INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-26
Psychrometric Processes-3

With
Prof. Ravi Kumar
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Hello, I welcome you all in this course on refrigeration air conditioning today we will continue with psychrometric processes and this is the last lecture on psychometric processes. Today we will be covering evaporative cooling, winter air conditioning, winter air conditioning we with recirculation winter air conditioning preheating with exhaust air.

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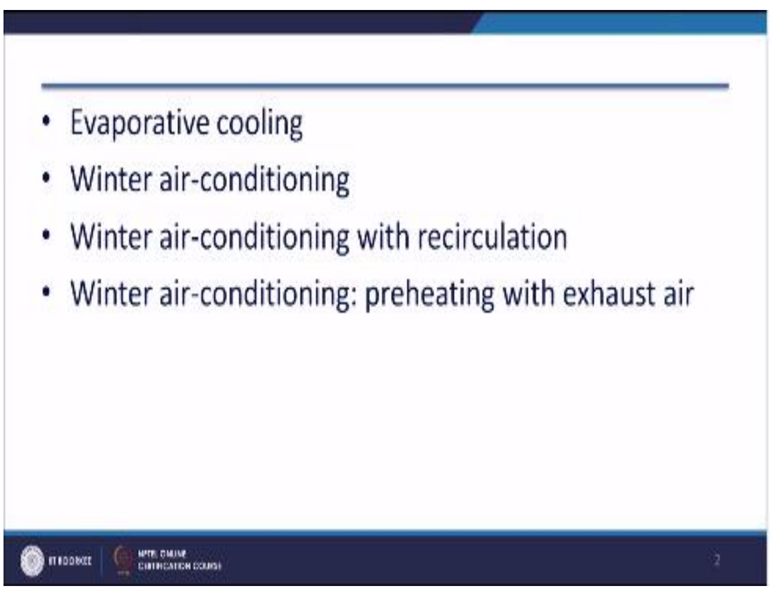

Now all these measures recirculation, preheating with exhaust here these are the measures taken in order to save energy in air conditioning system. Before we start because we are doing a lot of mixing in the air conditioning systems so I should repeat the concept of mixing that.

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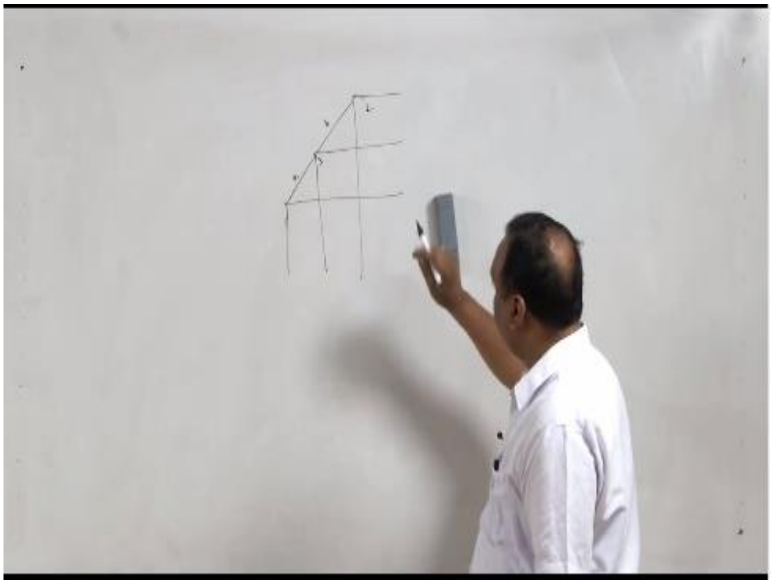

If they are to stream at state 1 and state 2 and they get mixed right, and the length mixed and we get this state 3 and this length is a this length is b, then m1/m2=b/a reciprocal of this section or on a psychrometric chart we can take in terms of temperature also this segment is t3-t1 segment b=t2-t3 or in specific humidity in the form of a specific humidity. In previous lecture also I explained you this. Now the benefit of mixing as I told you earlier is regarding the saving of energy.

