Fire Protection, Services and Maintenance Management of Building
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Lecture – 25
Introduction to HVAC

So now we look into Heating Ventilation and Air Conditioning, some ideas relate to that, some ideas related to HVAC, some ideas related to that.

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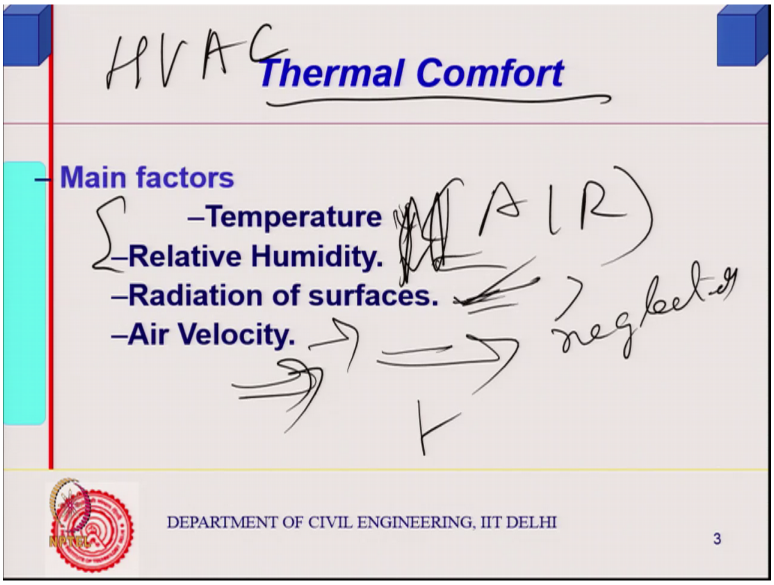

So, HVAC; now, first thing related to that is a thermal comfort. And some of you would have done a course earlier where we have seen that the main factors which you know, which controls our thermal comforts is that surrounding air temperature, and then, the relative humidity.

Why so? Because, the body cools by evaporation, you know the heat loss; if the moisture loss from the body results in cooling by evaporations, alright. So, relative humidity is important and then, if the surface are gone, this surfaces because, the sun light is falling on to the outer surface. The surface can be warm, warmer than the air. In that case, ration from the surface are also important and lastly, it is a air velocity which causes forced, ventilation forced, kind of forced. I mean, it causes forced cooling of the body convection forced convection and so, force evaporation.

So, this is this is what is important right, radiation on the surface air velocity. We have we have defining them, but typically one would control the temperature and relative humidity only because, in a controlled environment where in an air condition environment, surface temperature and room temperature wall surface temperature, ceiling surface temperature and air surface temperature. They are nearly same. So, radiations from the surfaces can be neglected and usually, it is a close room.

So, there will be little natural ventilation leakages could be there in filtration could be there, but that is taken care of. So, air velocity per say is not there to have good convective cooling. In that sense, significantly their velocity is not there and that also. So, it is by enlarge, still air it is closed from all sides and then we normally do not operate fans etcetera if they exist this is all being properly.

So, this is also not needed. So, what we try to control is these 2 temperature right, comfortable range of temperature. And generally, this is over a range as I said it would depend upon your social condition location in India. It could be you know to tropical people. It might be happy with 25 degree centigrade. The cold countries people might be happier at 20 degree centigrade. So, that is that difference is there clothing. So, in summary, you do not put on heavy cloths.

Therefore, all these are factors. So, these are fixed accordingly. These are fixed accordingly. So, relative humidity is important from 2 point of view; one it will cause you know, evaporation loss from the body. Now, if it is too low, you feel dry. If it is too low, there will be lot of moisture loss from your skin and you feel dry and if it is too humid, too moist. Then again there is a problem. The problem is that no evaporation takes place can work. You will be sweating, you might sweat, you know start sweating, not a very comfortable situation. So, we do not we whether desirable range of relative humidity general around 60 national building code you give the velocity.

So, 25 60 50 to 60-degree centigrade relative humidity would be a good thing right. So, these 2 controls with tend to control largely the temperature through supplying air. If you are doing cooling, this is what because, supply air at certain lower temperature which will enter into the room, absorb the heat from the room and as it is goes out exhaust, it will exhaust at room temperature.

So, air comes at cool temperature, but it comes at certain moisture level and absorbs the moisture in the room. Because, you will through a perforation sweating, may not be there by perforation, we lose some moisture and processes involved if there they will also lose some moisture. So, this moisture, it absorbs and then goes out. Therefore, in the process what it does? So, we have a fixed range of temperature as I said, 25 plus minus something 60, may be 60 degree. There will be 60 percent relative humidity plus minus something. This is what I want to maintain.

So, I supply air which absorbs both moisture as well as heat and goes out. Now, I you know what I want to do is, we control the temperature, ok. So, we have 2 type of actually, it take it away because, the air that heated up the fresh cool air which I have supplying it is get heated up. So, absorbs as sensible heat. It is temperature will increase. Now, our supply air temperature is lower. So, it absorbs sensible heat and it also absorbs moisture vapor. So, certain amount of latent heat. So, both latent heat and sensible heats are removed.

