Fire Protection, Services and Maintenance Management of Building
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Lecture – 26
Governing Equations for HVAC Process

So, we can now look into a little bit into the properties of the moist air and how you calculate out.

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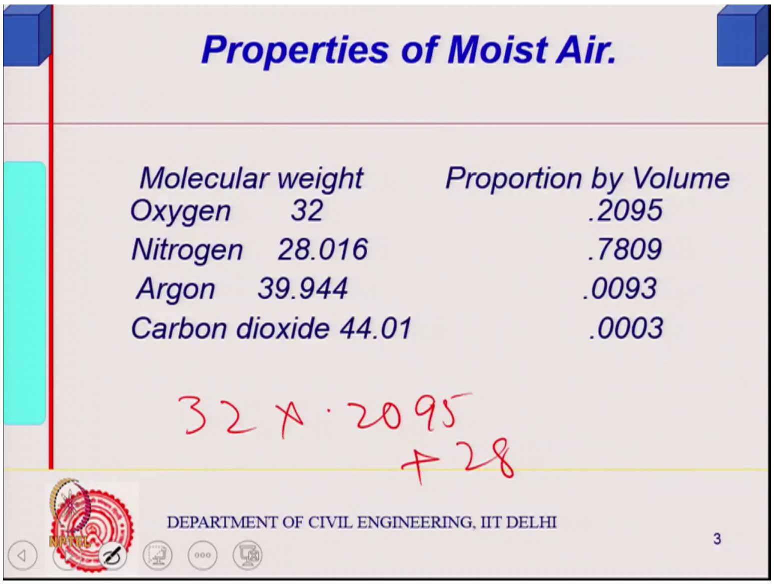

Now, if you look at air because the density would be needed all the time. So, we know that oxygen is around 20 percent you know 21 percent. So, proportion by volume and nitrogen, the molecular weight is this Argon is this much and then carbon dioxide is this much, so total overall molecular weight one can calculate out, right? Proportion you know, so therefore it would come close to somewhere.

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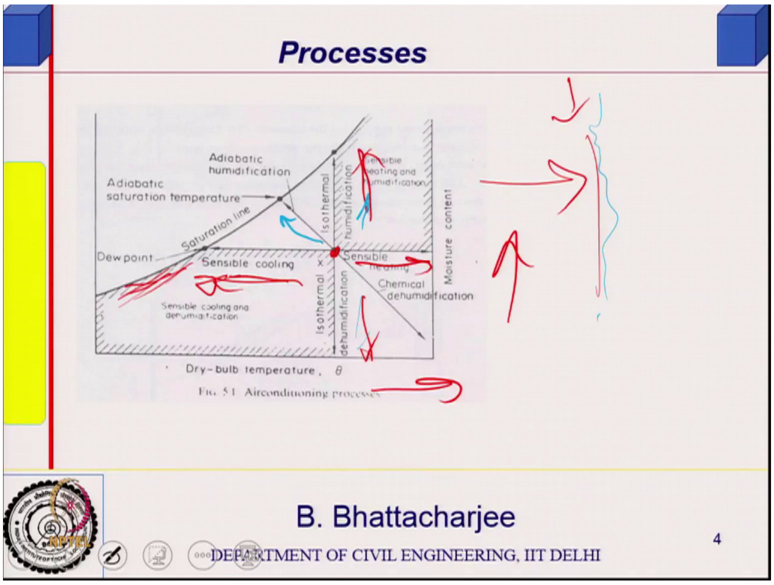

It will come close to close to Nitrogen actually. One can calculate this out 32 into for example, 32 into 0.2095 plus 28 into etcetera etcetera if you calculate out. So, molecular weight of air one can obtain.

Now, I have just I just mentioning you the process. So, you can see the process in a psychometric chart like this. So, this is dry bulb temperature, this is your moisture content. Now, what we you know the processes for example, this we call when I am just simply keeping the moisture content same and I am heating it; I call it sensible heating. There is no latent heat exchange occurring, so we call it sensible heating. And this obviously, the other side this is the initial condition. If I am going along this direction, I call it sensible cooling.

So, moisture content is not changing right? Now this is basically after beyond this point this will be condensation right? This will be this here this dew point condensation would occur. And then this if I am going vertically upward I am increasing the moisture content at a constant temperature. So, I call it isothermal humidification. This is isothermal de humidification, now supposing you know I am cooling it say example is a dessert cooler.