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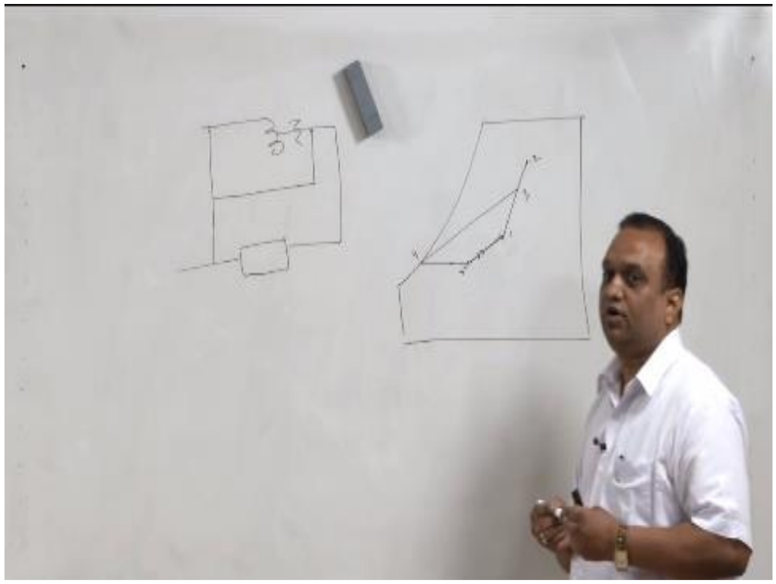

So in a psychrometric process the moment we mix the two streams the saving of energy takes place for heating we consider two cases where the mixing this was the return air this was a supply air and mixing took place and then heating and then this is return air and then heating and this is a room load line, this is this heat is attained in the state 1, state 2, state 3, state 4, state 5 this heat is attained inside the room.

Now mixing this is the mixing of exhaust air before the cooling coil, it means this is the cooling coil and this is room and air coming out of the room is mixed with the exhaust. In one of the cases if you remember that here also we mixed and part of the air is also mixed after the exhaust coil or after the heating coil. Now if it is mixed after the heating coil then the point mixing will take place between 5 and 1 and the point will lie somewhere here.

In some of the system heating coil is not there for example, small capacity system, split air conditioners, heating system is not there and they have certain bypass factor.

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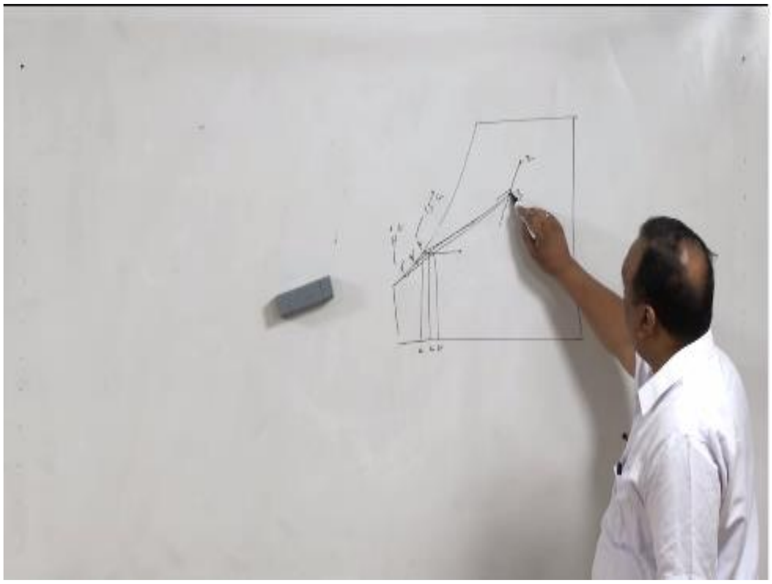

And air is directly supplied to the room after the cooling coil and here if the mixing takes place after the cooling coil split air conditioning there is no mixing at all, return air is mixed with the fresh air it is here not here. But in that type of system is mixing takes place after the cooling coil the position will be somewhere here we will solve some new miracles on actual air conditioning system in when we will solve those new miracles the concept of this mixing will be more clear to you.

Now second thing is bypass factor, now suppose I want to have state this state for cooling and reading in the so one possibility is this when bypass factor is 0 another possibility is this when bypass factor is let us say 0.1 then we will supply air temperature will rise a little, another possibility is when bypass factor is 0.2 or high bypass factor then supply will air will be at relatively higher temperature state ABC, A is the case when bypass factor is 0. Then bypass factor let us say bypass factor is 1, 0.1 we will be getting B higher bypass factor we will be shifting on this side.

But it does not mean that we are saving energy when we are shifting this set because when we are here then this much heating is required when this point is shifted to this point only this much heating is required when this point is shifted to this point only this much heating is required, and this is the supplier state of supplier say when the bypass factor is increasing we are getting p suppose q and r, the temperature of r is definitely lower than the temperature of p. Suppose this temperature is let us say 15˚C and this temperature is 10˚C right, outside temperature is same return temperature or mixing temperature is same or if you are taking 100% outside here let us take example of 100% outside here.

