Illumination Engineering and Electric Utility Services
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Lecture No. # 12
Illumination Systems – II

This course is on illumination engineering and electrical utility systems services. This today we are looking at the lesson 12, titled illumination system II that means we had a lecture on illumination systems one in lesson 11 wherein we covered for various applications what comprises the illumination system. In fact it's not enough if we have a source of light. Source of light essentially tries to create the conditions necessary for us to work and be able to take care, view the things and assimilate the information but having various types of sources, effective usage calls for a complete lighting system or a illumination system which consists of a source, gear or a hardware which supports gives the physical support which we call luminaire which was extensively covered depending on the type of application and trying to be integrated with the overall requirements of the environment. And then the ability to control the light flux is what we need. So that means in doing this there are certain accessories necessary to be able to use the illumination system in an effective manner. And in order to do that we look at in this lecture, the accessories necessary for complete lighting system.

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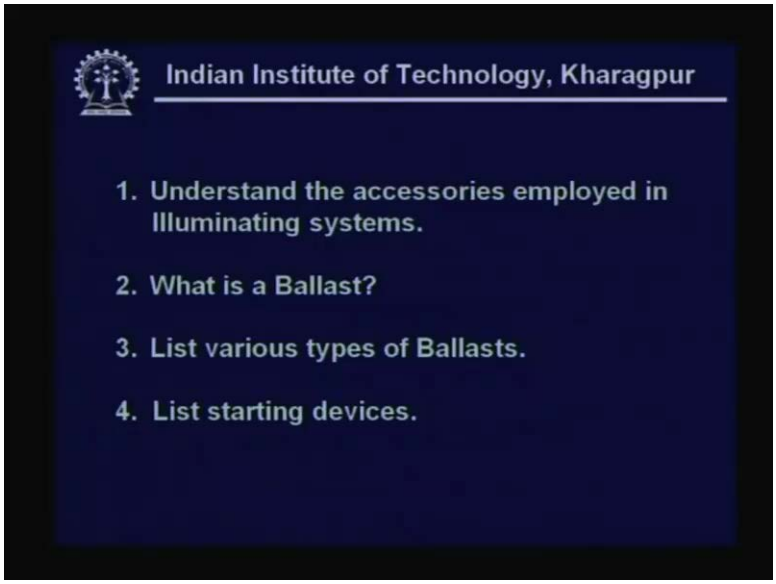

So, the first objective therefore would be to understand the accessories employed in illuminating system or one should be able to list the various accessories necessary to be employed in an illumination system. Then what is a ballast? And we find that most of these applications would have a common accessory as a ballast. So, the second objective has been therefore rightfully termed a ballast, third objective is there could be variety of ballast, so one should be able to list various types of ballast.

Now depending on the nature of the source, nature of the application one may have to use varieties of ballast because ballast by itself means the one which boost or creates the appropriate voltage current conditions. Remembering that most of these artificial sources are powered by the electrical energy that's to be borne in mind. Now it may not be enough if you have a ballast, you have a control gear in fact luminaire itself partially acts as a controller trying to direct the light flux in the area where it is required and at times there is a need to have some kind of a starting devices because we saw the various sources of light have been employing the principles of incandescence then electroluminescence and fluorescence.

Now all these if you except baring the incandescent they are some kind of a discharge lamps. There is a discharge in a gas or a metal vapor which means we find that the discharge has to be initiated and this initiation as may be as observed already and as may be seen calls for a higher voltage than the operating voltage. This is what makes it necessary to have a starting device.

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So, as we observed in the last lecture the fundamental thing is a lamp is the radiation source in a illumination system and the radiation source as is already told, it could be a lamp incandescent lamp employed in the principle of incandescence which is essentially a thermoluminescent phenomena where the filament being maintained at a temperature is of the radiation and this temperature rise is obtained by the passage of current flowing through the filament. Two is a luminaire, luminaire in fact we said primarily supports the lamp it has the lamp holders, secondarily it directs the light along the direction in which it is required. Say you have and we have seen that these luminaires come in variety of shapes and sizes, most commonly the luminaires are suspended from the ceiling, they could be mounted recess in the ceiling itself and there are certain diffusing luminaries which are essentially in the form closed envelopes like ellipsoidal or spherical which are used on certain ornamental lighting gardens which are also called as post top lanterns.

The control gear, what does it do? It helps in controlling the requested amount of flux on the work plane. Now in the early days, the only control was by suitably mounting the lamp and having luminaire with appropriate reflectors. The early reflector was some kind of a reflecting coating placed in the interior of the luminaire which directs the light on to the or in the direction of the task on hand but later on the, it has improved with the help of having mirror reflectors, prism reflectors so on and so forth. These are apart, there are certain applications where you may need varying levels of light flux with at different instance of time.

Now these are all possible quite conveniently with the help of modern electronic controls that is what would form one form of an accessory in controlling. Now let us say we have about 5 to 6 lamps placed in one luminaire each giving out say 1000 lumens but all the time we may not need this, 6 into 1000, 6000 lumens on the task. One may need much lower level at times or maximum level may be required when there is a critical task going on. The simplest control one can think of is a switching mechanism where you have few of the lamps based on the required illumination level are switched on or group controlled switches. These apart, there could be a mechanism of controlling the input voltage where by the light flux can be altered. That is you have what are called as voltage regulators placed in the input in switch similar to our fan regulators.

What do we have? We have a fan regulator is essentially in the crudest form is a set of rheostats for the potentiometric knob, so that by choice of the appropriate resistance amount of voltage applied, the fan is reduced or increased and there by the speed gets controlled. In a similar manner you could have a way of regulating the voltage and these in fact are being using alternating current invariably employ things based on the auto transformer action and in early days who are essentially being used for dimming or increasing the light control and hence commercially were being known as demostats II. Now this is apart, right in the beginning we said one of the objectives in this lesson has been to understand or say what is a ballast.

In fact in talking of the physical processes involving electroluminescence and fluorescence, we said both of them involve some kind of an electrical discharge which gives rise to illumination. And this discharge necessitates that there is a particular voltage required which is most of the times more than the normal operating voltage. To achieve this in fact a ballast is used, these are a part. Once the arc is struck, one needs to maintain the current. In fact arc voltage current characteristics are such that it tends to maintain a reasonably low voltage drop across that with the constant current level.

Now in order to have this and in order to avoid current building up, add infinitum there is a need to have current limiting also current limiting device in series which we can say is an impedance. Now they ballast which we are thinking of has two roles, one to give the necessary boost in the voltage so that the discharge takes place, two to limit the current when the arc is struck, the two have to be achieved.

