INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-31
Cooling Load -3

with
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Hello I welcome you all in this course on refrigeration and air conditioning today we will take up the concluding part of cooling load calculations cooling load three in this part today we will solve one numerical and in fact we will design a air-conditioning system for a restaurant so in this problem first of all total infiltration air is 250 CFM.

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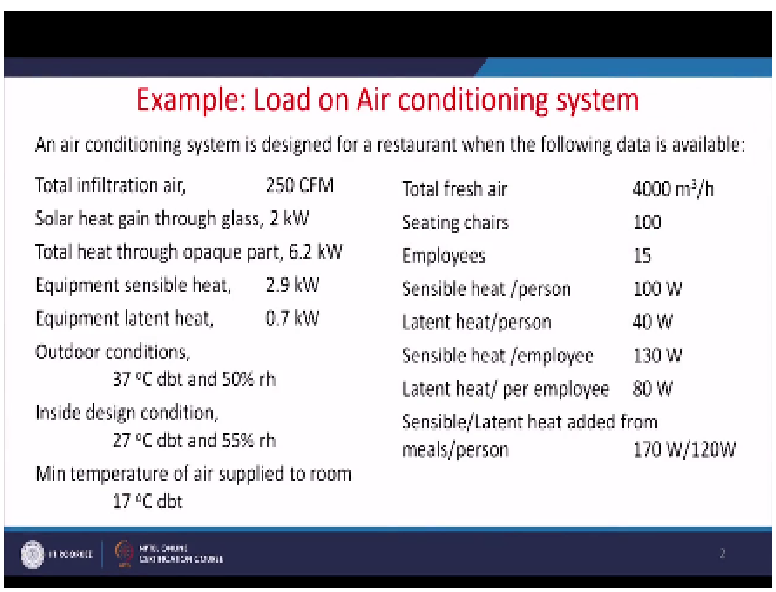

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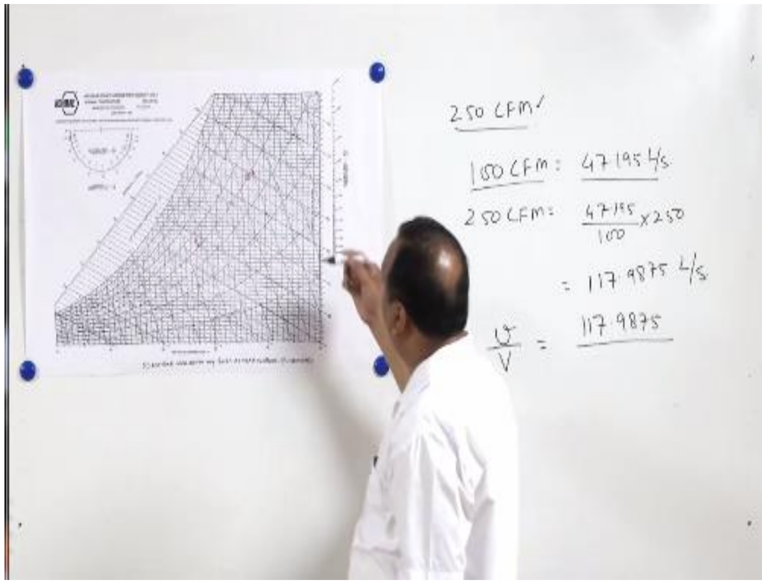

Because we have buildings which are not airtight further in a restaurant the customers they frequently come inside and they go outside so there is a lot of infiltration so this 250cm CFM of flow inside the building has to be converted into equivalent liters per second 1000 sorry100 CFM is equal to 47 0.195 liters per second this is the volumetric flow rate of air inside the restaurant and this will this air which is entering the restaurant is at ambient condition this is ambient air which is coming into the restaurant.

Now the restaurant is maintained at this temperature and air is coming from the outside definitely this air is bringing in latent heat and sensible heat on the Refresh air conditioning system the sensible heat so in order to find load on air conditioning coil first of all let us find out how much sensible heat and latent heat is contributed by in filtered air so in order to find that first of all we will convert CFM in to kgs per second so 2250 CF F is equal to 47 sorry hundred CFM is equal to 47.195 five liters per second.

So 250 CFM is going to be 47.195/ 100 x 250 and that is going to be equal to 1179875 liters per second right now this liters per second has to be converted into the kgs per second this we will do later on let us go through this problem there is a solar heat gain through glasses so in any building the entire building is not opaque part of the building has a fenestration and this fenestration is a village consists of the glasses and the solar heat gain through glasses is equivalent to 2kw total heat through opaque part opaque part means wall ceiling and floor of the building now in a building when the solar radiations falls on the building they fall from all sides there are direct radiations and diffusion additions and heat transfer also takes place through the floor also because outside temperature let us say 42 degree centigrade inside temperature is 22degree centigrade.

There is a temperature differential and heat transfer through floor also takes place and especially in the case of winter when outside temperature is low inside temperature is high the floor temperature goes down drastically and that is why in the building when the floor heating is done that is the best kind of heating in a building in winters when floor heating is done because I told you earlier also the heating should be heating should be done on the lower half of the body cold air should blow on the upper half of the body.

So when the floor heating is done subsequently this heat heats up the other articles kept into the room other objects kept into the room and a person who is occupying this room gets a feeling of comfort so here in this case the because this is summer air conditioning so in this case the total heat through opaque part is 6.2Kw equipment sensible load there may be a number of equipment like toaster heaters cube lights computers printers so their load is 9.2 Kw equipment latent heat some of the equipment they do contributes toward they do contribute towards latent heat also like coffeemaker frying pans right .