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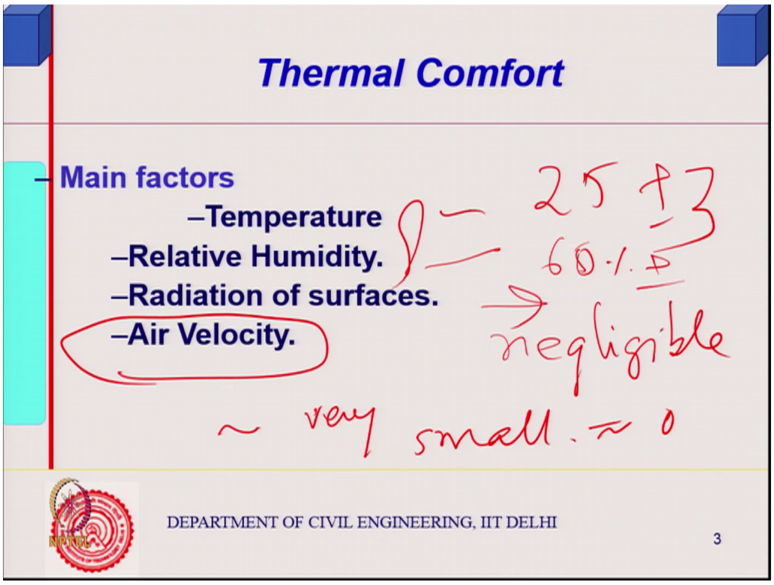

So, continuing with thermal comfort you know, we said that there are factors which affect the thermal comfort, because you are looking at HVAC, heating ventilation air conditioning in the you know, systems related to service system related to heating ventilation and air conditioning. So, we got to know what should be the condition inside the control space. So, that depends upon of thermal comforts. Now, all the details of thermal comfort, we are not covering in this course. But, you know the factors which affect your thermal comfort are.

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Temperature; obviously so we got to maintain a specific temperature. Then, relative humidity: relative humidity because, body can lose heat by evaporation from the skin and the amount of moisture that the body can lose will depend upon the surrounding relative humidity.

So, if the humidity is high, what it cannot lose? Heat and it has an effect of thermal comfort, alright. Similarly if it is too dry, then also skin gets dried. So, you know it is a there is a kind of discomfort related to this. So, relative humidity is other, then if the surfaces are hot, then radiation from the surface will also play a role.

But then, in condition building, surfaces are unlikely to be you know, sealing wall inside surfaces are unlikely to be warm. There will be similar as air temperature and air velocity is because, that can cause forced convection and evaporation from the body. So, it is also important. However in our case, this may not be important.

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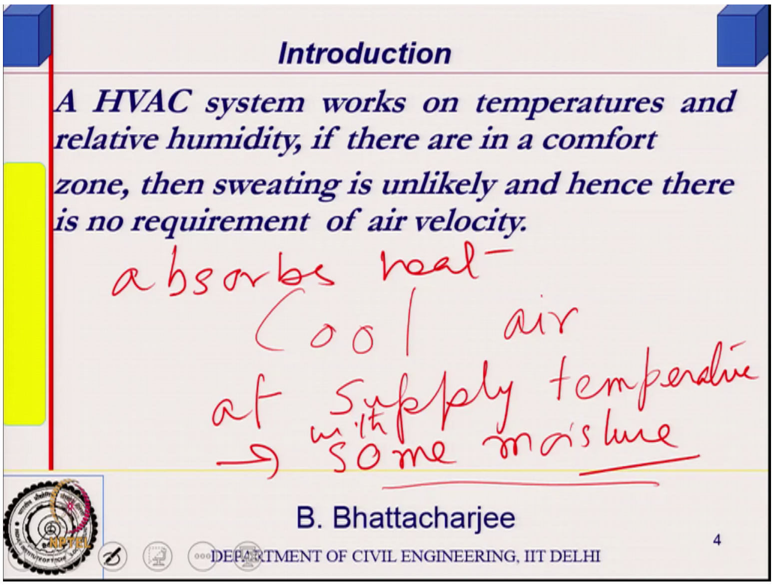

Because, you know, this may not be important because, we maintained a appropriate temperature and relative humidity within a given range as we said, operating differential of the design variable in control system we are talking about.

So, we said operating differential of the control variable. So, radiation from the surfaces that would be negligibly small in our case and air velocity will be very small nearly 0, because, we will not put on the fan. Nearly, you know, put on the fan or something of that kind for in inside an air condition room. So these are, but these 2 are very important.

So, for steel air condition, the desirable values of temperature, desirable values of temperature and relative humidity plus operating differential. That is what we consider. So, that is that is what we maintain. So, suppose you know, would be possible in Indian scenario. You would like to maintain 25 degree centigrade plus minus 2 or 3 and you know this might be 65 plus minus or 60 plus percent plus minus some percentages.