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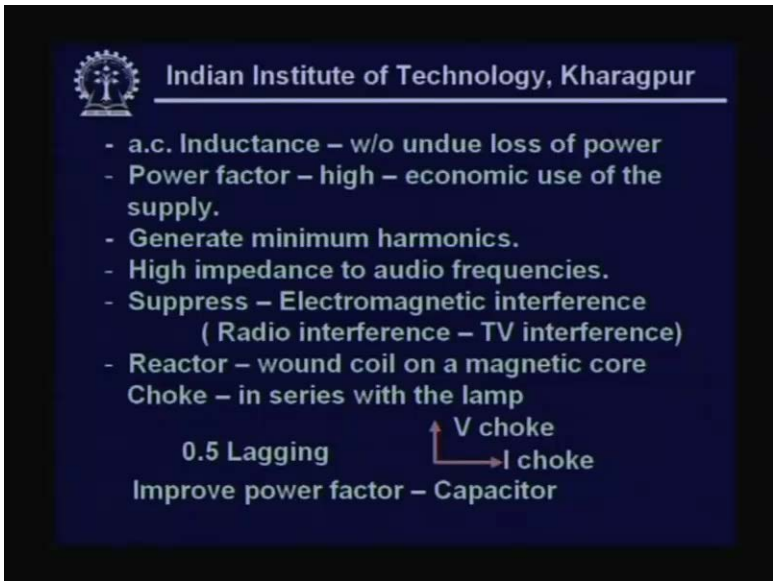

And in fact it is believed that both can be easily got in one shot especially on ac circuits having what we normally know as chock which is nothing but a coil and or it is an inductance having predominantly inductance property. The idea is inductance does give the required current limiting ability number one and one of our objectives has always been to optimally utilize the energy that means there should be no power loss in any of these accessories which we are using. So, inductance becomes a very good candidate in that sense that it acts as a current limiter without undue loss of power.

However the problem is of course that it being predominantly inductive has a low power factor. We try to choose or have circuits, accessories such that power factor is maintained as high as possible. Recall that although power loss is not there by virtue of the presence of inductor, there is a reactive power consumption by the circuit which amounts to having an increased line current from the supply and that is what means you are forced to have higher conductor cross section at the input.

In order to again optimize there, one needs to see what can be done to improve this power factor. And at the same time being an energy storage elements these tend to have their own natural frequencies which tend to generate harmonics. So, we need to design these coils, ballast in such a way that they generate minimum harmonics and it should not generate frequencies in the radio or tv frequencies, so that the interference takes place. And this in fact is these days, the generated interference signals due to such energy storage elements in the networks is what we call electromagnetic interference which was in early days called radio interference and tv interference. So, we need to have a ballast such that it does it operates near at a good power factor, does not consume energy, at the same time see that it does not create electromagnetic interference. Normally, we find that these are reactors or inductor coils, they are wound on a magnetic core in fact colloquially known as chock and they are kept in series with the lamp and typically they have a lagging power factor.

In fact this picture here shows the phasor diagram where v choke and I choke are in an ideal situation in quadrature but in practice it is very difficult to have an ideal inductance. We do find that there is certain resistance or loss associated with any coil wound with the help of a conductor and it seems to have power factors of the order of 0.5. Now incidentally introduction of a capacitor improves the power factor, it also acts as a device to minimize harmonics and suppress the interference.

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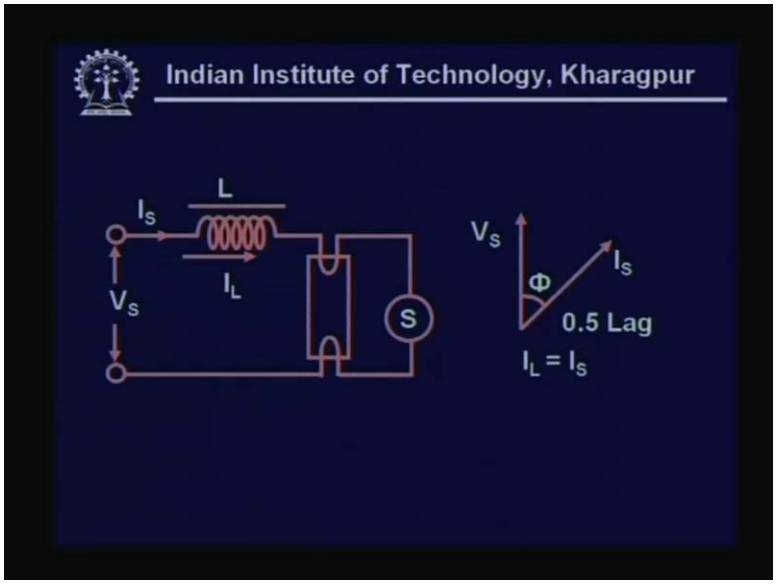

In fact here is the complete schematic of a discharge lamp with all its accessories and the associated phasor diagram where one could see in fact this inductor or the ballast in fact is a coil wound on a magnetic core. V_s I_s indicate the supply, the way it is connected is in series therefore the I lamp is same as the I supply or I_L is equal to I_S. Now, s is the starting device as already discussed in talking about the discharge lamps as well as fluorescent lamps, we did mentioned that to create the discharge one needs to create over voltage across the two electros. The vertical column rectangular column denotes the lamp, the two ends or the two filaments are which are the two electrodes across which the arc is struck. This shows how one has normally a 0.5 lack power factor.

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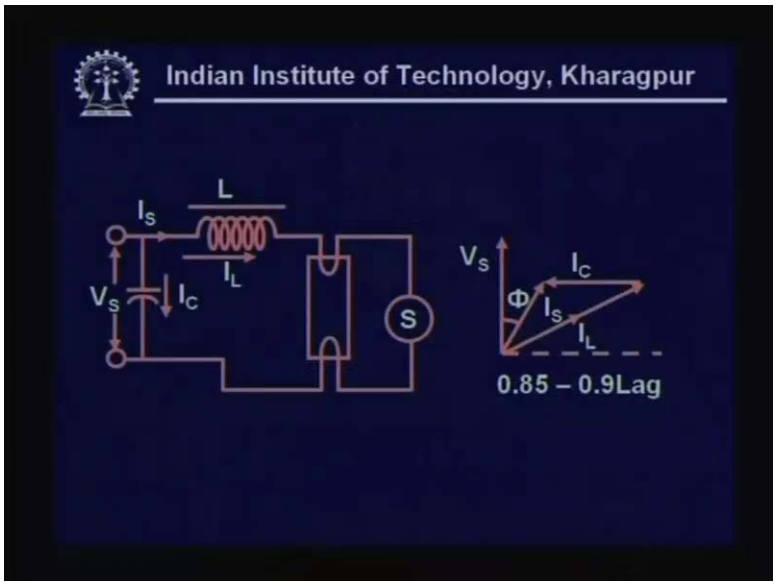

On the other hand if you place a capacitor in parallel, we find that although the lamp current still is lagging in nature, we improve the supply current as can be seen compared to the previous diagram. The power factor angle between the, or the phase angle between the voltage phasor of the supply voltage phasor and the current phasor has considerably reduced and this is one way. The other ways to achieve this are what we call lead lack circuits. Now we have seen in this when you have one lamp supported by one ballast gives rise to a lagging circuit. Supposing in a particular luminaire because it's a common practice in offices to have more than one lamp in one luminaire two lamps is a very common thing and larger work areas you do find trying to go closer to a sheet of light by having more than 2 or 4.