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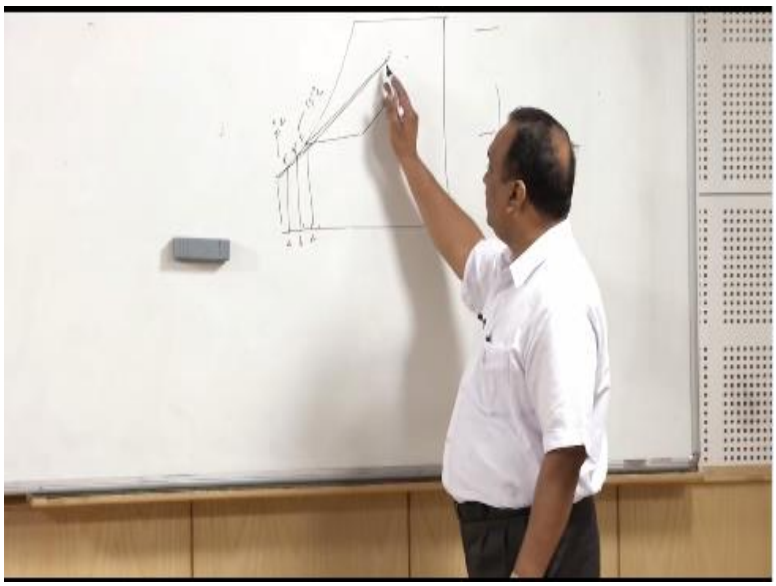

So if you are taking 100% outside air this is supply 100% outside here, 100% outside here and 100% outside here, this should be shifted to ABC, so if you are taking 100% outside here in that case also or it is a mixture this coil temperature is reducing if we are increasing the bypass factor, it means the temperature difference between condenser and the evaporator is increasing when this temperature is increasing it means we have to increase the capacity of the plant or for, or in induction we can say for same type of cooling effect we have to spend more energy.

So bypass factor is not a welcome type of thing bypass factor should be a slow as possible in order to reduce bypass factor the number of rows of the coils are provided that increases the fixed cost of the equipment but the recurring cost goes down because in this case energy consumption is less, so these two things I wanted to clarify because it appears from this diagram that if you have higher value of bypass factor you can save energy in the heating of here, but that is not the case.

Ultimately you will end up in paying more for the energy consumption. Now evaporative cooling system in evaporative cooling system as all of us know there is a washer and here is blown over the washer and when the air is blown over the washer.

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The air follows the constant wet bulb line, suppose air is available at state 1 it goes up to state 2 and after taking load it may at any state 3, but this process 1 to 2 is evaporative cooling then it follows the constant verbal line. There is a efficiency for a evaporative cooler also and that efficiency is this actual temperature drop and that maximum possible temperature drop this is known as effectiveness of evaporative cooler.

Because in evaporative cooler we never get 100% saturated here okay, we may get 90% or 80% saturation of air in that case the effectiveness of the operating cooler will be this temperature drop divided by maximum possible temperature drop now we will take winter air conditioning.

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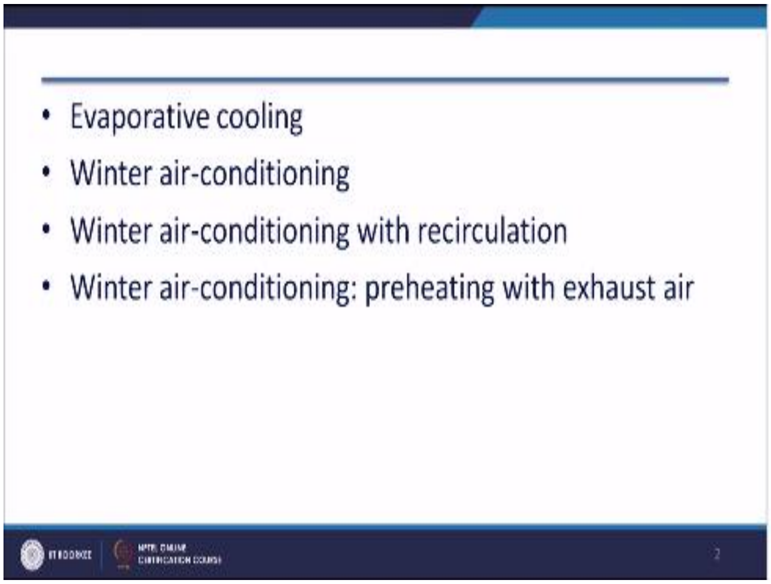

Now winter air conditioning, now winter air conditioning heating has to be done and as I explained earlier during psychometric processes.

