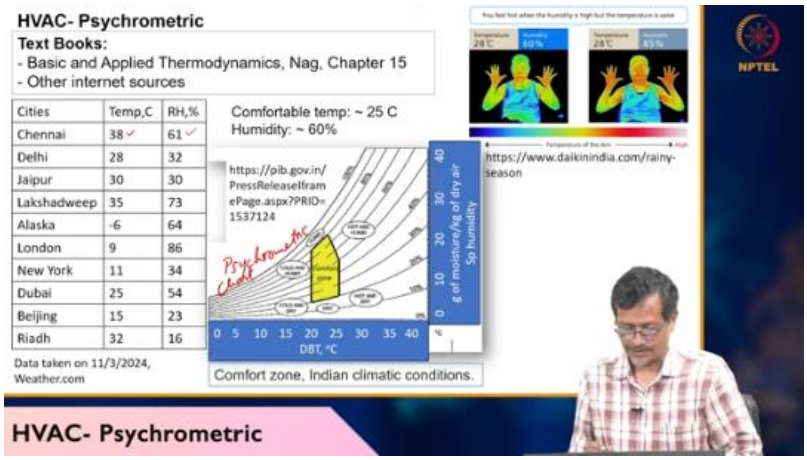
MARINE ENGINEERING

Lecture60

W9L5_HVAC- Psychrometric

Good morning everybody, today I will start HVC's other part that is psychrometrics or psychrometric chart and its effect and why it is required for your marine systems we will try to discuss. So basically the things content has been taken from basic and applied thermodynamics from P.K. Nag book chapter 15 and something from other internal sources for example the left side table it is taken from weather.com. for different cities you can see the temperature humidity temperature chennai 38 humidity 61 sometime relative humidity will go to 70 80 also sometime 90 also so you see the different temperature and different humidity in different cities then which is comfortable so for to find the comfortable uh zone actually you have to go through psychrometric chart okay matrix chart.

this chart says what will be your comfortable zone for human comfortable zone. You can see here this is called the x-axis is called dry bulb temperature. Later we will discuss what is dry bulb. and there will be wet bulb temperature WBT so well wet bulb line will be like this dry bulb line will be like this okay so if you know wet bulb and dry bulb temperature based on that actually you can find our comfortable zone whether present weather is under comfortable situation or not we can find that and same temperature if you have different humidity your comfortable feeling will be different for example in the top left corner we have one picture showing 28 degree centigrade temperature both but one humidity 60 degree another humidity 85 percent okay so 85 percent people will feel more hotter this is more hotter than this one because temperature is higher and sorry temperature same but humidity higher



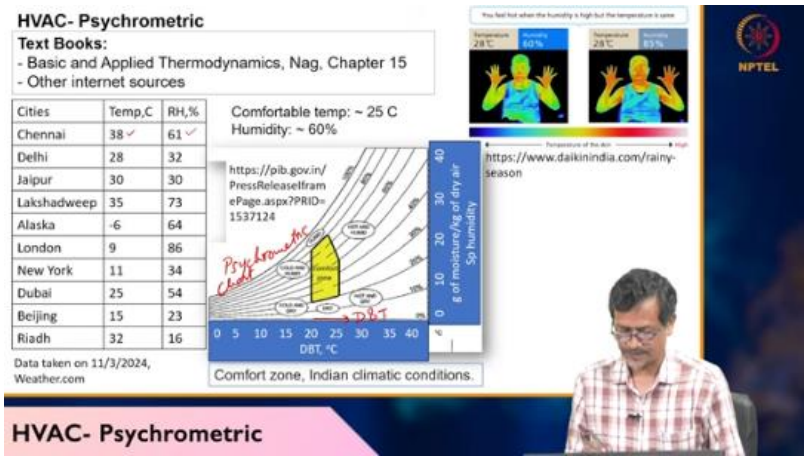
because skin temperature because if any water molecule coming coming out from the body that will not get evaporated this temperature same but humidity higher so in that case you'll feel very much uncomfortable at higher humidity all the temperature is the same and this is from back in india website and normally our in indian condition comfortable temperature will be about 25 degrees centigrade humidity will be about 60 percent And this also varies. For example, someone is in Scotland, they may feel 25 degree is very much higher temperature. But in Chennai, many people say it is lower temperature. they will try, in Chennai people try to keep temperature 25 or more normally.