In such a situation one could have a common supply point for a set of two fluorescent lamps or discharge lamps with one being fed by a lagging current other being fed by a leading current that means in a series with one of the chokes you have a capacitor to improve and as a result you have overall power factor improved. So, this is the thing, you have a ballast which is predominantly inductive. Now, since you have an inductive ballast what happens? Initially the current flows through the inductor through one end of the electrode of discharged tube and through the starting device s which is closed and the other electrode back to supply.

Now, if this circuit is broken at some point and the starting device opens, in fact one of the most common starting devices which we have been using is the bi metallic starter which on passage of current because of differential expansion opens out there by there is an interruption in what we call a RL circuit and leads to a transient. The current interruption in a RL circuit has already known gives rise to a voltage build up or a voltage transient which creates the discharge.

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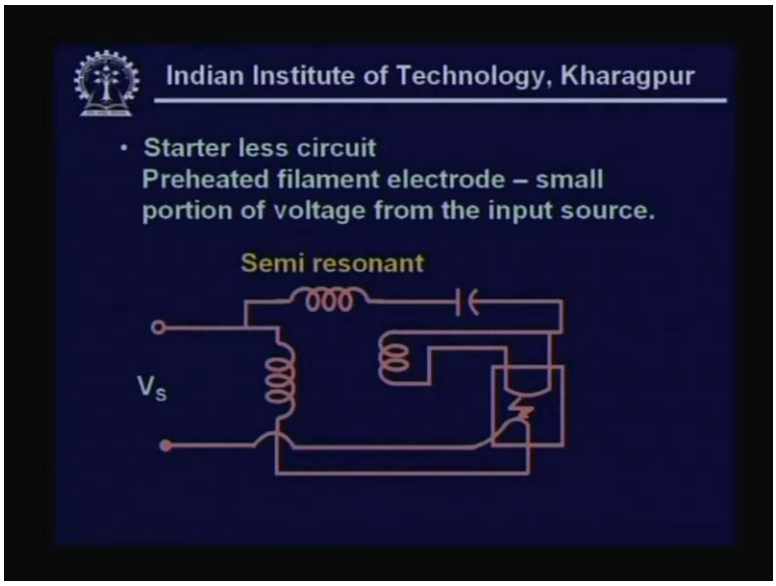

That is what is done but there are certain areas of application where one cannot have such an interruption that means one cannot have a starter. So, one looks for what are called starter less circuits that means there is a need to have some amount of pre-ionization in the discharged tube and this is obtained by having what we call the preheated filament electrode and these get from the same choke you could have a secondary of a smaller rating which gets the required voltage to heat the filament electrodes. This can be seen in fact what we see here is you have a choke or a inductance coil with the series capacitor in a resonant mode to create the required bore voltage.

Remember that is a resonant circuit in fact though maximizes the power drawn series this thing and creates a voltage build up across the energy storage elements. As you can see there is a single transformer which is feeding both and there is a reduced voltage is taken to heat the filament electrode. Now this becomes necessary in certain areas where you cannot allow any interruption in the circuit that is any opening may link to a spark which could lead to some explosion especially in the explosive environments this is preferred.

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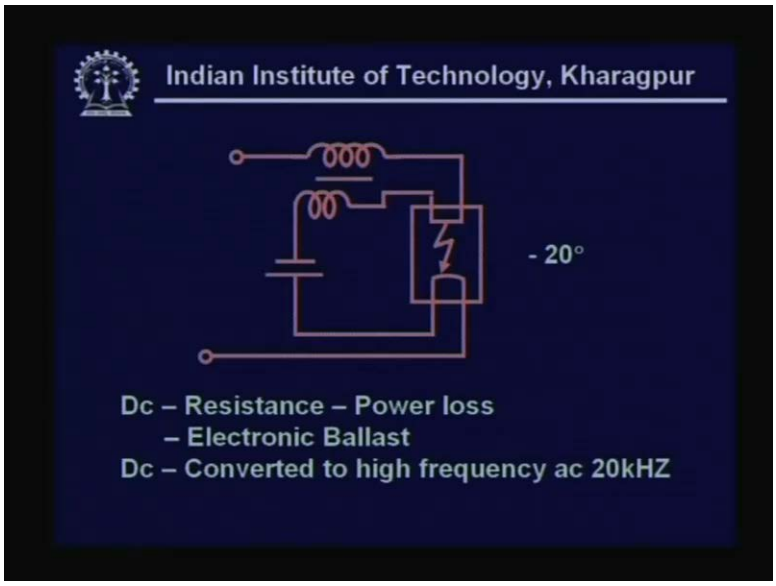

Now in fact this shows yet another scheme of having this and in fact the envelope of such a glass tube is to be taken care, so that even when you are operating in cold environments it does not transmit the low temperature, ambient temperatures to the filaments and thereby reduce the preheated that calls for high up this thing. Now this was fine as long as we were talking with ac, what happens in dc. Dc there is no option because recall that on to a dc excitation, the inductance behaves like a, does not really operating it behaves like a shut and therefore it does not offer any impedance and does not limit the current, yet you need to.

So, the only way out is to use resistors but we all know the usage of resistors leads to power loss. In fact this is where the modern day electronic ballast employ what are called as a power electronic circuits where by dc inputs is converted to high frequency ac around say 20 kilo hertz and then it runs a normal ballast there by the idea is, importance is you do not waste lot of power in the resistors. So that the other problem is the moment you use resistors, building up of the voltage over volting required for the discharge lamp becomes difficult. And how do we have to resort to having those preheated filaments only.