So, that is usually, the code gives you the values right. Just a order is similar what I said, but it varies from people to people. Some people might like to keep it at 20 who are from the cold countries. So, they would like to maintain it at 20 right, while Indian in Indian scenario, it is 25 is good enough. Otherwise, you start feeling good.

So, this is one aspect related to thermal comfort. So, this is what we maintain. Now, how do we maintain? We generally cooling is done, you know cooling is done by supplying cooling air at what is called supply temperature. So, cool air at some supply temperature, it would be supplied into the room and it will have specific moisture content. It will have with some moisture some moisture with some with some moisture, some value of moisture.

Now, as this cool air enters the room, it will you know, it will absorb heat, and the air can get out from the room either you have an exhaust through which we exhaust it can go or usually, it is usually the leakage etcetera, etcetera is there in filtration is there. So, it can go out on a stone because, supply air comes from outside. Obviously, the volume of the room remaining same the pressure would develop.

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And therefore, air will go out through any kind of leakages and similar sort of so infiltration. So, this is one way or the other ways of course, you also provide a kind of exhaust which will take out the air. So, it can be exhaust also.

So, depending upon the situation, whatever it is. So, what it does? The air that comes in absorbs heat because, it is at what temperature attains the room temperature and same volume of water will go out; volume of air will go out at the room temperature. So, the air that goes out is at room temperature, air that comes in is at supplier temperature. Similarly, air that comes in will be have a being a specific, I mean a some given moisture content. But, the one that goes will go out with a moisture content of the room itself. So, it might absorb some moisture from the room.

And also it will absorb some heat from the room. So, if you are looking at cooling, generally what heating is done through radiators, you know. So, you have actually radiating fins or plates or something through which you would be doing heating, heating. One problem associated with heating is ensuring uniform heat; close to the radiator temperature, it tends to be a higher and away from it, it is tends to be.

So, this differential becomes too much actually some time. So, anyway that is problem with heating will look into later on may be sometime. So, this is what happens, right.

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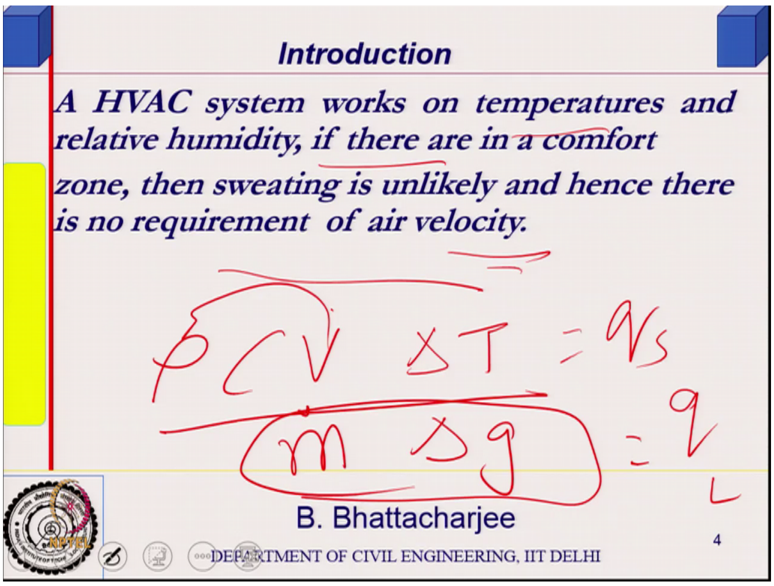

So, basically in case of HVAC, there is you know air velocity is not required. That is why, I said and you supply air at some temperature. At what temperature then the room temperature it absorbs. So, basically it will be C specific heat, you know specific heat rho, I mean volume rho C V mass into specific heat into delta T. There is the amount of heat or what is called sensible heat that will be removed, sensible heat removed will be this much.

But there will be some amount of latent heat removed also because, the moist it might absorb moisture. So, if it absorbs moisture, it would have taken out some moisture vapor right, moisture vapor. So, if the delta g is a moisture content difference between the supply air and the room air, then the amount of moisture. So, if mass flow rate you know, mass flow rate if this is flow rate I am talking about volume is a flow rate meter cube per second. So, mass flow rate will be corresponding density.

So, if we know the mass flow rate and the moisture content difference, then this will be what we call latent heat removal, latent heat removal. So, q L q S and whichever is you know, we what we do is, we try to control one, we try to control one, you know we try to control one in that. We will see that later on. Just few minutes later, we will see whichever is higher. According to that, we decide the supply air temperature.

But, supply air moisture content will be decided depending upon how much latent heat I want to remove. Because now, the flow rate you know, temperature, I mean not supply air temperature. The flow rate will be decided based on how much latent heat I want to remove, delta T of course, based on certain other considerations, we will come to that.

So, basically what we do? We supply air at some lower temperature and some lower you know at some moisture content. It comes in, absorbs the heat, attains higher temperature and at the same time it also attains some higher moisture content and then goes out. So, that is what we do. So, basically to bring; that means, that you know outside, you will have outside air which we will be actually outside air room temperature would be different than outside air temperature.