But in Scotland, they will be trying to put their temperature, AC temperature less than 25 degree normally. And humidity, comfortable normally 60% around, maybe 50-60%. So, let us say for our study purpose assume comfortable temperature 25 degree humidity 60 percent and again this is based on the location geography location if you are from let us say Alaska or from North Pole then your comfortable temperature level will be different than who are there in Chennai or South Africa. before discussing further we will try to discuss dry bulb wet bulb temperature let us say I have one thermometer another thermometer okay so thermometer normally in a if i put outside room then it will be showing atmospheric temperature okay so maybe your mercury level will be showing here let's say this is 30 degree centigrade okay now i have another thermometer which will be having some weak cotton weak maybe

cotton wick and soaked. What will happen? The cotton wick will be evaporating lots of water molecule from around the bulb of this mercury. that will take latent heat, latent heat will be reducing temperature of that area. the dry bulb

temperature will be lower than my wet, this is called dry bulb, dry bulb, this is wet bulb.

Okay, so dry bulb means there is nothing here around this mercury area. temperature will be higher, but if I put some wick and if we add water there, wick is soaked, then the water will take lots of heat, latent heat. That will reduce the temperature of the bulb area and my temperature will be showing maybe 25 degree. for example, I'm giving 30 degree maybe dry bulb temperature, wet bulb will be 25 degree. in that way, if you have two thermometers, actually you can find what will be your relative humidity, what will be present temperature so that you can find.



And to find this one, actually you have to use on psychrometric chart. the psychometric chart will have this is dry bulb temperature temperature or d b t wet blood temperature it will be showing so it will be w b t so d b t here and w b t here so there said driver temperature 30 degrees so 30 degree lines will be vertical in your psychometric chart normally this vertical science lines will be dry bulb temperature may be 20 30 40 50 okay and wet bulb temperature will be like slant lines okay and let's say you get wet bulb temperature here okay so this will be like 25 degree centigrade and it is crossing wet bulb dry bulb temperature certain point so that point will be giving you the relative humidity because relative humidity lines will be like this this will be your relative humidity lines okay so this relative humidity relative because 100% the top line then after that 90% if you see any psychometric chart then top line will be 100% then 90% then 80% 80% then maybe 70% then maybe 60% then maybe 50% okay so this way the amount of water content in the air you can find

If you know dry bulb temperature, if you can design on wet bulb temperature, just put around the thermometer, it will be reducing temperature. So, you know wet bulb temperature, you know dry bulb temperature and the crossing of that line, nearby relative humidity you can check. And if it is nearby like say 60 percent, 50 percent, then you can say okay, it is comfortable temperature and 30 degree maybe Chennai people will say this is okay for me. okay but in many cases you will feel very much hot in 30 degree centigrade or maybe sometimes summer temperature may be 40 degree in Chennai so if it is 40 degree temperature and drywall temperature is showing 25 degree so 40 degree means here and it is touching here so your relative humidity may be very low but in many cases, you have very high humidity plus high temperature.

in that case, actually you have to modify humidity and you have to modify temperature so that room will be comfortable. later we will discuss how to modify the temperature using air conditioner system and dew point. Dew point means when... the 100% relative humidity is there so that point line is called dew point line actually because if you want to add more moisture it will be creating small small water bubbles okay water will be condensing from air so air is having certain amount of water already and if you reduce temperature actually so some water will be separated from water so that is called dew point okay the temperature will be dew point and the line will be 100% relative humidity will be 100% in that condition okay Psychrometric chart I already told this one line is here is a curved line okay this is curved line is for relative humidity 100% RH equals this is 100% okay and this drible temperature dbt in degree or Fahrenheit many chart they will be giving in Fahrenheit

Many charts will be giving centigrade. let us assume we are using centigrade scale, x-axis centigrade scale. And we have this curved line. This is called weight bulb temperature or WBT. Yes! Here we go

This figure I have taken from Wikimedia. But again, I modified this line I redrawn. Yes! Here we go And 100% relative humidity. Then 80%, 90%, 70%, 60%, 50%, 40%.

