Refrigeration and Air-conditioning
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Lecture No. # 46
Space Air Distribution

Welcome back, in the last two lectures we discussed transmission of air. Once you transmit the required amount of air to the conditioned space you have to distribute it properly within the conditioned space. So that ultimately comfort conditions can be maintained inside the air conditioned building. In this lecture I shall discuss space air distribution okay.

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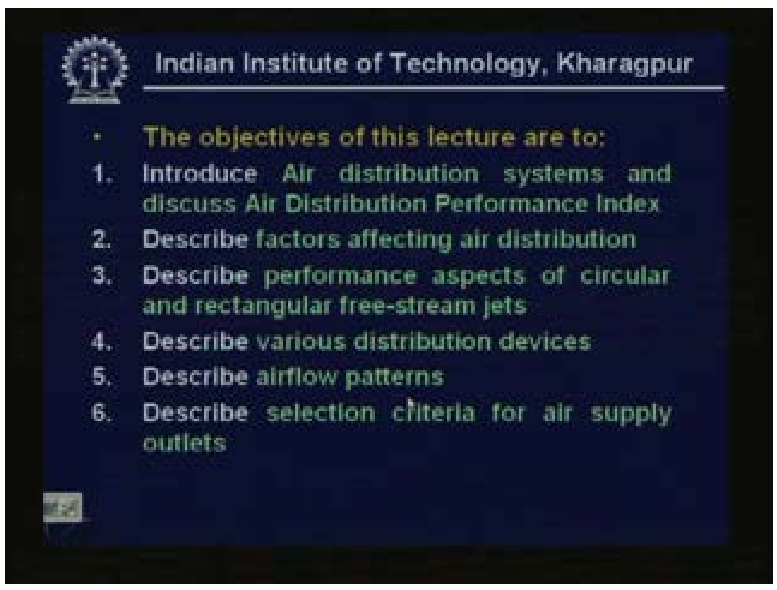

So the specific objectives of this particular lecture are to introduce air distribution systems and discuss air distribution performance index, describe factors affecting air distribution, describe performance aspects of circular and rectangular free-stream jets, describe various distribution devices, describe airflow patterns, describe selection criteria for air supply outlets. At the end of the lecture you should be able to explain the importance of air distribution and air distribution performance index, list factors affecting air distribution, define blow drop spread and entrainment evaluate performance of circular and rectangular free-stream jets list various distribution devices draw airflow patterns and finally list selection criteria for air supply outlets.

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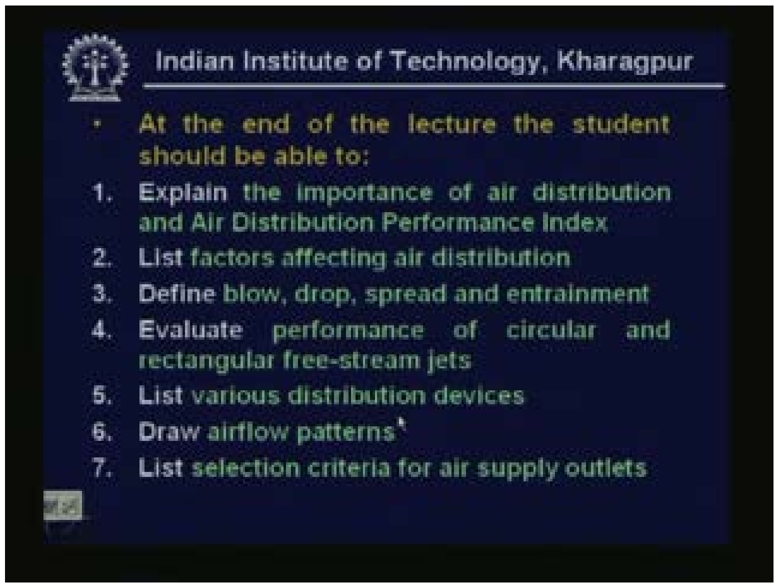

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So let me give a brief introduction to space air distribution. As I have already mentioned once a required amount of supply air is transmitted to the conditioned space. It is important to distribute the air properly inside the conditioned space. Thus it is important to design or select suitable air distribution system and the air distribution system selected should create a proper combination of temperature humidity and air motion in the occupied zone and it should avoid draft in the occupied zone. What do you mean by draft?

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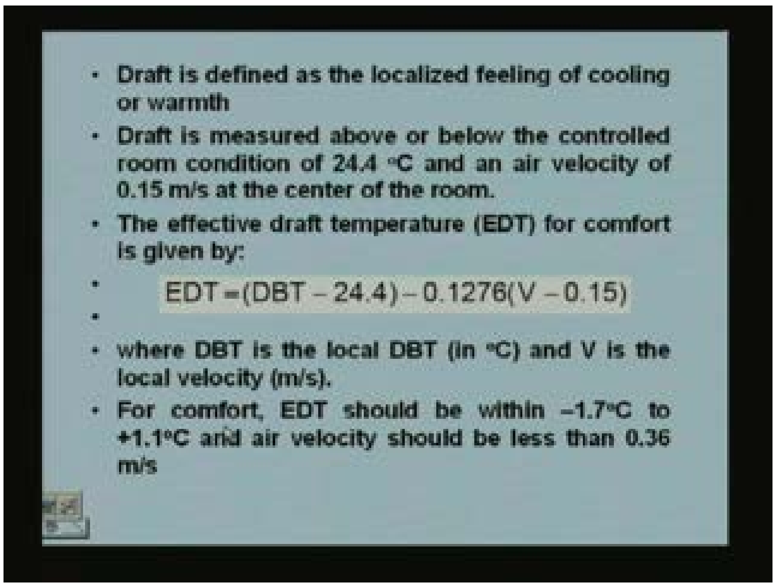

Draft is defined as a localized feeling of cooling or warmth draft is measured above or below the controlled room condition of twenty four point four degree centigrade and an air velocity of point one five metre per second at the centre of the room the effective draft temperature EDT for comfort is given by this equation. Effective draft temperature is equal to DBT minus twenty four point four minus point one two seven six multiplied by V minus point one five. Here DBT is the local drivel temperature in degree centigrade and V is a local velocity in metre per second. For comfort requirements the effective draft temperature or EDT should be within minus one point seven degree centigrade to plus one point one degree centigrade and air velocity should be less than point three six metre per second. So the air distribution system that we finally select or design must be able to maintain the space occupied zone within these effective draft temperature values okay.

Effective draft temperature can be negative or positive depending upon the air temperature and the air velocity okay.

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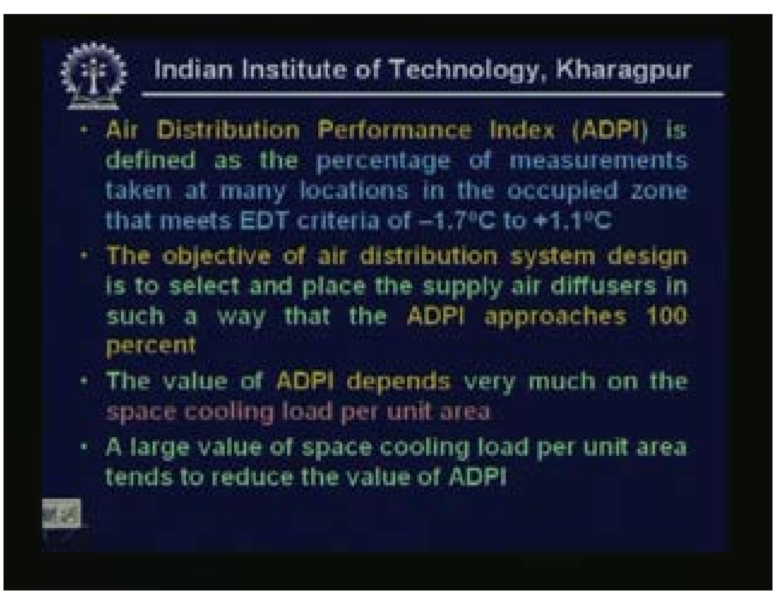

Air distribution performance index or short form ADPI is defined as the percentage of measurements taken at many locations in the occupied zone. That meets effective draft temperature criteria of minus one point seven degree centigrade to plus one point one degree centigrade. That means let us say that in an air conditioned building in the occupied zone you take hundred measurements okay. At various points and out of the hundred measurements eighty measurements fall within the effective draft temperature range of minus one point seven degree centigrade to plus one point one degree centigrade. That means the effective draft temperature of eighty locations is within this acceptable range.

Then the air distribution performance index of that particular conditioned space is eighty because out of hundred eighty points are meeting the requirements okay. So that is how the air distribution performance index is measured. The objective of air distribution system design is to select and place the supply air diffusers in such a way that the air distribution performance index approaches hundred percent. Obviously we would like to have a hundred percent air distribution system design. That means everywhere the conditions are fall within the acceptable limit of effective draft temperature. But this is not really possible. It is observed that the value of air distribution performance index depends very much on the space cooling load per unit area okay. So many watt per metre square of floor area let us say.

So a large value of space cooling load per unit area tends to reduce the value of air distribution performance index. So this is one of the indexes using which one can a value at the quality of the space air distribution.

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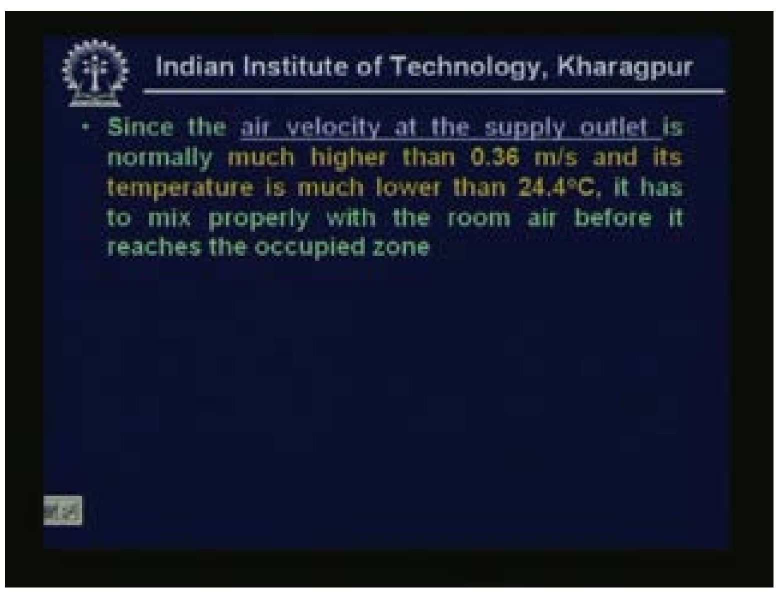

Since the air velocity at the supply outlet is normally much higher than point three six metre per second and its temperature is much lower than twenty four point four degree centigrade it has to mix properly with a room air before it reaches the occupied zone. Let me show the typical supply air velocities .

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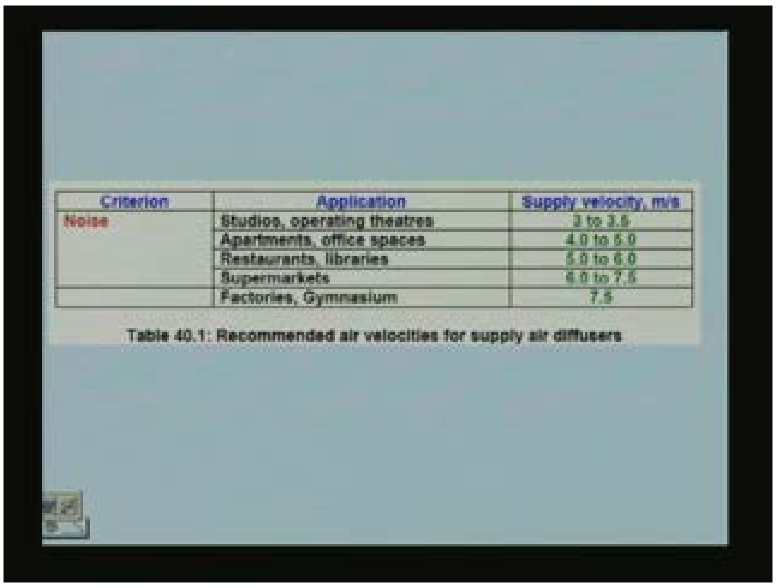

Criterion	Application	Supply velocity, m/s
Noise	Studios, operating theatres	3 to 3.5
	Apartments, office spaces	4.0 to 5.0
	Restaurants, libraries	5.0 to 6.0
	Supermarkets	6.0 to 7.5
	Factories, Gymnasium	7.5

Table 40.1: Recommended air velocities for supply air diffusers

This table here shows the recommended air velocities for supply air diffusers and here the criteria are noise that means if the velocity exceeds this recommended velocities then there could be noise which is objectionable. For example for studios and operating theatres the supply air velocity should be between three to three point five metre second. Whereas in apartments and office spaces it can be slightly higher that is from four to five metre per second. Whereas in restaurants and libraries it can be five to six metre per second in super markets whereas there is lot of background noise.

