Illumination Engineering and Electric Utility Services
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Lecture No. # 10
Discharge Lamps – III

Welcome to this course on illumination engineering and electrical utility services. Today we are going to take up lesson 10 which is titled discharge lamps III. We have been looking at discharge lamps in the last two lessons and as the name indicates the lamps operate in the principle of discharge in a gas or a metal vapour and they use the physical process of electro luminescence and fluorescence. The electro luminescence is essentially radiation by the arc discharge whereas we found that when we are using a mercury vapour, we do have radiation in the zone which we call as ultra violet. Recall that the complete spectrum of light can be categorized broadly into three groups. One, the ultra violet zone, two, the visible zone, three, the infra-red zone and in fact the fluorescence works in the principle of observing radiation in the ultra violet zone and reradiating in the visible zone. So we had a look at these some of these aspects in the last two lectures.

We continue with the fluorescent lamps a little more in this particular lecture. One important thing which we observe was that no matter what type of discharge lamp you have, you need to maintain the arc discharge which is a constant current phenomena and has to sustain the arc in the supply voltage variations which are inevitable. And that is where we need to have a device which maintains the current through the arc constant and this is how we have one accessory brought in all these lamps in the form of what we call ballast. It not only helps in creating the required higher potential in the beginning, they have the arc struck. And the other important term aspect which was to be noted with these lamps was unlike an incandescent lamp, they do produce a band which produce radiation which is band limited. It's not a continuous spectrum as it was in an incandescent lamp. In fact incandescent lamp would produce a spectrum which is quite close to natural sunlight and that is what, we are looking at all our sources when we are trying to design the lighting systems. The aim is to bring as close to the natural light as possible and to make efficient productivity, okay.

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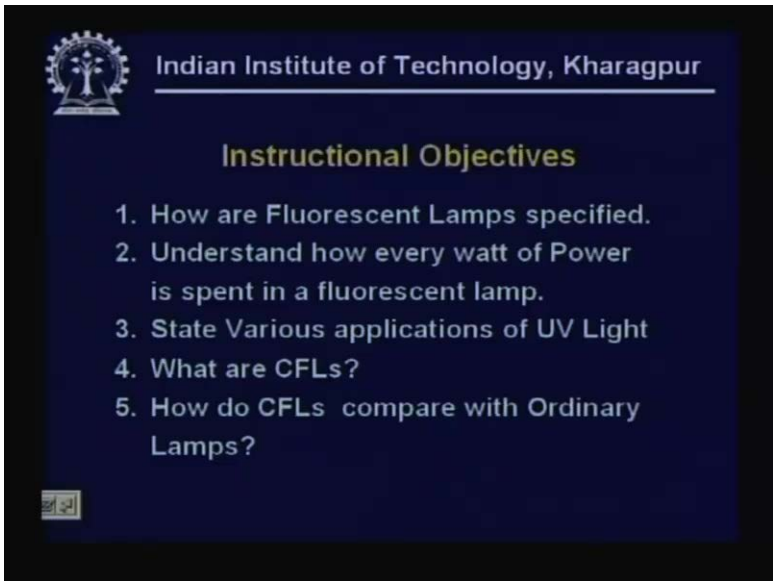

So with this in mind the instructional objectives for this lesson could be listed as how are fluorescent lamps specified. Understand how every watt of power is spent in a fluorescent lamp. Remember when we move from incandescent to discharge lamps, one interesting thing which enabled us to consider these was not withstanding the line spectrum the good light efficacy. Light efficacy recall was talked in terms of lumens per watt that is the light flux radiated per every watt of energy consumed. The other thing we say the first objective says how are fluorescent lamps specified, we are looking to it. In fact you remember most sources were talked in terms of the nominal rated power consumption and once we know the power consumption we know the nature of a lamp source.

We also have an idea of the amount of efficacy that it has depending on the nature of physical process that it uses. Now apart from using for illumination purposes which we say is for viewing things or making objects perceptible to us. There are the other applications of the ultra violet light, we try to address that. The third objective is state various applications of uv light. Now the trend these days all of us have observed these, they are what are called as CFLs or compact fluorescent lamps. So, we look at, have a look at what these are how they compare with the normal lamps, how do CFLs compared with ordinary lamps. So the lesson would be centered around this. So, continuing with the discharge lamps so we have logically taken in fact recalling that there were 4 physical processes thermo luminescence or incandescence was a body maintained at a higher temperature giving out radiation.

Yes, we did get reasonably good efficiencies compared to Edison's incandescent lamp but still the light I mean the efficacy, luminous efficacy of an incandescent lamp is still very low and that is what has driven us look for alternate applications. And in doing so we do recognize that the discharge lamps like sodium vapour and the mercury vapour which we have exhaustively covered in the earlier lecture are having good or high luminous efficacy but do not have good colour rendering. Colour rendering what do we mean? We mean colour rendering ability of perceiving the colour in its original state but we have recognized that there could be applications

where we may not need to have reasonable, I mean good colour rendering. It may be all right if we are able to get the objects in mac over sense and not worried about the details and that is how they are useful.

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Coming with, continuing with the fluorescent lamps, the fluorescent lamps the radiation depends on the current level in fact we said the luminous flux depends on the arc current and often times in fact the specification is what we are going to address to begin with. The people who have been using these lamps are not the common man but the personal working with the maintenance systems and architects and engineers are aware of a specification which is mentioned in terms of the tube diameter and is often specified as t sub n where n stands for the number, it could t_5 is a common thing which is being used. The important thing to be remembered all though it's a constant current thing, as the length of the tube increases the voltage increases.

Now here again another important issue which comes up. We had seen in the loss of illumination how the effect of light at a particular point which we call as the illuminance and we talk in terms of the lumens per unit area. That is lumens per meter square has lux, it depends inversely with the distance from the point source incandescent lamp could always be viewed as a point source. Now as against this if we consider a fluorescent lamp which has got a long glass tube in which interior is coated with phosphors can be considered to be as a line source in the sense that there are number of point sources placed edge to edge close by and if we see the lux or the illuminance levels with distance would therefore can be shown to be inversely proportional to the distance. And going this way if you had a number of fluorescent lamps placed one close to each other forming a plane, you can view the source of light to be a plane source of light and it can be proved that the light due to such a source on the work area is independent of the distance between the plane of the source and the plane of working. So in all interior applications where criticality is involved, we try to have as close to a plane as far as possible. Now coming to this line sources, the issue which we are talking about is the required voltage no doubt the variation in voltage is less but increases as the length increases.

The other thing is however this voltage has a certain decrees with the diameter. In fact I told a little while ago, we talk for these fluorescent lamps in terms of the diameter that's why we have a recent trend we would like to use the tube diameter to the maximum extent possible. And that is where we have got what are called as slim line tubes and in fact the modern day energy saving fluorescent lamps are very small diameter. And being a constant current phenomena, as the current level increases it has got a negative current I mean negative resistance characteristics voltage decreases as current increases.