So from these equipment a little latent heat is also added into the room outdoor conditions are 37 degree centigrade and 50% relative humidity so we will locate the outdoor condition on the psychometric chart on this axis there is a derive of temperature and these curved lines are relative humidity lines so dry ball temperature is 37 degree centigrade and relative humidity is 50% so 37 degree centigrade and 50 % so this is going to be the outdoor condition now let us call it state A.

So this is going to be the outdoor condition now let us take inside condition also that is 27 degree centigrade temperature that is dry ball temperature 27 degree centigrade dry bulb temperature and 55 % relative humidity so 27 this is 15 and this is going to be the 55 between 50 % RH line and 60 % RH line 27 degree centigrade dry bulb temperature this is going to be the state B so this is outside air condition this is the condition inside the restaurant the air which is getting in filtered into the system shall attain this temperature and this infiltration bring in certain latent heat and certain sense we will heat as well right.

In order to find the sensible heat and latent heat we need to have mass flow rate of air which is coming into the room so already we have volumetric flow rate and this volumetric flow rate when it is divided by specific volume this is volumetric flow rate and when it is divided by specific volume of air which is entering the room will get the mass flow rate so mass flow rate is 117.9875 divided by specific volume of air at outdoor condition.

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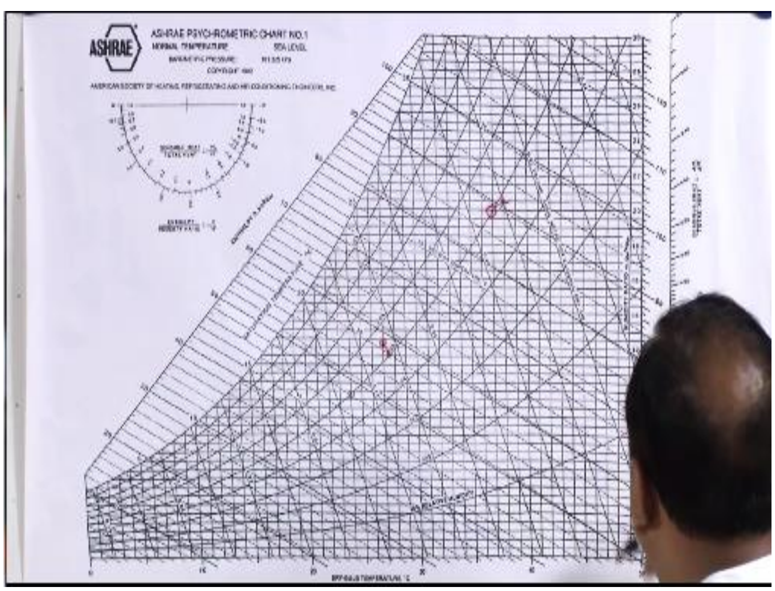

Now outdoor condition the specific volume here it is 0.90 this is 0.90 meter cube per kg line and this one is 0.91 meter cube per kg so this is going to be approximately 0. 9075 meter cube per kg this is liters per second so this has to be converted into meter cube per second meter cube per second of air which is coming into the room divided by meter cube per kg of air so this expression will give 0.13kg per second so the room the so air which is getting in filtered into the room is 0.1 3 kg per second now latent heat and sensible heat associated with this mass flow rate.

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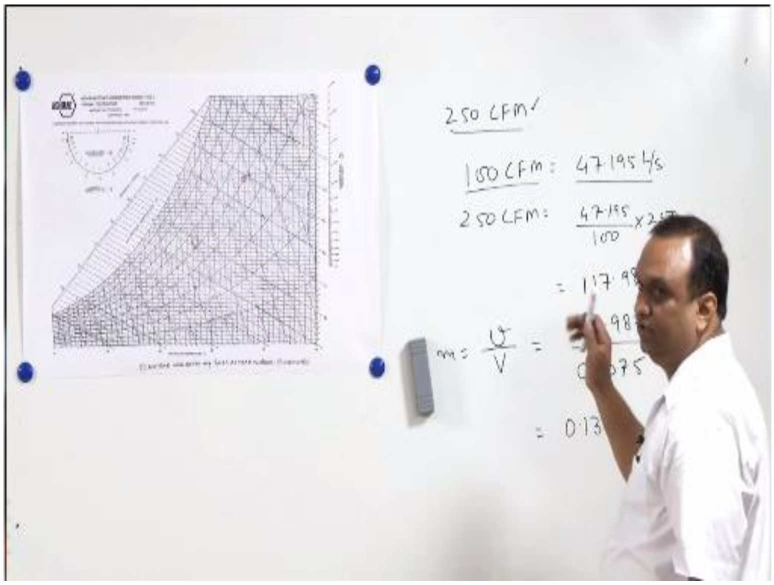

Shall come into the room in form of infiltration so sensible heat.