You can afford to go for higher supply velocity that means you can go up to six to seven point five metres per second. Similarly in factories and gymnasium you can go up to seven point five metre per second. So that is how the supply air velocities are decided or selected depending upon mainly on the noise criteria okay, which in turn depends upon the application. You can see here that these supply air velocities are much higher than the required velocities in the occupied zone which lies between point one five to point three six metre per second okay. So the supply velocity is at least one order of magnitude higher than the required velocities in the occupied zone okay.

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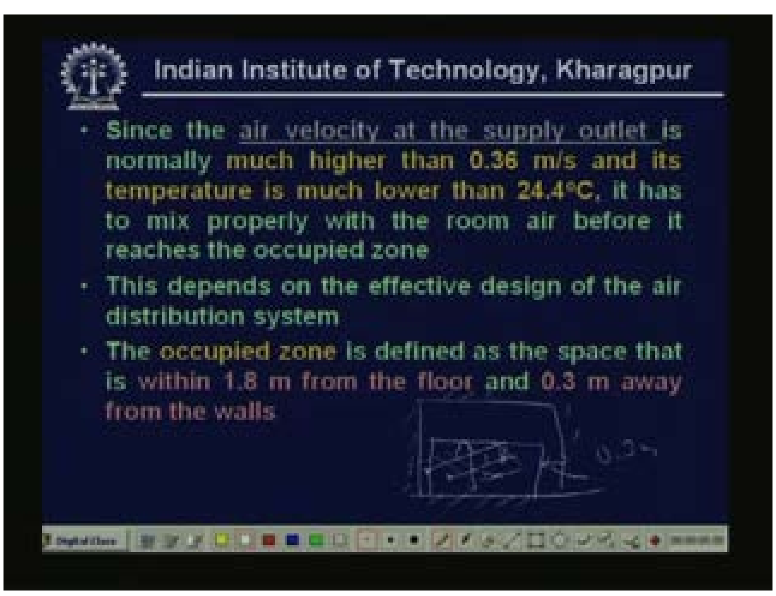

So there should be good mixing so that the temperature and velocity can be brought down to the required levels. So this depends on the effective design of the air distribution system the occupied zone here is defined as the space that is within one point eight metre from the floor and point three metre away from the walls okay. So let me just quickly explain this what do you mean by occupied zone let us say, that this is yours, let say that this is the condition space and this is the floor okay. So these are all the walls of the conditioned space. So the occupied zone is where as a name implies where the occupants are, so this is defined as all the space that is within one point eight metre from the floor okay, and one foot away from all the walls this distance is one foot or point three metres okay.

So this region is defined as the occupied region and within this occupied region we have to maintain the temperatures depending upon the comfort requirements okay.

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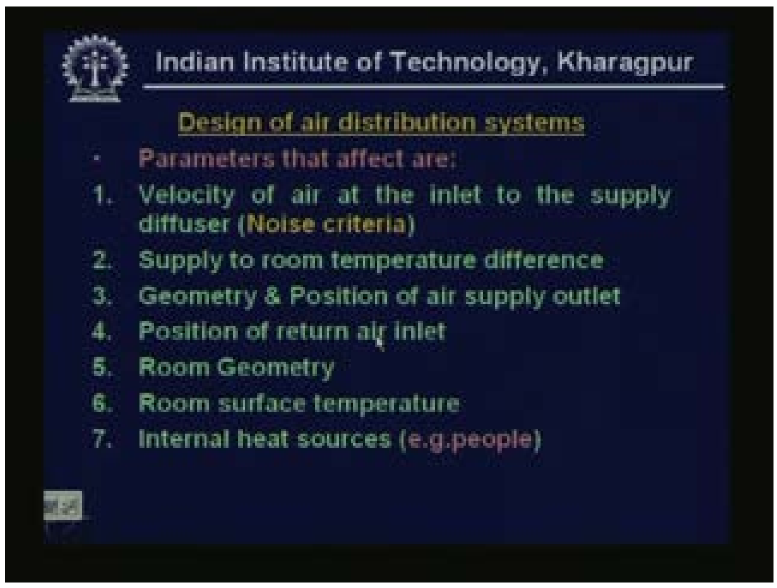

Now let us look at design of air distribution systems the factors that effect the design are. Velocity of air at the inlet to the supply diffuser mainly based on the noise criteria as I have already explained. Then supply to room temperature difference geometry and position of air supply outlet position of return air inlet room geometry room surface temperature and finally internal heat sources. For example people equipment lighting etcetera. So all these factors affect the design of air distribution systems.

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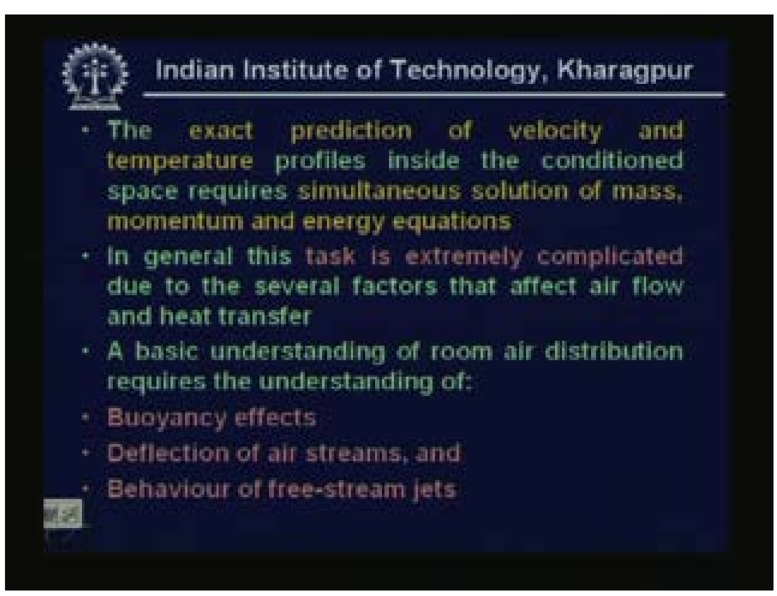

The exact prediction of velocity and temperature profiles inside the conditioned space requires simultaneous solution of mass momentum and energy equations. If you want to find out what is the temperature and velocity at a particular location inside the conditioned space. Then you have to solve all these three equations simultaneously but you find that this task in general is extremely complicated due to the several factors that affect air flow and heat transfer. So mathematically obtaining the exact velocity and temperature profile is very difficult however a basic understanding of room air distribution requires the understanding of the following concepts one is a buoyancy effect second one is deflection of air streams and the third parameter is behaviour of free-stream jets. So let us look at these three effects.

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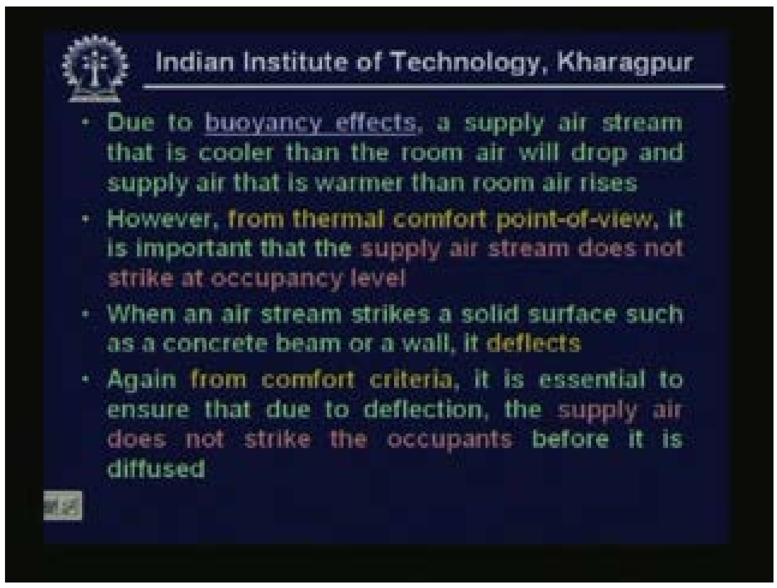

So what is buoyancy effect? As you know buoyancy effect is a result of temperature radiant which leads to density differences because of the density differences there will be fluid flow okay. So this is what we know as buoyancy effect. And due to buoyancy effects a supply air stream that is cooler than the room air will drop and supply air that is warmer than the air room air rises okay. That means when you are supplying cold air to the room okay. So because of the buoyancy cold air is heavier than the warm air so the cold air will tend to drop whereas if you are supplying warm air to the room that means air that is warmer than the room air. Then because of the buoyancy the warm air tends to rise okay. So we know this from our basic physics okay. However as far as air distribution for air conditioned buildings are concerned for thermal comfort point of view.

It is important that the supply air stream does not strike at occupancy level what it means is that the cold supply air stream. Let us say that we are talking about air conditioned system for summer, when you are supplying cold air to the room at a temperature of twelve degrees or thirteen degrees centigrade it should not directly drop and hit the occupants okay. Then the occupants will feel uncomfortable because the temperatures are much lower than the recommended temperatures of twenty three or twenty four degree centigrade okay. So this is an important factor to be considered. So next factor is as I said is deflection what do you mean by deflection. When an air streams strikes a solid surface such as a concrete beam or a wall it deflects. Again from comfort criteria it is essential to ensure that due to deflection the supply air does not strike the occupants before it is diffused okay.

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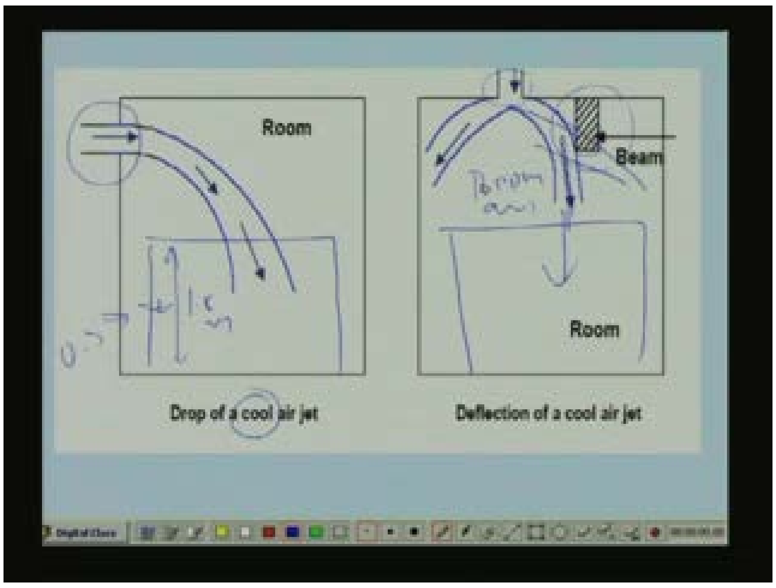

So let me show the, this, for example this is where let us say that the cool jet we are supplying a cool jet it is supplied at a height into the room. Let us say that this is our occupied zone that is one point eight metre and your point three metre from the wall okay. So due to buoyancy effect this cold air stream will tend to drop into the room that means it drops into the occupied zone finally okay. And due to the deflection for example you can see here that I am supplying cold air from the top okay. So as you supply the cold air from the top because of buoyancy it drops but on this side you have a concrete beam. So when the air stream comes and strikes this it deflects okay. So instead of spreading like this it deflects in the downward direction because of the presence of the solid beam here okay. So but because of this deflection it should not so happen that cold air is again directly coming into the occupied zone before mixing with the rest of the room air okay. So these are the two factors which have got to be kept in mind while designing supply outlets.

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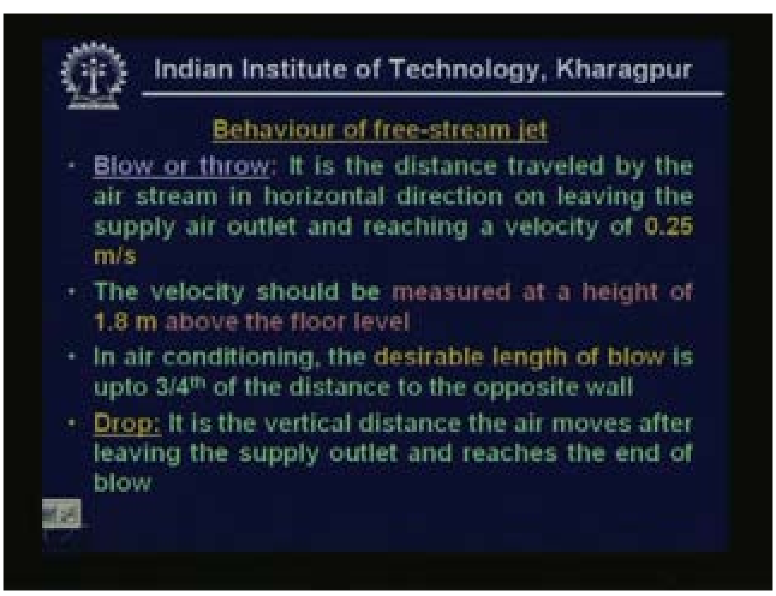

Next comes behaviour of free-stream jet. There are certain terms which we have to understand before we understand the behaviour of free stream jets and design of air supply outlets first one is what is known as blow or throw this is defined as a distance travelled by the air stream in horizontal direction on leaving the supply air outlet and reaching a velocity of point two five metre per second. So this is the horizontal distance as you can see from the definition travelled by the air stream okay, and at a point where its velocity reaches point two five metre per second.

