MARINE ENGINEERING

By

Prof. Abdus Samad

IIT Madras

Lecture61

HVAC-Numerical problems

good morning in the last lecture we have seen the psychrometric process when you want to add or remove moisture and you want to change your temperature uh how to to make your room comfortable now when you are making room comfortable means only reducing temperature will not help because it will be increasing your relative humidity again if you are increasing relative humidity that may also not will will not help in certain cases humidity is already higher in your reducing temperature that will be feeling giving your uncomfortable situation and living rooms. If you are having low humidity and you are increasing temperature, again humidity will be further down or reducing temperature, again increasing humidity will be there. So, how to represent the situation in psychrometric chart, I have explained already, but again you see for recapitulation purpose.

Okay, psychrometric chart will have dry bulb temperature or dB T and wet bulb temperature. So, dry bulb temperature will have vertical lines like this and wet bulb temperature will have slanted lines and I will have enthalpy values also here. okay in enthalpy case it is the lines will be parallel to wet bulb temperature okay now where is relative humidity relative humidity lines will be like this okay curved line so relative humidity it will be so it will be like closer nearby left end and wider right end okay so relative humidity this top line is 100 percent then maybe 90 percent, 80 percent.

So, gradually the relative humidity will be when you are moving towards right direction as dbt increasing your relative humidity will be reducing. Now, the right side axis, this one, this humidity ratio okay how how much water vapor or how much amount of water is there in air so that will be telling this one so gram per kg or gram per gram of air or kg per kg of air okay so just you can decide the unit and you can put the data So, horizontal lines, it will say, if I draw a horizontal line, it is like this, from humidity ratio, the humidity ratio if I go along the horizontal line, it will tell that the same humidity ratio we are maintaining, we are not adding any water, you are not removing any water, but your temperature is changing, you see this dbt is changing when you are moving from left to right. And if you are moving up to down in humidity ratio scale, so actually you will be adding some moisture or you will be removing some moisture.

Now, in actual situation, let us say certain weather, let us say Chennai weather. So, Chennai weather presently this is almost summer. So, temperature will be very high, let us say 35 degree centigrade. So, dBT. dbt so this google weather if you search the temperature will be giving your dbt dry bulb temperature and relative humidity it will give if you search weather in chennai so it will give dry bulb temperature and relative humidity so driver temperature let's say this is 35 degree okay and your relative humidity is here let's say 70 percent and previously i told that 35d is very much uncomfortable temperature very high temperature so you have to reduce the temperature so nearby 25

and relative humidity 70 percent also higher so we should make around 60 percent so how to reduce the temperature first if we are using air conditioner then you go along this horizontal line okay because humidity ratio is here emitter ratio means w w is here and right side axis okay i'll write w vertically better okay then along horizontal axis you go to 100 percent relative humidity line. So, 100 percent relative humidity line means air cannot take more moisture. So, then again you reduce temperature, you reduce temperature further. So, when you are reducing temperature further, what will happen, the air will be releasing some amount of moisture.

So, if you see backside of air conditioner, it is pretty air conditioner, then water droplet will be there, lots of water pipe will be there and water falling down. that means water is getting condensed relative humidity 100 percent so you cannot get more than 100 percent humidity so 100 percent humidity and you are reducing temperatures means it is releasing some amount of water then again increase temperature okay so that temperature can be maybe your 60 percent and temperature relative humidity will be 60 percent and temperature will be maybe 25 percent okay but 25 degree centigrade not percent okay this way you can reduce your temperature and humidity but if you want to use desert cooler which is used in the north uh north india especially dry weather situation north india or maybe middle east somewhere so there temperature high humidity low okay humidity low is here temperature is high here d b t w b t so wbt lines are slanted i told already right but dbt or dry bulb temperature will be vertical lines and my relative humidity lines are curved lines. Let us say this is my 30 percent relative humidity and temperature may be 40 degree centigrade.