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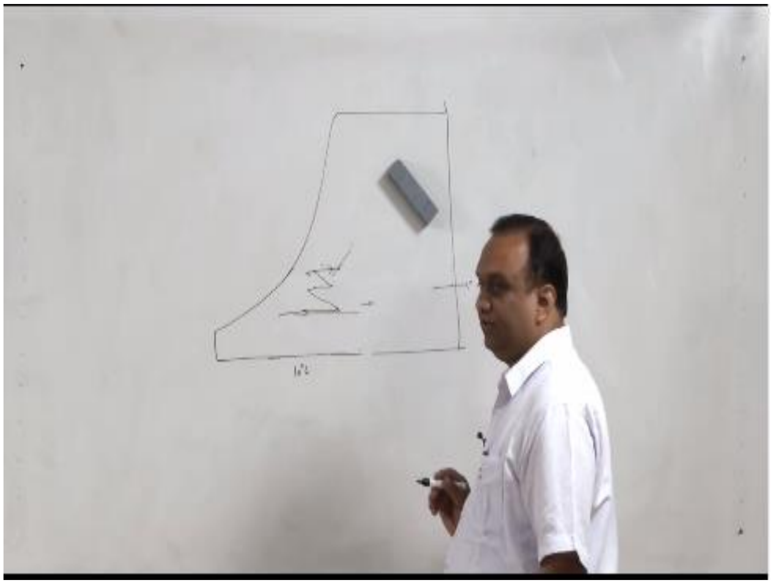

If the heating is done suppose this is something 10˚C when the heating is done sensible heating if you do sensible heating the radio community will in decrease this is maybe say this is 70% so this may reduce to let us say 30% you keep on heating the air the relative humidity will keep on reducing however the specific humidity will remain same. So while cooling we have to increase the humidity also, so how we can increase the humidity there is only one way of increasing the humidity is add some air at air sorry, add some water.

And water can be added by adding the, by putting the air washer on the circuit so the process can be like this initially we may heat initially we may heat, suppose this is the initial state, this is the initial state so initially we may heat and then it is pass through the evaporative cooler and then again reheating. In this case we can get so heating evaporating cooling and then again heating. So in such by following this path we can attain the final state.

Now this can be done in more stages but that will cost that will increase the cost of the system that you have ready cooling then heating then evaporative cooling and again you are getting this state. Because in heating with the moment you start heating the air the relative humidity starts reducing so definitely water vapor has to be added in the air so that humidity is maintained the same type of process we will draw on psychometric chart.

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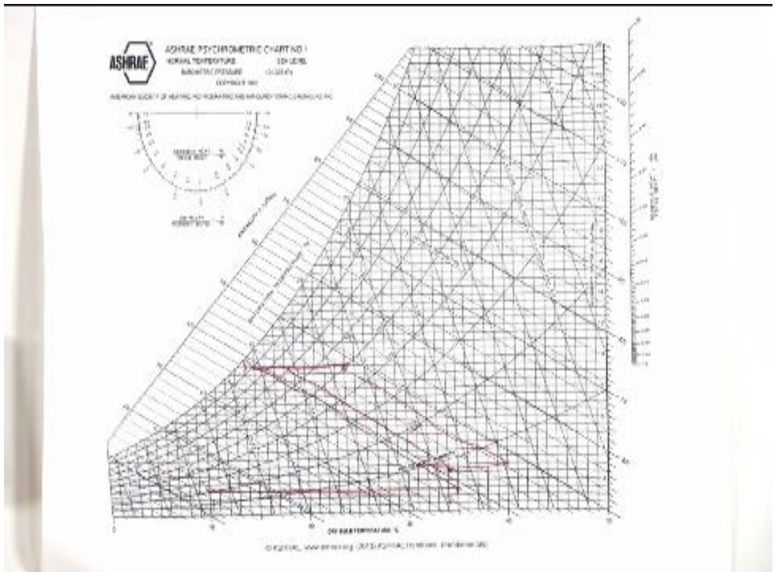

So here we can take some temperature let us say outside air is available at 8˚C or 10˚ let us take 10˚C and relative humidity is 20% it is dry air at 20˚C and we have to come here 25˚C I explained it earlier also that we are taking this 24˚C temperature and 50% relative humidity as supply condition for the sake of convenience only. Otherwise in a normal air conditioning system the supply temperature is less than this, only then we can get temperature in the air after picking heat in the room we can get temperature of air approximately let us say 24˚C and the temperature of air leaving the room maybe at 26 or 27˚C.