The velocity should be measured at a height of one point eight metre above the floor level that means just at the upper boundary of your occupied zone.

In an air, in air conditioning the desirable length of blow is up to three fourth of the distance to the opposite wall this is as far as blow or throw is concerned. Then comes drop is the vertical distance the air moves after leaving the supply outlet and reaches the end of the blow okay. This is the definition of drop so let me show this schematically.

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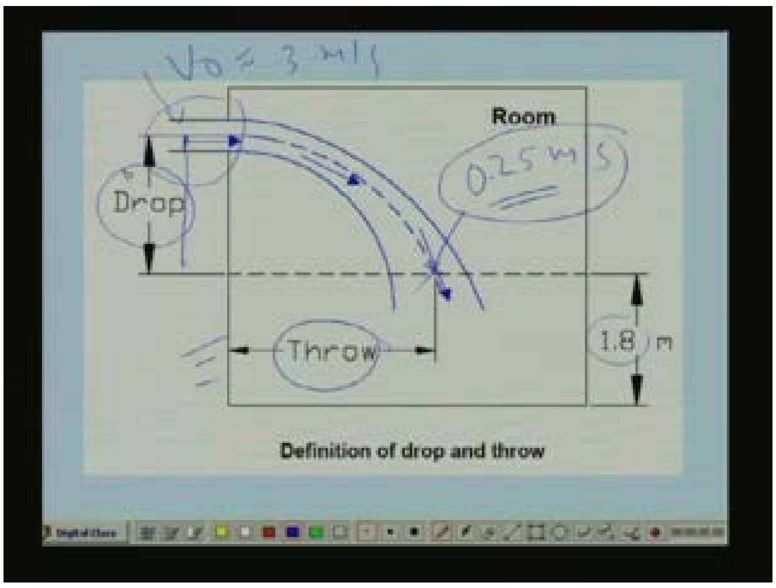

You can see here that again we have cool air jet coming from the top because of the buoyancy it drops down okay. So this is coming at some velocity let us say V naught so this is coming at some velocity let us say V naught okay. V naught is, let us say this is coming at V naught which is equal to say three metre per second. So as we shall see this later but as this air jet leaves the supply outlet and flows into the room its velocity decreases and simultaneously it also drops down because of buoyancy okay. So here throw is defined as the distance from this point. That means from this point to a point where the velocity is equal to or velocity has reduced to point two five metres per second okay. So when the velocity of the centre centreline reduces to point two five metre per second and which is when measured at height of one point eight metre that distance is called as throw.

So this is your throw okay, and what is the drop is nothing but the point at which the air stream has reached a velocity of point two five metre per second and the centreline of your supply outlet. So this is your drop okay.

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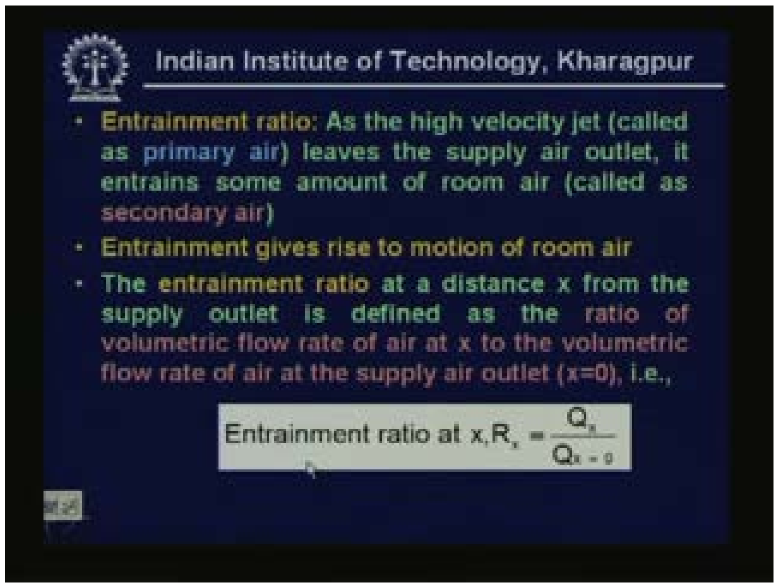

Next, that is an very important concept that is entrainment ratio as the high velocity jet called as primary air leaves the supply air outlet it entrains some amount of room air this is known as secondary air okay. So as I have already explained where you supply a air to the conditioned space at a height high velocity and low temperature okay. This high velocity air as it flows into the room it entrains some room air okay. The, that means already the air that is already existing in a room is entrained by this supply air. The supply air is called as primary air which is of high velocity at the outlet and this mixes thoroughly with the room air okay, the room air is called as secondary air.

The primary air plus secondary air is called as total air and this process is known as entrainment okay. The, that means entrainment of the room air by the primary air entrainment is gives rise to motion of room air and the entrainment ratio at a distance x from the supply outlet is defined as the ratio of volumetric flow rate of air at x to the volumetric flow rate of air at the supply air outlet that means at x is equal to zero. If I take the coordinate system with x is zero has the supply air outlet then entrainment ratio R subscript x is equal to Qx divided by Qx is equal to zero where Q is the volumetric flow rate of air okay. So this is how the entrainment is defined entrainment ratio.

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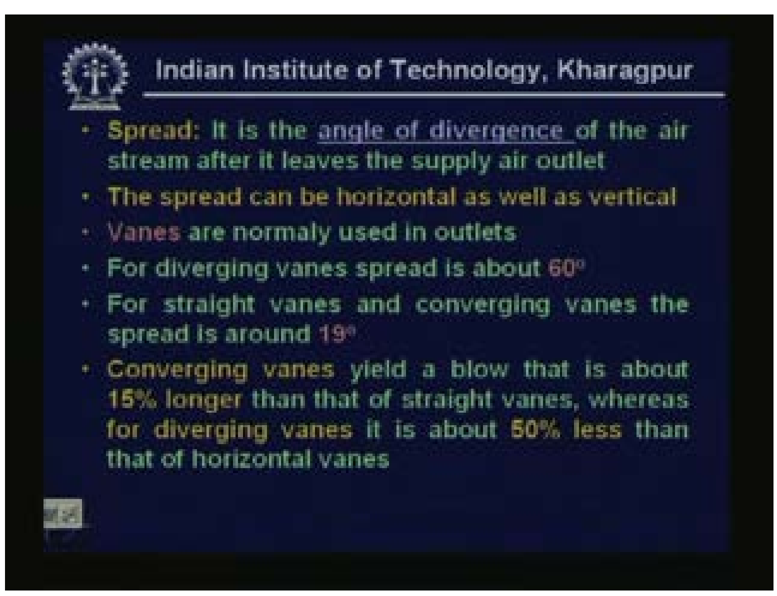

Next important aspect is what is known as spread is angle of divergence of the air stream after it leaves the supply air outlet. The spread can be horizontal as well as vertical normally vanes are used in outlets and for diverging vane the vanes can be horizontal diverging or converging and for diverging vanes the spread is about sixty degrees and for straight vanes and converging vanes the spread is around nineteen degrees and converging vanes yield a blow that is about fifteen percent longer than that of straight vanes. Whereas for diverging vanes it is about fifty percent less than that of horizontal vanes okay so let me show this.

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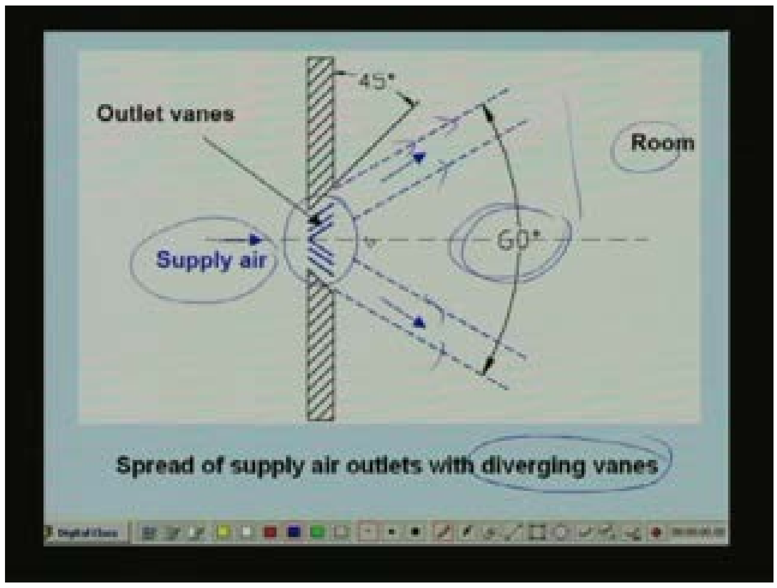

The angle of divergence for a diverging vane okay, so again as I said this is your supply this where your supply air is coming at high velocity and it this is your room okay, on this side you have the room. So it leaves the supply air outlet and as it leaves it spreads. So you can see that air is flowing like this. So this is your spread and in terms of angle for the vanes are here these vanes are diverging vanes as I have as this mentioned here. For diverging vanes the spread angle is sixty degrees okay, whereas it in nineteen degrees for converging or straight vanes okay. And this spread can be this is in vertical direction it can be horizontal direction also that means perpendicular to the board okay.

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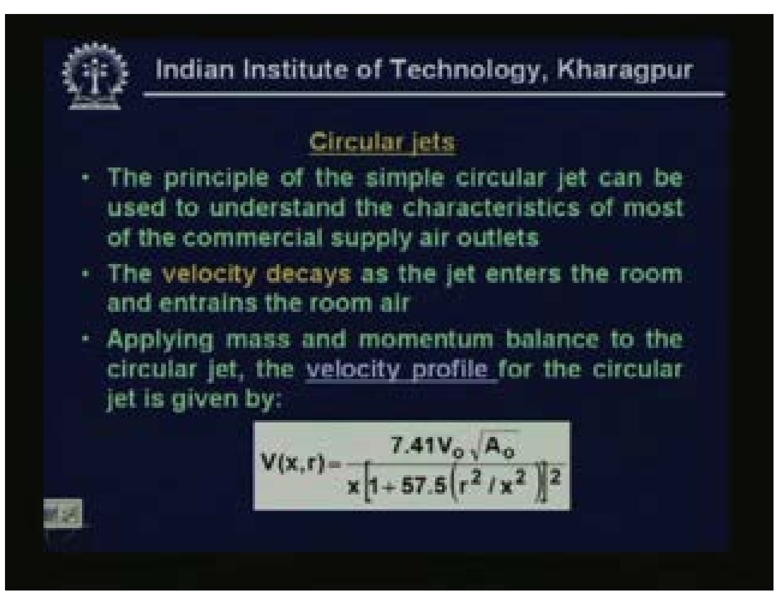

Let us look at circular jets the principle of the simple circular jet can be used to understand the characteristics of most of the commercial supply air outlets okay. That is why we study this because it is simpler to analyse okay. And it also has application and the as I have already mentioned the velocity decays as the jet enters the room and entrains the room air and applying mass and momentum balance to the circular jet the velocity profile for the circular jet is given by this equation. Vx r is the velocity of air at any point defined by the coordinate system xn r that is equal to seven point four one V naught square multiplied by square root of A naught divided by x multiplied by one plus fifty seven point five into r square by x square whole square okay. So this is how the velocity profile is defined so let me show this in the picture it will be clear.

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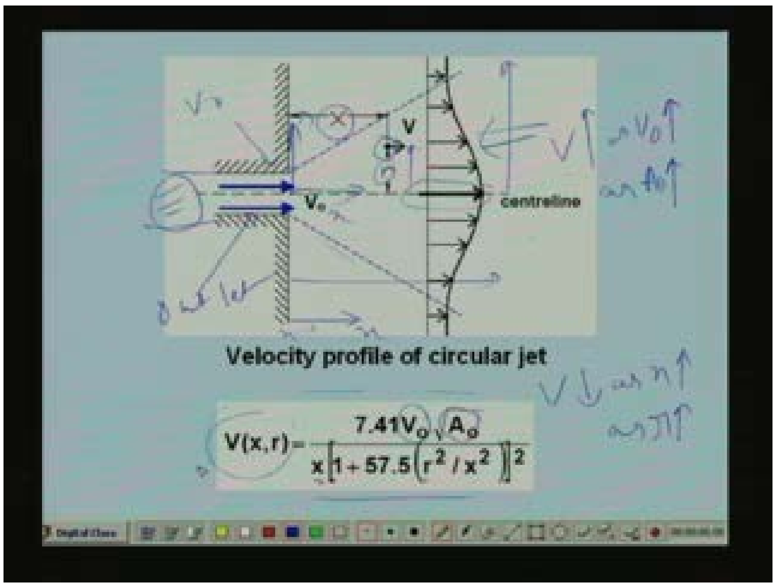

So this is your circular jet okay. That means if you look at from this side this is circular in shape okay. So the jet is leaving the outlet. So this is your outlet. So as it leaves as I have already explained its spreads okay. The air jets spreads and its velocity varies continuously okay. And if I define our, my x coordinate, so as the supply air outlet x is zero okay, and r is like this the centreline r is zero right. So the coordinate system is like this is x is here and r is here okay. So at any point for example which is defined by r and x the velocity profile is given by this okay. So you can see that the velocity varies in the r direction and it also varies in the x direction okay and the centreline velocity is always obviously highest okay. So as you as r increases for a given x as r increases the velocity reduces. So this is the typical velocity profile for a circular jet and as I have already said this velocity profile is mathematically given by this equation where Vx r is this velocity profile and it’s a function of x. It is a function of r it is a function of the supply air velocity V naught. That means velocity at this point and it is also a function of the area of the outlet okay that means this area okay. So from this equation it is very clear that for a given V naught and A naught V reduces as x increases as r increases.