what will now if you want to use desert cooler like you are adding moisture only you do not have any air conditioner evaporator thing only moisture you are adding so in that case what will happen when you are adding moisture this line will be moving towards saturation line okay towards saturation line. And you can see this horizontal line if I draw A and B, initially point was at A and you reach to point B. So, that means what you did you see right side this is added humidity, added moisture or humidity or water. okay and you see dbt a to b actually temperature reduced okay so 15 to 20 degree temperature reduction is very common in north india actually if we add moisture in the air okay that's why this desert will be working but if you want to add moisture again you want to get little higher temperature also so in that case again from b you can move towards sea maybe again you can add moisture and you can change your location okay normally air can be in india this or india or anywhere in the world the comfort zone will be like this it's comfortable like 20 to 30 degree within that zone there will be one comfort zone okay

so i am shading this one you see left side picture i am making this shaded portion that will be like almost comfortable zone okay so if we move towards left of the comfortable zone that is very cold zone right side very hot zone if you go to upper side upper side means very humid and hot okay and if you are moving towards very lower side that actually dry side dry air will be there lower side when dry air is there screen scratching and other issues will be coming up if a very high amount of moisture is there again there will be some sort of bacterial growth so that will be a problem but if you are moving towards left side it is very cold temperature so in that cold temperature actually you have to use heater to increase temperature when again you are using heater your relative humidity will be down when relative humidity is down you will feel uncomfortable actually then you can use your some moisturizer like evaporate cold steam you can generate in room and you can increase your humidity level in the room so that will make more comfortable staying in room now we'll go towards solving some problems so first problem this is from your gate naval architecture marine engineering naval architecture paper 2022 In a vapor compression refrigeration cycle using R134 refrigerant you are using. So, first you plot TS diagram.

And the enthalpies are 240 kg per kg at the beginning of the compression. So, where compression is happening? So, here somewhere. So, compression is happening here. Then 1.

then you are moving towards 2. So, h1 is given h1 equals 240 kg per kg and 275 kg at the end of compression. So, h2 is given 275 kg per kg, but they are not saying the location of

A whether it will be on saturation line or separated zone or inside the vapor envelope or two phase zone. 2 also not specified. So, you can draw whatever you like.

So, 2 to 3, then 3 to 4 will be throttling process, 4 to 1 again the cycle will be completing, evaporation section. Now, 275 and 96 kg per kg beginning of throttling, that means H3 also given. 96 kg per kg okay now what is h4 h4 equals h3 equals 96 right because in throttling we are not adding or removing any energy in okay now what is the cop the cop first the definition of cop equals refrigeration effect divide by work done by the compressor, work done by the compressor. Now, COP equals refrigerating effect means H1 minus H4.

ah no yes h1 is higher temperature h1 minus h4 and work done by compressor that means h2 minus h1 h2 minus h1 so what are the values h2 2 h1 means 240 minus h4 h4 means 96 h2 275 minus h1 h1 is 240 okay so this is giving 4.11 okay so coefficient of performance is 4.11 so already i told that coefficient of performance and efficiency is not the same efficiency means like compressor efficiency you can find you can find heat transfer other efficiencies but cop actually it is showing it refrigeration effect how much heat is getting transferred because of work of compressor okay so this problem 2 also it is taken from gate paper a simple vapor compression refrigeration cycle with ammonia is working fluid here they are taking ammonia and it is operating 30 degree to minus 10 degree centigrade as shown following okay figure also given so ph figure is given instead of ts diagram does not matter so one to four actually they should draw dotted line Anyway, does not matter. So, it is saying like minus 30 degree.