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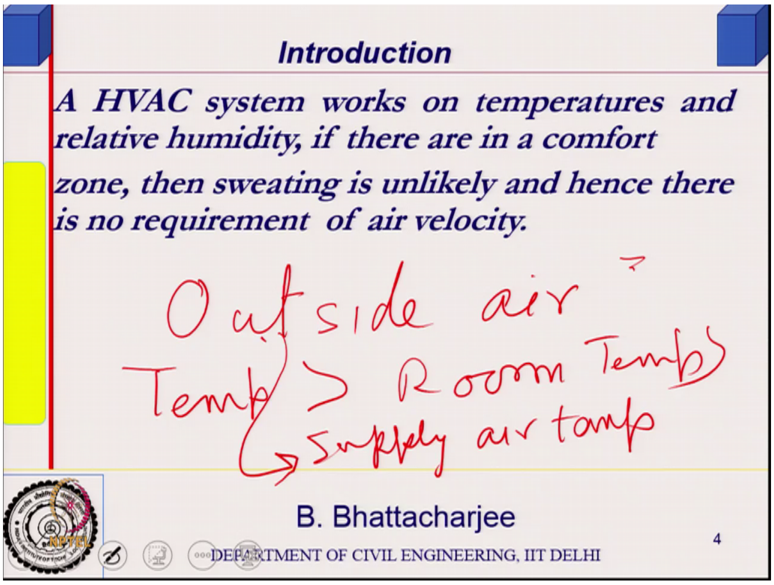

First of all, outside air temperature will be possibly higher because, we are talking of cooling scenario in tropical climate. So, outside air temperature is higher is greater than the room temperature, and this will be further greater than the supply air temperature. This will be still greater than the supply air temperature, right.

So, what I have to do? I have to cool this to this temperature cool the outside air to this temperature, but and what is done is normally, total quantity of air that we supply cool air that we supply is not all from the fresh air from outside a portion of the air is re circulated, you know the supply air is re circulate air. What we do? That means, the air which will go out of the room, you take a part of it and mix it up with a fresh air.

And then, re supply it now. Otherwise, because of economy, so but the how much minimum fresh air we require? That depends upon the hygienic requirement, because you also got to remove carbon dioxide and similar sort of thing from the room. So, for that you need certain amount of fresh air supply right, because, that is called flight hygienic ventilation requirement.

So, minimum fresh air supplies required because, as the inside room would have also you know taken like it also have higher carbon dioxide content or similar sort of order or similar sort of thing content, because of you know, room temperature will have more compare to fresh air because of people, etcetera sitting inside.

So, minimum fresh air supply must be maintained and that is from hygienic point of view, that is called we call it hygienic ventilation; so minimum fresh air. So, what you do you take part outside here and part room, air re circulated room, mix it. Now, if you see and simple air conditioner room, air conditioner which you might have seen, you would see that it has got fins.

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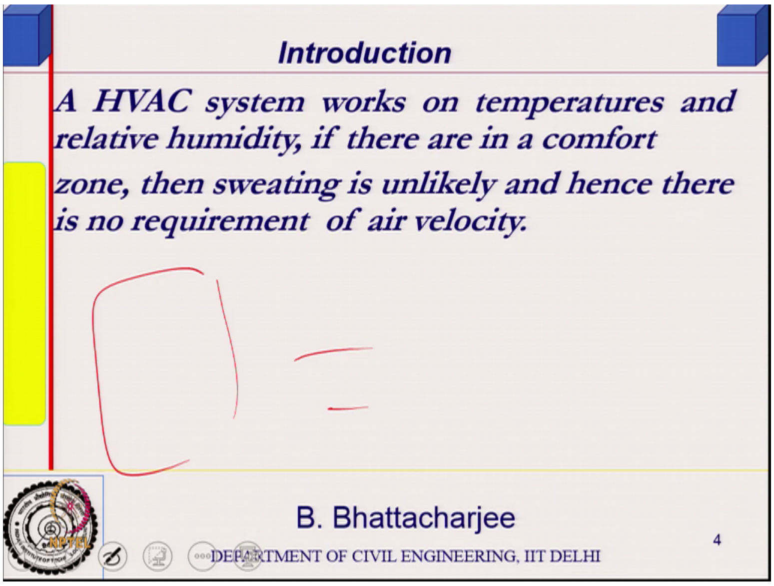

It has got a portion through which it actually supplies fresh air, but there is a filter you know, if you have seen that there is there is a kind of fins, they have filter. This filter through which actually takes the room part of the room air, it actually succeed right, mix up with a fresh air, cool down at lower temperature.

So, you do supply fresh air and re circulated air. You actually mix them up and then cool it down to a lower temperature. So, cooling is important. So, if we want to look at the cooling, then you should look at a little bit into the simple principle of refrigeration system. Because, if you want to cool it, then have you actually do simple principle of refrigeration and that is very simple you know. So, in this one it has got a 4 cycle typical refrigeration, will have a 4 cycle scenario.