So obviously as you move away from the outlet the velocity reduces. Similarly as you move away from the centre line again the velocity reduces okay. And at a given x and r you can see that the velocity increases as supply air velocity V naught increases and as the area of the supply air outlet A naught increase okay. So all this things can by deduced from this equation this equation is derived analytically and it is available in the book bash listing on boundary layer theory.

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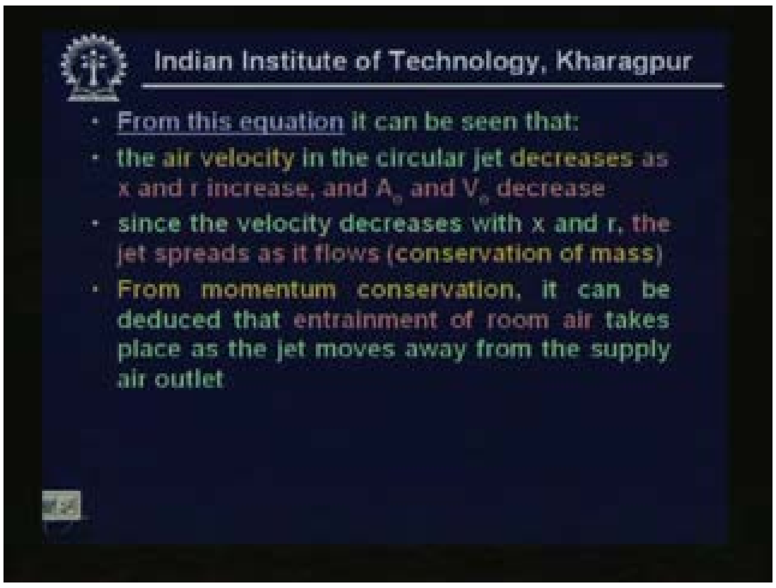

And as I have already explained from this equation it can be seen that the air velocity in the circular jet decreases as x and r increase and as A naught and V naught decrease. Since the velocity decreases with x and r the jet spreads as it flows okay. So this is you can easily deduce this from the, this equation that since the velocity reduces mass flow rate has got to be conserved okay. So mass flow rate is given by rho into A into V if you are assuming the rho is constant then A into V should remain constant. So as V is reducing obviously A has to increase okay. This comes from your conservation of mass okay. A has to increase means the it has the air jet has to spread okay.

So you can get this conclusion from the equation given above okay. Again from momentum conservation it can be deduce that entrainment of room air takes place as the jet moves away from the supply air outlet okay. So momentum has got to be conserved so if its velocity of primary jet is reducing obviously it has to entrain the secondary air so that the total momentum remains constant okay.

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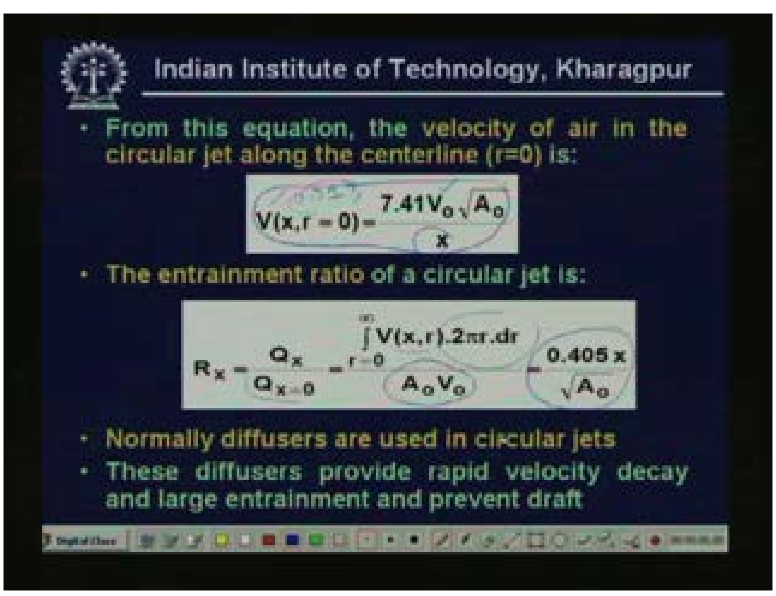

And from this equation the velocity of air in the circular jet along the centre line that means when r is zero is given by this equation vx at r is equal to zero all that you have to do is put r is zero in the equation shown before. So you get this expression seven point four one into V naught into square root A naught divided by x okay. So this equation actually can be used to obtain the blow or throw okay. Because you know that the velocity has to reach let us say point two five metre per second okay. At a, that is a distance called as blow. So if you put point two five metre per second then for a given V naught and A naught you can find out what is x, that x is nothing but your blow or throw okay, and the entrainment ratio of circular jet is given by this equation as I have already explained before. Rx is equal to Qx by Qx is equal to zero. That means you have to integrate this Vx r or the entire area okay, two pi r dr if r varies from zero to infinity divided by this is the flow rate at the supply air outlet A naught into V naught.

So if you substitute the expression for Vx r and integrate it from zero to infinity ultimately you find that the entrainment ratio is given by this equation. That means the entrainment ratio is equal to point four naught five x divided by square root of A naught. Again from this equation you can see that the entrainment ratio increases as x increases and entrainment ratio decreases as A naught increases okay. Normally diffusers are used in circular jets.

Normally you do not have hollow circular jets okay. The diffusers are used in circular jets what is the purpose of the diffusers these diffusers provide rapid velocity decay and large entrainment and there by prevent draft okay. So that is the reason why diffusers are used.

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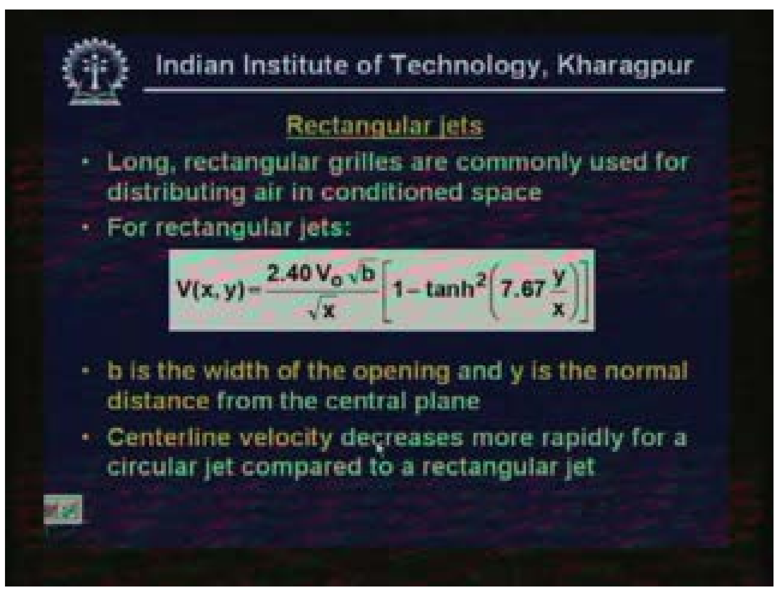

Next for rectangular jets long rectangular grilles are commonly used for distributing air in conditioned space okay, so both rectangular as well as the cylindrical jets are commonly used.

So for rectangular jets the velocity profile is given by this equation Vx y is equal to two point four zero multiplied by V naught multiplied by square root of b divided by square root of x multiplied by one minus tangent h square multiplied by seven point six seven y by x okay. And here what is b, b is the width of the opening and y is the normal distance from the central plane okay and central, centerline velocity decreases more rapidly for a circular jet compared to a rectangular jet.

If you compare these two equations you find that for a circular jet the centreline velocity decreases much more rapidly compared to a rectangular jet okay.

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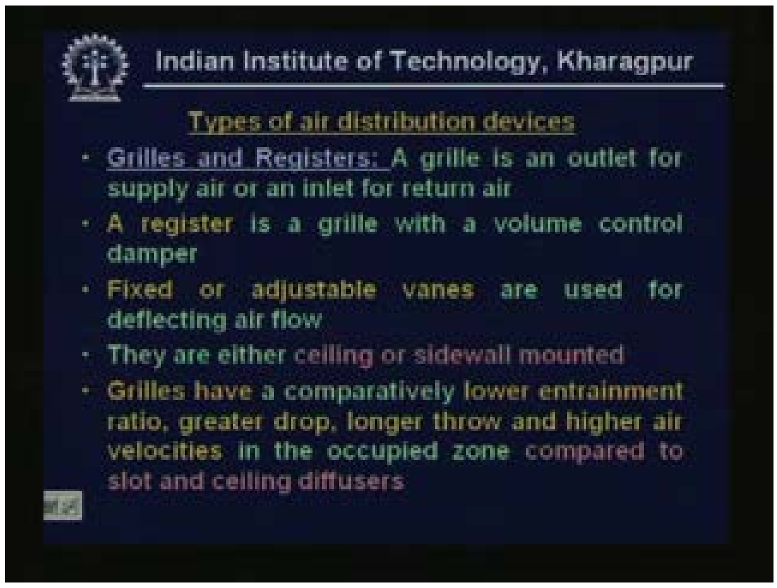

Next let us look at types of air distribution devices first most commonly used air distribution device is called as grille or register. A grille is an outlet for supply air or an inlet for return air a grille can be used both, for both as an outlet for supply air or as an inlet for return air okay. And what is the difference between grille and register a register is a grill with a volume control damper. That means grilles do not have any volume control dampers. If you have a volume control damper on a grill you call it as register and they can have fixed or adjustable vanes for deflecting air flow and they are either ceiling or sidewall mounted and grilles have a comparatively lower entrainment ratio. Greater drop longer throw and higher air velocities in the occupied zone compared to slot and ceiling diffusers okay. So let me show the schematic of a grille.

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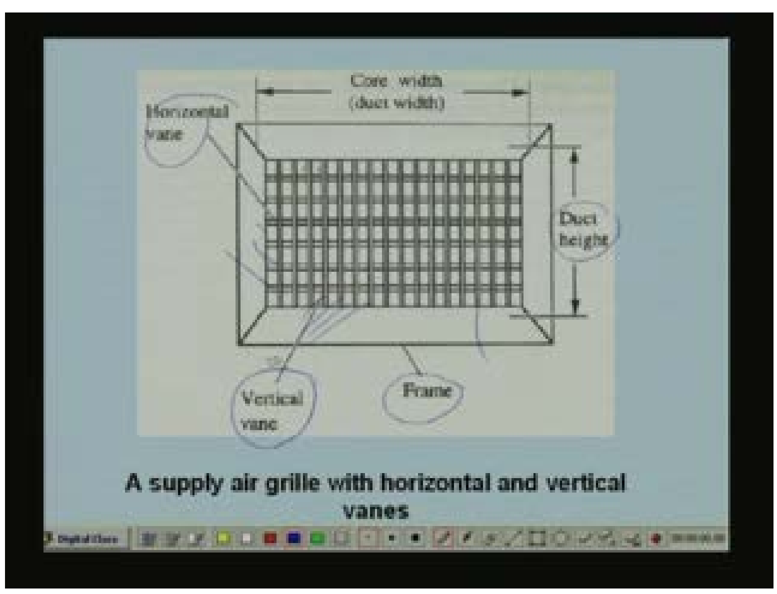

You must have seen this kind of grilles in air conditioned buildings. As you can see that this is where the open areas are where from the supply air comes out okay, supply air comes out like this and it has this grille has vertical vanes and horizontal vanes okay. These are the vertical vanes okay and all these are the horizontal vanes okay. So behind the grille you have the supply air duct okay. From the supply air duct supply air comes flow through the opening in the grille and enters in to the conditioned space and gets distributed properly okay. And you have an outer frame right and as I said these vanes the vertical and horizontal vanes can be fixed or adjustable. For example in our some of the air conditioners they are adjustable vanes you can adjust them so that you can deflect the air flow.