Now in dessert cooler what happens? Air enters through a filter, you know and where water percolating? Water is percolating, water park percolate from top right. So, air enters in this manner and is dry air usually it is effective only in dry summer, you know dessert cooler is not effective in?

Student: Moisture contain.

Contain area, so, the coastal area of India dessert cooler actually does not work while in a northern India or Rajasthan etcetera it still works. So, because the air is dry sufficiently dried in a hot summer and what happens is the; as the moisture enters I mean air enters this way it absorbs some moisture from liquid state to the vapor state. Now, to vaporize it let us heat, it absorbs that heat from the hot air itself. So, this is a process where you are not supplying any heat from outside, but there is a change it takes the heat from inside itself and gets cooled, so that is a adiabatic process.

So, that is actually you know it is adiabatic humidification, that is what happens in case of a dessert cooler; it increases it is moisture content, looses it is own heat. So, therefore, there is a reduction in the temperature, so this is adiabatic humidification. Similarly, supposing you know I pass it over you know that can be chemical moisture absorption. I can spray of course, moisture straight way, but if it is the same temperature there is no problem. Same temperature if I met then it is actually you know, if I this is this would be isothermal, sorry isothermal humidification if I am here right.

But supposing, this I said that adiabatic humidification I said. Now, supposing I pass it through a bed which can absorb moisture kind of a desiccant, pass it through a desiccant right. As I pass it through a desiccant, the moisture from the air will be absorbed by the desiccant right by the it will be absorbed by the desiccant right.

So, if the desiccant absorbs it at the temperature do not change, temperature is remains constant then; obviously, it will be isothermal dehumidification, but chemical dehumidification also there is an increase in temperature because you are, you know if you basically if you are if you are taking out the moisture vapor moisture vapor; so some amount of latent heat exchange is also occurring latent heat exchange is also occurring. And that a you know that can cause increase in temperature. So, that is chemical dehumidification is this sensible is. So, you can explain all the processes in a psychometric chart like this processes in a psychometric chart like this right ok. So, this is what I ex I mentioned you all here.

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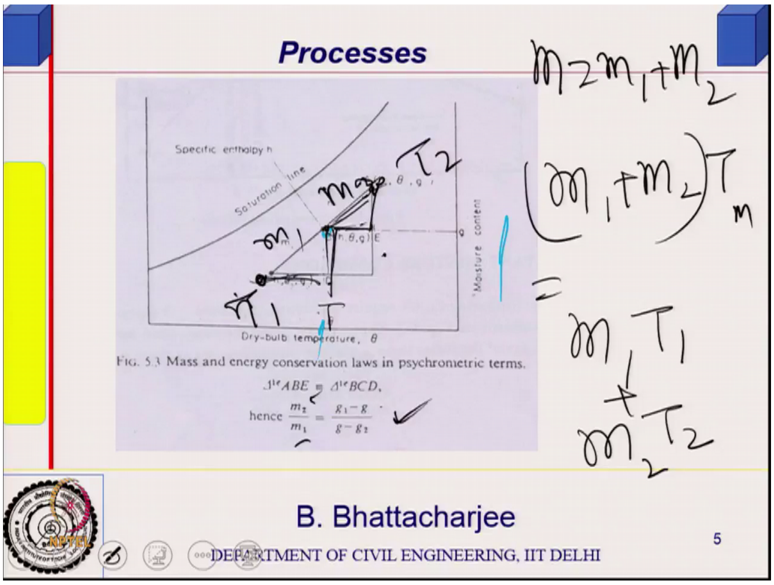

And then next look at this one, now, this is again in the psychometric chart I have got a moisture content, and I have got a I have got the dry bulb temperature here and this is my point. So, what I said is I; if I mix it the low of mixture follows, what I am doing my process would be I have some fresh air and some re circulated air.

And I am mixing them at and each of them are at different temperature. So, if the mass of one is mass of one of them, say in m 1 let us say recalculated air is m 1 and mass rate I am talking of mass rate only, you know in k g per second. And mixing them m 2 and this is at temperature T 1, and this is a temperature T 2 then after mixing in the duct my rate now would be a m 1 plus m 2. And since there is no loss in temperature this multiplied by final temperature T, which is a mixture temperature must be close to a m 1 plus T 1 plus m 2 plus T 2.