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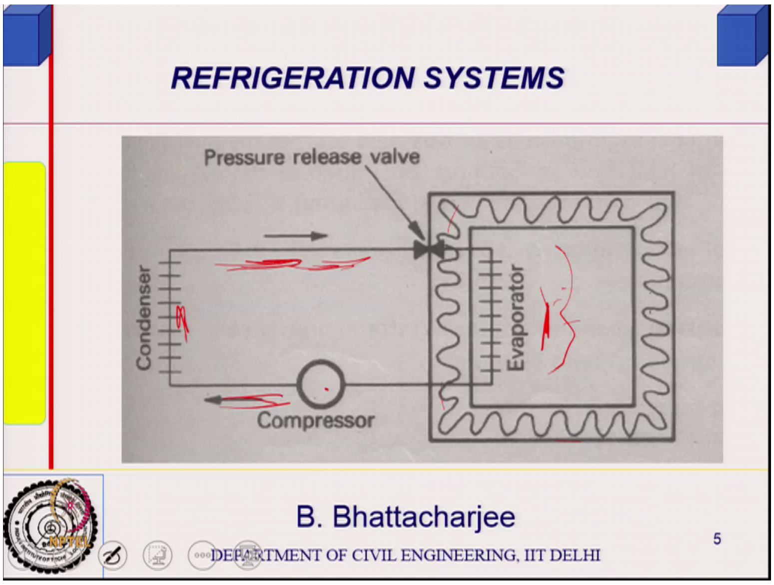

So, you have you what you do? You have an you know basic principle is you have got refrigerant right. Like you know, I mean one on understand this through carbon dioxide which if you know if you increase the pressure after at, it given a given a given at given temperature. So, isotherms let us say.

So, at certain pressure, as we will go on increasing the pressure in a constant volume or you know volume would change and after certain period of time. It will actually become from gas to it will turn into liquid. And then, if you if you can it if you circulate this liquid refrigerant, it will absorb water, absorb heat and again.

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(Refer Time: 18:51) So, it is a. So, you can always take this is the basic principles. So, what is it? You compress it, compress the refrigerant here right, the compressor. So, the compressed after compression, this is in you know liquid form where then it there is a small pressure, release wall and it evaporates here and this is all insulation. It evaporates here. This is simple principle, actually evaporates here. So, as it evaporates, it go to take the latent heat of evaporation, it takes from the surroundings base.

And becomes gas again where it is further compressed condenses into liquid. So, compressor condensation and then there is a, it is gets condensate the liquid. Then, this is allowed to expand certainly and evaporates. So, this is a 4 stages of refrigeration actually.

So, it will go on cooling this because, it takes continuously take heat from this space, if you it will go on cooling this space and this is all insulation. So, this is how a here are you know refrigeration system works. So, that is you know that is we cool the air using this kind of principles, right.

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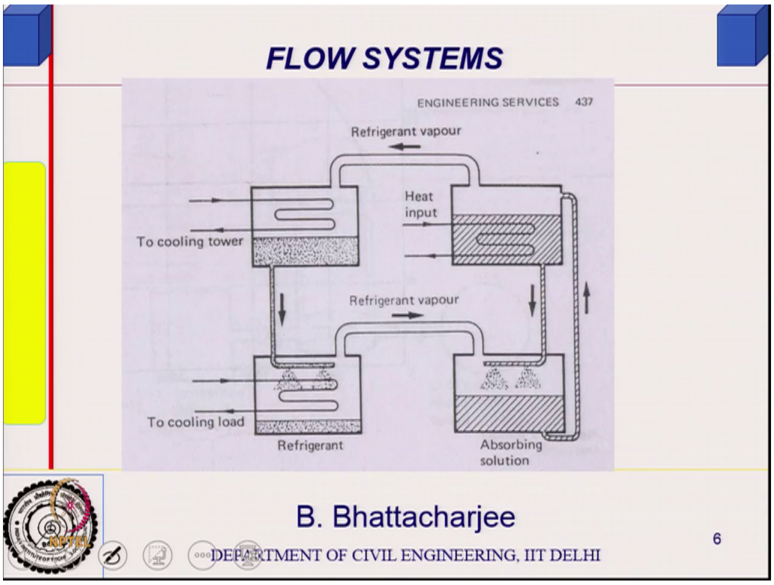

Now, you can understand. We will come to this a little bit later on.