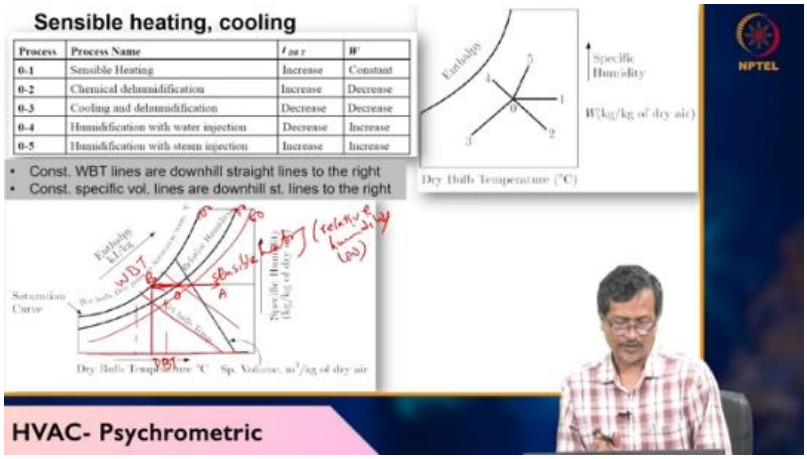
30 percent 20 okay so if you go from top to this side so your relative humidity is going down now your wet bulb temperature wet blood temperature will be like this okay so these are slant lines these are wet blood temperatures okay wbt this

is also again centigrade so normally uh if i say wet bulb temperature 30 degree 30 degree in presently so 30 degrees 100% saturation is there okay if I increase temperature then it will be unsaturated okay let us say certain amount of air you take and you reduce temperature so once you reduce air moisture carrying capability will be lower so in that case at lower temperature air will be saturated with the present amount of water okay now sensible heating and cooling we have seen our wet bulb temperature and dry bulb temperature this is dbt or dry bulb temperature and this is wet bulb temperature or dew point temperature or saturation temperature okay now dry bulb temperature lines will be vertical lines and wet blood temperature will be sand lines okay now if I increase let us say you take certain amount of air increase temperature So, if you increase temperature, actually relative humidity will be going down. Yes! Here we go

How do you know? So, let us say my present condition is here. Now, increase temperature. Yes! Here we go OA, you are increasing temperature.

So, OA means it is sensible heating. So, when you are sensibly heating, so your actually relative humidity will be lower. Yes! Here we go relative humidity because you see these lines 100%, may be 70%, 60% humidity lower. When you are heating you are not adding extra moisture or you are not removing moisture from air.

So, in that case your temperature increasing. So, relative humidity will be lower. But , if you are cooling same air, let us say B line, then what will happen? You are cooling, so temperature going down, relative humidity will be increasing, although you are not adding moisture. But after a certain time, it will be 100% saturated.



Saturated means, so when you are reducing temperature, air will be saturated. Hence air cannot take more water. okay so you take that when you are reducing temperature air will be saturated you although you are not adding water okay ah so you take certain amount of water sorry certain amount of air atmospheric air you reduce temperature so after certain time certain reducing temperature water will be completely saturated and if you reduce further temperature what will happen certain water will be condensing and it will be forming water droplet at the bottom of the pot that point water starting create the droplets this is called dew point temperature okay so this will be touching the hundred percent relative humidity line but if you are increasing then that situation will not come in that case actually your relative humidity will be going down so take certain amount of air reducing temperature will be increasing humidity increasing temperature will be reducing humidity okay because air is having a water carrying capacity certain amount of water it can take but it cannot take more than certain amount of water at certain temperature okay when it is 100 saturation it will not take more water especially during rainy season if you see cloth will not get dried okay so what happens during any season uh

In Kolkata or Chennai, several days continuous rain will be there. humidity will be almost 100%. in that case, clothes will not get dried and it will be smelly also. because high amount of moisture is there, it will not get dried. So, lots of bacterial growth will be there because of high moisture.

And your skin disease also may come up actually because of high moisture. Like eczema and other sort of disease during rainy season you will find because of moisture. Skin will not get dried quickly. in that case, you will not feel comfortable. you have to reduce moisture that time.

Although temperature is lower, but humidity higher, so you will not, because of humidity higher, you will not feel comfortable. But if you can remove the humidity, the same temperature, you will feel very much comfortable. Now, you see this one, process 0 to 1, sensible heating. here sensible heating is here then what will be sensible cooling just opposite of this one sensible cooling okay so let us say a i made is sensible say if i ask you sensible cooling then o a then If you have chemical dehumidification, so if you are using certain chemical, then your humidity can go down, your temperature can go down, you can manipulate.