So, basically mass flow rate would increase m will be given by now my mass, mass of the mixture will be m 1 plus m 2, mass of the mixture mass flow rate of the mixture will be m 1 plus m 2. And it is temperature so if 2 I am mixing, if I mixing at 2 different temperature you know we can show that is linear, but less look at the algebraic part first.

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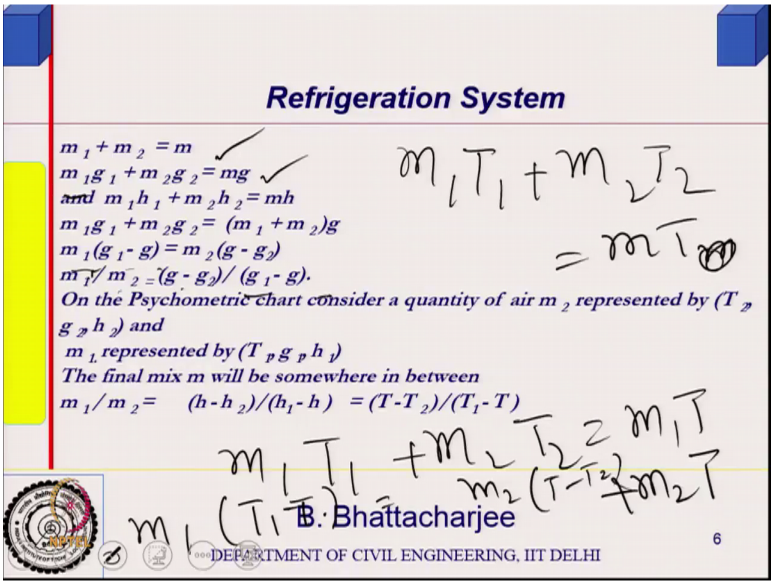

So, it is something like this; the mass will be m 1 plus m 2. The temperature would be m 1 plus T 1. Temperature will be given as m 1 T 1 plus m 2 T 2 is equals to m T mixture or T if I all make it simply. Similarly, the moisture content will be given as m 1 g 1 plus m 2 g 2 is equals to m g. And similar also specific enthalpy, so law of mixture follows and you can see that simply you know this one can write this like this m 1, if I have this expression simply I can write it in this manner.

You know I can write it in this manner, I can write it in this manner, simply I can write it in this manner ok. For example, I said this is the relationship. So, m 1 T 1 plus m 2 T 2 is equals to m 1 T plus m 2 T right? T is the final temperature of the mixture. So, I can bring it one on side m 1 T 1 minus T is equals to m 2 T minus T 2. Or something I can do for g, we can see that m 1 g 1 minus g is equals n 2 g minus g minus g 2. The ratio of m 1 by m 2, so that change in moisture content or change in temperature, ratio of change in temperature is kind of inversely related to rate of (Refer Time: 09:26). For example, m 1 and g 1 minus g m 2 g by g minus g 2.

So, this can be expressed again, this can be expressed in a psychometric chart like this for example, this is this is point a point 2. Now temperature you know this is the this would be m 2 m.1 supposing this was in this one is T 1 this is T 2 right T 2. So, proportional it would change accordingly because this you can I can see that T minus T 1, T minus T 1 or T minus T 2 this similar triangle this 2 similar triangles are similar. You know for T minus T is this T minus T 1 divided by m 1 must be equals to T 2 minus T 2 minus T divided by m 2. You know so this relationship for g or T or anything H it is valid actually. M 2 by m 1 is equals g 1 by g divided by g minus 2. So, it can one can express this in psychometric chart also.

But does not matter we just for this for sake of explanation because today I know will generally be calculating this very simply from the equations given. So, supposing I tell you, the rate because one of them say; fresh air supply I need from hygienic condition. Now my this T if I have fixed my supply air temperature differential, then T 2 also would be known to me you know. So, finally, the [prop]- how much will be the fresh air supply, you know I can I can using this equation I can calculate this all. So, we will do this example, but just let us let us go back to this.

So, that is you know that is one on the psychometric chart all this kind of this thing you can explain for all you can represent them. But for our understanding or calculation purpose we will simply use a as every equations. So, so that is number one.