So here we will come back to the this heating process so 10˚C and 20% relative humidity the air is heated, air is heated air can be heated up to let us say 30, 35˚C right, and after heating 35˚C evaporative cooling can be done we can follow this constant wet bulb temperature line, we will follow this constant wet bulb temperature line and then from here the heating can be done, right. So the entire process is like this, so the entire process is like this, from state 1 to state2, state 2 to state 3, state 2 to state 4.

Suppose air is available not at 20%relativehumidity let us say 40% relative humidity, same dry ball temperature and 40%relative humidity in that case less heating will be required, less heating will be required and we can again take this constant wet bulb temperature line and we can come here. We can heat the air up to this is a designers choice we can heat the air up to this point if you are heating air up to this point then you will have to follow this line and then heating. Now the question is cannot we heat the air up to this point so that there is no reheating is required you can heat the air up to this point. I will explain I will draw this on the board then things will be clearer to you.

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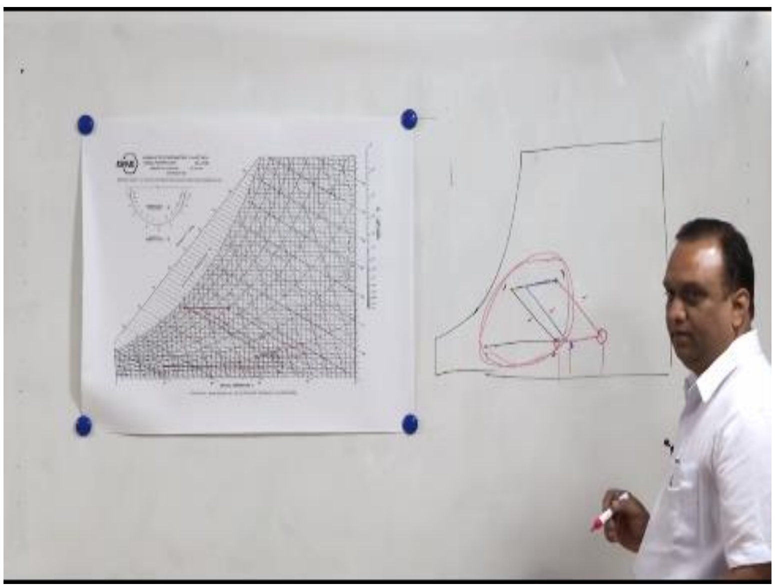

In a psychometric process when the weather is outside weather is cold then heating following the evaporative cooling at that again reheating now 1,2,3,4 and we are getting this state. Now instead of going up to here if you heat up to another temperature, if you heat up to another temperature let us say temperature 3 and then we can heat and we will be saving some energy here. Further we can further heat up to here and then do evaporating cooling, so which process we should adopt should we go for this process, this process, in this process.

Now if you notice in this process the air which is emerging from heater is on higher temperature, air which is emerging heater is from lower temperature. So these process this process 1,2,3,4 is confined to the low temperature, right. The moment we are shifting on this side high capacity heaters will be required, now high capacity heaters will have right, definitely will consume more energy so definitely this is a preferred process 1,2,3,4 in this case.

If we go up to this from here you can see we will have to heat air upto 40˚C and after 40˚C it will go for evaporative cooling, so unnecessarily we are adding this heat and we are then removing the heat, so this can be avoided if we choose judiciously choose a path which can provide minimum energy consumption in attaining final state from the initial state.

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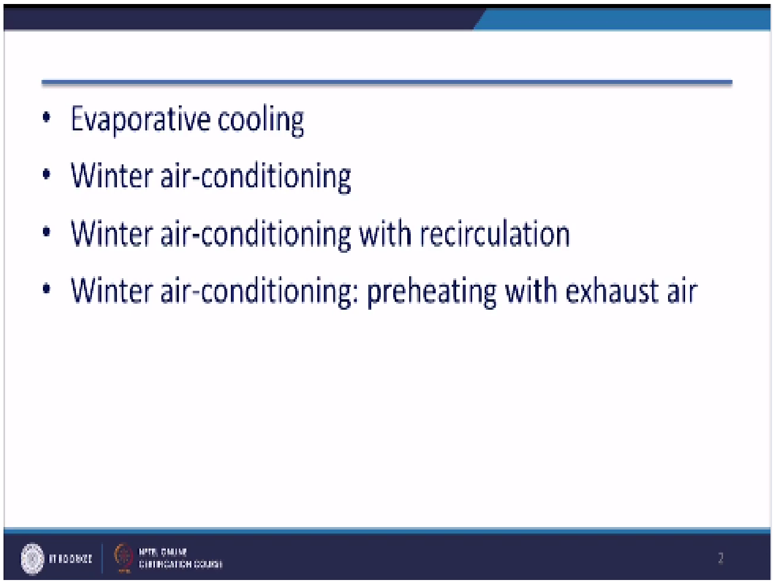

Now last one is winter air conditioning preheating with exhaust air, now exhaust air coming from the room. So if we draw a circuit for exhaust air.