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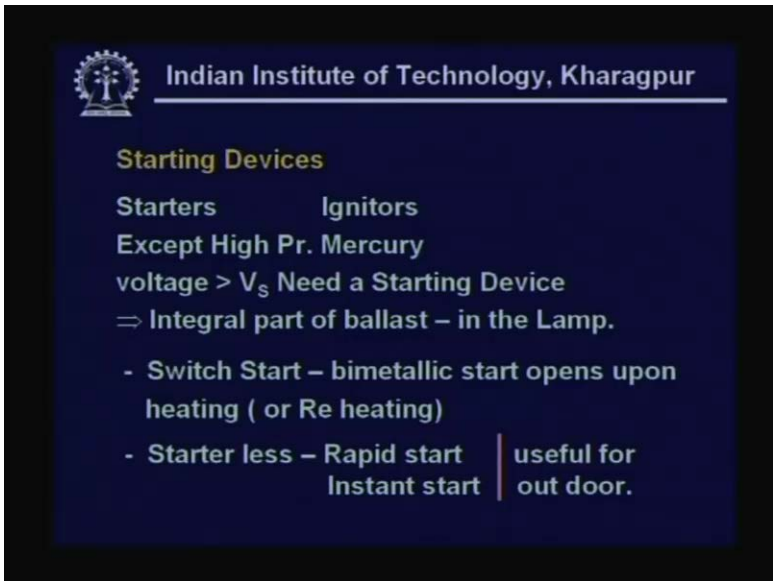

Having said so much about ballast, it's time we had a look at starting devices. So, we saw the first and foremost thing was to have a ballast which was an inductance ac and a resistor on dc or an electronic version which basically converts the input dc into a high frequency ac. Now in order to have the lamp glowing because what lamps are we looking at. We are looking at the lamps based on electroluminescence and fluorescence that is gas discharge lamps like sodium vapor lamps, mercury vapor lamps and normal fluorescent lamps or tube lights which we use quite often. This has not much of accessories are necessary for the incandescent lamp apart from control gear which are integral part of the luminaire.

Now here the over volting is necessary for the arc discharge to takes place and that’s obtained through starting devices. So there are two things that are two categories of starting devices which are called starters and ignitors. Starters are simple devices which all of us are familiar, the familiar cylindrical object placed in an open fluorescent lamp on a batten type is a starter. So, simple switch is a bimetallic switch which upon passage of current gets heated and there by creates the required interruption in the series RL current. As opposed to this we have a category of starters which are called ignitors. The only exception to this requirement is the high pressure mercury vapor lamp because they operate voltages and the pressurization of the mercury gives the required ionization. Whenever the voltage, this stays voltage greater than V_s we need a starting device, what do we mean by that.

We mean that the voltage required to initiate the discharge is greater than supply voltage and often times it is placed along with the ballast and this could be part of the luminaire. In fact the most street lamps which we are seeing based on sodium vapor or mercury vapor they have the complete accessories located within the luminaire. We talked about say preheated filaments that means there is a certain transformer located within the luminaire which gives the required lower voltage to keep the electrodes continuously heat it. All this is possible by having the whole thing within the luminaire.

The simple thing as a starter, known as starter is a switch start. As already told it is a bimetallic strip or which opens upon heating or preheating, when cool they again close and the circuit is completed. Now as long as the lamp is glowing this remains open, so this is the most simplest form of starter. The only as we said we talked about the thing, there are certain areas where you need starter less circuit, rapid start or instant start. These are highly useful in certain explosive areas where the operation of a switch which may lead to a spark is not permitted or such places we do use and they are very useful for explosive environments and outdoor because outdoor application of light, see the moment you have a starter you do find that there is some finite time delay. In talking of discharge lamp we talked about the startup time and though start up times which were very large in the initial stages though have come down to 3 to 4 minutes these days but it is considerable and therefore you have a starter less circuit, it's very good for the outdoor application where you want very fast buildup of the light flux.

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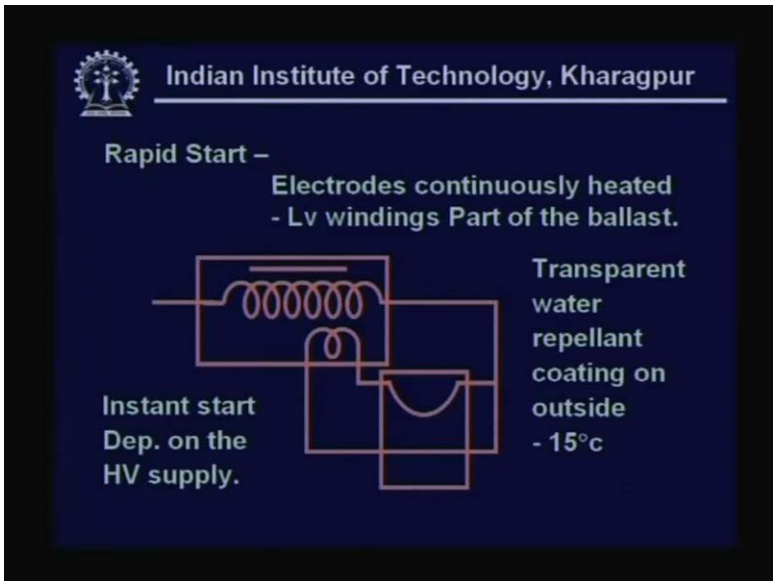

These are termed rapid start and they are continuously heated electrodes as already told they have a low voltage winding which is part of the ballast and the remember these lamps are again apart from having the preheated elements filaments, they also operate on much higher voltages. That’s one lacuna and they are coated with the water repellant coating on the outside so that there is no condensation on the envelope which can reduce the temperature of the element filaments which may come in the way of a heated elements, filaments remaining heated all the time.

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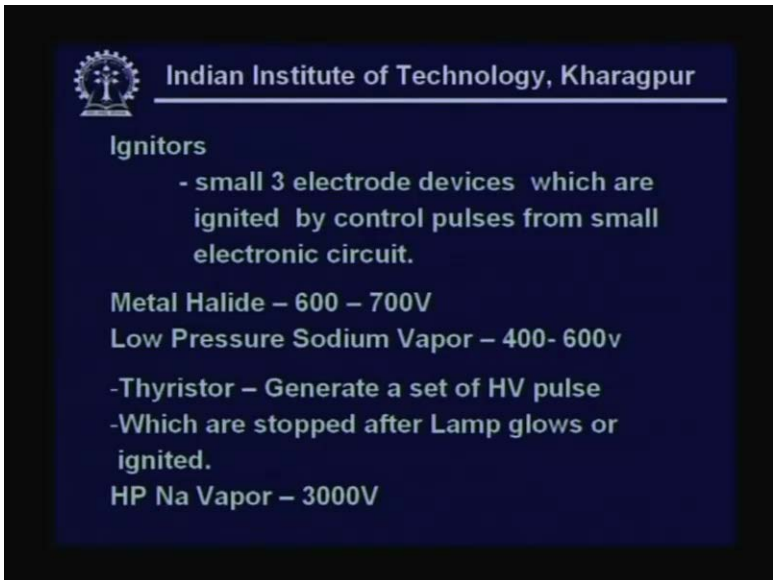

As opposed to this we said there are other starting devices which are called as ignitors. These are small 3 electrode devices, how are they? These are like our transistors or thyristors or triodes. These are basically 3 electrode devices wherein by a control pulses given to what we call gate electrode, they go into conduction mode or and they can be disconnected and these are often found used in the discharge lamps employed like sodium vapor lamps. Now in fact if you look at the voltage of operation required for the discharge to takes place, you have metal halide having anywhere from 600 to 700 volts, low pressure sodium vapor lamps needing 400 to 600 volts.