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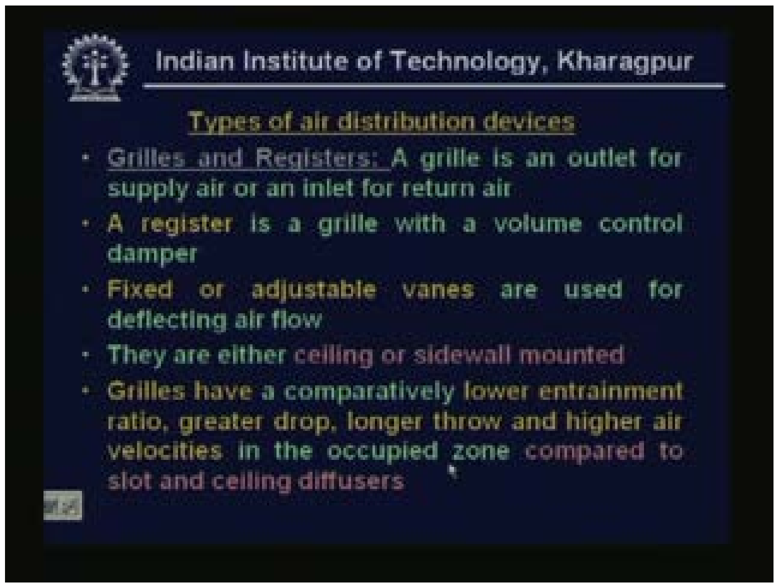

So grilles and registers are quite commonly used.

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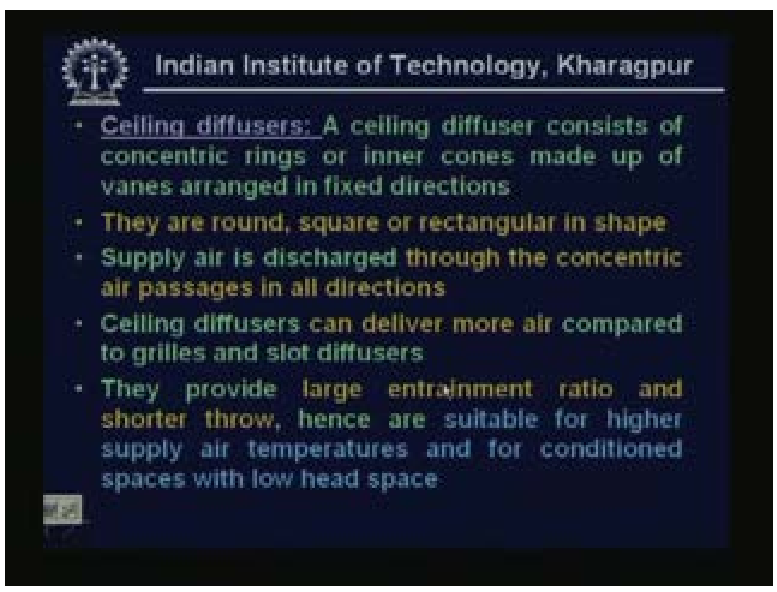

Next commonly used air distribution device is what is known as ceiling diffusers a ceiling diffuser consist of concentric rings or inner cones made up of vanes arranged in fixed directions.

They are round square or rectangular in shape that means you can have round ceiling diffusers square ceiling diffuser or a rectangular ceiling diffuser and supply air is discharged through the concentric air passages in all directions. Ceiling diffusers can deliver more air compare to grilles and slot diffusers. So these, the characteristic of ceiling diffuser and they provide large entrainment ratio and shorter throw okay. So because of these characteristics they are suitable for higher supply air temperatures and for conditioned spaces with low head space okay. That means if you have a air conditioned building with low ceiling height then you can use ceiling diffuser because their throw is less so the air diffuses fast okay.

So there is no danger of cold air entering into the occupied zone okay so these are typical characteristics of ceiling diffuser. So let me show a schematic of ceiling diffuser.

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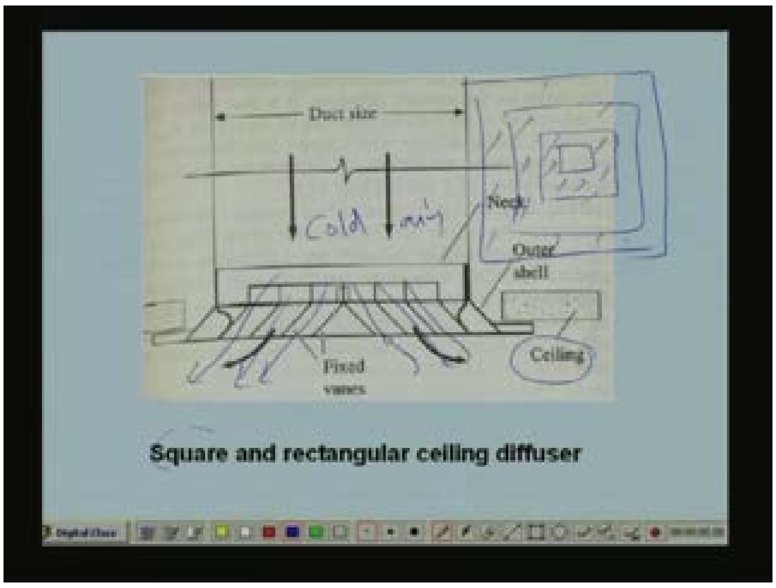

Yeah this picture shows schematic of ceiling diffuser. So cold air comes from as this you can see this is your cold supply air okay. That comes like this and you have the concentric areas flow areas through which flow takes place okay. And this is two dimensional this thing that means it can be either square or rectangular. That means if its see from the bottom you can have something like okay, it will be something like this okay, it will be looking like this.

So air will be coming from here from here okay, from here so it is discharged in all directions okay and this is mounted on the ceiling as you can see here that is why you call them as ceiling diffuser and in this picture fixed vanes are shown but you can also have adjustable vanes okay.

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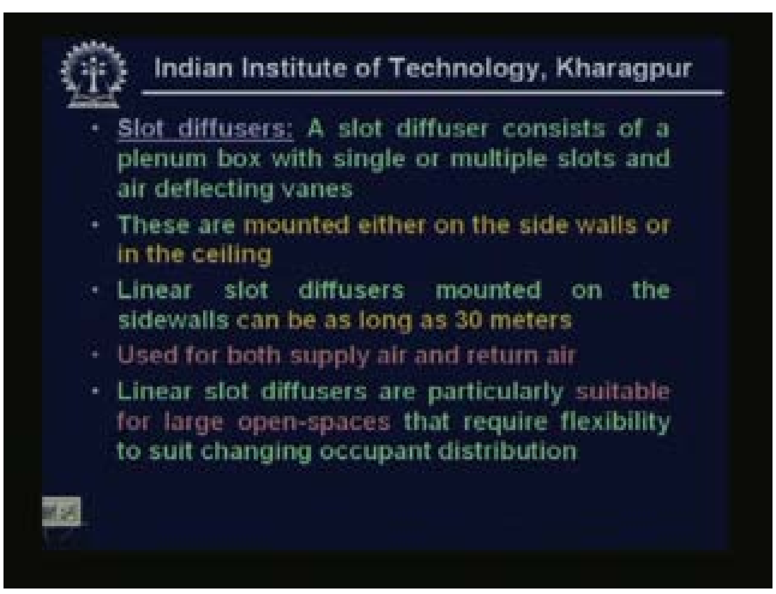

Next very commonly used air distribution device is what is known as the slot diffuser a slot diffuser consists of a plenum box with a single or multiple slots and air deflecting vanes and these are mounted. That means the slot diffusers are mounted either on the side walls or on the ceiling okay. So you can mounted them on the walls or in the ceiling and linear slot diffusers mounted on the sidewalls can be as long as thirty metres okay. And these slot diffusers are used for both, supply air as well as return air and linear slot diffusers are particularly suitable for large open spaces that require flexibility to suit changing occupant distribution okay. So these are our typical application of linear slot diffusers let me show a photograph where linear slot diffusers are used.

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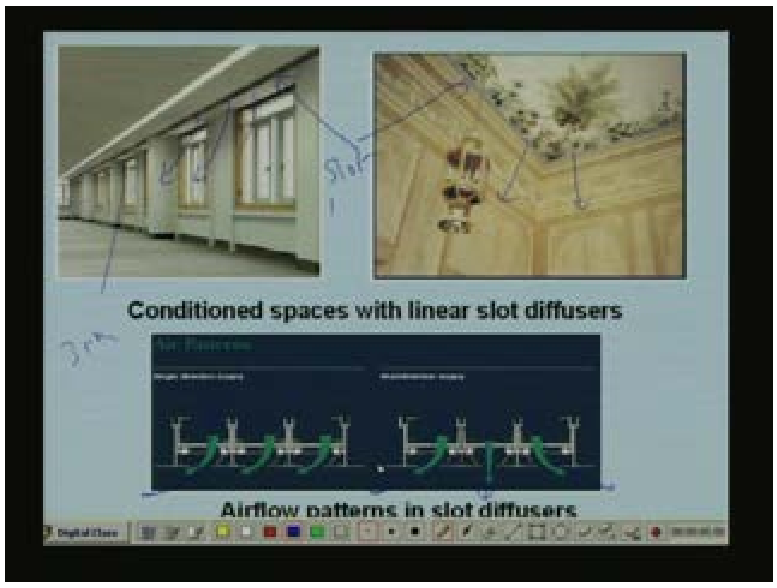

These two photographs show these are the okay, diffusers again here these are the diffusers okay.

This is slot diffusers so cold air comes from this point okay similarly here cold air comes from this. So we can that this is the very long diffuser okay it can be as long as I said thirty metre okay, in length right.

So we can see that it really matches very well with the building and it looks very nice that means they have very good aesthetics okay. The slot diffusers and they match very well with the background and in this picture the air flow patterns in slot diffusers are should, for example for singled direction supply the air supply air comes like this and it goes in one direction okay. Whereas you can also have multi direction supply that means air comes in this direction in this direction and in this direction also okay. So depending upon the type of slot diffuser you can have both the varieties.

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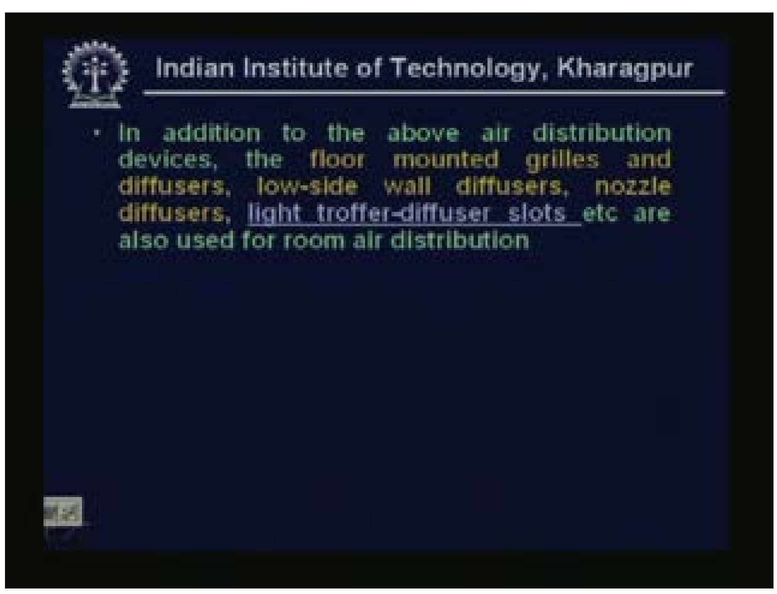

In addition to the above air distribution devices we you can also have floor mounted grilles and diffusers low side wall diffusers nozzle diffusers light troffer diffuser slots etcetera okay. Of course the most commonly used ones are the slot diffusers and the ceiling diffusers and grilles and registers okay. But there are some special applications where you may have to mount the diffusers on the floor okay. Then you call them as floor diffusers okay. You can also have side wall mounted diffusers okay this is also depends upon the application. For example some of them are good for heating some of them are good for cooling okay. So depending upon the specific application we have to select a suitable outlet device okay. That the also a special device called as light troffer diffuser slot okay.

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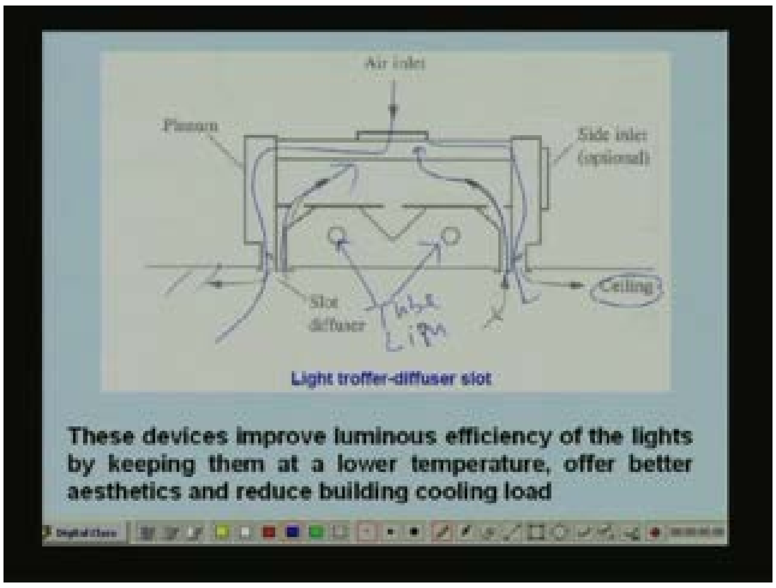

Let me show a schematic of this is, this schematic shows light troffer diffuser slot it consists this actually is a housing which includes fluorescent lamps. These are the fluorescent tubes okay or tube lights okay and they are installed in the ceiling you can see that it is installed in the ceiling and the same housing consists of return air inlets. That means return air goes like this okay, back to the air handling unit and they also have supply air diffusers okay. That means the supply air comes like this okay. That means the same unit combines the light troffer that means where the fluorescent tubes are located and it also consists of supply air diffuser and the return air slots okay. This kind of unit is called as light troffer diffuser slot. What are the advantages of light troffer diffuser slot the first advantage is that since the tube lights or fluorescent tubes are surrounded by somewhat colder air.