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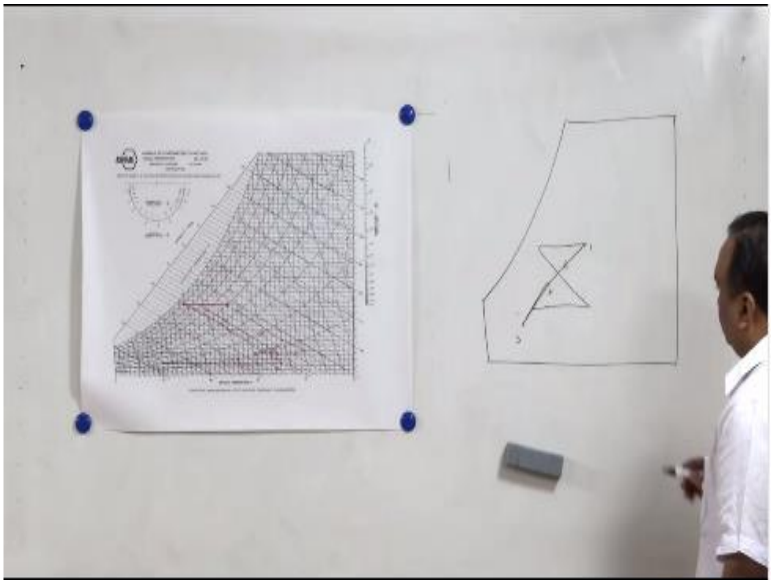

Winter heating then sorry, we will start with the exhaust because, heating up with the exhaust air is taking place so this is load line let us say 1, 2 this is exhaust here heating it is getting mixed with the outside air 3 is outside air, so this is it means at state 1 the air is entering the room and state 2 air is leaving the room this air get mixed with the outside air and then after mixing the heating takes place heating evaporation and then heating. Now if we want to display this process on psychrometric chart let us assume outside air is at.

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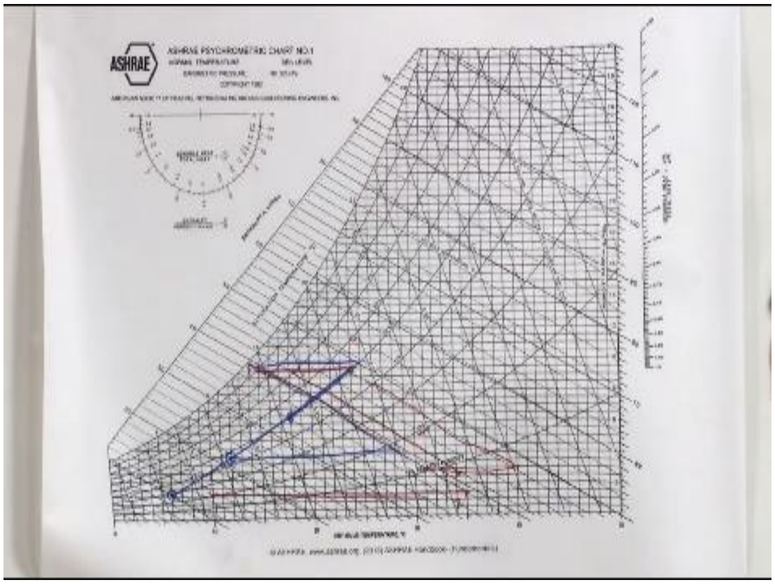

6˚C, so 6˚C air is mixed with the exhaust air suppose the exhaust air is available at 18˚C or 18˚C and 50% relative humidity so this is the load, load line mixing let us say 50 50 mixing is taking place so 50 50mixing means 50% of this and 50% of this I am just taking approximate value this is the mixture state of the mixture, now this state of the mixture will shall be again heated and the same process will follow. If we want to show this on it on a schematic diagram then the diagram shall be like this.