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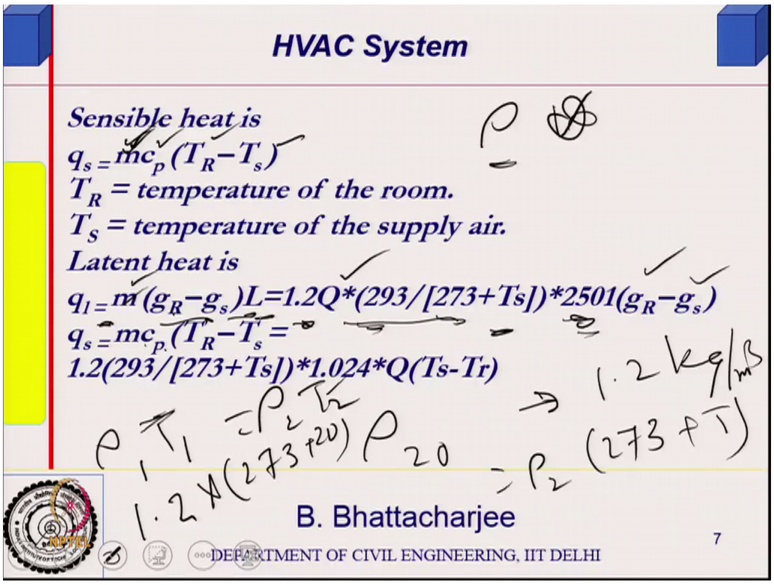

Number 2 is issue is as I said sensible heat removal is given by mass flow rate into specification into room temperature minus supply air temperature. And latent heat removal is same mass flow rate g R minus g S into latent heat. Now mass is nothing but rho into volume. Rho itself is a function of temperature and what we do we know that at 20-degree centigrade rho at 20 degree centigrade is 1.2 kg per meter cube. And we know that rho 1 you know this is rho 1 T 1 is equals to rho 2 T 2 from ideal gas law. From ideal gas law rho 1 T 1 is equals rho 2, right.

So, therefore, this is 20 degree centigrade 1.2 multiplied by 273 plus 20 is equals to rho 2 into whatever that T is, 273 plus you know this is all in absolute temperature for 273 into whatever my T is. So, this therefore, what we do is 1.2, q is the flow rate let us say not v we are not using v, here Q is a flow rate into 293 divided by 273 plus supply air temperature right? This is latent heat this is latent heat of latent heat of evaporation of moisture is 2500 0 1. And this is a moisture content minus the room moisture content minus the supply moisture content.

So, this is this q l latent heat transfer is given by this formula because latent heat transfer is mass flow rate into L into delta g. Mass flow rate into delta g into L. Sensible heat will be mass into specific heat into T R minus T S, and which you can write which you can write as 1 minus same you know density part of it into the Q flow rate into T S minus T r whatever it is and.

Student: Not TS minus T r, it was Tr minus TS.

Well depending upon I mean it should be T R minus T S only, there is no you know T S because T r will be always higher. So, this will be T r minus T S.

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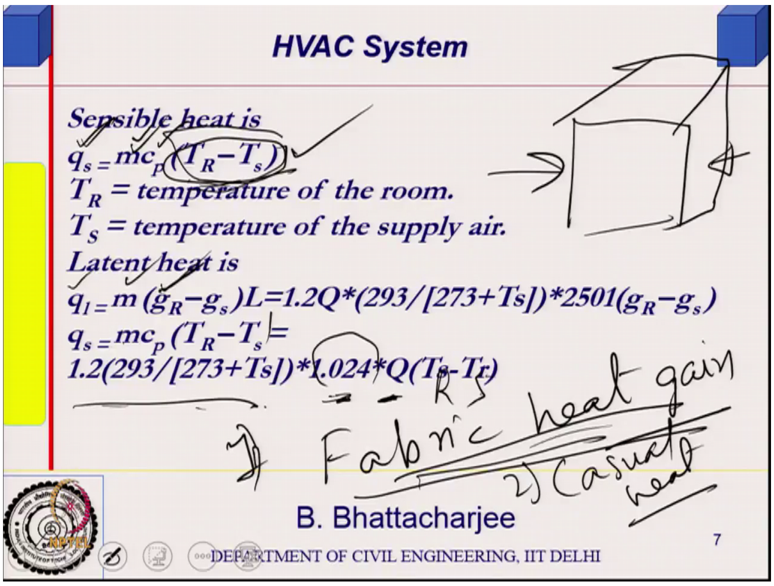

I mean you want to absolute value of that has to be taken anyway T R minus T S, and specific heat is given by 1.024 specific heat is taken to be 1.024 right ? So, this is the density there is a you know Q is a volume, in this specific into T R minus T S, so that is what it is.