So, here 30 degree centigrade temperature will be there, here minus 10 degree. Minus 10 degree means evaporated temperature should be there. As you are following, the saturation liquid and vapor enthalpy is at 30 degree and minus 10 degree given the table. So, this table is given. So, temperature, HF, fluid, ammonia, ammonia liquid, ammonia gas.

ammonia gas what is the enthalpy when ammonia is fluid or liquid so what is the value it is given if the cop of the cycle cop is given actually okay cop equals 5.6 the specific enthalpy at the inlet of the condenser so inlet of the condenser means h3 here h3 not given okay now how to solve it cop first write down the formula cop equals i said like refrigeration effect refrigeration effect divide by work done compressor Work done by compressor. So, refrigeration effect means H2 minus H1 divided by work done by compressor means H3 minus H2. Now, put the values.

So, COP value even 5.6, 5.6 equals refrigeration effect. So, H2, H2 value what? From the table actually we have to find H2 value. So, H2 is given 1, 4, 2, 0. H2 is given 1, 4, 2, 0 because we are assuming this is gaseous phase.

After evaporation, heat absorbed, the ammonia heat absorbed, it become vapor. And H4, H4 temperature we know 30 degree and it is liquid stage because after condenser, all heat is removed. So, it is under liquid stage. so h4 the temperature 30 degree and it is liquid gas so it will be 320. 320 okay this is liquid this is gas okay and after condenser it is liquid after evaporation it is gas okay now h1 what is h1

h1 equals h4 because we are not changing any enthalpy right in throttling process so now we put the values h2 is one four two zero h1 is three two zero h3 i don't know h4 one four two zero so finally h3 is becoming one six one six point four okay four three you can say So, this is your calculated value. They are asking the specific enthalpy at the inlet of the condenser. Inlet of the condenser is H3. So, that value we found 1614 kg per kg.

So, we will move to next problem. Yeah, this problem also from gate paper 2012 from mechanical engineering paper actually. A refrigerator operates between 120 kPa and 800 kPa. so pressure is given so t is ts diagram first you draw okay then this is your constant pressure line this is your isentropic process then evaporation process this is throttling process so put number one two three four So, refrigeration offers 120 kPa.

So, this is 120 kPa. So, 3, 2 that line actually this is constant pressure line. So, this is 120 kPa and lower pressure is 800 kPa. So, this one 800 kPa. In an ideal vapor compression cycle with R134A refrigerant, the refrigerant enters saturated vapor.

so saturated vapor that means H1 is saturated vapor, vapor enthalpy. Saturated and leaves condenser saturated liquid, so H3 saturated liquid enthalpy. Mass flow rate also given, m dot given 0.2 kg per second. R134a property table you can get from table, but here in the problem it is given.

So, what is the value of H1? H1 equals Hg at 120 kPa So, Hg means gas, gas at 120 kPa, what is the value? 237, you can see, 237 kJ per kg. Now, H3, H3 value also we can find from the table, H3 800 kPa and it is fluid, so 95.5.

So, it is a 95.5 kg per kg. Now, heat extracted Q equals heat extracted equals H1 minus H4, but mass also have to multiply m dot. Now, h1, now again you see h3 equals actually h4, h3 equals h4 equals 95.5 kg per kg. So, the values h1 is given 237 minus h4 is given 95.5

m dot already given in the problem 0.2. This value is coming 28.3, 28.3 kg per kg. I will not write here, I will write below. It was 28.3 kg per kg. So, T is 214123.

And now power required by the compressor, so process is 1 to 2 process. So, w equals m dot h2 minus h1 equals now s1 equals s2 we are assuming ideal condition. Not actual condition, this is ideal situation. It is written there. So, S1 equals S2 equals 0.95.

It is given the problem and H equals 276.45. In the table, it is given H2 value. Actually, superheated refrigerant will have this much value, kg per kg. You see the previous table here. This value is taken.

ah now wqs 2 0.2 in 276.45 minus 237 so this is giving 7.89 okay so this is giving the value range within this to 7.9 kilowatt okay so in gate exam or in our online exam if we are taking if you are sitting for nptel exam so then range of values will be given so whatever result you get you have to your result must be within this range if it is going outside the range then actually you are not getting marks okay so you should remember that So, another problem here pressure of drywall temperature and relative humidity of air in room is given 1 bar and 30 degree centigrade 70 percent. So, if I see my psychrometric chart it is like this temperature 70 percent relative humidity temperature 30 degree centigrade 30 degree centigrade and pressure is given 1 bar if the saturation pressure at 30 degree is 4.25 the specific humidity of the room we have to find.