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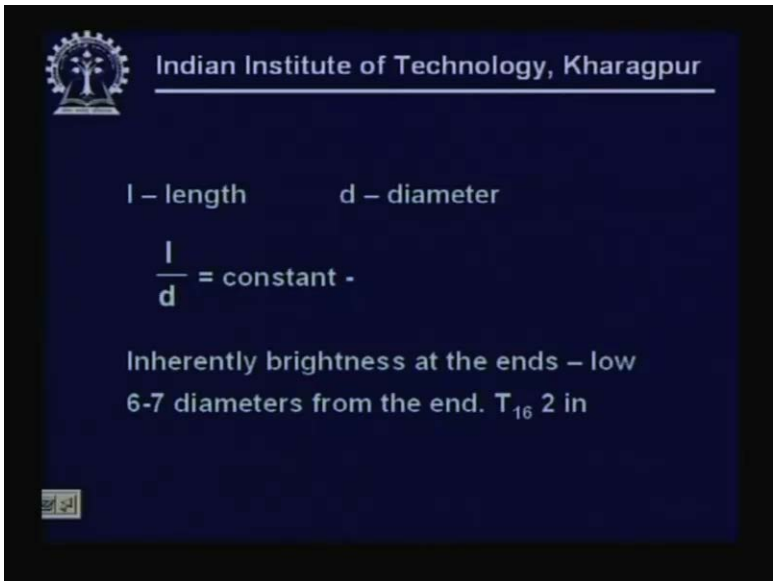

So as I said length and diameter play a role and often times designers ensure that this ratio of length to diameter is kept constant. So, in any fluorescent lamp attempt is made to keep length to diameter constant and that is a very valid I mean important issue. We have seen some of these fluorescent lamp based table lamps which are there, they have much thinner tubes than what are used for illuminating the rooms. Inherently you will find at the ends is brightness is low and one can observe this is a very important issue probably around 6 to 7 diameters from the end. See normal fluorescent lamp which we are using is around 24 mm about an inch in diameter which means about 6 inches from one end, you expect reasonably uniform brightness to develop. So that is why a very short fluorescent lamp tube may not be a very good idea, okay. Now coming to the specification how do we go about, I said T sub n is a common way of specifying and we are coming across in the market these days what are called as T_5.

We did mention a little while ago that the voltage decreases as diameter increases. Now T_{16} I have shown would mean traditionally in fact the metric system, the system was in use which meant T_{16} would convert as a tube of a fluorescent lamp whose diameter is 2 inches.

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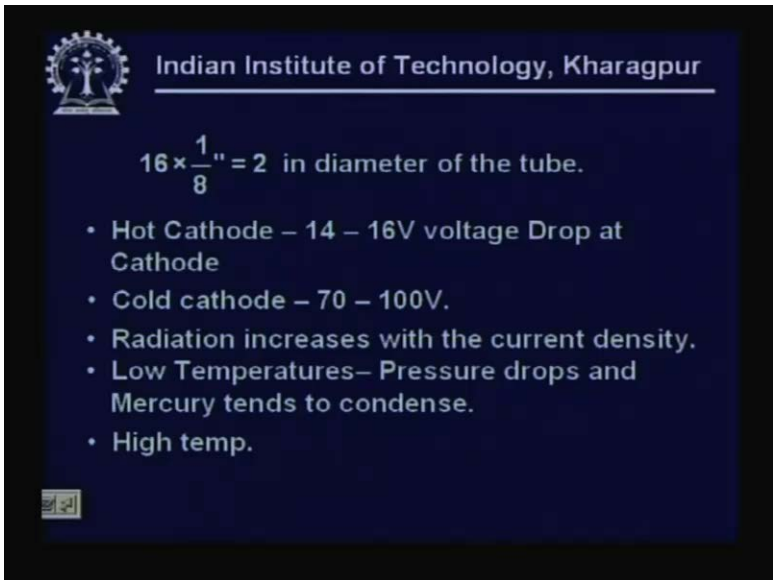

That means if I have 16 as a number in this specification T_{16}, you multiply that 1 over 8 that would be the diameter of the tube in inches. So T_{16} would cannode 2 inch dia fluorescent lamp and that is how we would mention. And here remember this is still a discharge lamp which would expect a discharge in a gas and recall it is the low pressure mercury vapour which is the… Now in all gas discharge lamps they depend on the electron emission. The processes that are responsible for electron emission are thermionic emission, electric field assisted emission and photonic emission or impingement of light. And we have also said therefore fluorescent lamps could be of two categories, one which depend on thermionic emission called as hot cathodes. And they have small drop at the ends or the, at the cathode of the order of 14 to 16 volts whereas if we had a cold cathode, there would be a large drop.

We did mention in the earlier lectures also that there would be a requirement of a higher voltage source in order to have electric field assisted emission and is not. Therefore the understanding of incandescence becomes even more important. We have a similar filament either end which are heated by the passage of current thereby produce the discharge. So radiation obviously increases with the current density, higher the current density you have higher radiation of ultra violet ray which impinges on the phosphors coated in the interior of the glass envelope which we call tube in fact colloquially we refer to these lamps as tube lights. The low temperatures there are some problem pressure drops and the mercury does tend to condense. Now recall in usage of the gas lamps, in order to ionize we can have small amounts of rare gases included which have low ionization potential in that aids the vapourization of the main gas and creating the… So, reasonably high temperatures has less problem and in fact commonly we have the hot cathode tubes.

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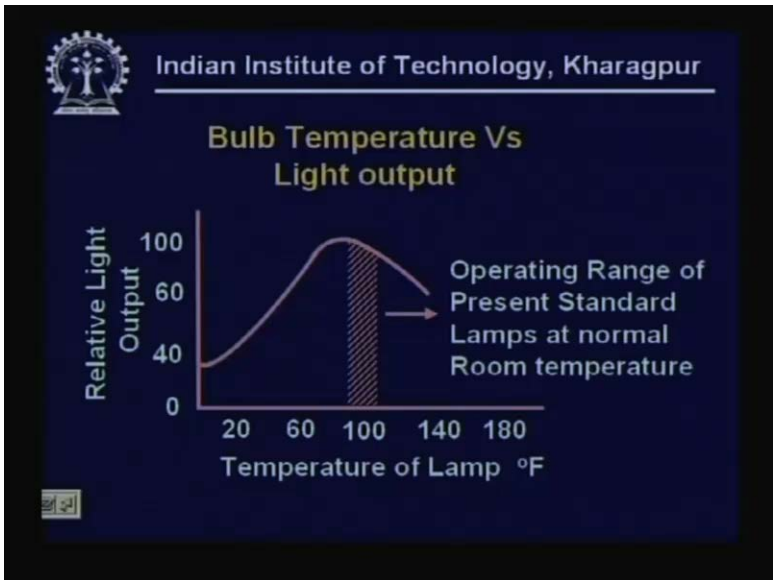

Now let's have a look at the light output versus the lamp temperature shown here. We find that this is in degree Fahrenheit, if you recall there is a shaded zone which is marked as the operating range of standard lamps at normal room temperature. You can say normal room temperature is often considered, you can consider as a comfort temperature for the human beings, it's around 25 degree centigrade. Now, you look at this, it's around 100 degree Fahrenheit which would come around 35 to 36 degree centigrade. So you look at it this way, this is in terms of the gradient with the normal temperature is also not very high. If you have a very large gradient, there is a large amount of heat radiation and that could necessarily increase your air conditioning load.

In fact yes, you can by choice of the appropriate physical process and lamp source, one may achieve good illumination levels at low energy consumption but at the same time any lamp that's employ its heat output needs to be considered because it's going to add to the air conditioning load. Here once again though we are talking about the various alternatives, the building design should always include the ability of exploiting the natural light to the extent possible by suitable design of the openings both from lighting point of view as well as the air conditioning load because ultimately every watt of energy saved is a useful resource.

Now one could observe that if you have around 80 to 100 is when you have the maximum light output for these lamps and we are operating these lamps around the zone where the light output is around 80 to 90% of the maximum possible. This is the bulk temperature which can be felt at the and so we are looking in to how every watt of electrical energy pump into this fluorescent lamp gets converted into light heat and how it is propagated out or how it is spent.