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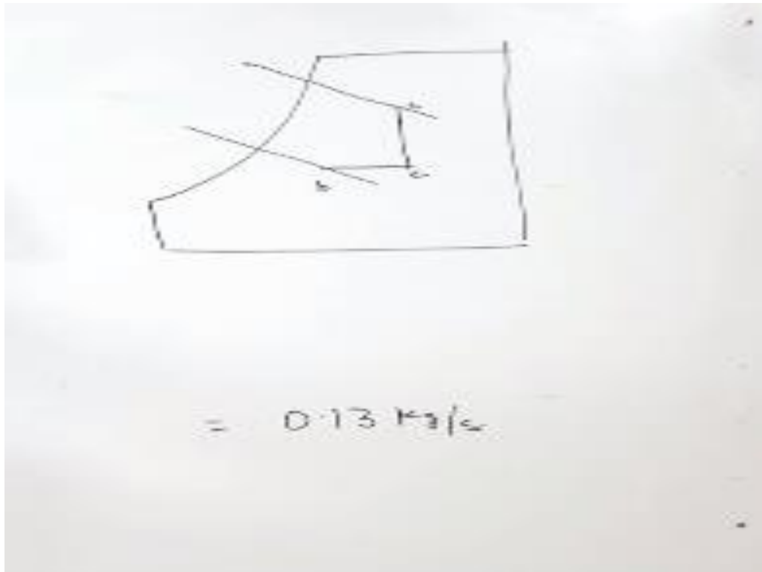

Q infiltration sensible is equal to mass flow rate of air sorry we will get it directly from here we need not do this you will be getting directly from here because here enthalpy is already given so enthalpy is already given enthalpy at A and enthalpy at B we can take from this chart and there is another Point C enthalpy at C we will also take from this chart so enthalpy at A is let us try to find enthalpy at A enthalpy at a is this one.

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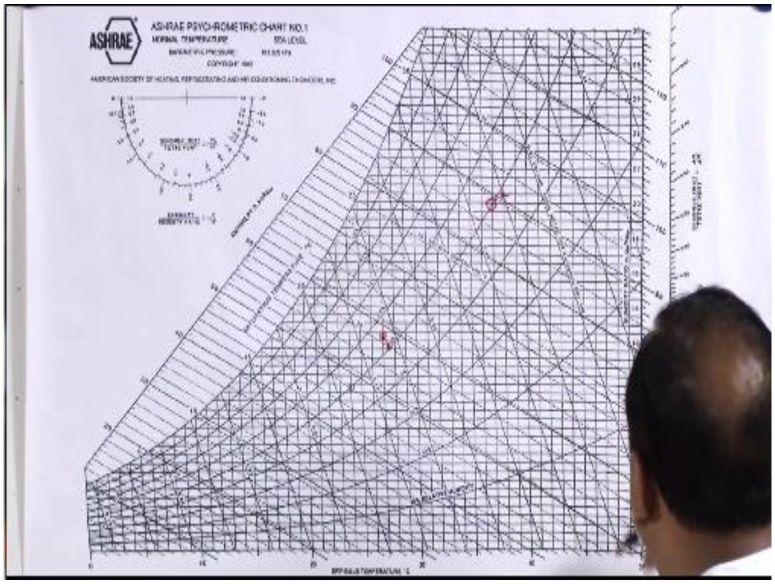

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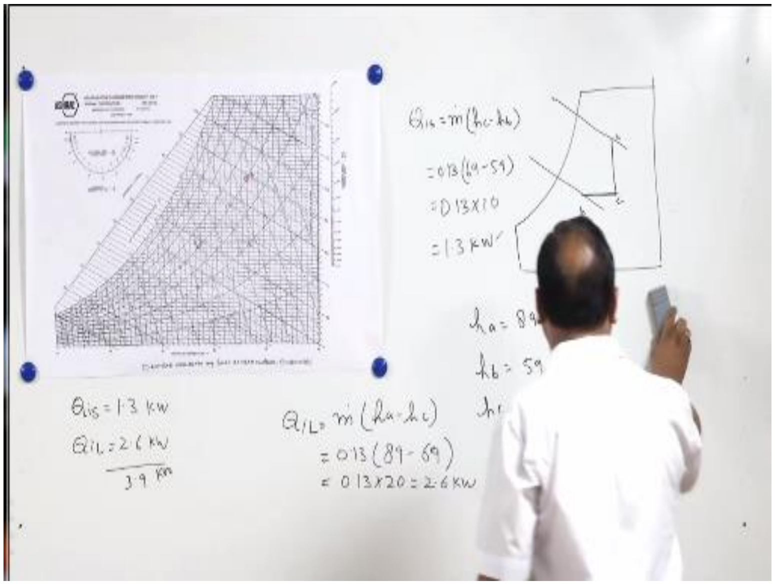

This is enthalpy at A is 89 kilo joules per kg of air hb now hb is this one 59 hb is 59 kilo joules per kg of air and hc first I will have to locate Point C on this chart this is Point C this is Point C and at Point C it is 69 so HC is 69 kilo joules per kg now sensible heat which is coming into the room this is QIs is equal to mass flow rate of air infiltration air x hc- hb so mass flow rate is 0.13 per second hc is 69 kilojoules per kg - hb is 59 kilo joules per kg and that is going to be equal to 0.13 x 10 1.3 kw because kilo joules per kg this is kilo joules per kg and mass flow rate is kg per second.

So kilo joules per kg x kg per second will give k kilojoules per second that is going to be in terms of kw so the heat which is coming into the room is approximately1.3 kilowatts as a sensible heat now regarding latent heat also we can do calculations QIl latent heat is mass flow rate multiplied by ha – hc mass flow rate is again point 13 kg per second he is 89 kilo joules per kg and sc is 69 kilo joules per kg now this is going to be 0.13 x 20 or 2.6 kilowatts so we will write here infiltration sensible heat is 1.3 kilowatt and infiltration latent heat is 2.6 kilowatt.

If you look at this the total heat is coming into the room is 3.5, 3.9 Kw through infiltration it is almost one ton of cooling is required for this only so one ton of cooling will be required for cooling the air infiltration air from this point to this point now we will make a table for sensible heat and latent heat so in order to make a table on sensible heat and latent heat first of all infiltration sensible heat.