And cooling and humidification, 0 to 3. What is happening? Cooling and humidification. So, first, once you are starting cooling, so temperature will be going down. At the same time, if you see, it will be crossing your...

so cooling and dehumidification means you are reducing you see this temperature is going down and again you see right side is showing amount of humidity is there okay specific humidity means how much water content is there in here so 0 to 3 you are going that means you are reducing water content dehumidifying and at the same time you are reducing temperature also so it is going to 0 to 3 again 0 to 5 this opposite is happening heating and heating and humidification you are adding humidity okay so 0 to 5 you see humidification with steam injection means you are adding more moisture okay now I have moisture in air how to measure there is hygrometers. The term is called hygrometer. sometimes they are calling moisture sensor, humidity probe, psychrometer or humidity meter.

here you should remember the spellings, not psycho, this is psychro. R is there. So a hygrometer is a device used to measure relative humidity in open and closed space. Mechanical, electrical and many other type of hygrometer people develop so that they can measure temperature. specific humidity once you know the relative humidity specific humidity accordingly you can design your air conditioner okay mechanical hygrometer like organic substance like human hair also can be used for your hygrometry so with a water content human hair can be a changing its length okay electrical hydrometry is also there it will be changing your resistance proper property of wear so that way you can measure

humidity content in air. another is dew point hygrometer is there and psychometers are used to find wet bulb and dry bulb temperature. if you know the relative humidity and if you know your dry bulb temperature then you can manipulate to your wet bulb temperature also. Now, we will go to some formulation properties of atmospheric air.

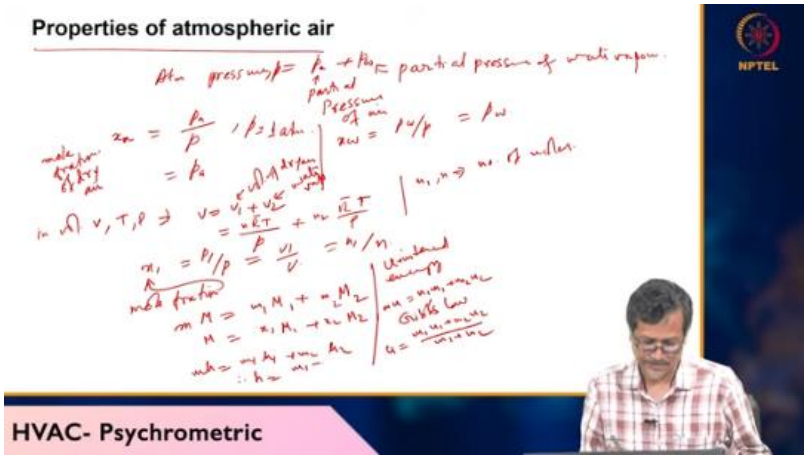
atmospheric air pressure atmospheric pressure equals Pa plus Pw. So, partial pressure of partial pressure of air and Pw partial pressure of of water, water in the air. or water vapor you can say. mole fraction dry air mole fraction of dry air equals P A by P total pressure and p equals 1 atmospheric pressure we are

assuming okay so that means p a x equals x w p w by p again p equals 1 so it is p w okay in volume temperature and pressure

V equals V1 plus V2. If we use this formula, N1 RT by P plus N2 RT by P. So, V1 volume of dry air, volume of dry air, volume of water vapor. okay so n1 n2 your n1 and n2 is your mole number number of moles so x1 equals p1 by p equals v1 by v equals n1 by n okay so mole fraction x1 equals p1 by p equals okay this is a mole fraction okay mole fraction i do not need to write it is here okay now m capital m equals m small m capital m small m capital m 1 1 2 2 so capital m equals x1 m1 plus x2 m2 x1, x2 is a mole fraction.

u is internal energy. So, mu equals m1 u1 plus m2 u2. So, this is Gibbs law. So, u becomes m1 u1 plus m2 u2 divided by m1 plus m2. And if I write in terms of enthalpy mh equals m1 h1 plus m2 h2.