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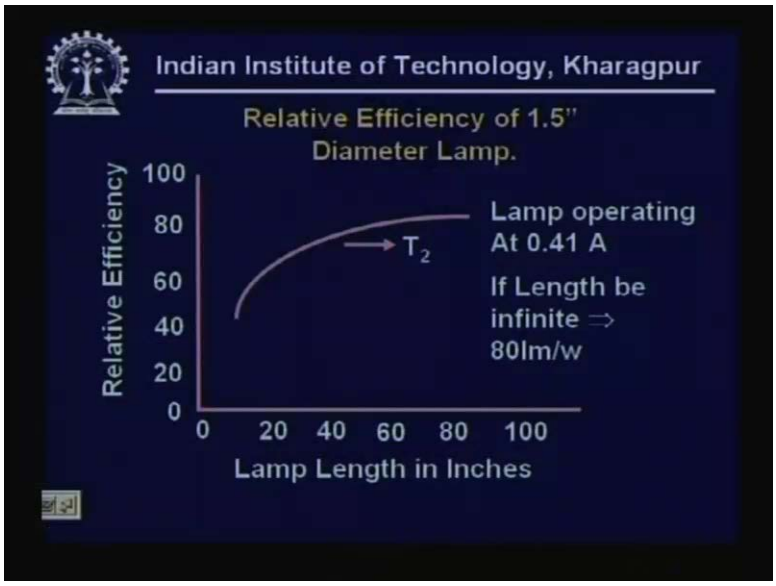

See this is the efficiency of a one and a half inch dia lamp. It's marked T_2 2 into T_2 and it's believed to be operating at a current of 0.41 amperes. The light efficacy for this is found to be around 80 lumens per watt and one can observe that this curve is between the relative efficiency and lamp length in inches. Now you see the curve begins with somewhere around 40 to 45% of the maximum possible light output says around 10 inches that is well beyond 4 to 5 diameters. Here the diameter of tube is taken as one and a half inch and 4 diameters would come to around 6 to 7 so 4 to 5 diameters beyond that. And as we go along we observe its well above 80% somewhere around 80 inches. 80 inches would essentially mean about 80 inches is around 1.6 meters that is the kind of a length.

Now it also says that if we had this tube of a very long length, if the length be infinite the overall efficacy which is estimated is around 80 lumens per watt. Now here I must mention the two standard rates ratings of the fluorescent lamps which are in use, one is a one foot one another is a three feet one, each rated for 20 watts and 40 watts respectively.

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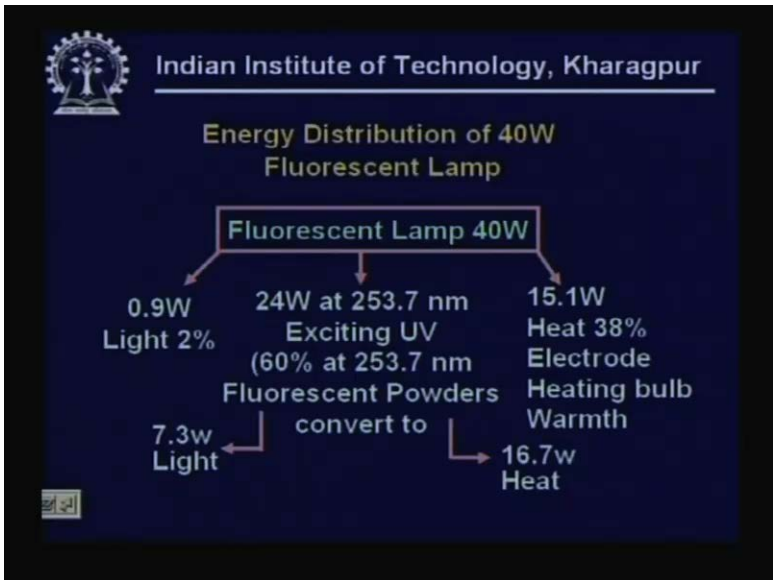

Now let's look at a typical 40 watts fluorescent lamp which most of us in fact we find the 40 watt lamps are extensively used all around in our offices invariably in illumination systems consisting of more than one tube in one luminar and 20 watts we find in most of our transport systems, railways, buses probably aircrafts. Now if you look at fluorescent lamp, out of the 40 watts that is got in by virtue of thermo because we have hot cathodes, there is an initial light only about 2% but around 24 watts is used in exciting the ultra violet radiation. We said we are using a low pressure mercury vapour lamp which is allowed to have peak radiation around 253 nanometer wave length which corresponds. And so what does it mean? Around 60% this is the beauty of this particular lamp, otherwise we talked about the light utilization factor, we found of the two discharge lamps mercury and sodium which are extensively used, sodium has had a better utilization ratio because most of its energy radiator was in the yellow orange band which was close to the high sensitivity peak.

Out of the rest about 15 watts goes essentially in heating the electrodes at the two ends and this is what is responsible for the temperature rise of the bulb which we were talking a little while. Now of these 24 watts around 16 watts still what happens to this 24 watts of uv light? It is converted into visible radiation and there is an associated heat evolution which can be split as 7.3 watts of light that is through the process of fluorescence, we have had a good look at the various fluorescent powders where the two issues which come up, one is the range over which fluorescent powder observes the radiation energy and the zone over which it reradiates, both had their own peaks. So we have about 7.3 watts that means what is it mean? If I pump in about 40 watts, 7.3 watts through the fluorescence about 0.9 watts directly that is a sum total of about 8.2 watts is what really converted into the useful light and close to about 31 watts gets in as heat. But the advantage, remember if we had using incandescent lamp most of it is only through its heat that light is produced.

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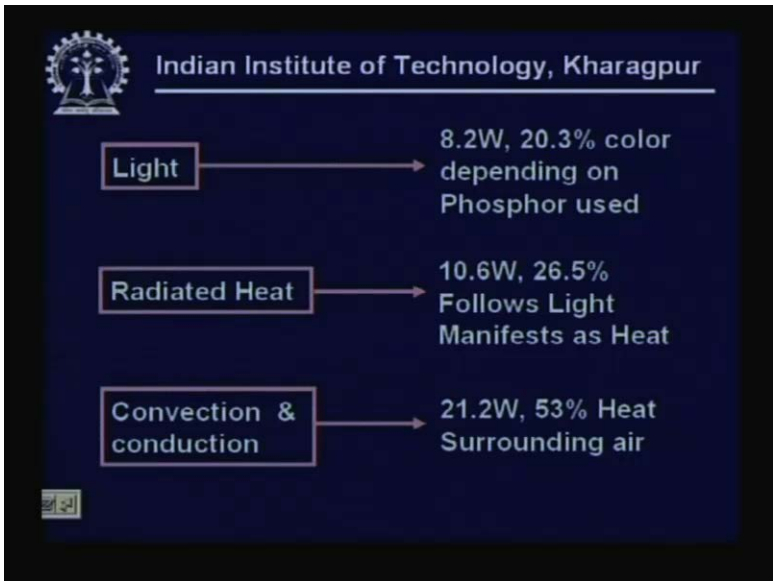

So essentially we get about 8.2 watts and 20% of the energy is being used and colour off course depends on phosphors used. To some extent colour can be altered by way of the usage of appropriate what you call the envelopes. The radiated heat is around 10 watts which goes along with the light. So one, if one looks at the heat on the task table this is the kind of a thing which one could expect along with the light, this together accounts for 50% almost. Convection and conduction are responsible; they could be controlled by proper design of the luminar as a whole. So this is what tells us how we are able to effectively use the energy pumped in. So this is the distribution, so what does it say? 20%, close to 20% is what comes out as the useful light output, around 27% gets radiated has heat which goes along with the light and about 53% is by conduction and convection.

