the calculation the same type of calculations now from this pH diagram we can comfortably take ha ha enthalpy at a we can directly read from here okay it will be approximately 385 or 390.

Sorry 390 whatever the value we are getting from here the same value we will be getting from here so I looking at this p-h diagram if I want to take enthalpy at state one and state two then hb is approximately 420 kilo joules per kg for 20 kilo joules per kg it is H B and H a is if I want to take ha then ha also I can take from here and it will come around 380 kilo joules per kg.

Now HC is equal to HD now SC is here if I simply extrapolate this line here it will come around 257 kilo joules per kg now with the help of these three values I can comfortably find for CoP of the system R is equal to ha – hd that is 380- 257 and that is equal to 123 kilojoules per kg work is 420 - 380 is equal to 40 kilo joules per kg if you want to have Co P in this case so Co P is going to be 123 by 40 it is going to be three point zero seven five three point three point zero seven five and refrigerating effect this 123 divided by three point five will give tonnage of the order of thirty five point one four tonnes.

Of reference so you can find this slight deviation in the values CoP in the previous case here it is three zeros three point zero seven five when we use the T Phi diagram it was three point zero two and the nage was approximately thirty four point nine so this calculations from p-h diagram may be may not be as accurate as in the case of when we take thermo physical properties of refrigerant but in refrigeration In air conditioning when we design the system the high order of basic accuracy is not required.

For example when we are very accurate the CU p is three point zero two from this we are getting C UPS three point zero seven five or from pH diagram we are getting today – thirty five point one four tonnes of refrigeration in case of temperature entropy diagram we use thorough physical properties the rating was thirty four point nine and tons of refrigeration if you compare these two values if I have to purchase a refrigerating platter I will go for a 35-ton plant because thirty five point one four or thirty five four thirty four point.

One nine there is not much difference if I go to the market I will get a plant of 35transliteration capacity or 40 tons refrigeration capacity so definitely I like to go for 35 ton refrigeration capacity plant so in pH diagram it is very convenient to find the performance of the system but these this process may not be as accurate as in the case of temperature entropy diagram but that much of accuracy is not required in case of refrigeration related applications now I think I have covered all the points for today's lecture now in the next lecture we will be covering the actual refrigeration cycle on temperature entropy and pH diagram.

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