Remember this is not the operating voltage, if you receive carefully the utilization is at 400 volts three phase which translates to 240 or 230 volts on single phase. So they do need a starter, we said whenever the voltage required for initiation of the discharge is more than the supply voltage one needs a starter. The starter could be a simple switch or an ignitor. In fact it is like a thyristors which generates a set of high voltage pulses and they are interrupted once lamp glows. Incidentally the high pressure sodium vapor requires about 3 kilo volts as the starting or initiation voltage. So these give us a clear idea that we do need a starting device, we do need a device to control the current or the current limiting which we got in the form of a ballast. So we have the accessories wise from a control point of view apart from luminaire. Luminaire itself is the fundamental control device which directs the light flux where it is required and then you have ballast which enable getting the required over voltage like we see that metal halide needs about 600 to 700 volts, starting voltage. This is obtained by having a starter. The starter could be a simple switch or an ignitor.

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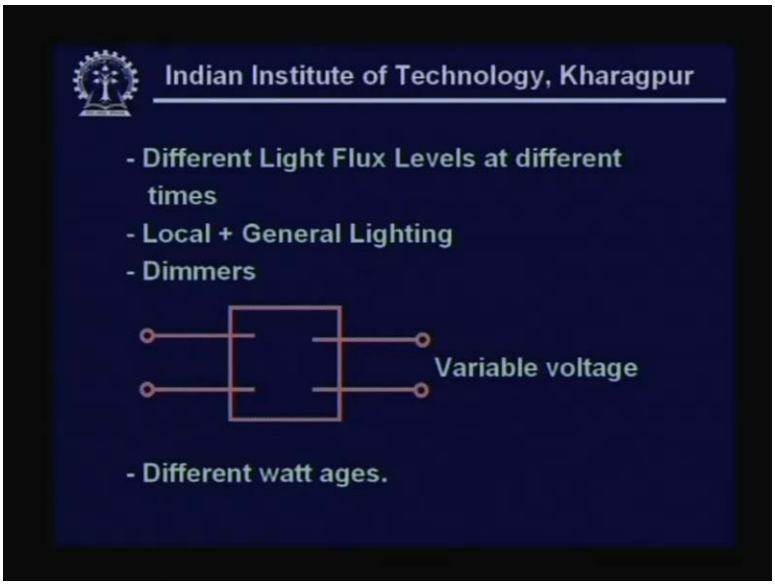

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Now this is apart, from a control point of view we were saying we could need different flight light flux levels at different times. You consider a typical drawing room of a residence and the different situations like when you are basically doing some study, the amount of light required on the work table is more compared to when you are basically sitting and relaxing, listening to the music. Now this is often achieved in different ways, one could be having two categories of lighting systems, one for the general lighting of low level then two some local lighting which can give the increased light levels on the task. So this is what we call local plus general lighting that is you have a general lighting for the complete movement in the room and the other activities which do not require intense light flux but critical tasks of writing, swing or may be soldering these need more light that could have a local lighting.

These apart, the general lighting itself may need to be controlled and this is possible with the help of an electronic controls. And one of the important controls that may be used are known as dimmers. The dimmers per say are nothing but which control the input voltage, in fact if we are using incandescent lamps so very convenient thing, how do we do. We reduce the voltage there by the light output reduces. This voltage regulation employing dimmers is possible and these dimmers as already told are just like the regulators that are employed to control the speed of the fan. This blog in fact represents a dimmer would have a constant voltage as input with a variable voltage coming out. In fact since we are using ac's electrical alternative current, the best variable device would be a kind of an auto transformer. Auto transformer is basically working on a principle of a conductance transformer.

Now that is how in fact since the early days small auto transformers were employed essentially for light controls in getting the reduced levels or increased levels using our transformers, they were also known as dimmers stats. Now there is another application which is possible is to have different wattages. Imagine having a light illumination system with two levels of wattages.

Electronically one could control getting the light output at different wattages depending on the requirement and one area where you could think of two distinct light flux levels are for street lighting. The major aim of street lighting is easy movement people on the road and the vehicular moment. And as can be seen, more the number of people using the road larger the traffic vehicular flow, the higher would be the levels of light required. When do we need? We need essentially from sunset to sunrise.

However remember most roads are hardly used say beyond midnight, may be these days close to midnights earlier days it choose to be say around 10 pm. So this is where it's very interesting that one control scheme could be that you have two distinct circuits, one circuit for every alternate lamp. So during the increased traffic levels say from sunset to midnight, all the lamps are on. This will be again reviewed when we are talking about the highway and street lighting. The other approach would be to have each lamp having or each lamp system having two sets of lamps or wattages. In fact these days we do get the accessories meant to be operated at different wattages. So, we can suitably program the controllers to switch on higher wattage from sunset to midnight and later on the lower wattage. This is, other simple thing would be you have two lamps in parallel during sunset to midnight and possibly one lamp switched off after that.

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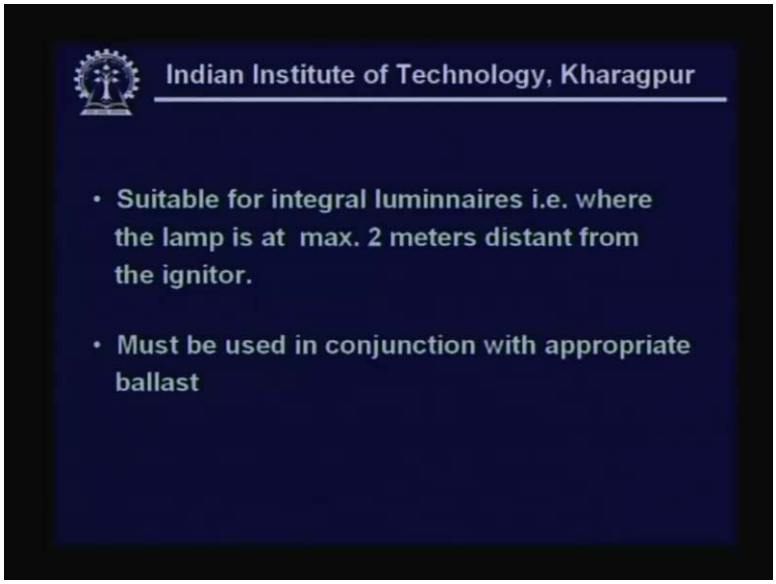

This is all possible and they are employed in luminaires and typically lamps when employing ignitors are kept at a distance of at least two meters from the ignitor. Now whenever we are using ignitors, ignitors we are being talking about are controlled switching devices which are employed essentially in discharge lamps of that kind.