therefore h equals m1 plus h1 plus m2 h2 m1 plus m2 m equals m1 plus m2 so specific humidity or humidity ratio ts diagram will draw okay actual temperature of moisture is called dry bulb temperature of moist air and G equals mass of dry air, M equals mass of water vapor. So, W equals M by G equals V by V v w v by v a equals v a by v okay so humidity ratio is called humidity this is small w actually humidity ratio this one now this is ts diagram and Td is dew point temperature superheated state of water vapor heated state of water vapor in unsaturated air in



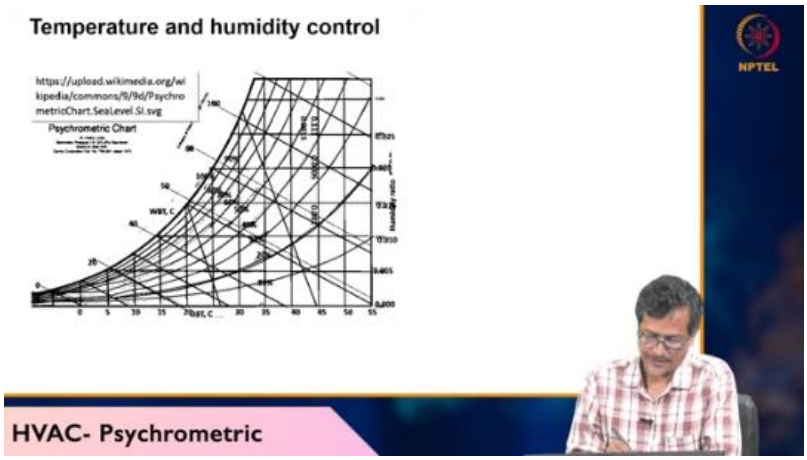
unsaturated air. So, in atmospheric, the water vapor will be in superheated state. Saturation pressure P water. Now, P w is very small. The saturation temperature at P w is less than T atmospheric.

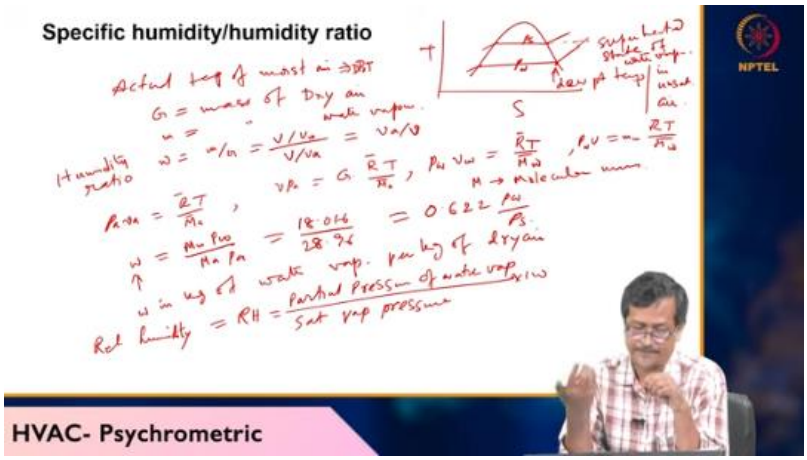
So, water vapor in air exists in superheated state. Water vapor exists in air in superheated state and air is said to be unsaturated. Since, both the dryer and water vapor behaves individually as ideal gas. Pa Va equals Pa Va equals R T by Ma and V Pa equals G R T Ma. then Pw Vw equals RT Mw Pw V equals Mw RT Mw bar.

G is dry air mass already I have written M capital M is molecular mass. So, Pw Vw now specific humidity ratio. Mw Pw by Ma Pa equals 18 molecular mass 18.016 divided by 28.96. it is coming 0.622 pw by ps.