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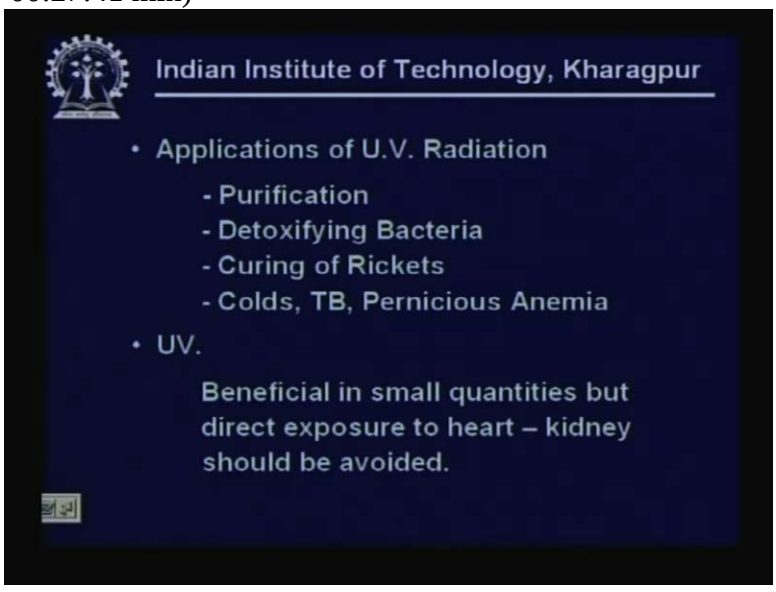

So if we have small difference in the temperature between the temperature of the bulb and the ambient, there will be less scope for conduction and convection. Applications (Refer Slide Time: 00:27:42) if you look at this is one application we thought of uv radiation but there are other applications all of us are aware these days in fact you can't think of drinking water anywhere and water purification systems are ramping and therefore a uv is used for purification of water and it does essentially by detoxifying the bacteria or and there are certain other therauptic applications where the diseases like rickets are taken care and colds, TB and anemia. However the uv is beneficial only in small quantities, this has to be borne in mind. The exposure to the two vital organs concerned with our circulation and detoxification in the body, the heart and kidney are to be avoided. So we do find good use in fact this is how the lamps employ radiation in the uv zone used for therauptic purposes are called black lights because we don't see any visible light but it does give some radiation which is beneficial.

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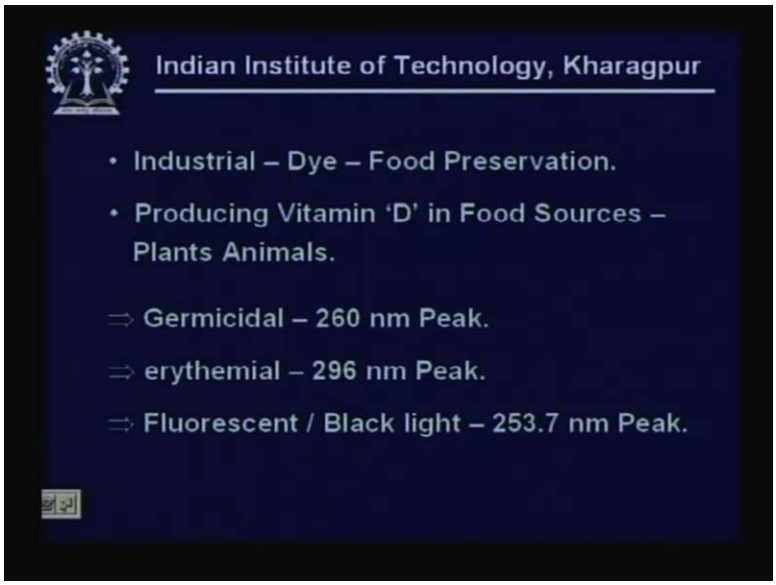

Industrial dye and food preservation is done in fact it is believed food preservation industry able is able to preserve the food over long periods by subjecting it to these things and the vitamin D is enhanced by subjecting it to small quantities of these things and it's believed a peak of radiation centered around 260 nanometers is highly useful for as a germicidal and is a peak around 296 nanometers peak is used as erythemial application and 253 which is close to what we are using in your fluorescent lamps for illumination. In fact fluorescent lamp after it is radiated is reconverted into the visible zone by the help of the phosphors quoted on the interior of the lamp. If we do not have any of these phosphors, this light is what we would call black light and this is used for therauptic purposes and it could be for any of these applications.

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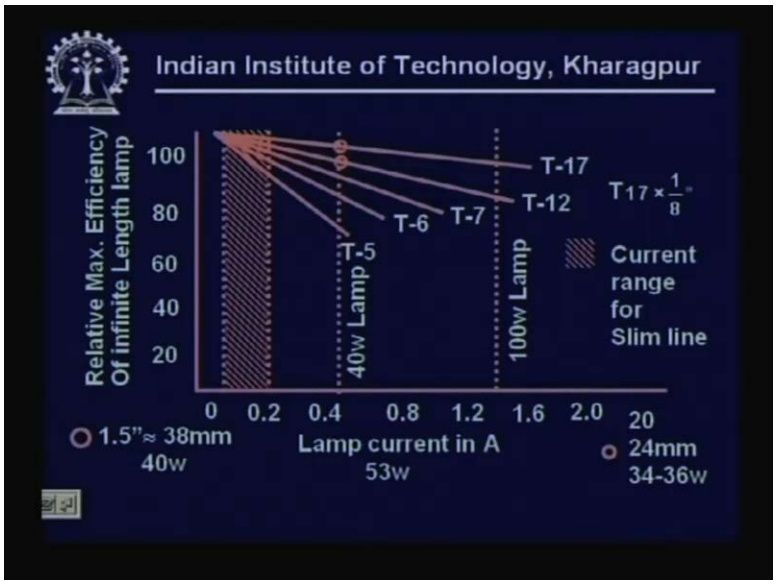

Let's look at the relative efficiencies of the lamps for varying diameters with respect to their lamp current and what do we find. We have here lamps marked from T_5 to T_{17}. There are two particular lines marked which are 40 watt and 100 watt vertical lines. Of course this figure supposes to the operating voltage is around 110 volts that's one you get this kind of a current level which are shown. See it's around 1.4 amperes for 100 watts and 0.5 amperes for 40 watt lamp and there is a shaded zone. Shaded zone is what we call for slim line.

Now here again we have, all of us have seen lamps which are called slim line, they consume they are marked as 34 to 36 watts. See the power level becomes very important because all the time for a light system artificial light we are talking in terms of the wattage and for a bench mark or a comparison, it would be the incandescent lamp. Recall because that's the one which produces nearly close to natural sunlight as far as spectrum goes. Hence it would be necessary to know, I would like to compare let's say I take this lamp, how does it compare in terms of the light output, in terms of the ease of use, in terms of the colour rendering, in terms of the burning hours all these. Now you do find 38 mm or 1.5 inches is a normal lamp which we have been using and they are known to consume 40 watts.

Now here I must caution that this 40 watts is the power consumed within the fluorescent lamp or the tube it has accessories. So you have to add additional energy that is lost in the ballast and probably this is where you have the advantage of having the mordant electronic ballast in the sense that they avoid wastage of energy. The other thing is you have slim lines which are called they have typically 24 mm diameter, 24 mm diameter would mean it's about an inch that's about you could call and consuming around 334 to 36 watts. You do have certain high power lamps of the order of 53 watts. Now what we are trying to see is that when you are operating the lamps say below 0.2 amperes of the current, you do not find much change in the relative energies or relative maximum efficiency of the lamp with the length for all the diameters that constitutes.

You have T_5 to T_{17} if you see, let's say I consider an ordinary 40 watt lamp if I use T_{12}, T_{12} corresponds to T_{12} into 18 is a 1.5 inch diameter tube. What is the output I have? If I operate around 0.4 amperes, I have output the same as 80, 89 to 90% to as that of a lamp of infinite length that's the issue. But as I come closer you find the change, let's say you go around 0.2 amperes whether it is T_{12} or T_7 I would have similar levels of this thing. Now why this is necessary? This is necessary because we look that how the length to diameter is maintained constant and it also looks at applicability of using a particular source that is available. We want to have optimize all these factors.