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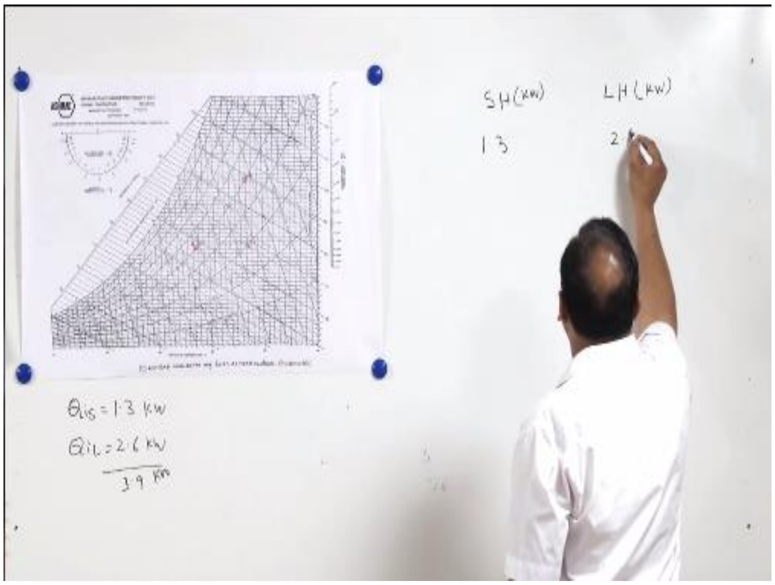

And this one is latent heat so through infiltration the sensible heat is 1.3 kw if this is in kilowatts this is also in kilowatts and latent heat 2.6 kilowatt.

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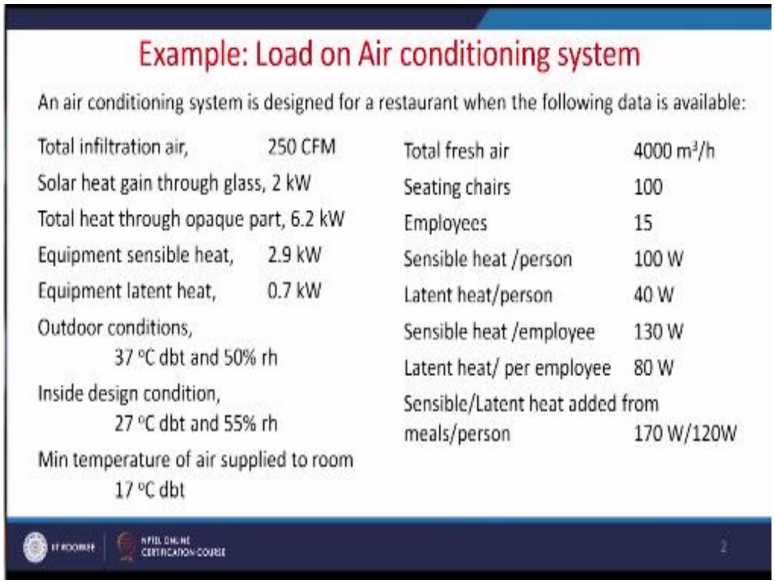

Now second is solar Hyena glass through glasses so solar heat gain through glass is 2kw so this is going to be 2.0 kw that is sensible heat total heat through opaque part is 6 blows opaque part there is only sensible heat transfer the radiations are falling on the outer wall of the building.

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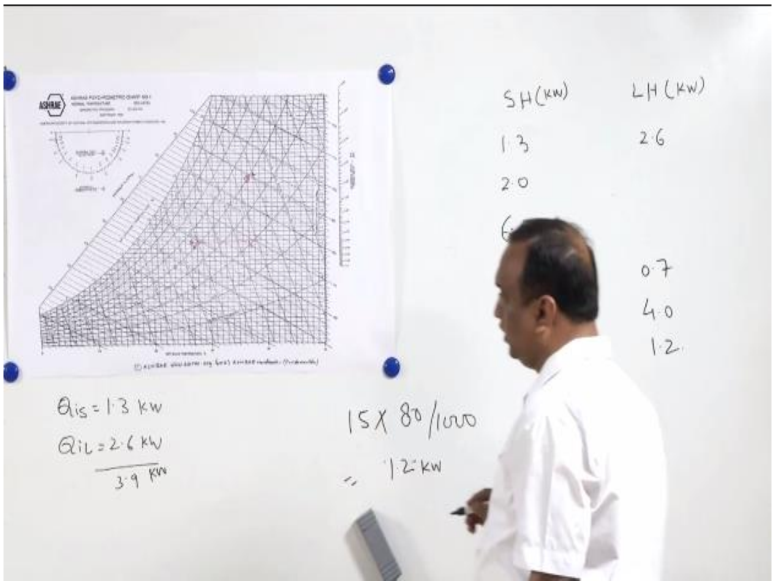

And what wall is getting heated up right and that heat the heat which is absorbed by the wall is subsequently transmitted to the room because outside temperature is high inside temperature is low so there is a transmission of heat from ambience to the room through different opaque parts of the building so this heat is 6.2 kw equipment sensible heat that I have already explained you that is 2.9 kw equipment latent heat is 0.7 kw.

And the restaurant has 100 years there is a seating arrangement in the restaurants for 100 persons to say it and as you know when we are sitting in a room we also emit certain amount of heat and when person is not doing anything I mean just sitting on the chair then sensible heat addition to the environment is of the order of 100 watts it means if 10% are sitting in a room they are already contributing 1kw heating to the room so here the sensible heat per person is 100w maximum capacity is 100 watts.