Now, there are 2 equations available to me first of all for a given room supposing I have any room on any space basically, what will contribute to the latent heat? I mean sorry sensible heat; the heat coming from outside you know, heat coming from outside fabric heat gain. So, what we call as fabric heat gain. And you we elaborate ways of calculating this, but in this class you are not doing that ok.

So, you have elaborate weight of calculating this because this would involve you know like; if we are looking only at the capacity. So, I will consider the pick situation, pick it, but otherwise it varies from time to time of the day and you know fabric heat gain because solo radiation outside would change temperature outside would change. So, one has to depending upon you know the location that you are dealing with say Delhi or other place. And every orientation of the walls, roof etcetera, you know so many is fairly you know elaborate process. But our purpose here we take the design fabric heat gain for which I am designing the system right, for which I am designing the system.

So, fabric heat gain is one issue then there is casual heat gain. Casual heat gain would come from a appliances inside. So, 1 is fabric heat gain 1, 2 is a casual heat gain which will come from the appliances and people etcetera. So, casual heat gain would be this casual heat gain. So, all this heat gain some of them might have sensible casual heat gain. For example, fabric casual heat gain is largely sensible heat gain right temperature changes related sensible heat gain is related temperature changes, but casual heat gains some of it could be even latent heat gain how?.

Because you know perspiration from the human body generous moisture and that is to be removed, so that is absorbed by the supplier. So, there is a latent heat changes, similarly supposing I am working in a space where this you know chances of some for example, let us a laboratory and temperatures to be maintained. There is some processor air moisture is evaporated. So, that that would also contribute to the latent heat because you will removes that much amount of moisture vapor, that much corresponding latent heat have removed, on an restaurant or kitchen. So, there the you know some amount of the latent heat also get also is removed.

So, you remove we remove both latent heat as well as sensible heat. Now what we do is; we find out which one is higher. First we first calculate this now calculation is fabric heat gain, casual heat gain coming from a appliances and human being occupant etcetera etcetera. So, this totally sum up right rate of heat gain we sum up actually. And also both separately we do and we just now find out which one is higher.

Supposing this is higher sensible heat gain is higher which is a case usually or let us say latent heat is higher. Now let us say sensible heat gain is higher then what we do; we have to decide upon this based on the principle that I mentioned earlier, what is that principle? Because if you make this too large if this differential is too large then your insulation record will be more. So, cost of insulation will increase. And if you keep it too low then this has to be.

Student: Increased.

Higher, so duct size will increase and if you want to keep the duct side at lower the velocity then will increase the noise could be there. So, based on this is bi enlarge fixed we first decide that will keep a 10-degree differential or 8-degree differential some differential fix it up. Once I have fix it up this is what I have calculated from fabric heat gain etcetera etcetera. Sensible and latent heat gain I mean sensible heat gain from fabric or you know otherwise from casual gain. So, in that case; I have calculated this is known to me this I have this I have decided, this I have of course, I cannot do anything there is already is a you know is related to the air itself. I can find out the flow rate, mass flow rate I can find out.

Now for this given mass flow rate, mass flow rate is now fixed and I would like to know what is my g R, g R is also known because relatively humidity inside the room is known. So, when relative humidity inside the room is known; from the known from the known relative humidity corresponding moisture content I can find out, either using psychometric chart of using some equations. Either using psychometric chart or using some equations right I can find out this g R values, I can find out this g R values.

So, moisture content within the room will be known and then how much I want to remove, because g S would depend upon you know g S if, if g R and g S is same no moisture will be removed. So, latent heat and it to be removed, I calculated it out because casual heat gain might result in some requirement of latent heat removal.

So, latent heat how much I want to remove that I know, m S been already fixed, g R I is known. What should be the value of g S; that then I can find out. So, first step is calculate out the sensible heat gain and latent heat gain. Some information must be available to you for example, how much is a fabric heat again that has to be known to you for which you are designing fixed value not changing a fixed value because your duct etcetera etcetera is fixed for a given value. So, fabric heat gain what is a possibility of fabric game that you would like to know for which you are designing.