So, for that we have specific humidity formula, humidity formula is there, 0.622 p partial pressure of water vapor, p air minus p water vapor partial pressure. So, P water vapor pressure, so relative humidity into saturation steam pressure, saturation steam pressure. So, this is giving, relative humidity is given 70 percent, so 0.7, so this is given 0.7 into ps saturation pressure saturation pressure is 0.0425 it is given here okay so now you can multiply this one and you get 0.02975 bar because this one you convert into bar actually okay and so Therefore, W equals 0.622 into 0.02971 minus 0.02975.

So, this is giving 0.0191 where P atmospheric is taken 1 bar. This is given. Given the problem 1 bar. You can see. So, answer is this one.

So, this is actually vapor absorption system. In aqua ammonia absorption system, heat supplied generated by condensing steam 0.2 MPa at 90% dryness fraction. Temperature to be maintained refrigeration minus 10 degree and ambient temperature 30 degree. Actual COP is 40%. of the maximum cop the refrigerating effect 20 20 t ton of refrigerant the required flow rate will be you have to find okay now first you draw this vapor absorption system so vapor application system first you will draw this one this is temperature ammonia vapor ammonia vapor so ammonia vapor formate is from a condenser so condenser

So, condenser will have cooling coil T2 because 30 degree centigrade is given and cooling water. So, from there it is coming throttle valve. So, now liquid ammonia you got because after condensation ammonia released heat it becomes liquid. Liquid ammonia to it is going to evaporator. evaporated and it will be absorbing heat minus 10 degrees centigrade ton of refrigerant is given here here the temperature q e it is absorbing and ammonia become vapor okay after ammonia vapor it is absorbing

absorber will be releasing certain amount of heat this is t2 temperature and from here generator okay so generator will be giving lean mixture to absorber and it will be taking mixed rich mixture and will be pushing to generator okay uh now this is temperature qg qg this is tr temperature this is qc temperature qc temperature t2 this is t1 and vapor is going like this arrow direction is correct and reducing valve this is throttle valve uh observer this temperature t2 this temperature tr ammonia cooling water is here okay now q e is given 20 tons q e equals given 20 tr or tons okay the maximum power the maximum cup of absorption of v v vapor absorption refrigeration cycle equals cop max equals t 1 minus t 2 you see the formula t 1 minus g 2 t 2 minus t r into t r divided by t 1 this is the formula okay so t 1 is generator temperature generator temperature t 2 equals condenser condenser and absorber temperature okay so generator temperature is given 120.2 plus 273 equals 393.2 k kelvin 30 degree atmospheric temperature plus 273 equals 303 k okay tr equals evaporated temperature evaporated temperature equals minus 10 plus 273 equals

ah 263 k now cop max equals 393 you see that you put the temperature 0.2 minus 303 303 minus 263 into 263 by 392.2 equals 1.5 so you can see cop will be lower than your vapor compression system so actual cop equals 40 percent of this cop of max cop okay plus 1.5 into 0.4 equals 0.6 okay now cop uh equals q e by q generator q g how much heat you are giving so 20 by q g okay q g equals m dot into q supplied equals m dot x h f g phase change occurring there okay so q g equals 20 into 3.5 divided by 0.6 is becoming 116.667 kilowatt okay therefore m into 0.9 0.9 is satisfaction 22 0 1.9 equals 116.667 so this is giving m 0.05887 kg per second Okay, this is your answer.

This ends the 9th week lecture where I taught you about refrigeration, air conditioning, heating, ventilation and sensible heating and some calculations. Next week we will come with new topic. Thank you very much for today's lecture. See you soon.