So let us go for the maximum capacity the restaurant is full so when the restaurant is full then 100 kw multiplied sorry 100w x 100 watts and that will give 10,000 w and or 10 kw so sensible heat addition to the room is 10 kw by occupants latent heat per person so latent heat per person is

40w, 40w so that is going to be equal to 4000 watts or 4kw so each person is contributing latent heat equal into 4kilowatts and sensible heat 10 kw altogether 15 kw.

So approximately it comes around 2.5 tons of cooling will be required for dissipating the heat contributed by the occupants non sensible heat per employ because employees are moving here and there so heat liberated by the employees is more than the person who are occupying the seats in the restaurants so employee each employee is contributing 3130w and their 15 employees so 15 in x 230/ 1000 and that is going to be equal to 1.95kw so sensible heat added by the employees of the restaurant is 1.95 kw.

Now latent heat latent heat by the employees is 80w so again 15x 80/ 1000 so it is going to be equal to 1.2 kw I am dividing this expression by 1000 just to convert watts into the kilowatts so it 1.2 kilo watt.

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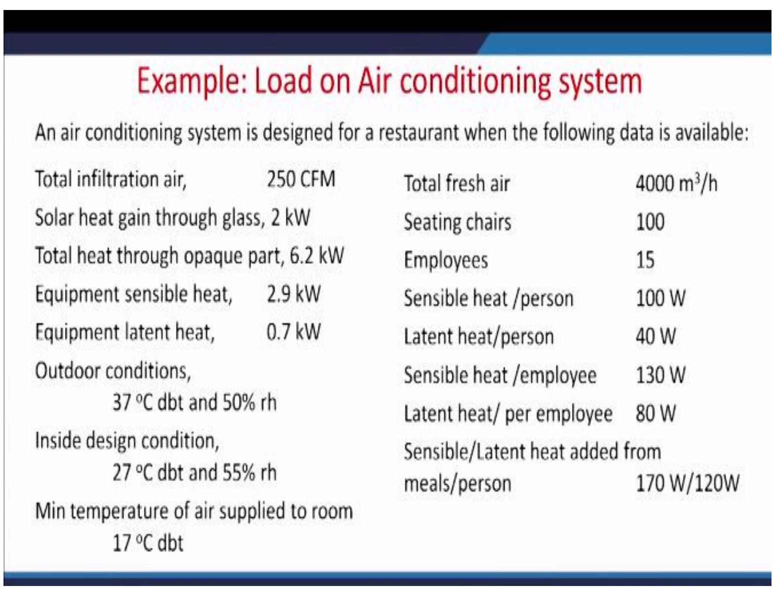

Sensible latent heat added from meals per person, now the meals which is served to the occupants is also contributing towards sensible heat and latent heat, restaurant is fully occupied suppose be 75 percent persons 75 percent of the occupants are taking food and 25 percent are waiting for their food so now what we can do here 75 percent are taking food.

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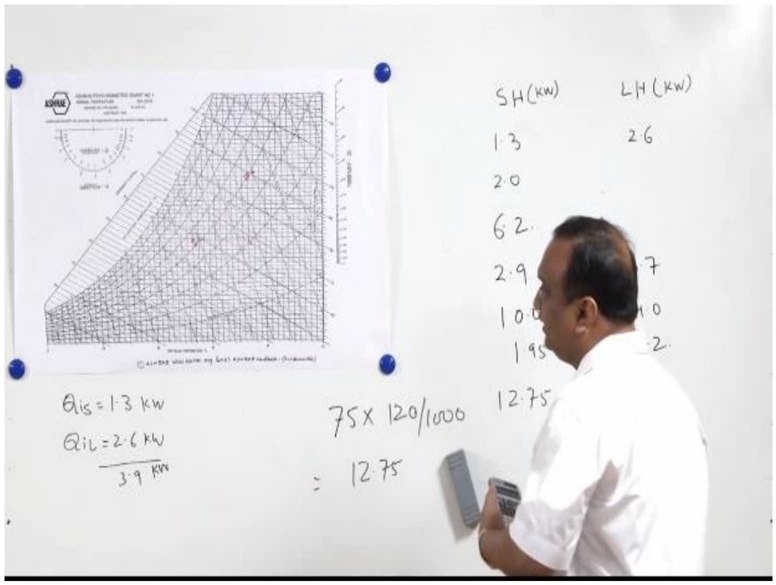

Multiplied by 170 divided by thousand this will be the sensible heat added by the food that is going to be 75, 170/1000 12.75 kilowatt. So12.75 kilowatt is the heat sensible heat added by the meat by the by the food now latent heat it is 120 so 75 x 120/1000 that is 9.0 kilowatt so now we have I think all the load on the building.

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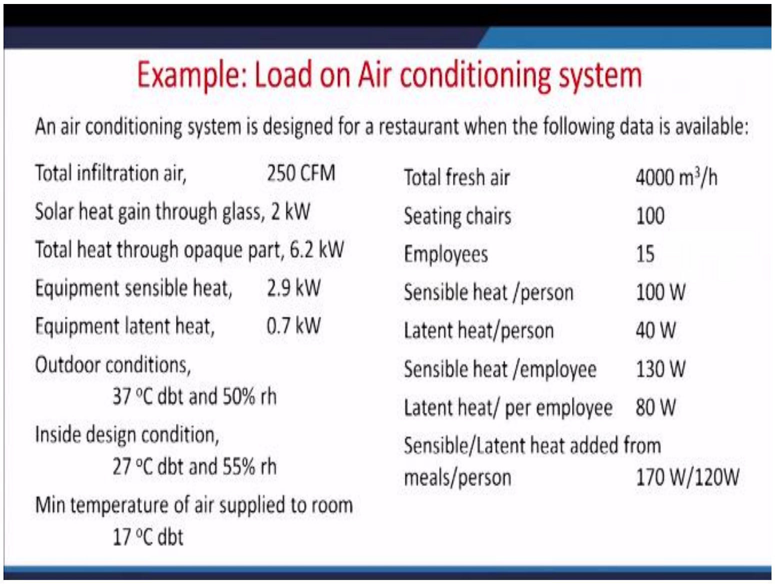