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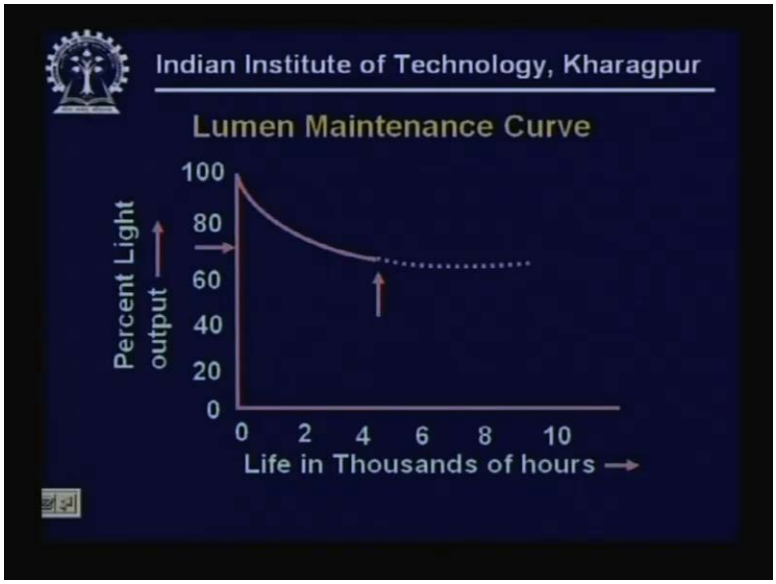

Now the other issue which comes is the virgin lamp has certain light flux output. How does it maintain during its life? If you recall typical 100 watt incandescent lamp which we use these days is talked in terms of at least 1000 hours of burning and you take any of these other lamps, the fluorescent lamps they are claimed to have few thousand hours. So what we observe is that there is a rapid fall of light output initially but somewhere around 3000 to 4000 it tapers and maintains around the same level which is around 70%. This is a very important issue that means if I take a lamp which has say 1000 lumens at in a virgin state, for a very long period assuming are the factors like the phosphor coating remains, filaments are stable and intact, the lumens or the light flux will be maintained reasonably around 700 lumens that is the thing which one can interpret out of this curve.

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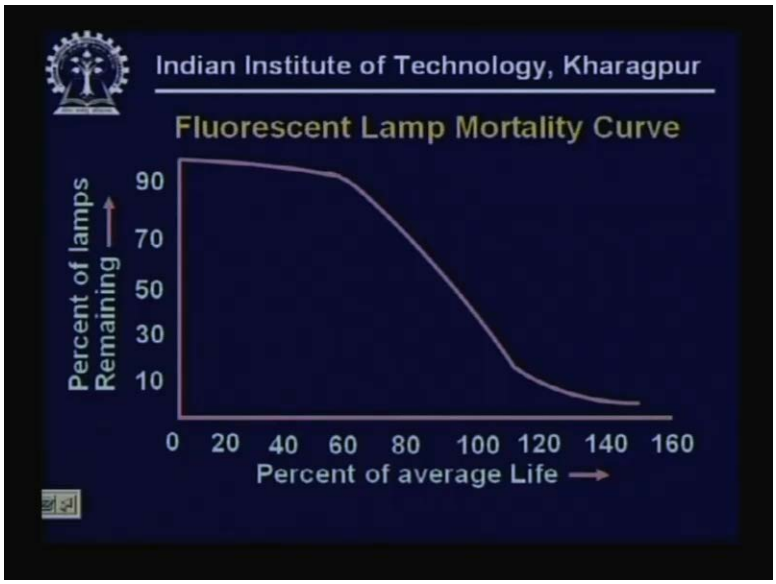

The other issue which comes is how many of them really have. If we start with the as you can see 80% average life is maintained by close to about 75 to 80% of the initial units that are developed that means you could expect around 10 to 15% of the units to fail faster and this is what we found even in the case of our incandescent lamps. So this becomes necessary especially when you are having large number of systems. We did mention in the beginning that we could view a fluorescent lamp as a line source of light and incandescent lamp as a point source of light. We found the illuminance due to a fluorescent incandescent lamp is inversely proportional square of the distance because it's a point source and it would be inversely proportional to a distance in case of a fluorescent lamp because it's a line source.

Now going by similar thing one could show if you have large number of line sources placed closed one another, they form a plane. A plane of light source would make light flux independent of the distance. So going by this, supposing I had to illuminate a table using point source or a line source, I may have to resort to have lower distance of separation between the ceiling and the working plane but it may not be required in the case of a use of a plane source of light which can be got by having a matrix incandescent lamps. That is large number of rows and columns of incandescent lamp or the fluorescent lamps and that is where when you need to have such large number of lamps. The mortality curves become very important; one has to look at such curves given by the manufacturer. In order to understand when does one do the replacement because if one has to do replacement of lamps one by one or unit by unit, it's going to be not cost effective. If one has to make it cost effective, it has to be done wherever there are large number of lamps involved, it should be a group replacement and based on such mortality curves that tell us.

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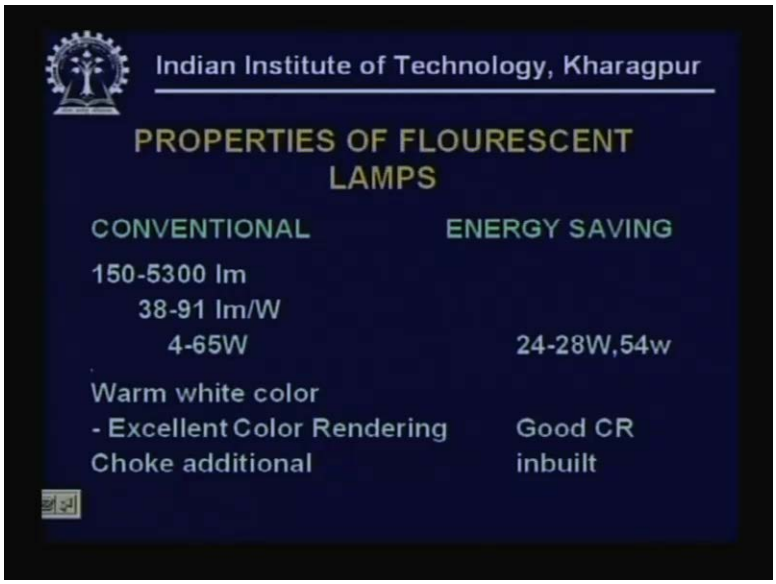

If you compare these the fluorescent lamps, we have conventionally varying in fact you have tiny fluorescent lamps which can give around 4 watts, they operate anywhere from 150 lumens for a small one to about 5300 lumens for a large one consuming about 65 watts, these are available in terms of energy savings we I did mention that energy savings, energy saving of energy has become a key word these days. In fact one way of achieving this has been to go in for smaller diameter tubes which with more efficient phosphors and better filament electrodes. They also give similar levels of light flux but with similar efficacies but consuming lower. If you consider a conventional fluorescent lamp which we have been using a standard 140 watts can be replaced conveniently using these energy saver units around 24 to 28 watts.

At the other end for the higher power rating, we get 54 watts and they are so designed that remember in a fluorescence though the radiation initially is a band radiation, by the process of fluorescence it's converted into a visible zone, so it has a warm white curve with a good or excellent colour rendering whereas reasonably good colour rendering cr here denotes colour rendering is possible with energy savings. Now this being a discharge lamp, it did require an accessory to create the discharge by way of enhancing the voltage which we call as a ballast which is reactive in nature with a choke which is being replaced by what we call electronic ballast. We will take it up in the control aspect whereas most energy savers come with an inbuilt ballast. The other issue is there is some, if it is a reactor or an inductor coil, it does have certain resistance and it does have some heat dissipation. So as a rough idea, one can attribute total energy consumption of a 40 watt lamp to be around close to 60 watts whereas this is minimized in an energy saver unit.