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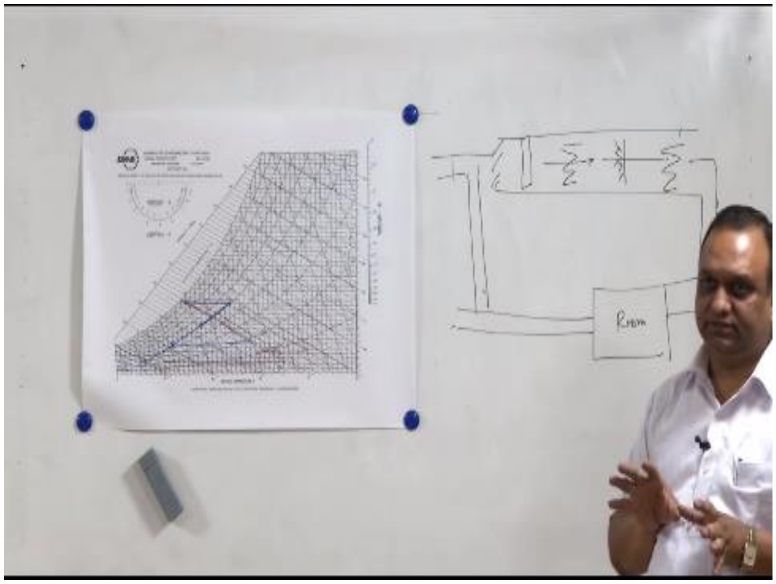

Initially there is a heater this is a duct, it has tempers any filter then there is a heater which is heating the air after heater there is a washer, this air washer after air washer again there is a re-heater and after re-heater the room is the air is supplied to the room, air is supplied to the room now air coming from the room this is again fluid and this part of this air is mixed with the supply air as we did in the case of summer air conditioning.

In summer air conditioning the cold return air was mixed with the hot air in order to save energy here hotter relatively hotter returned the air is mixed with the cold outside air for the purpose of heating of the system. Because these air conditioning systems they are centralized air conditioning system and they consume a lot of energy and these are all mixing processes are all energy saving processes.

So this processes allow us to save energy while doing air conditioning of the building. Now we have completed almost all typical air conditioning processes in winter summer and winter air conditioning processes we have covered the hot and dry weather we have covered hot and dry and hot and humid weather we have covered the winters in I mean winters and we have covered the preheating of the air with the winter during winter and with the exhaust and in for the summer pre-cooling of air with the exhaust. Now before I end this psychometric processes I have forgotten one process is chemical dehumidification. In evaporative cooling the vapor is used for sorry.

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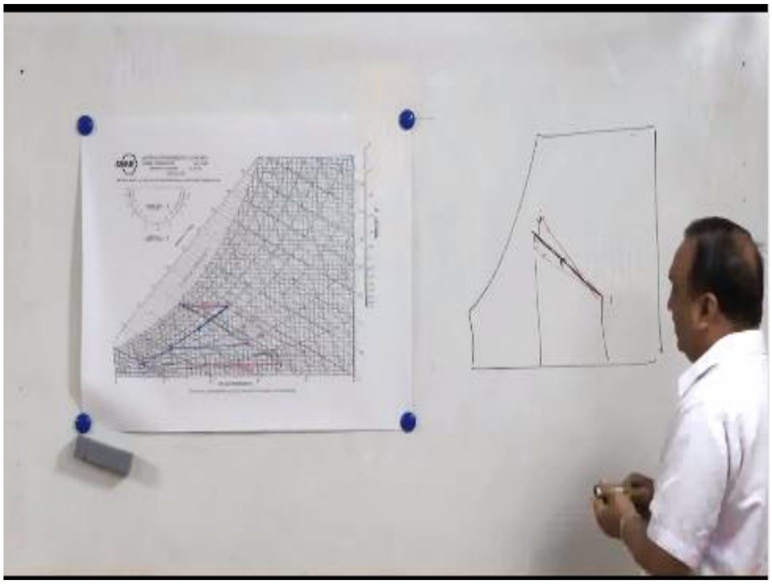

The water is used, the water is used for the for the cooling purpose and evaporation of water brings the temperature down this is during evaporating cooling state 1 to 2 and this line follows the constant wet bulb temperature line, now this is possible only in the case when temperature of water is equal to temperature of wet bulb temperature or temperature of the wet bulb. If the temperature of water which is being used in this process is less than that temperature of wet bulb we will be getting this line.

If temperature is more we will be getting this line, this line so it is always stated that during evaporative cooling the process follows the wet bulb temperature line but wet bulb temperature line can only be followed in the case where the temperature of water is equal to the wet bulb temperature. Otherwise there is going to be a deviation if what temperature of water is less this line will be followed if the temperature of water is more, this line will be followed.