When w in kg of water vapor per kg of dry air, w in kg of water vapor per kg of dry air. relative humidity or RH or sometime many people will be writing phi also RH equals partial pressure of water vapor. at certain temperature the same temperature saturation vapor pressure into 100. So, the ratio of amount of moist air relative to the amount that can be given that will be absorbing more water. Relative humidity 100 percent means it will not absorb more water, but relative humidity less than 100 percent means same temperature it will be absorbing more water vapor.

these two ratios at the same temperature let us say certain temperature you have certain amount of moisture and the moisture total moisture will be there if relatively humidity humidity 100 percent so the two ratio is called relative humidity okay temperature and humidity control so what happens let us say certain today temperature is for example let us say 30 degree 35 degree centigrade and 30 percent relative humidity okay now If I ask you make it 25 degree centigrade and I need humidity 60 percent, what will you do? This is 60 percent line and this is 25 degree centigrade temperature. initially you say today 35 degree centigrade and let us say 35. say 30 percent efficiency humidity okay so but you have to go to comfortable temperature 25 and 60 percent so what will you do so first take 30 degree line okay 35 degree line here and 30 percent efficiency here so this point then you have to reduce temperature to 25 25 is here





But you need humidity 60%. Yes! Here we go So what you do? You reduce temperature. Yes

But you are not reaching that humidity. So what will happen? You reduce temperature. Then you have to add some moisture also. Yes

Then you add some moisture. You add some moisture and make it comfortable. You can see if we reduce the temperature directly, sensible cooling, so it is crossing 60 degree here. So it is more than 20 degree but still you are not reaching your temperature, desirable temperature. So what do you have to do?

You have to add more moisture actually. in that case if you add moisture then only you can reach your 60 percent humidity ratio humidity ok. only cooling is not helping you rather you have to increase add some moisture also ok. how can you do that one? if you use desert cooler in North India you are using desert cooler right.

in desert cooler what happened what happens you have one cotton wick or some Quare will be there. Through this one, air will be passing and you have lots of water splashes. that water splash will be adding lots of moisture. When we are adding moisture, actually temperature will be going down directly and it will be reaching your humidity nearby 60%.

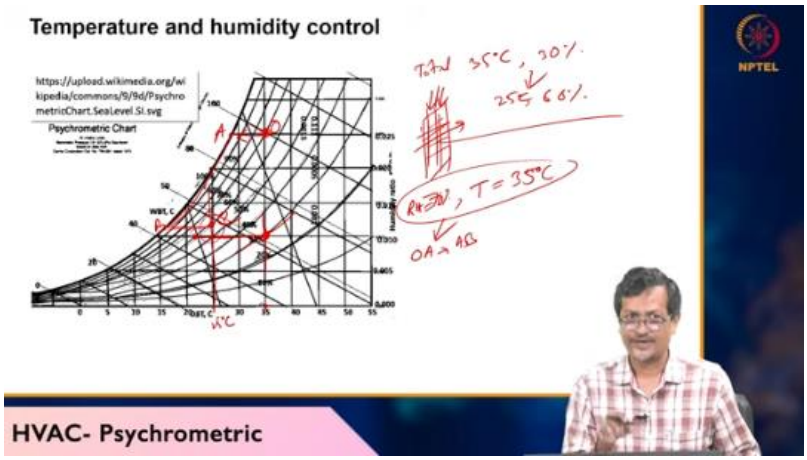
Then you are feeling comfortable. That is fine. But in certain situation, let us say assume temperature, present temperature is 35, but your humidity is 70%. 60, 70%. okay if you are having 70 percent humidity let us say 70 percent relative humidity and your temperature is 35 degree okay so what will happen if you add moisture so if you add moisture your relative humidity will be increasing so if you are increasing relative humidity temperature will be going down So, temperature will be going down, but your relative humidity increasing.

So, that will be very much uncomfortable. So, then what you have to do? In air conditioning system what they will do? They will reduce temperature, let us say O, A, then A to certain level they will be reducing temperature further, your target temperature 25 and here. reduce temperature, reduce, reduce, reduce, reduce.

And you go to here, here. So, B, C. So, if this one you want to make comfortable, then what you have to do? OA, first you cool it. Then you cool further, A to B. A to B, what will happen? Lots of moisture will be condensed.

Some water particle will be drained out. Then again, B to C, you increase temperature. When you increase in temperature, you are maintaining that 60% and your desired temperature. okay then then you are reducing moisture as well as your temperature but you have already low moisture then actually you cannot reduce moisture so in that case you can add moisture when you are adding moisture you are making your room comfortable so North India You can see lots of desert cooler will be there.