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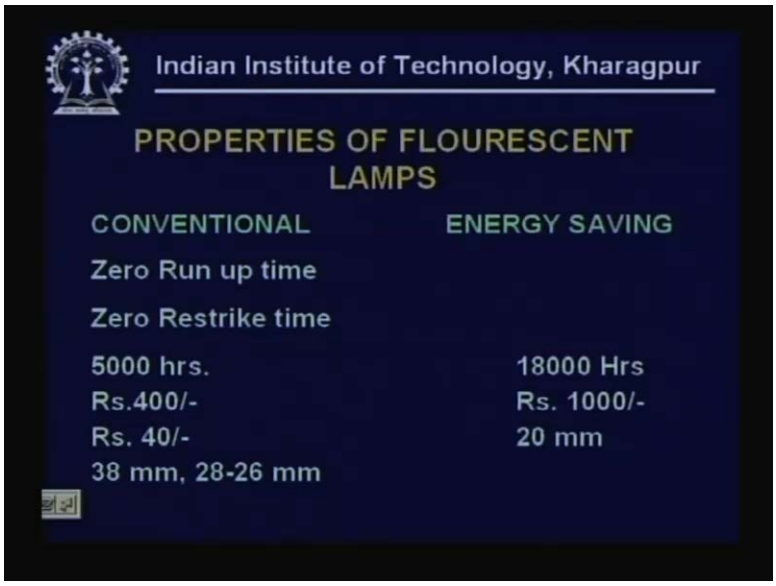

Continuing with that off course these two lamps, these days are possible with very little run up time or restrike time unlike your conventional mercury vapour lamps or sodium vapour lamps. And the conventional fluorescent lamps are possible to have with a burning life of around 5000 hours. As I already told you have the standard length of standard ones which are 38 mm in diameter and slim line variety with 28 to 26 mm. Now here the idea of putting cost figures is to get a relative comparison. You have 5000 hour burning life as against energy saver having about 18000 hours of burning life. The total unit along with the accessories may come at today's cost around 400 rupees whereas lamp alone in case of an energy saver would come around 1000 rupees and the diameters of course is 20 mm, remember that.

Replacement point of view fluorescent lamp the conventional one, the tube alone cost about 40 rupees. So it is the initial cost is quite high though the energy saving is there but because of its long burning life it may, it outweigh the long run but keeping in mind the flow mortality rate one has to look at.

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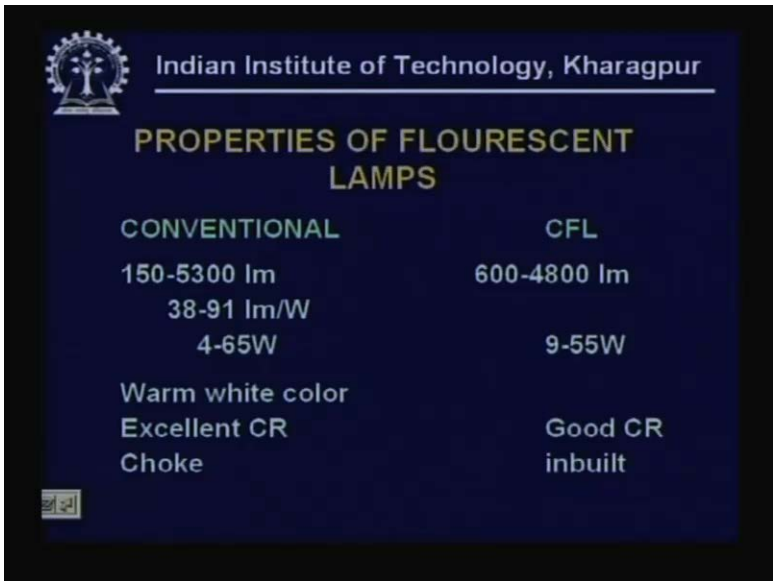

Now the other thing which is coming up is what we call compact fluorescent lamp. Now imagine being able to get high efficacy low pressure mercury vapour lamp to be used in the same outlet where I was using an incandescent lamp that's the issue and in fact that is why most CFL parameters are compared with a typical 100 watt lamp. 100 watt lamp is more or less a standard lamp as far as interior lighting goes. So you will find the, you do get CFLs with the range of light flux between 600 to about 4800, they also have good colour rendering. And as the name implies it's a compact thing which means it has got all the accessories. We talked about a starter, we talked about a ballast, ballast is nothing but a inductor which enables to maintain the constant current nature of the arc and it also enables a high potential initially to give the discharge.

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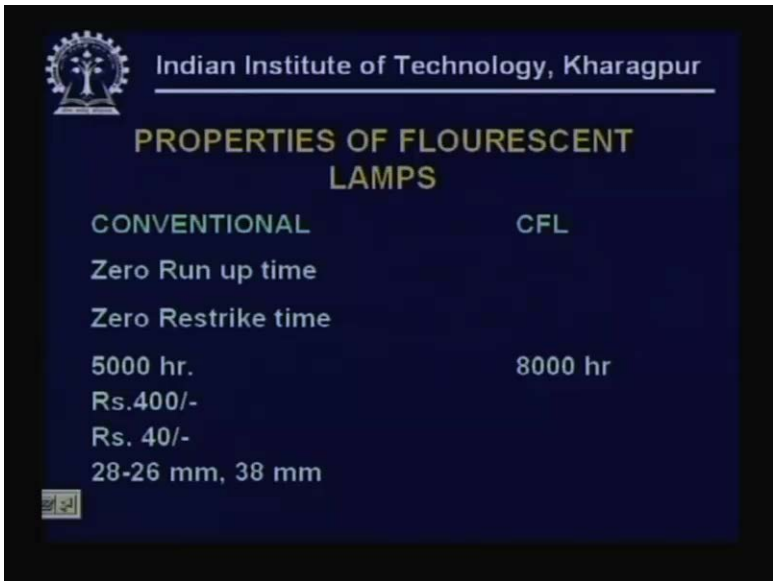

So you find from the light efficacy I mean light output point of view typically a 18 watt lamp is known to give similar light output as a 100 watt lamp. And continuing with the further properties you do find they are really comparable, no doubt in today's market a simple 18 watts CFL may cost around 150 to 200 rupees but it has a long burning hour of 8000 hours. And the most important advantage of a CFL is it can go into the traditional incandescent lamp outlet which we call as a bulb holder, the same thing that is the beauty of that, okay.

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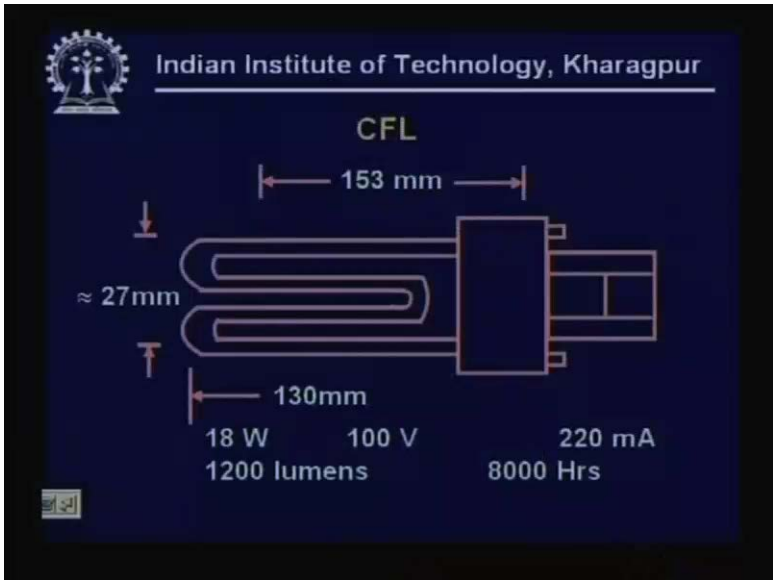

There are some units available much cheaper also but reasonably good CFLs are available around 150 rupees. Now this shows a typical CFL with its all dimensions to be operated on normal 220 volt thing. The 100 volts which we are talking about here is the drop across the fluorescent element. In fact you need to have, remember one thing we said the light output is not a maxima at the ends of the fluorescents tube, its few diameters away 5 to 6 diameters. So to get that kind of a length, you have a spirals placed. We have seen, all of us have seen and this is known to have about 8000 hours of burning life with 1200 lumens output. All the dimensions are given as you can see this fits into the standard bulb holder. The one only one objection with this kind of a lamp may be the intense, the envelopes have not improved to that extent in the sense unlike a conventional fluorescent lamp, light is not comfortable and the glare levels are high. Therefore as it's found to be used in the naked form should be avoided. They are good if they are used together with proper diffuses one, two when placed in a recessed luminar's that is recessed holders in the ceiling they are very good.