They can have or they can be provide better luminous efficiency okay. So if you may keep the lights cool there luminous efficiency increases okay. So this is one advantage of having light troffer diffuser slots. Second advantage is that in one unit you get everything okay. The light installation and supply air and return air inlets okay and it also give provides very good aesthetics okay. So this kind of units are also sometimes used.

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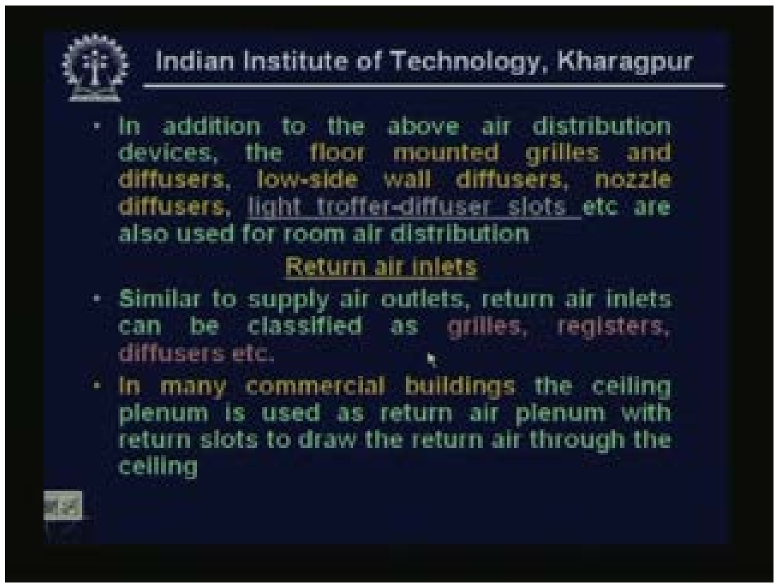

Next let us look at return air inlets. So far we have been talking about supply air outlets. Now let us look at return inlets similar to supply air outlets return air inlets can be classified as grilles registers diffusers etcetera and in many commercial buildings the ceiling plenum is used as return air plenum with return slots to draw the return air through the ceiling okay. That means in most of the commercial buildings you do not have any return air duct okay. That means the ceiling plenum itself is used as the return air duct. That means the space above the false ceiling the entire space is used for return air passage okay.

Of course the ceiling plenum may consists of supply air ducts so whatever space is left that means except the supply air duct that is used for return air passage okay, in such cases you have to install return air slots in the false ceiling okay. So that the return air can leave the conditioned space through these slots and flow through the ceiling plenums okay.

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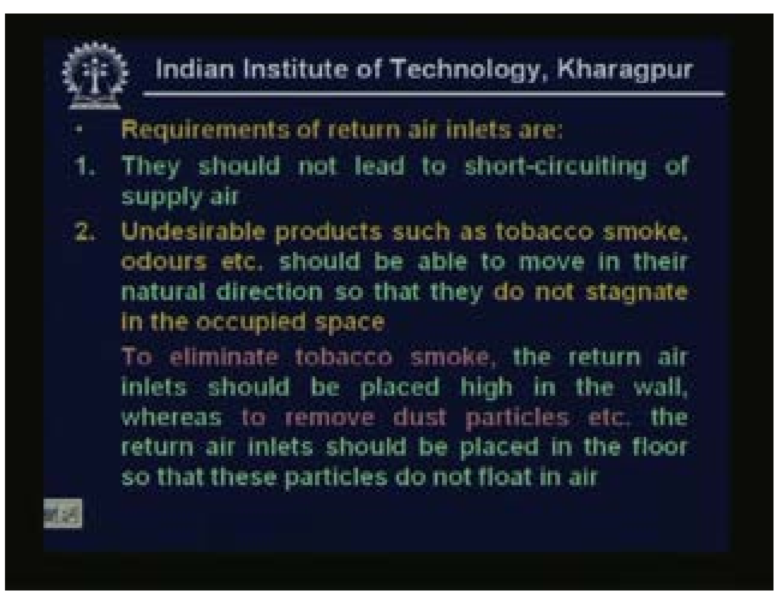

Now though there are certain requirements of return air inlets these requirements are they should not lead to short circuiting of supply air. That mean the cold air without mixing with the room air should not simply go back to the return air passage okay. So short circuiting should be avoided and undesirable products such as tobacco smoke odours et cetera should be able to move in their natural directions. So that they do not stagnate in the occupied space this is very important and this decides actually how where you locate return air inlets. For example to eliminate tobacco smoke the return air inlet should be placed high in the wall.

So that the tobacco smoke rises because of buoyancy and if you keep the return air inlet at the top it naturally flows in that direction and go leaves the conditioned space okay. So for tobacco smoke elimination you have to put the return air inlets high in the wall whereas to remove dust particles etcetera which tends to settle down on the floor you must keep the return air inlets near the floor okay. So that the particles do not float in air okay these are some of the typical characteristic and which must be kept in mind while designing return air inlets.

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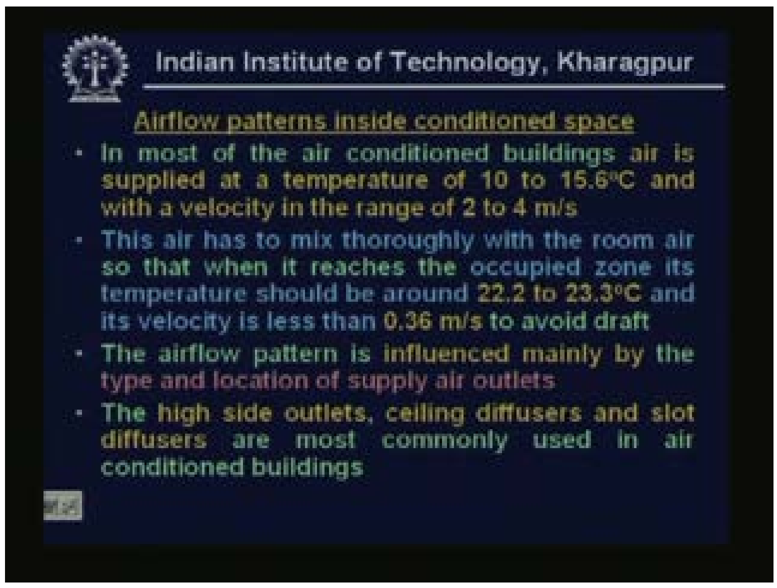

Now let us look at air flow patterns inside conditioned space in most of the conditioned buildings air is supplied at a temperature of ten to fifteen degree centigrade fifteen point six degree centigrade and with a velocity in the range of about two to four metre per second okay. These are general values it can be slightly lower are higher okay. These are I am just giving general values this air as you can see that the supply air temperature is much lower than the required comfort temperature and the velocity is much higher. So this air has to mix thoroughly with the room air so that when it reaches the occupied zone its temperature should be around twenty to twenty three degree centigrade and its velocity is less than point three six metre per second to avoid draft this is very important. The airflow pattern is influenced mainly by the type and location of supply air outlets. The high side outlets ceiling diffusers and slot diffusers are most commonly used in air conditioned building. I have discussed, I have described these outlets and in general compared to supply air outlets the affect of return air inlets is not so significant on air distribution inside the conditioned space okay. The supply air outlet is very important right.

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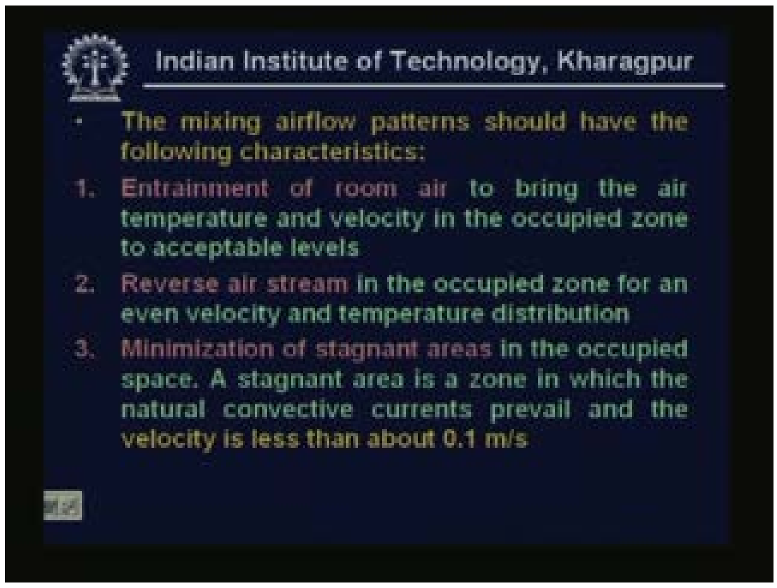

And the mixing air flow patterns should have the following characteristics entrainment of room air. As I have already told you to bring the air temperature and velocity in the occupied zone to acceptable levels reverse air stream in the occupied zone for an even velocity and temperature distribution and minimization of stagnant areas in the occupied space the there should not be any stagnant areas in the occupied space. What do you mean by a stagnant area a stagnant area is a zone in which the natural convective currents prevail and the velocity is less than about point one metre per second okay. So the air airflow pattern should take care of all these factors.

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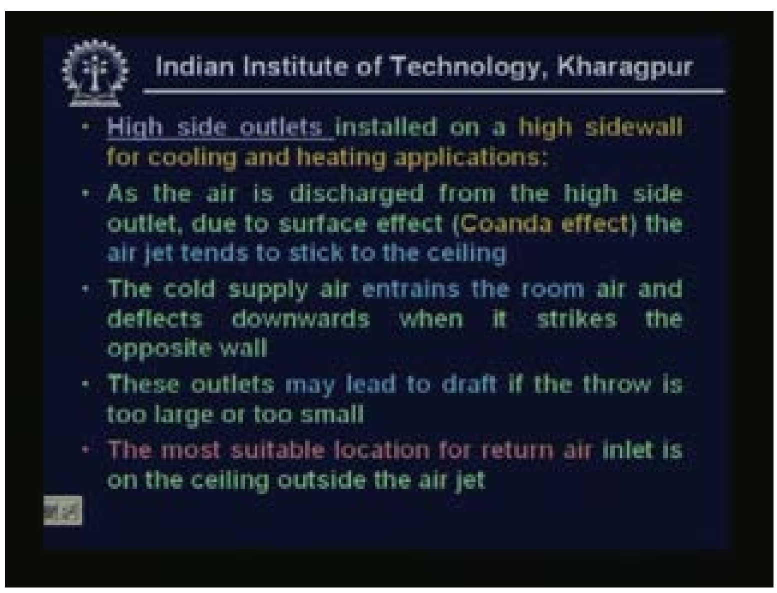

I am sorry airflow air distribution devices okay. Now let us look at high side outlets high side outlets installed on a high side wall for cooling and heating applications what is the air flow pattern of these. First let me describe the airflow pattern as the air is discharged from the high side outlet due to surface effect also known as coanda effect the air jet tends to stick to the ceiling. The cold supply air entrains the room air and deflects downwards when it strikes the opposite wall these outlets may lead to draft if the throw is too large or too small. The most suitable location for return air when you are using high side supply air outlets is on the ceiling outside the air jet okay.

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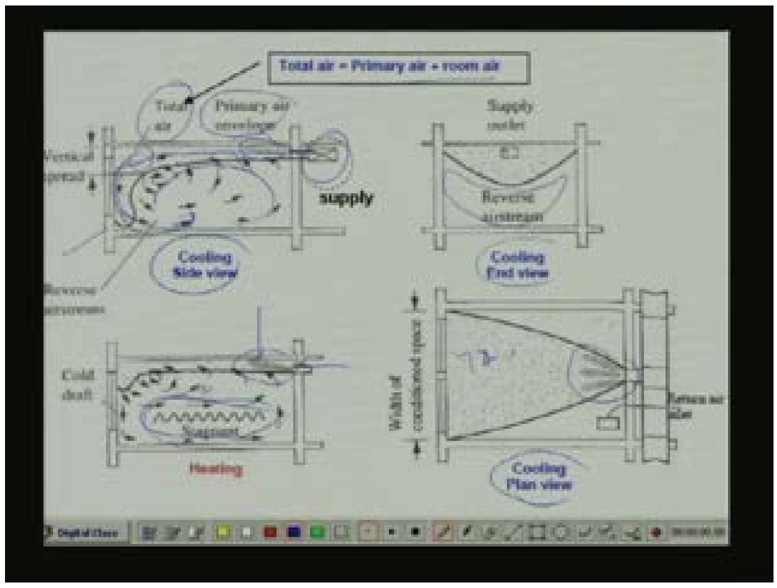

So let me show a schematic of air flow patterns using high side outlets. So we can see here that this is where you have the supply air duct and supply air is coming like this okay. So you have the primary air envelope this dark area is your primary air envelope right. So it is this jet leaves the supply air outlet at high velocity and because of the high velocity and as it flows as it leaves the, this thing it entrains the room air. So you can see that room air is entrained. So you here you have total air which is a mixer of primary air plus room air okay. And if this is designed properly what happens is this air total air and primary airs go right up to the opposite wall. You have a opposite wall here and strike the opposite wall get deflected like this okay and the reverse air stream flows in this direction okay. That means air comes like this gets deflected and flows like this okay.