That is due to infiltration two kilowatts is coming from fenestration direct solar radiations 6.2 by opaque part of the building wall ceiling and the floor of the building 2.9 and 0.7 are coming from the equipment in the restaurant sensible heat and latent heat.

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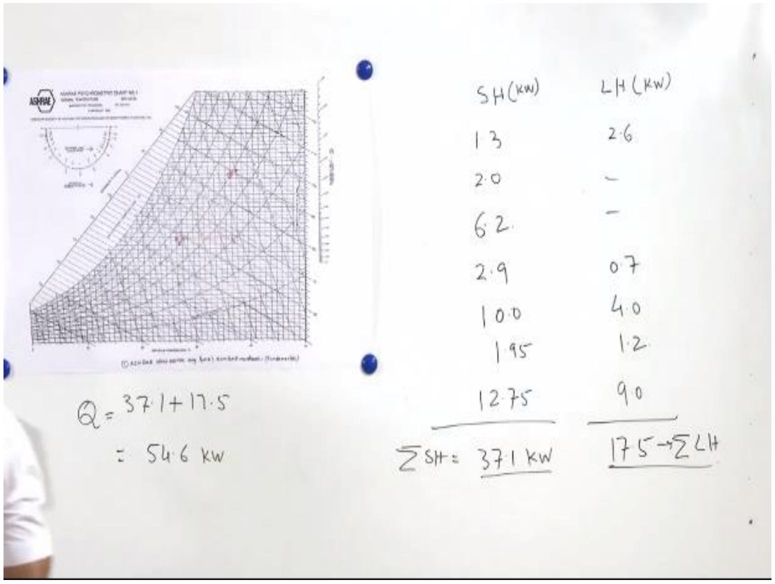

10 kilowatts occupants load one point and sensible load and four kilowatt latent heat load 1.95 kilowatt is coming from the employees as a sensible heat and 1.2 kilowatt is a latent heat and this 12.75 and 9.0 kilowatt is for sensible heat added by the food and they and latent heat added by the food respectively, now what we can do now we can have to calculate the total load, so the total load is sum of sensible heat load.

Sum of sensible heat load that is 1.3 + 2.0 + 6.2 + 2.9 + 10 + 1.95 +12.75 it is 37.1 right, now you can also do calculation along with B so if there is any mistake you can identify well this is named now here latent heat load is 2.6 + 0.7 + 4 + 1.2 + 9.0 and that is equivalent to 17.5 that is latent heat, so latent heat load is 17.5 sensible heat load is 37.1 so the total load is in the building is 37.1 + 17.5 and that is going to be equal to 37.1+ 17.5, 54.6 kilo watt.

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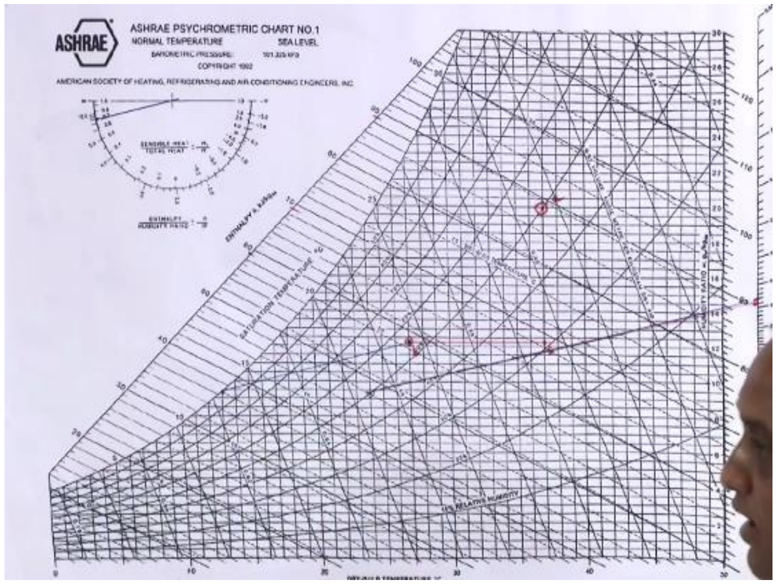

Now 54.6 kilowatt is the cooling load in the building suppose I asked you to find the tonnage of AC plant, so tonight of the AC plant you can immediately find just by 54.6/3.5 and you will get 54.6/3.5, 15. 6 tons of refrigeration, now 54.6 plus divided is fifteen point six tones of refrigeration or you can require a 50 ton capacity plant for this restaurant.

So in this case sensible heat is 37.1 kilowatt and latent heat is 17.5 kilowatt now next thing we are going to do we will find the sensible heat factor now the sensible heat factor is sensible heat divided by total heat and sensible heat here is 37.1 divided by total heat is 54.6 and this will give the sensible heat factor as 0.68, now in this case the sensible heat factor is zero point six eight in this chart in the psychometric chart here.