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This is equivalent to a 100 watt incandescent lamp and it can have whereas an incandescent lamp has only 1000 hours of burning life whereas that would be comparable to a 20 watt lamp which has about 5000 hours of convention. So this is the comparison one could have for an 18 watt CFL.

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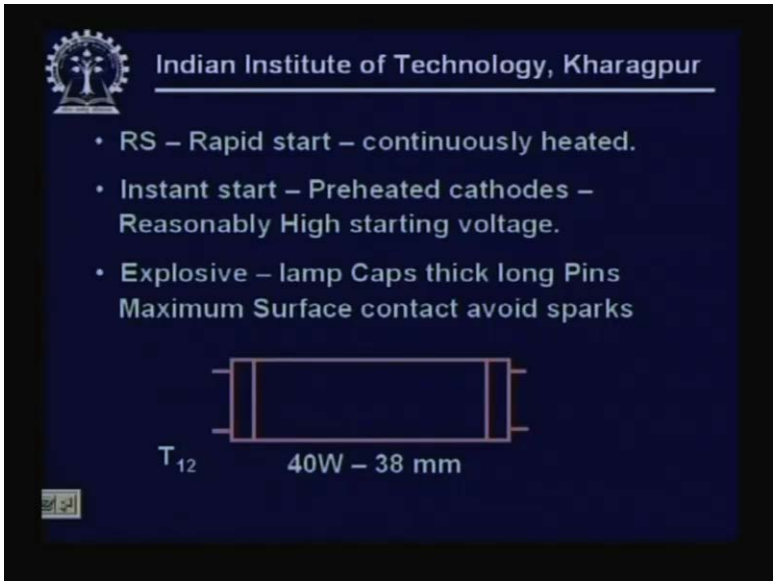

And this notwithstanding, we do have a category of fluorescent lamps which are call rapid start or instant start. This is achieved by having the heaters placed in the two ends and the special cathode elements that are used and together with small amounts of ionizing gases, ray gases plays so that ionization potential is low and quickly enables the lamp to go into discharge mode.

Now one has to have long thick pins of use of the lamp camps and the sparks, surface contact maximum surface contact avoids the sparks, sparks should not be there and other one danger which we have because it is supposed to operating at a low pressure. In sometimes at the end of the thing, if there are strong sparks there is a tendency for the lamp to explode. This is a standard lamp how it looks.

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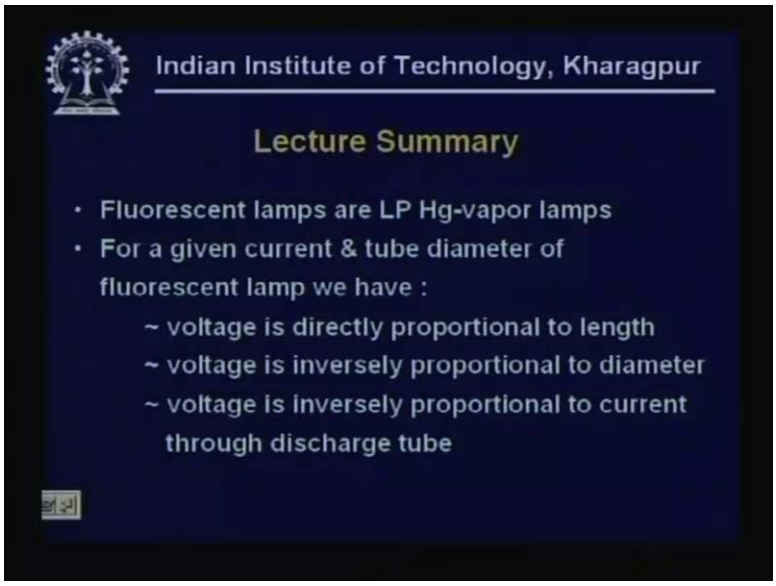

See in effect what we have seen today is the low pressure mercury vapour lamps which are used as fluorescent lamps are specified in terms of what we call T sub n, n gives us the diameter n into 1 by 8 like T_8 if I say it's a one inch diameter that's the thing. For a given current and tube diameter of fluorescent lamp we have voltage proportional to the length obviously. Now one needs to have long lengths essentially because the radiation is a maxima not at the ends of the electrodes but it is few diameters away from the electrodes 6 or 7 diameters. It is inversely proportional to the diameter, so that's a thing but there is tendency to go in for smaller diameters and inversely proportional current through the discharged tube.

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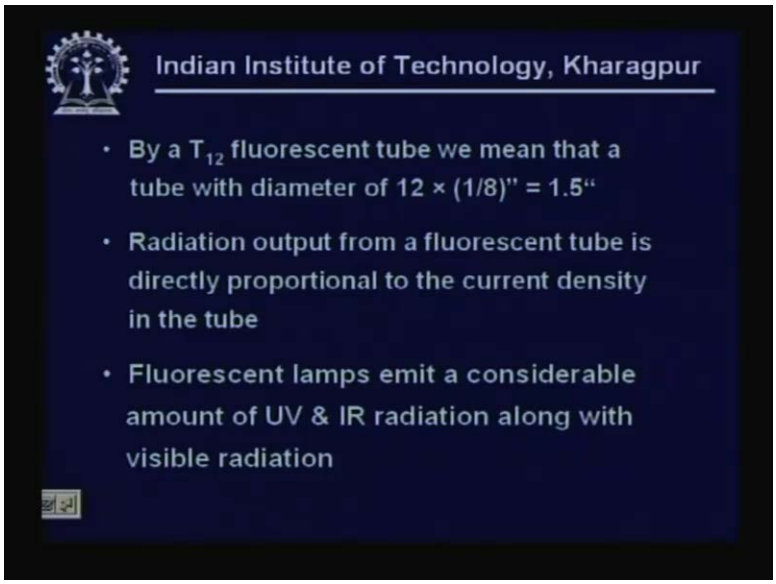

By a T_{12} we mean that it's got a diameter of one and half inch radiation output from a fluorescent lamp is proportional to the current density in the tube. This fluorescent lamp emits considerable amount of UV and IR radiation along with visible radiation and UV radiation is beneficial in small quantities.