So as it flows like this it entrains the room air and there is thorough mixing in the conditioned space and there are no stagnant zones when you are using it for cooling okay. That means this particular picture is for cooling and when you are looking from the side okay. The same thing when you are looking from the end that means this end view is something like this, where you are supply outlet is there okay. So this is your total air right and the reverse air stream is in this area okay and this is the cooling plan view okay. So you can see that these are the primary air jets this is the total air okay, and this is where you have return reverse air streams okay. So as far as cooling is concerned these outlets are quite good because you can see that there are there is hardly any stagnant zone whereas if you are using these jets for heating you find that there is a possibility of a stagnant zone okay.

Because when you are using it for heating and when you are supplying warm air because of buoyancy effect it tends to stick to the ceiling okay, rather than coming down okay. So as a result near the floor you may a stagnant zone okay. And you can see here that the air stream for example in this picture and in this picture as it leaves the outlet it tends to stick to the ceiling okay. It is sticking trying to stick to the ceiling this effect is known as surface effect or coanda effect.

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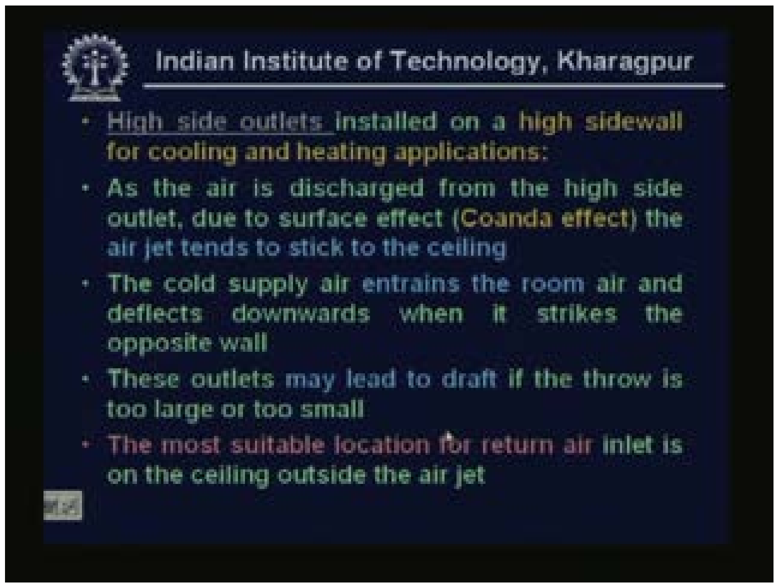

Okay so this is the air flow pattern for size high side outlets.

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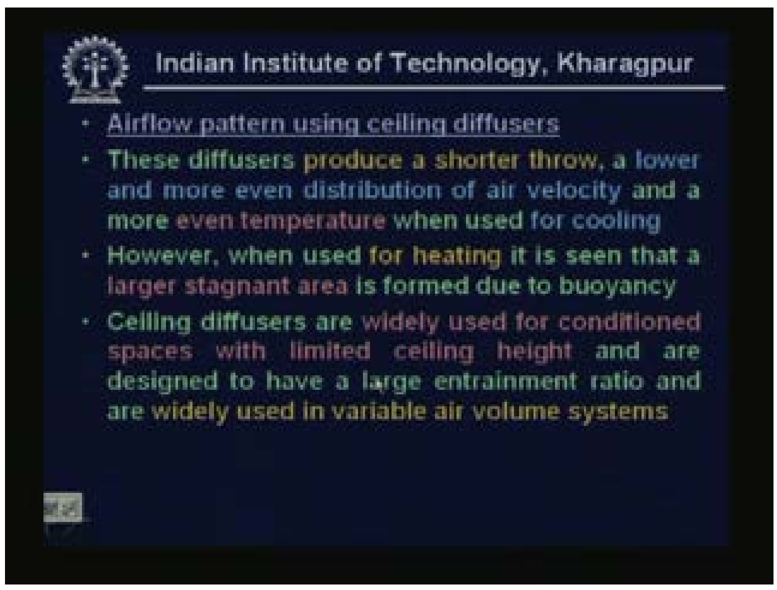

Now let us look at air flow pattern using ceiling diffusers these diffusers produce a shorter throw a lower and more even distribution of air velocity and a more even temperature when used for cooling. However when used for heating it is seen that a largest stagnant area is formed due to buoyancy ceiling diffusers are widely used for conditions spaces with limited ceiling height as I have already explained and are designed to have a large entrainment ratio and are widely used in variable air volume systems okay.

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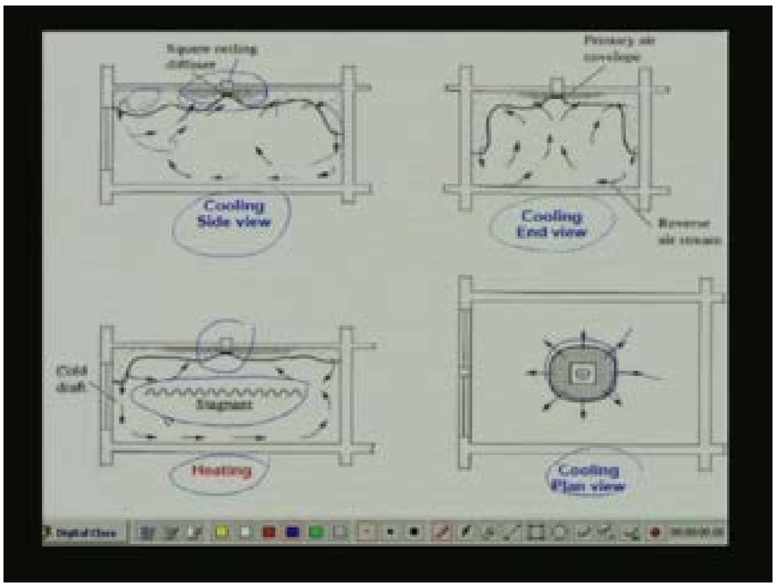

So let me again show the airflow pattern when used for cooling this is the side view okay. So this where you have the primary air and this is the diffuser. So it first sticks to the ceiling because of coanda effect then entrainment talks place and you have the total air here then the reverse streams start like this and there is hardly any stagnant area in this when you are using it for cooling. Similarly this is the end view and this is plain view okay, means you have in this particular you have only one ceiling diffuser and the air is distributed in all directions okay.

However you find that if you are using this for heating application there is a possibility of developing a stagnant zone okay. Again because of buoyancy effect the warm air tends to rise up rather than come down so near the floor you may have a stagnant zone.

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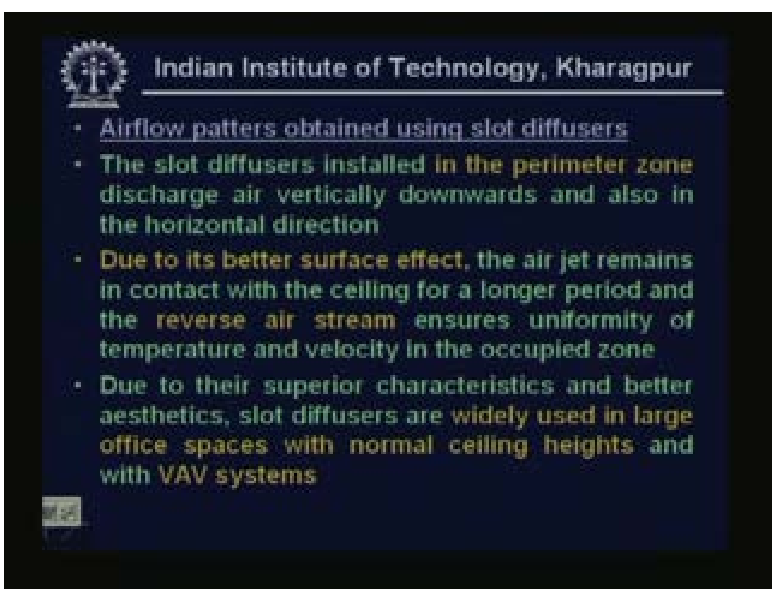

Again you can also have air flow patterns obtained using slot diffusers. The slot diffusers installed in the perimeter zone discharge air vertically downwards and also in the horizontal direction. Due to its better surface effect the air jet remains in contact with the ceiling for a longer period and the reverse air stream ensures uniformity of temperature and velocity in the occupied zone. Due to their superior characteristics and better aesthetics slot diffusers are widely used in large office spaces with normal ceiling heights and with variable air volume systems or VAV systems.

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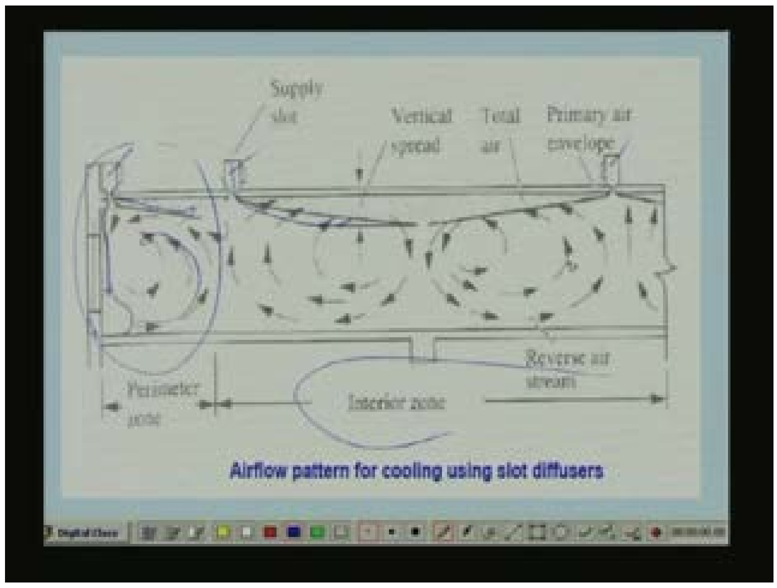

So again this picture shows the air flow pattern for cooling using slot diffusers. So here this zone is perimeter zone. That means near the wall and this is your interior zone okay that means away from the wall. So you have supply slot this is one this is one this is one okay so the supply slot near the perimeter it air flows in the horizontal direction air also flows in the vertical direction okay. Again you can see that the reverse air stream is taking place like this whereas the air that is supplied at the interior zone it flows in the horizontal direction okay. Again the reverse air stream takes place and you again find that there is hardly any stagnant zone so again these are very good for cooling applications.

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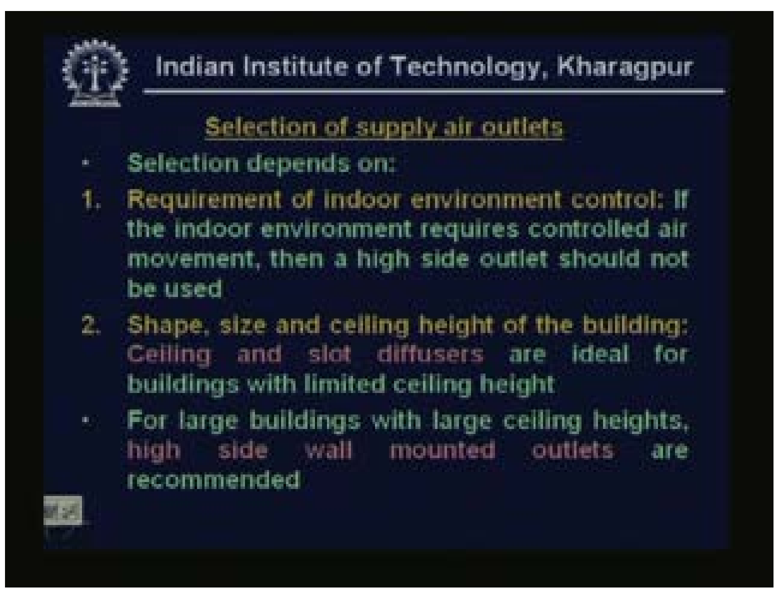

Next let us look at selection of supply air outlets selection depends upon the following criteria requirement of indoor environment control. If the indoor environment requires controlled air movement then high side outlet should not be used okay. Control air movement means you want air movement only in certain locations not every where then you cannot use high side outlets because you do not get very good control here and it also depends upon the shape size and ceiling height of the building. Ceiling and slot diffusers are ideal for buildings with limited ceiling height for large buildings with large ceiling heights high side wall mounted outlets are recommended okay.