And then what are the you know function of the room for example, knowing the function you can find out how much will be a casual heat gain, say if we considered a classroom it might be operating, let us say 80 percent population is full. So, 80 percent means that class capacity let us say is 60. So, about 50 you might design for 50 full right so because you take at even diversity factor you can take into account might design for something like 50 or something of that kind.

And then for that many persons; how much you can expect the moisture perspiration from per person that is known. And therefore, that much latent heat is to be removed that you can find out. So, will do an example calculation and we will see for a restaurant case. So, you can find out how much latent you want to heat you want to remove, and if there are 50 people there be metabolic heat gain from each person, sensible heat gain from each person.

So, fabric heat gain capacitor you know pick fabric heat gain you know, you know at this design condition what will be the heat coming from people etcetera etcetera. Total heat to be gift to be taken out, sensibility heat to be taken out and latent heat to be taken out even find out. Once you have done that this being known rate you can find out. Rate is known moisture content you can find out because this is known so that is what it is. So, this is you know this what would be our exercise, this is what would be our exercise.

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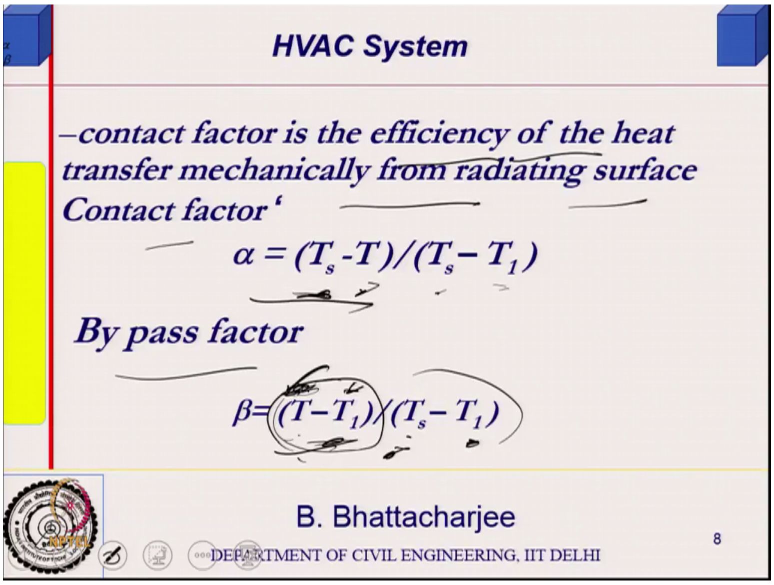

But there is one issue of course, we must take into account is that the something called; you see you have supply air coming in from?

Student: Outlet.

Outlet of the duct, but then it is in a whole room temperature could be quite different then near the duct temperature right? So, there something called contact factor contact factor is efficiency of the heat transfer mechanical from radiating service this is more important for heating actually, because they are the radiating surface is near the surface temperature is very high, room temperature is lower. And you know alpha is what is called contact factor beta is bypass factor. So, sum total of this 2 is equal to 1, contact factor is given as supply air minus the room temperature right ok. And average room temperature and supply temperature. This is the room temperature and this is near the duct itself, near the duct itself.

Student: (Refer Time: 24:10) near the duct.

Yeah because this is the bypass factor no, this is the amount that is bypassing this is the amount supply you know this just a minute. Because this is the amount which is by passing; that means, this is not available to me. What I am getting is yeah this is this right. So, this is what is T is a room temperature, if it is a heating system, cooling system this will be lower; this will be higher in fact, near the surface. If it is a heating system room temperature would be in all cases is a cooling system, if it is a cooling system this would be higher and this would be higher, this would be lower yeah that is right.

So, in a cooling system this will be higher this will be lower, near the duct this is what it is so T is room temperature is higher than the near surface temperature. So, this is what is the bypass, actually this is what is the bypass factor. Sum total of this is equals to 1, actually it should have been same. Supply air temperature should have been all you know near to the I mean the basically the near the duct and room that should have been same actually. Here there is a basically there is a difference. So, this difference this is contact factor this is called one of them is a bypass factors some total of this is actually is to 1.

So if I sum up actually T gets cancel T S minus T 1 the other sort of this it is. So, one is bypass factor means that is not a variable that is you know that is going out, so that is what it is.