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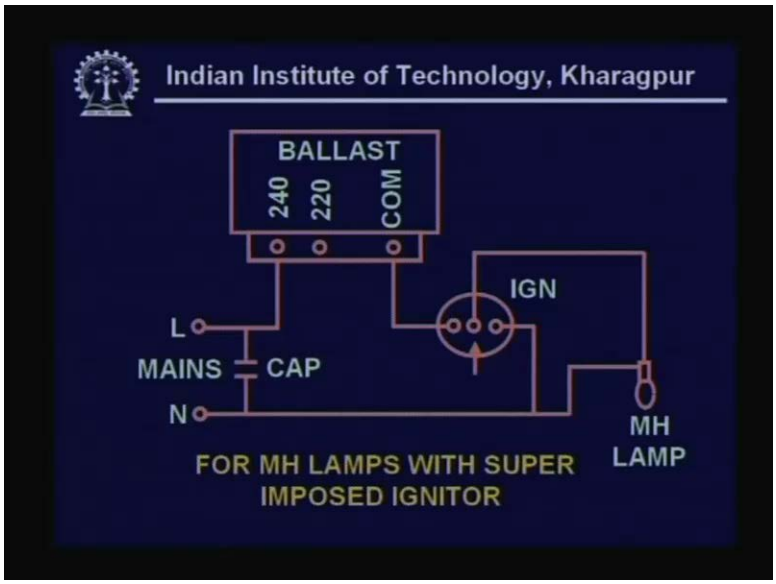

Now this shows the ignitor along with the ballast and power factor correction capacitor and the metal halide lamp. Now we said metal halide lamps are one which have a starting voltage anywhere from 600 to 700 volts. Observe one thing, the ballast out here has got a marking 240 and 220 that is in fact it's also has got a provision to operate or choose the required inductance based on the input voltage. This is because there are certain areas where you may have consistently low voltage or certain areas where consistently higher voltage level though we are expected to have certain guaranteed voltage. This is designed to take care of both circuits. As can be seen power factor correction capacitor is placed right across the line and neutral.

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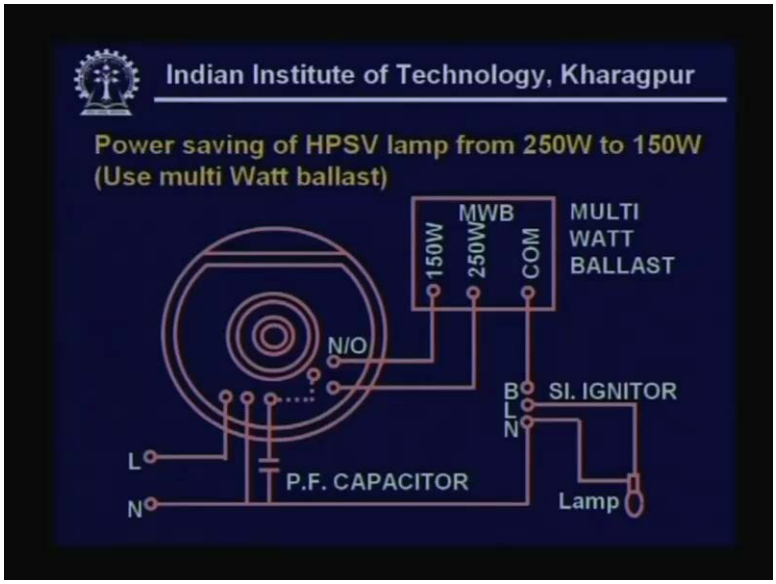

So the power saving we were talking about using a multi watt situation, in fact this is also possible in the way of having what are called as a multi watt ballast. When we were talking about the multi watt application, we talked about a scheme which may be useful in lighting the roads. We said typical road lighting is necessary from sunset to sunrise with increased illumination levels during the heavy traffic that is from sunset to say midnight and some residual lighting necessary only from the security point of view from midnight to dawn. So in these situations we can have we said two lamps located or two circuits, one circuit for the heavy traffic period, the other, as alternatively we do have ballast available for multi watt consumption.

In fact here is a circuit which shows two distinct wattages 150 watts, 250 watts and this is termed as multi watt ballast. So if we are using this let us say we allow the lamp or wire the control circuit such that the lamp operates at 250 watts say from evening to the midnight when the vehicular traffic is very high and then later we allow the lamp or the control circuit switch over to 150 watts. This is possible through electronic control circuits which are based on clocks or timers these days. Now in fact this is would have been difficult earlier days because if it had to be manually switched off but since we have reliable electronic timers available these days clock based switches we can do this.

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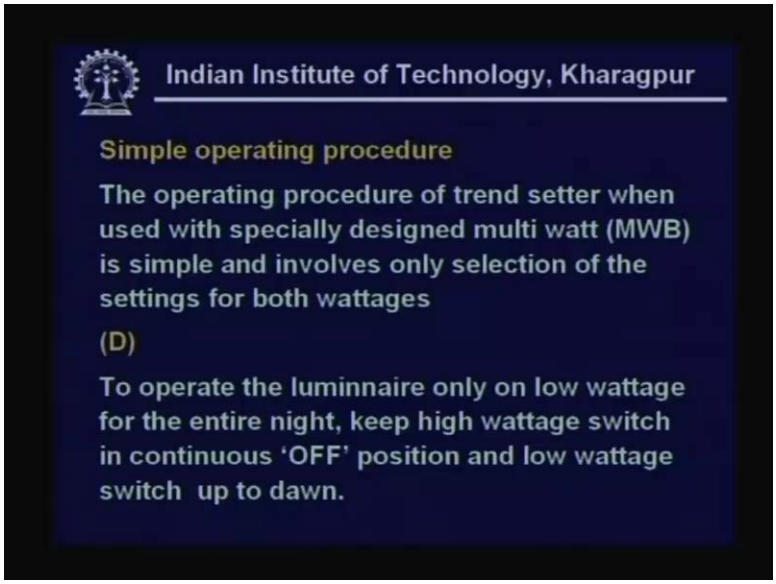

Now in fact these are also called trend setters and they as already told they are using multi watt ballast and the important thing is to select the appropriate setting. In fact a more easier control mechanism could have been to use light operated switches that may not be useful in selecting the wattage but control point of view instead of a manual switching on or switching off, you have a light operated switch which basically detects the ambient light, switches on the circuit or switches off the circuit like you need to switch on the lamps at say 5 in the evening. Then detecting the low ambient light, the circuit goes on. Basically it works on what are called as a light dependent diodes and they go into conduction mode. The same thing can be used by the suitable design of windows based on the light entering; one could in fact have controls design.