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Then comes volume flow rate per unit floor area side wall outlets are limited to low specific volume flow rates and compared to slot diffusers the ceiling diffusers can handle efficiently a larger flow volumetric flow rates and this table here.

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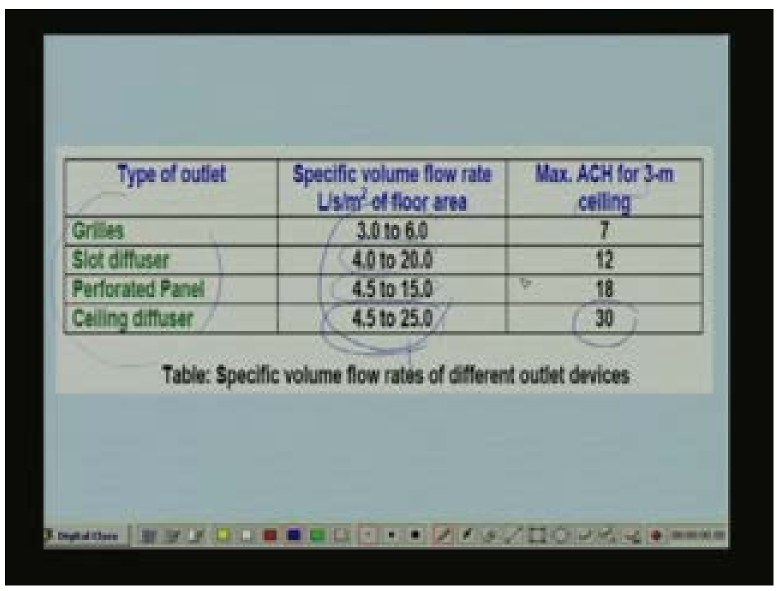

Type of outlet	Specific volume flow rate L/s/m^2 of floor area	Max. ACH for 3-m ceiling
Grilles	3.0 to 6.0	7
Slot diffuser	4.0 to 20.0	12
Perforated Panel	4.5 to 15.0	18
Ceiling diffuser	4.5 to 25.0	30

Table: Specific volume flow rates of different outlet devices

Shows the specific volume flow rates of different outlet devices okay, so here you have the type of outlet grilles slot diffusers perforated panels and ceiling diffusers. Here the volumetric flow rate per metre square of floor area okay. So this is litre per second per metre square of floor area.

So you can see there for grilles it is three to six litres per second per metre square whereas for slot diffuser it's higher perforated panel at four point five to fifty and for ceiling diffusers you can see that compared to the other types. You can have so much higher volumetric flow rates per unit floor area okay. Again the same thing is given here in terms of maximum air change for air change per hour for a three metre high ceiling okay. So again you can see their ceiling diffuser can handle large volumetric flow rates.

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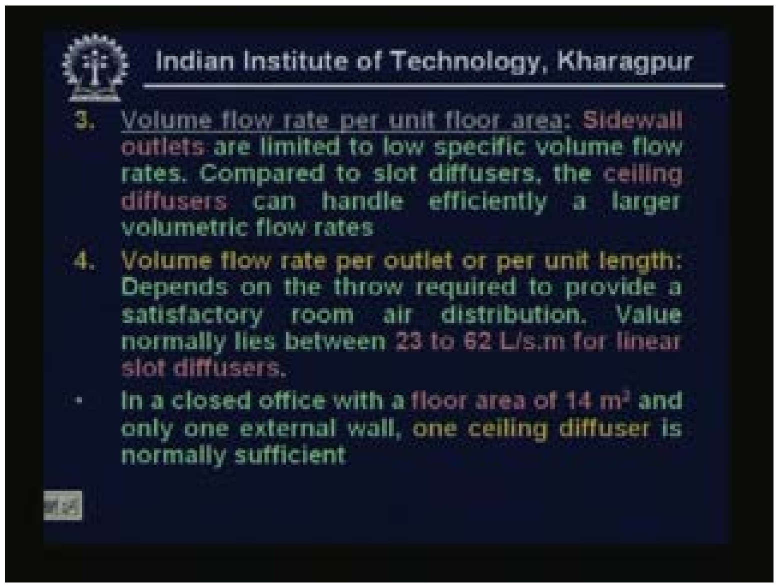

Next important criteria is the volume flow rate per outlet or per unit length this depends upon the throw required to provide a satisfactory room air distribution okay. And this value normally lies between twenty three to sixty two litres per second per metre for linear slot diffusers. So if you know the total volumetric flow rate you can find out or you can calculate what is the length of the slot diffuser required because you know the volumetric flow rate per unit length okay, and for ceiling diffuser for example a thumb rule says that in a closed office with a floor area of fourteen metre square and only one external wall one ceiling diffuser is normally sufficient okay. So again depending upon the floor area you can decide the number of ceiling diffusers.

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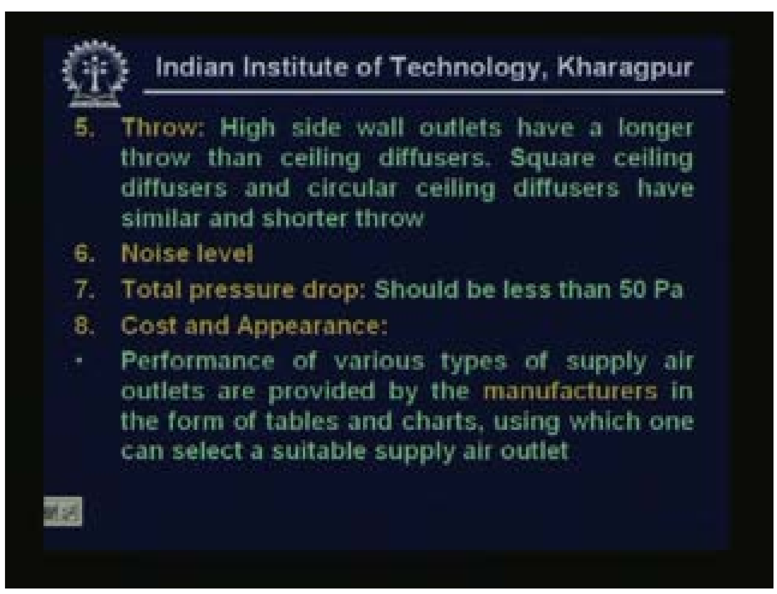

Next comes throw we have already explained what is the throw high side wall outlets have a longer throw than ceiling diffusers. Squared ceiling diffusers and circular ceiling diffusers have similar and shorter throw okay. So these are the characteristics of different devices so depending upon your throw requirement you have to choose accordingly then noise level okay, so obviously this is very important then comes total pressure drop. Total pressure drop generally varies from five to fifty Pascal depending upon the type of the outlet and depending upon its design and the flow rate and normally it should be less than fifty Pascal then comes cost and appearance. So these are also important in some applications cost is more important and some applications appearance is more important.

So depending upon the specific requirements again you have to select the required type of outlet.

Normally performance of various types of supply air outlets are provided by the manufacturers in the form of tables and charts using which one can select a suitable supply air outlet okay. So the manufacturers after thorough testing they give their or they publish or print their catalogues. Where you can they normally specify the characteristics of supply air outlets in terms of the flow rates throw okay, pressure drop etcetera. So and noise criteria etcetera the so depending upon the requirement and using this catalogues one can select the required type of outlet and depending upon the area or depending upon the flow rate requirement one can decide the number of outlets okay.

So this is how the room air distribution system has got to be designed and as I said this is the last stage of an air conditioned system okay. Because once you transmit the air to the conditioned space the only thing that is left is to distribute it properly okay. If everything is right but distribution is not proper then ultimately the purpose is lost because inside the conditioned space because of improper distribution you required conditions cannot be maintained even though the flow rate everything is all right okay. So the air distribution system design is very important okay. So with this we come to the end of this course on refrigeration and air conditioning okay.

So I would like to briefly review whatever we have learned or whatever we have discussed in this course.

So we began this course with a short history of refrigeration then we have discussed the applications of refrigeration and air conditioning. Then we briefly discussed the fundamentals of thermodynamics fundamentals of fluid flow and fundamentals of heat transfer okay. After that we discussed what are the various methods by which low temperatures can be obtained okay. Then we started our course proper with air cycle refrigeration systems okay. So the different cycles ideal cycles and the analysis of air cycle refrigeration systems have been discussed in the in that lecture okay. We have also discussed briefly the cycles for air craft air conditioning okay. Next we started vapour discussion on vapour compression refrigeration systems and this we have studied in great detail because this is one of the most widely used among all the refrigeration systems.

So we discussed starting with the ideal vapour compression refrigeration system actual vapour compression refrigeration system analysis of the cycles okay. And the difference between actual and ideal cycles then we have also discussed various multistage multi evaporator and gasket cycles and their performance characteristics and the analysis performance analysis of these systems okay. Next we discussed again in somewhat detail detailed manner vapour absorption refrigeration systems. In vapour absorption refrigeration systems we began the discussion with water lithium bromide systems in which water is used as the refrigerant and lithium bromide is used as the absorbent and as I have already told you if you remember this is mainly used for air conditioning applications okay.

Next we discussed vapour absorption refrigeration systems based on ammonia water which can be used for both refrigeration as well as air conditioning applications. Finally we also discussed triple fluid or pumpless vapour absorption systems briefly okay. So next we discussed the system refrigeration system components. So compressor is one of the most important components of vapour compression refrigeration system. So we studied this component in great detail and during this we have studied the performance characteristics of reciprocating compressor centrifugal compressor and other positive displacement type of compressors okay. Next we also discussed the performance characteristics design aspects of condensers and evaporators. We have seen different types of condensers and evaporators and how to design them okay, from the given input.

Then we discussed expansion devices starting with capillary tubes, thermostatic expansion valves, automatic expansion valves and their performance characteristics okay. Then finally we have discussed the analysis of a complete vapour compression refrigeration cycle how do we balance a components okay. As you know in a typical vapour compression refrigeration cycle four basic components are there. So how balancing between the four basic components take place this was discussed briefly okay. Next we also discussed the very important topic of refrigerants okay, what are the selection criteria and what is the importance of refrigerant. Refrigerants in view of the ozone layer depletion and global warming potential what were the older refrigerants which was replaced because of these environmental problems and what are the new refrigerants which are eco friendly okay. So these aspects were discussed in the lecture on refrigerants okay.

Next we started discussion on air conditioning with psychrometry okay. So we defined basic psychrometric properties then we have looked at psychometric chart okay, and various isoclines on psychometric chart. Then we have drawn or we have analysed various psychrometric processes using the psychrometric charts okay. So this is the fundamental to the analysis of air conditioning systems okay after the psychrometric this thing. We have psychrometric processes and psychrometric charts psychrometric properties etcetera. We looked at air conditioning systems okay, different types of air conditioning systems and the psychrometry of these air conditioning systems.

Next we studied how to select the required design inside outside and supply conditions. So for selecting the inside conditions we have to take into account the comfort criteria as far as the comfort air conditioning is concerned. So I discussed the thermal comfort criteria what are the different factors that affect thermal comfort right and based on that how do you fix the required temperature velocity and relative humidity inside the conditioned space which have got to be maintain by the air conditioning system okay. Next we have also seen how to select proper outdoor design air condition based on the weather data okay.

Next we began a very important discussion on the design of on the cooling and heating load estimations okay. This is very important to arrive at the required cooling capacity or heating capacity. So in this particular lecture which we have studied in somewhat detailed manner you have seen how to take into account the solar radiation how we, how to take into account opaque walls transparent walls right and the radiation loads etcetera. And how to estimate finally the required building cooling load and the system load using the heating and cooling load calculations okay. Then we have seen air conditioning systems different types of air conditioning system and their characteristics like all air systems all water systems unitary systems air water systems etcetera okay, performance characteristics and the layouts of these systems right. Then we have discussed transmission of air basically what are the basic laws that govern the transmission of air through ducts and how to design ducts and we have looked at three basic duct design methods.

That is static regain air velocity method and equal friction method and we have also seen fan laws and how to use the fan laws finally we have discussed space air distribution briefly okay.

What are the different factors that affect the space air distribution how to select or design the supply air outlets return air inlets et cetera okay. So with this complete this course okay, there are certain topics which have not covered are refrigerants and air conditioning system control and refrigeration and air conditioning systems for mobile applications. For example transport refrigeration or mobile air conditioning systems et cetera okay. So these aspects I could not cover because of time constraints.

So you can refer to advanced books or standard books on refrigeration and air conditioning for details on these aspects okay. I would like to mention here that refrigeration and air conditioning are very important at especially in present day's world. Where they have become in fact essential items refrigerators and air conditioners and since they consume lot of energy and they have an impact on the environment. One has to understand, at least the engineers should understand various factors and we should be able to design or select suitable refrigeration and air conditioning systems so that they serve the purpose with the minimum energy cost and with minimum damage to the environment okay.

With this I take leave thank you very much before talking leave I would like to give some reference books which can be you referred to for basic understanding or for further reading. Thank you.

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