But since these lines are very close to each other the difference is minimal, very less so even if there is a difference in the temperature of air and cooling water it can be taken as the following the wet bulb temperature like. In some of the psychrometric charts you will find that wet bulb temperate there is no deviation in wet bulb temperature line and constant enthalpy line, so therein those chart you can comfortably follow the constant enthalpy line for adiabatic cooling. Another process which I forgot to tell you is adiabatic dehumidification. In case of adiabatic dehumidification it is reverse of suppose.

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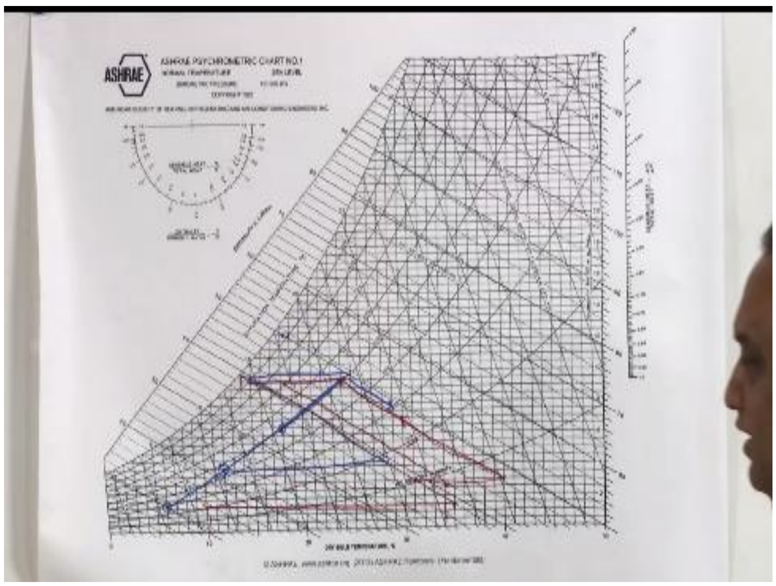

Outside air is at 40˚C and this is adiabatic humidification, now if the process is takes place in reverse direction, reverse direction means in this direction then this is known as adiabatic dehumidification this process is taken into account when the temperature and humidity both are high suppose there is a air available at 21˚C and 19˚C but the humidity is very close it is close to100%, 95% so such type of air supply is also not recommended, very high humidity if I want to reduce then this adiabatic dehumidification process can be adopted.

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And here in pH diagram sorry, in the psychometric diagram it can be shown like this following the constant wet bulb temperature line. now adiabatic dehumidification is done with the help of chemicals and these chemicals they do absorb water in the way from the vapor and water is the water vapor is associated in these chemicals they become wet and it is associated with these chemicals in the form of as so like silica gel.

So if you put the silica gel in moist air the silica gel will absorb the water and in this process the latent heat of condensation is liberated and due to this latent heat of condensation the heating of the air takes place and the temperature of air rises. So it is a reverse it is almost reverse of evaporative cooling in evaporative cooling due to evaporation of water there is a drop in temperature here due to condensation of water there is a rise in temperature of temperature of air.

So this process is also very useful in the case when the humidity of the air is very high, now I think I have completed almost all processes typical processes in air conditioning. I have completed psychrometric processes for the cooling during hot and dry summer or hot and wet summer. I have covered the psychrometric processes for adiabatic humidification, adiabatic dehumidification.

I have covered the winter air conditioning with is recirculation and through air exhaust, but we should remember that in air conditioning processes two things are important well designing a system there one is bypass factor bypass factor should be as low as possible in order to save energy and wherever is possible we should take advantage of waste heat or waste energy so that net energy consumption in the system is minimum. With this I conclude my today's lecture from the next lecture we will take up the infiltration in the buildings. Thank you.

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For Further Details Contact

Coordinator, Educational Technology Cell

Indian Institute of Technology Roorkee

Roorkee- 247 667

E-Mail: etcell@iitr.emet.in.etscell.iitrke@gmail.com

Website: www.nptel.ac.in

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Prof. Pradipta Banerji

Director, IIT Roorkee

Subject Expert & Script

Prof. Ravi Kumar

Dept. of Mechanical and

Industrial Engineering
IIT Roorkee

Production Team
Neetesh Kumar
Jitender Kumar
Sourav

Camera
Sarath Koovery

Online Editing
Jithin. K

Video Editing
Pankaj Saini

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Binoy V.P

NPTEL Coordinator
Prof. B. K Gandhi

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