This of course shows how that multi watt ballast could be used on low wattage for the entire night and high wattage for such a period when you really need in the evening.

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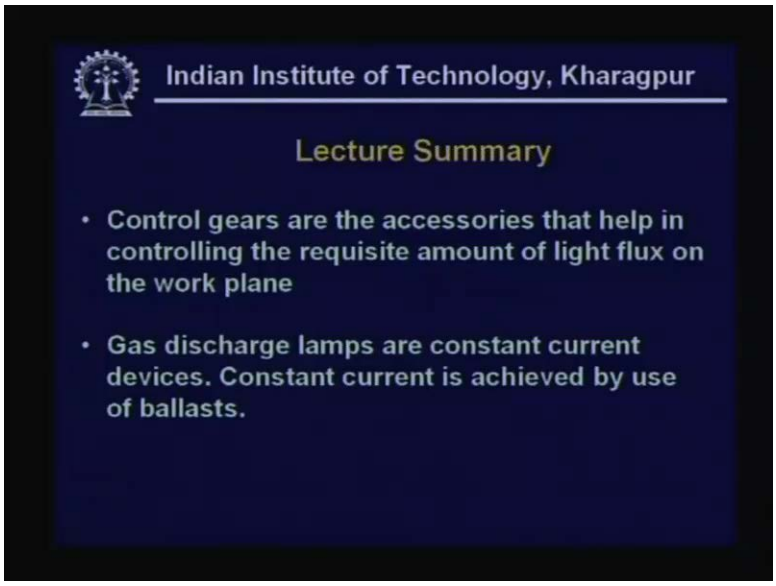

So in at sense what we have seen? The illumination system which comprises of the lamp and the luminaire, luminaire being the physical structure which supports the lamp which has protects the lamp from the environment depending on the area of use, it needs to give all the protection like outdoor situation it has to see that there is no moisture entry and it has the power controls. In fact the primary control of light flux is through luminaire itself which may have a reflecting coating on the interior of the luminaire or it may have reflectors based on mirrors placed behind the lamp or it could be prismatic reflectors that is the primary control. Then the electronic circuits which can selectively choose the lamps within a set of lamps that is if you have a luminaire with 4 fluorescent tubes, depending on the requirement one may need to switch on 2 or 4 depending on the flux levels one can have controls in built.

In fact today one could control them through remote controllers, electronic controllers. Then the most common applications have been to have electroluminescence and fluorescence which are all discharge lamps requiring that the current be limited. In order to limit the current and in order to have good start up we need accessories. So, in summary control gas or the accessories that help in controlling the represent amount of light flux on the work plane, gas discharge lamps are constant current devices this is achieved by use of ballast.

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Requirements of good ballast are, it should not have any power loss, it should offer high impedance to audio frequency, it should suppress EMI/ RFI or TVI and provide ideal starting conditions. And at the same time power factor has to be maintained as good as possible and this improvement is done using capacitors in series.

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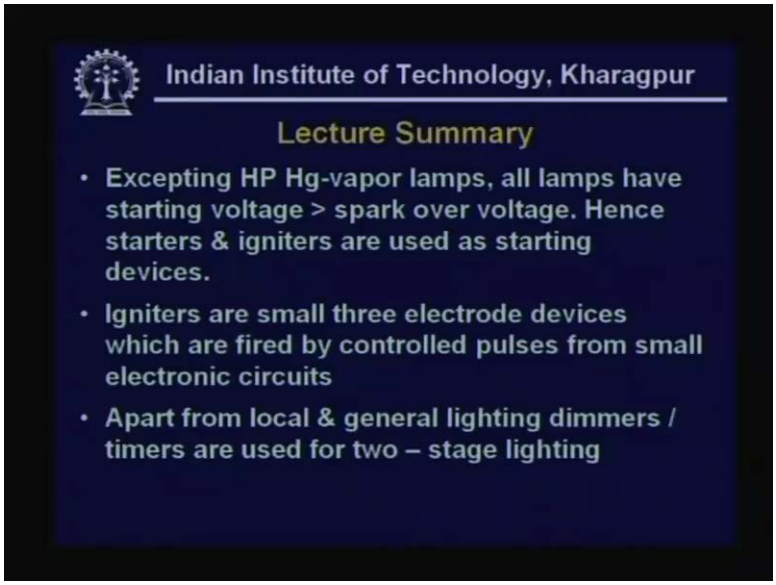

The excepting high pressure of mercury vapor lamp, all vapor lamps have the starting voltage requirement much higher therefore than supply voltage, therefore starters and ignitors are required are used as a starting devices. Ignitors are basically small three electrode devices fired

by controlled pulses from small electronic circuits. Apart from local and general lighting dimmers and timers are useful in controlling the flux levels as well as the energy levels.

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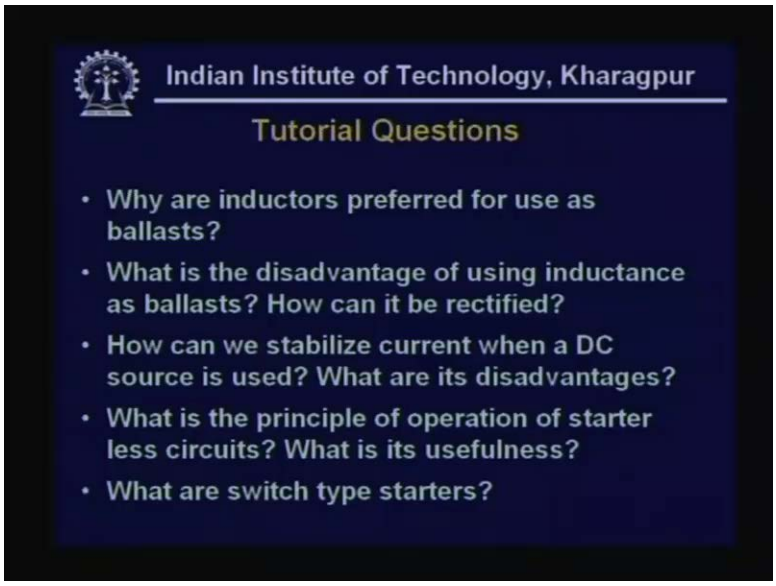

The tutorial questions are why are inductors preferred for use as ballast? What is the disadvantage of using inductance as a ballast? How can it be rectified? How can we stabilize current when a DC source is used? What are it's disadvantages? What is the principle of operation of starter less circuits, what is its usefulness, what are switch type starters?