These marks are for said our show these marks show the sensible heat the ratio of sensible heat and total heat that is sensible heat factor and these parks are starting from 1 to 0.3 and which covers all type of indoor environment, now one means sensible heat factor one means there is no latent heat so that is going to be a horizontal line and this horizontal line is going to be like this because if I want to have suppose in this case the sensible heat factor is 0.68.

So 0.68 is going to be here 0.65 and 0.7 between these it is divided in five parts so the last 0.68 this one second last this 0.68 and this 0.68 is joined with the ideal condition that is twenty-four degree centigrade there is a circle here so this point has to be joined with this one, this is sensible heat factor line for this is a sensible heat factor line for 0.68, so I am repeating first of all we identified the 0.68 mark here.

And that 0.68 part is connected with this small circle center of this small circle that depicts 24 degree centigrade temperature and fifty percent relative humidity, so we are getting this line is going to be this line right, there is another way also for drawing this line there is a half circle here the inside marks of the whole circle show the ratio of sensible heat and total heat that is sensible heat factor.

So here also I can locate 0.68 that is going to be like this 0.68 and any line parallel to this line will show the sensible heat factor of point six eight so these infact these line and this line they are parallel so I you can choose either of the way either you choose this path or you choose this half circle you will be getting the same results, so this is our sensible heat factor line and this line.

Now room condition room condition is this right so a line parallel to this line passing through this point will give the sense sensible heat factor line passing at the room condition so what will do will draw a line parallel to this line passing through the inside room condition so that is going to be this line, so this is cutting this line at 30 degree centigrade, now this is your inside design condition, right.

And this is your sensible heat factor line it is also stated here that the minimum temperature of air supplied to the room is 70 degree centigrade.

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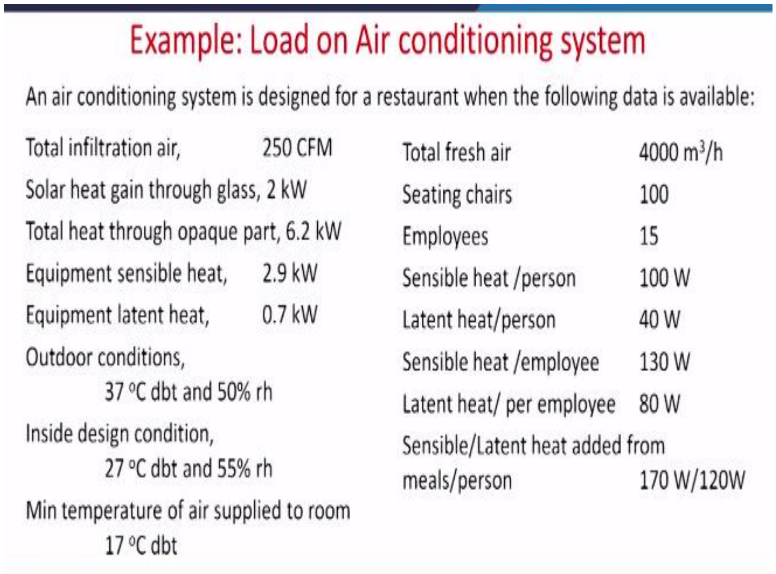

So air which is supplied to the room is at 70 degree centigrade.

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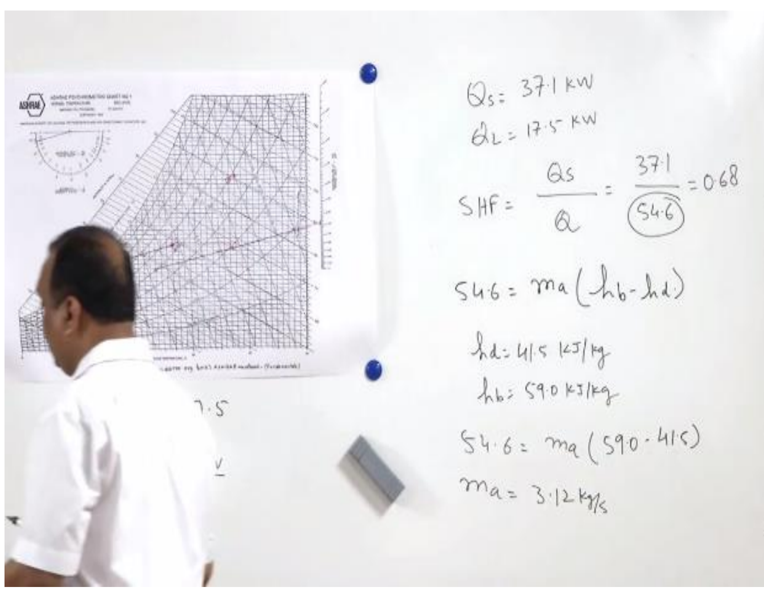

So this is 15, 17 so we will draw a vertical line because we do not know the location we will draw a vertical line from 17 and this is the state this is the state from where the air is supplied to the room, let us say this is state is D now air is entering the room at this state that is approximately 85 % and it is leaving the room it is leaving the room at this temperature that is 27 degree centigrade rival temperature and 55 percent relative humidity.

And this is the load line this line is known as load line so all the cooling load here all the load in the room is heating in the room is taken away by this air, so in order to find how much air has to be we shall be required for the cooling for the purpose of cooling in this room we can use this total heat this one 54.6 so 54.6 is equal to mass flow rate of air multiplied by HB – HD, now HB is HB is already we have taken 59 and HD is approximately 41.5.