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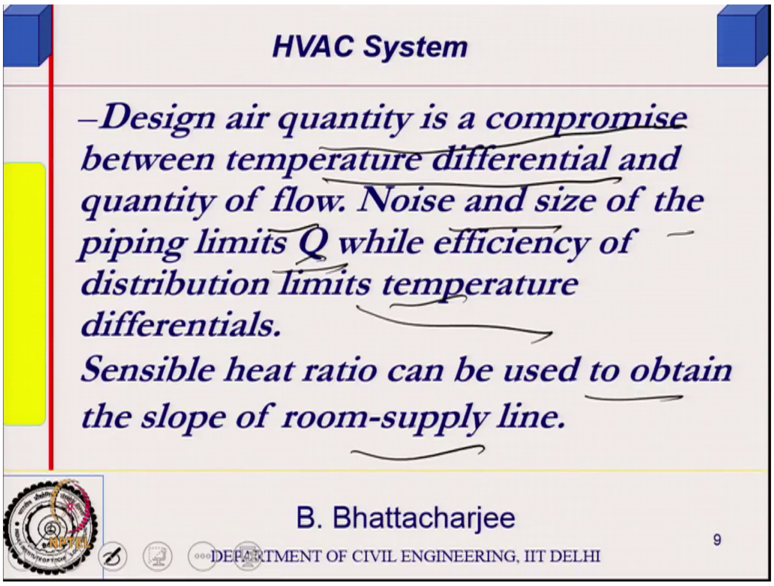

So, that is right that is that is sum of this thus is a 2 issues separate issues just I discussed. Now, summing it up then, design of air quantity you know what I mentioned earlier, I am just again summing it up. Air quantity is a compromise between temperature differential and quantity of flow. Noise and size of the piping limits Q right? Quantity of flow because if you want to size if you want to Q, either size you already increase or velocity you will have to increase. So, therefore, noise and size of piping restricts Q limits Q, while efficiency of distribution limits temperature differential right?

Efficiency of the distribution means insulation required losses would be higher. If you what if you know if you put if the supply air is at if you cool it to a lower temperature, the tendency of losses it would be higher, because rate of heating now from the surrounding you know absorption heat from the surrounding. If the temperature is low it will tend to absorb more heat, so this is what it is.

So, this is this is this is what dictates. Sensible heat ratio is basically ratio of sensible heat to total heat removal for example, Q S divided by Q S plus Q l, how much proportion of the total removed is this much. So, this can fix the slope of the whole thing ok, obtain the slope of a room supply line right. So, then this is this is basically this basically the guideline I mean idea; why we you know how we why and how we keep the temperature differential fixed. And then you know why you keep the temperature differential fixed first to find out the flow rate, and then estimate basically the you know temperature, supply temperature and supply moisture content ok.

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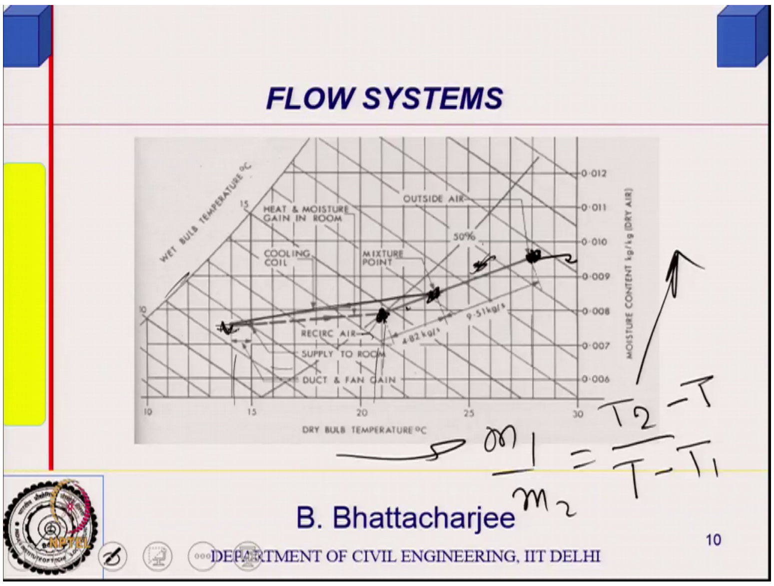

So, let us see now how it looks in a psychometric chart again. So, it is it is something like this let us say this is this is let us say outside air temperature. This point in a psychometric chart, this is absolute immediate moisture content this dry bulb temperature. Therefore, outside air I can represent in a psychometric chart. So, this the moisture content of the outside air this is the temperature, this is the outside air right. Now room air is sum where here right.