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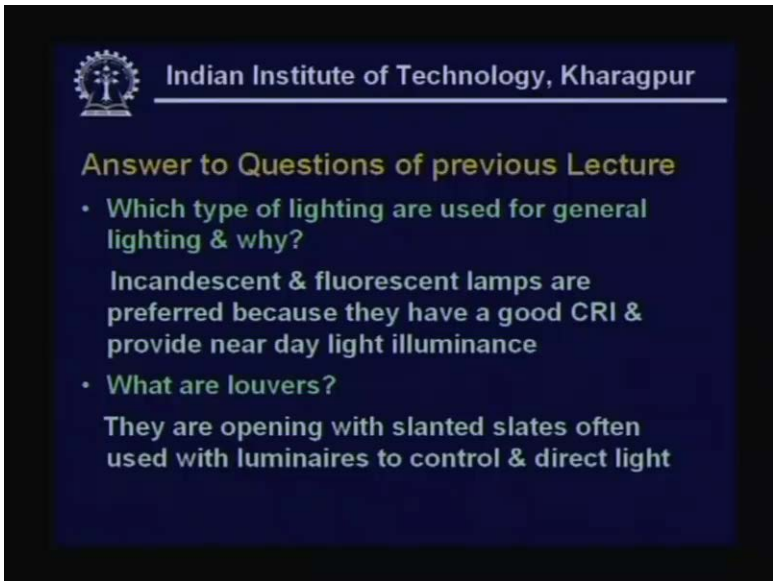

Answer to question of the previous lecture: which type of lighting are used for general lighting and why? Incandescent and fluorescent lamps are preferred because they have a good colour rendering index and provide near day light illuminance. What are louvers? Louvers are the openings with slanted slates often used with luminaires to control and direct light.

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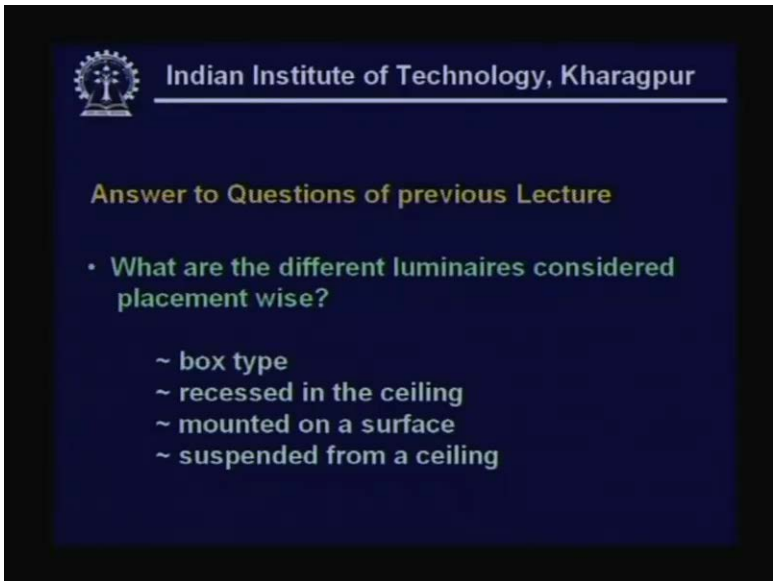

What are the different luminaires considered placement wise? Box type, recessed in the ceiling, mounted on a surface, suspended from a ceiling these are the various types of luminaries one may come across.

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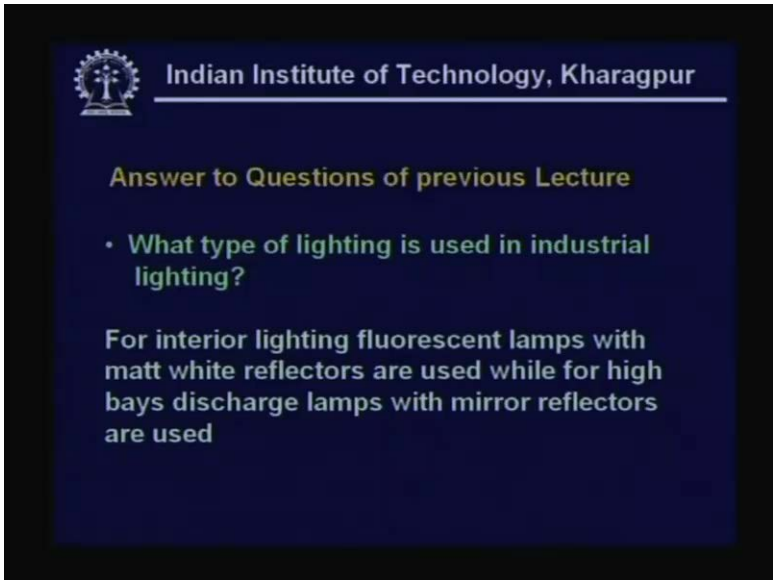

What type of lighting is used in industrial lighting? For interior lighting fluorescent lamps with matt white reflectors can be used whereas for high bay discharge lamps with mirror reflectors essentially employing sodium vapor lamps is used.

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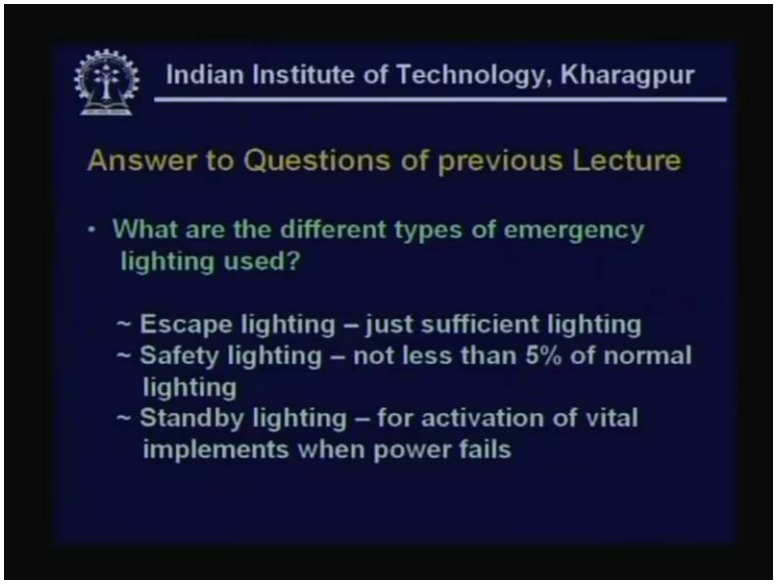

What are the different types of emergency lighting used? Emergency lighting is escape lighting which is just sufficient lighting. The safety lighting about 5% of the normal lighting then standby lighting for activation of vital implements when power fails. Thank you.