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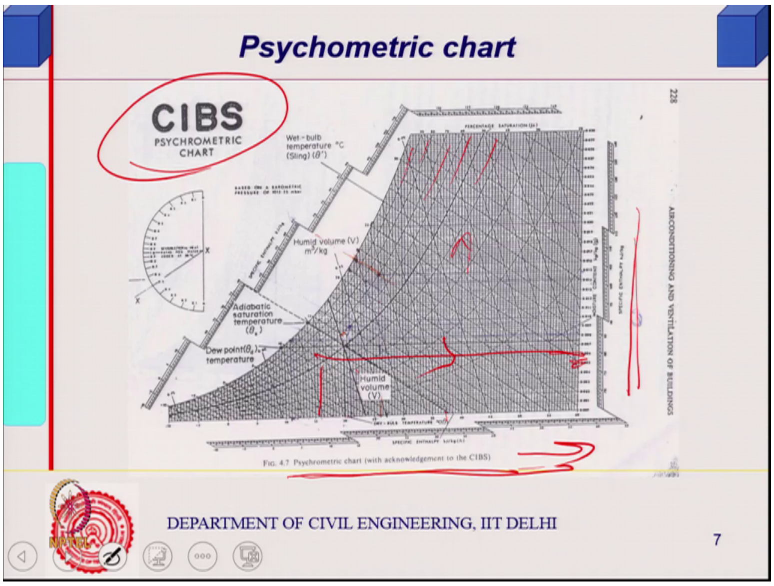

We can understand this in a psychometric chart. If you re-collect, I am not sure whether I have talked to you related to psychometric chart. A psychometric chart is in this side I have got what is called drival temperature. Now, this is taken from chartered institution of building (Refer Time: 20:39) engineer. They have the most elaborate 1, you find this in s p 41 and you find in at it is there in open source, plenty of it.

So, this is you know, you have got a psychometric chart. In this one, on this direct, this axis you have got dry bulb temperature, what you call an dry bulb temperature. You know, dry bulb temperature and on this side you have got absolute humidity. The moisture content are absolutely humidity. Both will be there and this line is saturation line. This line is saturation line, then 90 percent relative humidity, 80 percent 70 percent etcetera, etcetera.

So, psychometric chart is a chart which shows variation of you know variation of a I mean these excesses are dry bulb temperature, what you call dry bulb temperature, dry bulb temperature and absolute humidity, moisture content, right and it shows various relative humidity curves. Now, you can also plot several things here. One of them is called wet bulb temperature, other is specific enthalpy and so on. So, quickly, although you know, in on some other class, I have actually talked about wet bulb temperature that wet bulb temperature is one where that the actually the you know the in a environment, if I have the thermometric bulb, bulb of the thermometer is where there will be evaporation taking place.

So, there will be a depression, wet bulb depression compared to the dry bulb temperature. See, if I keep at thermometer which is whose bulb is you know liquid thermometer, let us say bulb is dry, it will have let me show indicate some temperature, but if I make, it is take wet jute or similar sort of thing, if I put it on cotton, wrap it around in the bulb, there will be evaporation taking place. So, you will find there is a depression. So, this is called wet bulb temperature.

So, difference between the or wet bulb depression as well you call it difference between dry bulb temperature and wet bulb temperature this difference is an indicator of relative humidity. When you have no difference; that means, it is 100 percent saturated, no evaporation is taking place. So, there are lines for wet bulb temperature in this one. Now, in this one, we can express the refrigeration processes. We can express also in this diagram refrigeration process. For example, if I am heating with the moisture content remaining same, the line will be simply horizontal line, right.

So, this is what is called you know, simply I am I am heating, heating. Temperature is changing, right. I am simply heating it and if I am keeping the temperature same, and increase in the moisture content right, increasing the moisture content. So, this is this you know, this will be simply a vertical. This process is can be expressed as vertical line. So, several such each process can be expressed in psychometric chart. So, let us see how do we do it.

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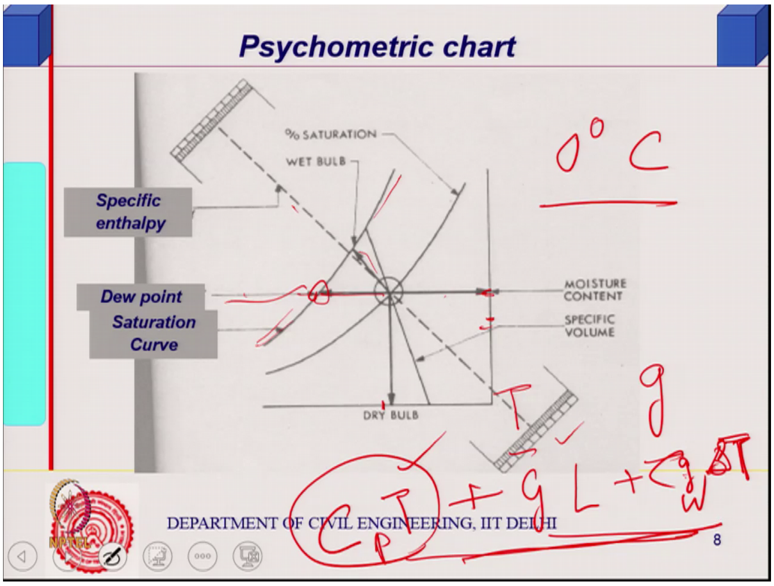

So, this is what it is now. So, as you said ok, this there is something just I would like to explain. So, this is constant moisture content. This is a dry bulb temperature, this side is moisture content and 100 percent saturation line is this.