It is approximately 41.5 kilo joules per kg and HB is already we have calculated that is 59.0 kilo joules per kg, so 5400 point six is equal to mass of the air multiplied by HD,HB minus HB has HB that is 59.0 – HD that is 41.5 and in this case we will get a mass flow rate of 54.6/59-41.5 , 3.12 kg per second, right. Fresh air available is four thousand meter cube per hour outside air.

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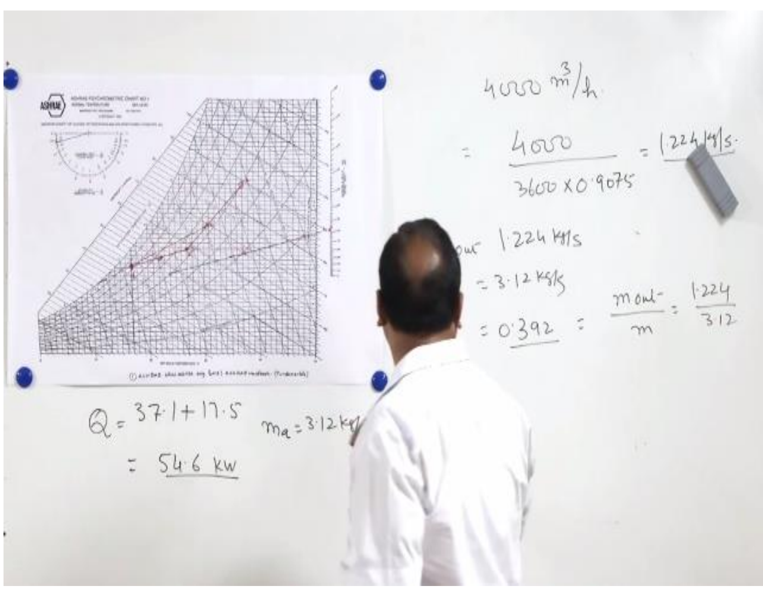

The outside air which is coming in so mass of the air we will write here mass of the air is 3.12 kg per second which has to be circulated inside this room, now fresh air is four thousand meter cube per hour and if we convert this into kg per second again 4000/3600 multiplied by a specific volume of air at state 1 that is 0.9075 and this will give in kg per second mass flow rate in kg per second.

And that is going to be equal to 1.224 kg per second, now this much of mass of air is available outside but we need three point one two kg per second where from the gap will come the gap will come through recirculation of air inside the room the air which is leaving the room it will be mixed with the outside air and this mixture will be circulated inside the room, so here in this case outside air is 1.224 kg per second total air is outside air or total air is required 3.12 kg per second.

So percentage of or the part of outside air which has to be circulated in the room is approximately 0.392 that is the ratio of M out divided by M or 1.224/3.12, now how to take this mixture now for taking the mixture of outside air and inside here we will join these two lines we will join these two lines we will join these two lines and we will take 0.39 so this part will be 39.2 and this part is going to be 70.8.

And in if in this ratio if we take the values so we will be getting somewhere here, this is 0.E so this is 0.392 and this part is 0.608 right so point this part is 0.608 and this part is 0.39 2and this mixture this mixture of fresh air return air they will enter the room and this so this is the room supply condition so they will be entering the room so we draw we will connect these two lines so outside air now the arrangement is like this for the air conditioning of this restraint.

Outside air is taken and it is mixed with the re-circulating air in the ratio of 0.392 and 0.608 now this mixture enters the cooling coil and enters the cooling coil or it passes over the cooling coil and attains the temperature of 70 degree centigrade then air is supplied to the room it picks from the heat from the surroundings and the air which is leaving the room is at 27 degree centigrade and 55 percent relative humidity.

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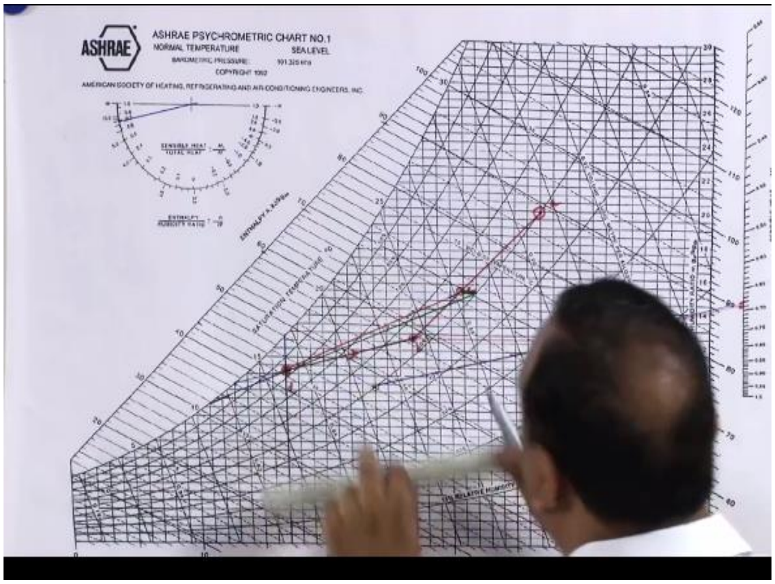

Now for the circulation of air inside a room if fan is also provided now there are two situations either fan is provided before the cooling coil and after the cooling coil if M is provided after the cooling coil then it becomes the part of the load in the system then it will be add to the sensible heat so the heat provided by the fan or heat added by the fan shall become a part of the sensible heat and again we will have to calculate sensible heat factor.

Now if the fan is provided before the cooling coil in that case sensible heat added by the fan shall be added here and in that case this will become the line for cooling of mixture of air that is all for today, in the next class we will be taking air distribution system inside a room, thank you.

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