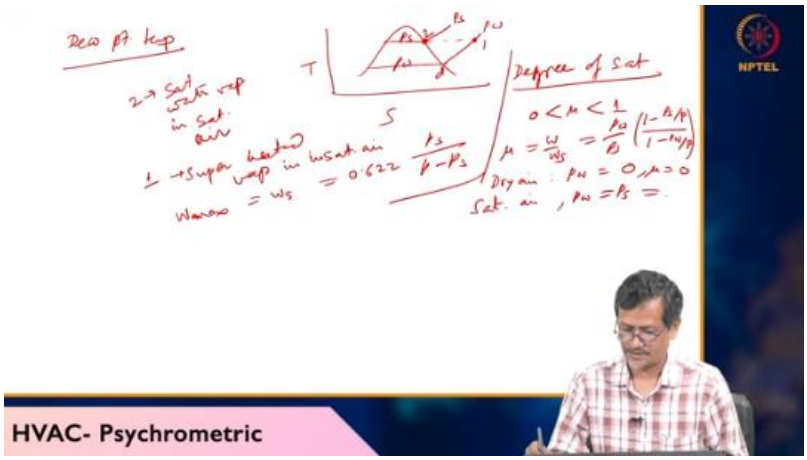
So desert cooler will be reducing your temperature and increasing humidity. But in South India, if you are using same desert cooler, it will not help because it will be adding more moisture. So that will make your life more uncomfortable. Okay, so southern India, especially Chennai or Kolkata, you need air conditioner which will be draining out some water from air. So whenever you see any air conditioner, especially split air conditioner, there will be long pipe coming out and some water droplet will be there.



Okay, so those water droplets actually your condensed water because you are modifying humidity also. So dew point temperature. So TS diagram if you draw, so your vapor envelope, then your pressure line will be like this. PS, saturation line, P water line and D1PW, this is PS. saturated water in vapor.

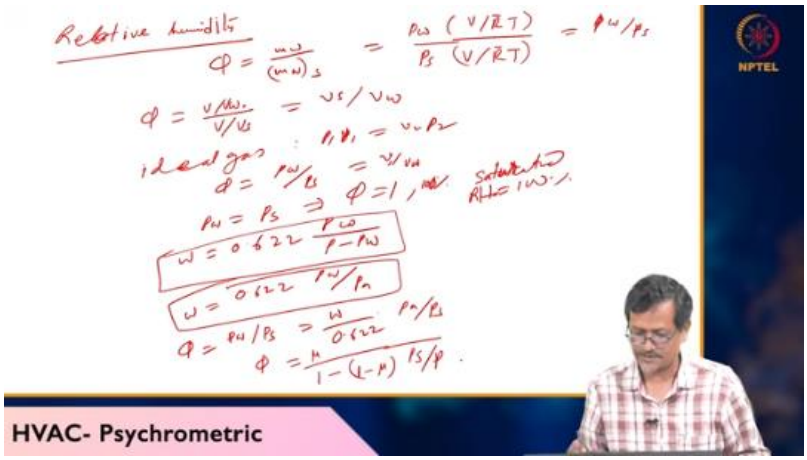
point 2, you see saturated water. 2 is saturated water vapor in saturated air, but point 1 this is superheated water, superheated vapor in unsaturated. So, moisture maximum can be Ws equals 0.622 Ps P minus Ps. So, maximum moisture means like saturation state your how much moisture will be there so that formula is this one. But normally it will be instead of Ps you will be putting Pw degree of saturation.

degree of saturation. 0 to mu to 1 formula is this W by W saturation P W P s P 1 minus P s by P 1 minus P W by P this formula you should remember. if there dry air is there dry air p w equals 0 mu equals 0 and saturated air saturated air p w equals p s equals mu equals 1 so relative humidity so this small formula is there based on this we will try to solve problem relative humidity phi equals mass of water in saturation condition.



Pw V by RT bar P s V by RT Pw by P s. So, ideal gas condition you have to apply phi equals V by Vw V by Vs equals Vs by Vw ideal gas. P1 V1 equals V2 P2. Phi equals Pw by Ps Vs by Vw. Pw equals Ps implies Phi equals 1.

air is 100% saturated or relative humidity RH 100%. W equals 0.622 pW p minus pW. You should remember this formula. equals 0.622 pw by pa phi equals pw by ps equals w by 0.622 pa by ps so phi coming mu 1 minus 1 minus mu P S by P. Okay, these formulas are taken from your Pikanag book, so you can go through it.



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