So, you have wet bulb temperature something like this because, at 100 percent saturation, dry bulb temperature and wet bulb temperature will be same, they will be same. So therefore, one can plot them and you know as I cool it, let us say I have some moisture in the air and I go on cooling. So, I am going along this direction from here.

Now, if I reach here, 100 percent saturation, after that I can cool it. Further, if I cool it, there will be condensation. So, this point is called this point is a due point, due point you know. So, if I cool it further, then there will be condensation occurring right because, the air has got a fixed capacity to hold moisture you know, at a given temperature.

So, that is the saturation moisture content. So, air has got a fixed it is got a max capacity to hold moisture at a given temperature. So, due point corresponds to that case where the temperature is gone. So, low that it goes to for a given moisture content, it is gone to such a low level that. Now it you know, it is reach this saturation point.

So, we try to further cool it. You cannot go further along this line. Rather, you will go along this line. So, there will be condensation occurring right. So, there is a similarly, there is something called specific enthalpy and I will come to this. So, in psychometric chart, actually you can explain or all processes right. So, let us see something more.

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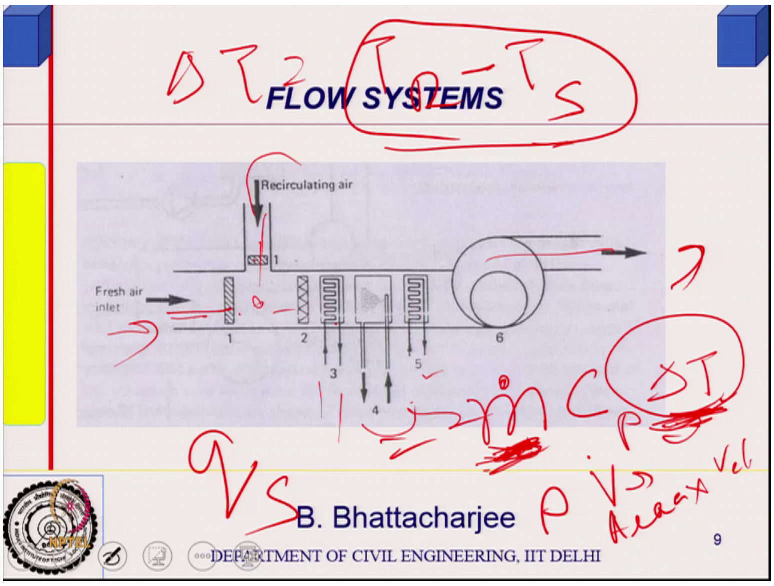

I will come back to this. I will come back to this or just let me explain this then, ok. So, you can explain, we will do that. Now, what is specific enthalpy or what is enthalpy? Enthalpy is a heat content right. So, you talk in term terms of heat content, content per unit mass of air. Let us say heat content per unit mass is the air, right. So, the specific enthalpy, now you cannot know absolute change in enthalpy. You cannot least measure change in heat content of air or gas you can actually measure it, right. So, we take a datum point and this datum point is taken to be 0 degree centigrade.

So, enthalpy change above 0 degree centigrade we consider and we assume that all evaporation takes place at 0 degree centigrade. So, supposing that air is at a temperature it is at a moisture content of g and temperature of T; let us say then it is specific enthalpy will be because the evaporation has taken place at 0 degree centigrade.

So, g into latent heat of evaporation g into latent heat of evaporation L, that is the amount of it would have absorb right, plus specific heat of specific heat of water right specific heat of water into delta T or T. Because, we are taking delta T here, corresponds T degree centigrade minus 0. So, C w plus this is the moisture content in unit mass of air, unit mass of air.

So, basically you have I have unit mass specific heat of air multiplied by specific heat of air plus you know C p plus T. So, this is for the air part of it, this is for the moisture part of it into g. Of course, C w g into delta T because, for unit you know, unit I mean unit mass of air g is a moisture content.

So, C p g C w g delta T; so you will you know, this will the specific heat. I am not sure this is the notation. I am using later on, but just to explain you right now or appropriate notation we will use later. So, this specific enthalpy temperature and moisture content only therefore, I can express this is a function of temperature and moisture content only.

So, specific enthalpy lines can be found out corresponding to the given moisture content. Specific enthalpy value corresponding to a given moisture content and given temperature I can find out. Therefore, I can draw a line. So, these are the you know, this is a specific enthalpy line and this is wet bulb temperature line, wet bulb temperature line. So, that is how it is. Now, a system would look something like this.

System would look very simply. Since system would look something where a simple cases as I said just to explain, I have some fresh air coming in, there is a filter. This one is a filter, some portion of it will be recycled air, some portion of it will be recycled air. They get mixed up, they get mixed up, they get mixed up together then you know, I might I might basically depending upon the situation.

There is a cooling that is occurring here right there is a cooling and their further there you know this is this is the evaporator, this is the evaporator of the refrigeration system that I talked about. So, the evaporator is kept here. Rest of the system is somewhere there. So, this would. So, the cooling would actually occur here. So, the air that comes in re circulated air fresh air passes through some filter again and then this is.