So, room air is sum where here this is the room air and then I mix them up in some proportion. I like to keep the fresh air requirement to a minimal because I mean; you know room air outside air that is the fresh air require to a minimal, why? Because if I keep it high, my cooling cost will increase. Like to maximize recalculated air now, but there is a minimum requirement minimum comes from hygienic condition. So, therefore, I mix ups and mix temperature, mixture temperature will be somewhere there because it will be between T 1 and T 2 depending upon the proportion that I am mixing that by that formula that we have talked about you know. So, m 1 by m 2 is equals to it was T minus T 1 and T.

Student: T2 minus T.

T 2 minus?

Student: T.

T, something like this yeah; so you can see that it would depend upon so it will be somewhere in between, I can join them in a line and it will be somewhere in between. So, so this means you know that from similar triangle, this will be my m 2 or proportion of the relative proportion of the or a amount of amount of re circulated air and this is the amount of fresh air. Because you know in inversely proportional as you have seen. So, finally, somewhere in between the temperature will be somewhere in between right?

Temperatures so temperature will be somewhere in between, and g also will be somewhere in between. Now then what I do; I cool it, cool it to a temperature much lower than the room temperature. And if required I might cool it and heat it also a little bit to control the moisture content.

So, I might go somewhere there where the there will be some amount of condensation as well may be if it is reaching the dew point, but of the condensation is required not required I will simply this is the supply air temperature and moisture content. Then it will come it will room you know it will absorb this much of this is the amount of this you know it absorbs this much of heat. So, it will have 2 component, the horizontal component will talk about the sensible delta T changes correspondingly. There will be some sensible heat removal there is a vertical absorption or moistures. So, there will be some latent heat removal as well. So, that is why you know; so if it is straight line then sensible heat gain. The air will have some sensible heat gain and it will have some latent heat gain also.

So, that is that is the process actually, so supply air is somewhere there. There will be some losses you might have to take care of the some of the losses in the duct. So, supply air temperature still work because it take care of the losses in the duct. So, losses in the so, that is how one can you know this is the process is something like this.

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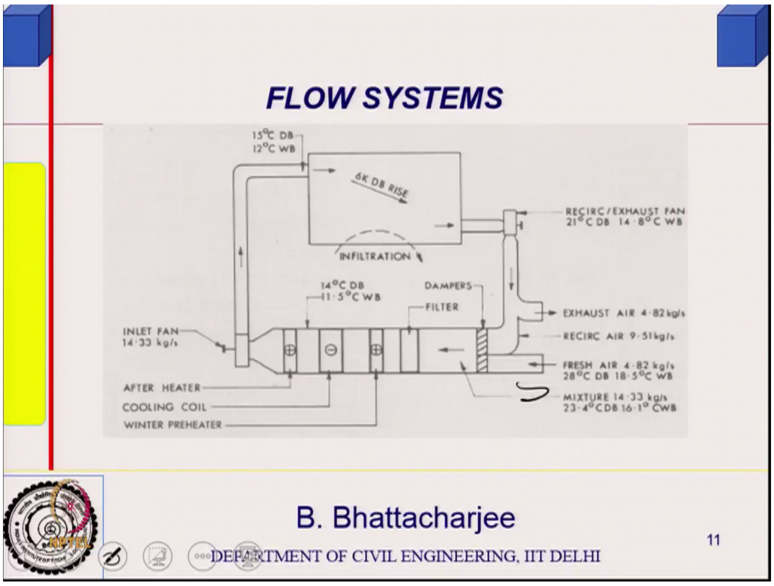

So, what will do is; in the next class we will look into this is a same thing it is been what I showed earlier. And then will take up in a example case and solve. You know this is a form of an example case actually, where we have fresh air supply is given then you got re circulated air right? From the room it is coming they get mixed up there are dumpers, and filter, and then there is re heating winter heating, and then there is cooling and air heater etcetera etcetera. So, that is what that is, what it is all right. So, we will look into that in the next class.