Student: (Refer Time: 30:16).

This one is no, this is not an evaporator, this is not an evaporator. This is recycled circulated air, fresh air entering and this is a filter. This filter this is also a filter right, no evaporator here, no evaporations occurring. Evaporation is number 3 similar you know. So, here the cooling is actually occurring cooling is actually occurring and then after cooling. After cooling, it is you know if I might if it depends depending upon the situation. I mean, I might be I might require there can be condensation occurring.

Because, if I cool it to a lower level, there might be condensation occurring or if I have to humidify, I might have to spray water or something. So, I will do. So, this part is done some where there. It is condensation means water is simply come out. For example, you might have seen in room air conditioner. There will be lot of damages during monsoon season.

So, lots of drainage occur that because condensation, condensation takes place at the temperature. The moment you reach the dew point, if you want to cool it, further if the supply temperature is lower than that, then there will be condensation. So, moisture loss occurring. So, absolute moisture content now reduce and you want to add moisture, then there will be spray. You have to spray or add some moisture. Then you know if you want to remove, if you want to do remove some moisture from the air, you might have to cool it below, cool it to a level where the moisture content after condensation, sufficient condensation occur to bring the moisture content to a low level.

So, if you want some force condensation to occur you, in fact, you lower the temperature than the supply temperature further. So, that moisture will condense out. Then, you heat it back again. So, that is the heater. There can be a possibility of a heater on this side, then there is a circulation.

So, basically steps of such an air conditioner would actually a simple. Air conditioner with wall, some filter re circulated air pressure, they get mixed up together, then they are cooled 12-watt temperature sometime, condensation can occur. So therefore, you have a condenser and after condensation, if it goes to a lower temperature, then required you might even have to heat it up a little bit.

So, that is what it is; that is what the system looks like right. So, basically from our point of view, what would like to know is, first thing what would like to know is how much is a size capacity of such an air conditioner right. So, from our point of view, we would like to know what should be a capacity of an air conditioner and also possible you would like to suggest what should be you know room temperature is known.

But obviously, if you that is I mean room temperature and relative humidity, etcetera you know, but then use you would also it is better to be to have the knowledge related to what is the supply air temperature, quantity of supply air and quantity of supply air required and it is moisture content and similar sort of information or similar set of ideas. Although, it is apart you know it is a part basically, it is in the purview of mechanical engineering or air conditioning engineers services engineer.

But then, whom I we would like to also have this ideas ourselves now hm.

Student: (Refer Time: 35:02).

Which one?

Student: (Refer Time: 35:04).

6 is a fan. So, this circulates into the room. It is a fan, this actually the fan. So, it circulates into the room right. Now, 2 things this we must know because, this is something to do with a economy the you know; how do we fix this? As I said, the variables are our variables are one. Obviously, you fixed our design condition that is temperature.

Student: Relative humidity.

Relative humidity that we have said that ok. This is we have fixed now. Then, we would you know, the next thing we want to know is, how much what should the rate of supply of cool air. Now, that would depend upon how much heat I want to remove, how much heat I want to remove right. That would depend upon how much heat want to I want to remove, then that is a rate.

But rate is also a function of at temperature. I am supplying the cool air because, if we supply at you know, if we supply at much lower temperature, then because, it will mix up right. So, by heat removal, latent heat sensible heat removal is mass into either flow rate is m dot. Let me call it mass flow rate is m dot because the rate mass flow rate into specific heat into.

Student: Delta T.

Delta T; now, out of this room temperature is delta T is nothing but room temperature minus the supply, supply air temperature supply air temperature. Now therefore, I can keep this high, then this will be low. I can keep this high, this will be low. What is fixed to me is that how much heat I want to remove, q sensible I want to remove that is fixed to me.

So, I can keep this high, then this will be low in keeping this high means, I will keep my supply, temperature supply air temperature at lower level. It is implication is that you need more insulation, it is insulation, it is implication is that you need more insulation, if it is a centrally heated system right. So, more insulation cost of insulation will increase, but that size will reduce that size will reduce. That size will reduce.

Because, my rate will be less, rate will be this is this is higher means, this will be less. The this part has got another aspects also because, this is rate which means that m dot is nothing but rho into V. V dot if I may call it meter cube per second which would depend upon the which is basically nothing but area multiplied by area of the duct multiplied by you know it is flow is basically area into velocity.

So, this is area multiplied by velocity. So, if I want to keep this high, this is function of 2 things, the size of the duct and velocity. Now I have constant on each one of them. If I have higher velocity, noises will be higher. So, velocity cannot be increased beyond a point because of noise ok. Then, other thing is I make area of larger which means my cost will increase.

So, it is a balance between this 1 delta T is a balance between all this things, one issue is insulation cost and other issue is velocity cannot be very high. So, I cannot I cannot you know make delta T too small to have m higher, because, velocity too high means there will be no as in the duct and sizing also is aspect. So, keeping all this is in mind, normally up to about 10-12 degree is a supply air temperature differential. That is what we call it.

So, we look into that.