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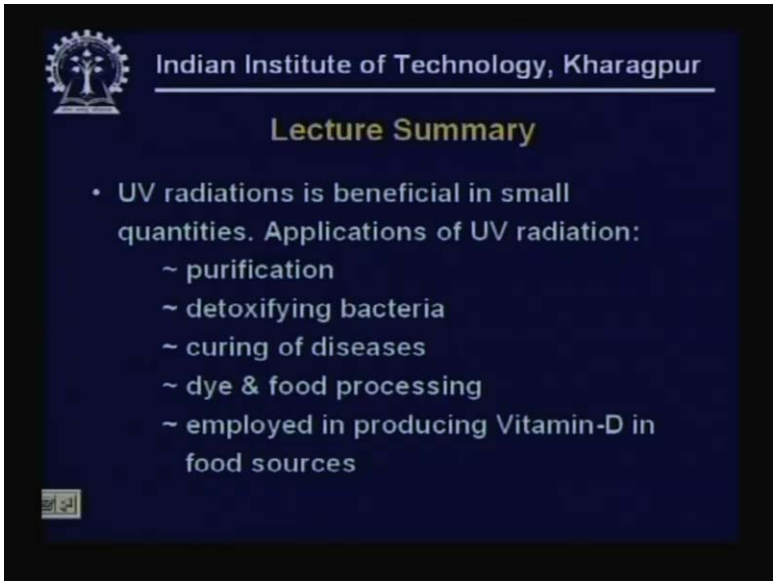

There are other applications like purification, detoxifying bacteria, curing of diseases, dye and food processing employed in producing vitamin D in food sources.

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CFLs are compact efficient energy saving and have life time but reasonably good colour rendering I said colour rendering is not so good. All the accessories are in built and therefore they are usable in the conventional lamp holders where incandescent lamps were employed.

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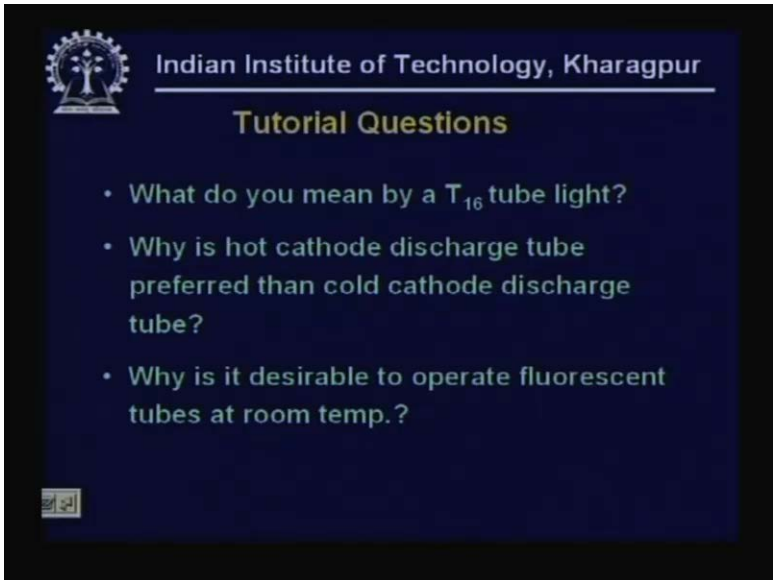

What do you mean by a T_{16} tube light, why is hot cathode discharge tube preferred? These are some of the tutorial questions that can be addressed from this lecture preferred than cold cathode discharge tube. Why is it desirable to operate fluorescent tubes at room temperature?

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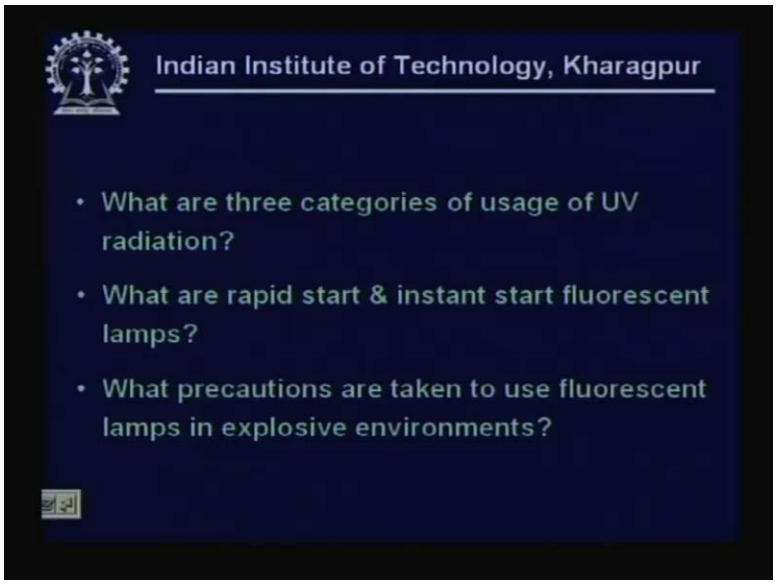

What are three categories of usage of UV radiation, what are rapid start and instant start fluorescent lamps, precautions are taken to use fluorescent lamps in explosive environments.

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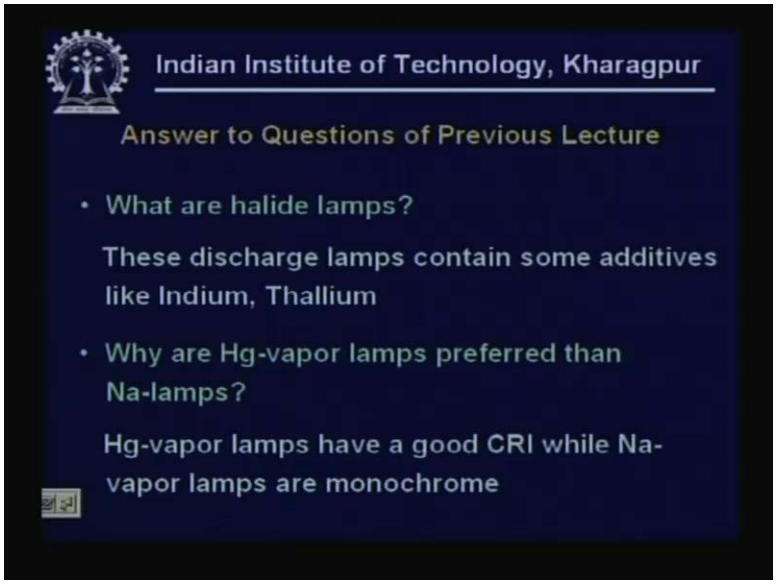

Questions asked in the previous lecture there are some of the answers to them. What are halide lamps? These discharge lamps contain some additives like indium, thallium. The mercury vapour lamps why are they preferred than sodium vapour lamps? Mercury vapour lamps have a good colour rendering while sodium vapour lamps are monochrome. However sodium vapour lamps are being used extensively because of their high utilization of their radiation.

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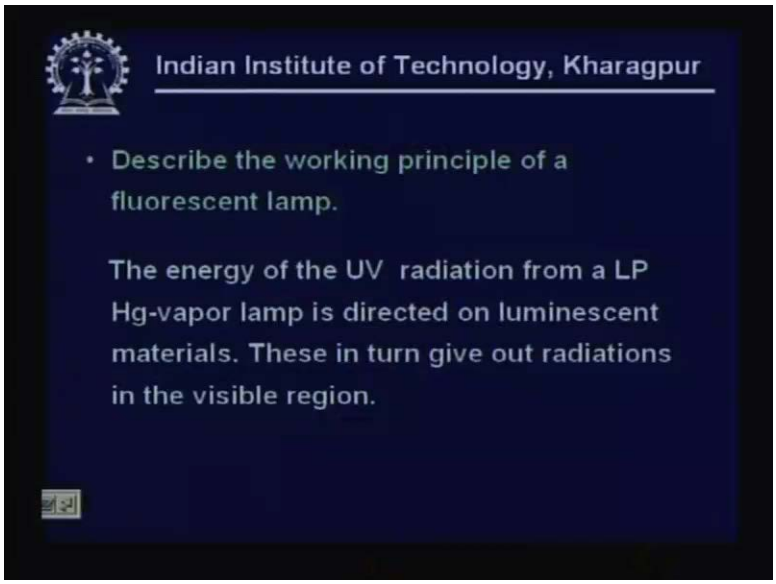

Working principle of a fluorescent lamp? The energy of the UV radiation from a low pressure mercury vapour lamp is directed on luminescent materials or phosphors; these in turn give out radiation in the visible zone.

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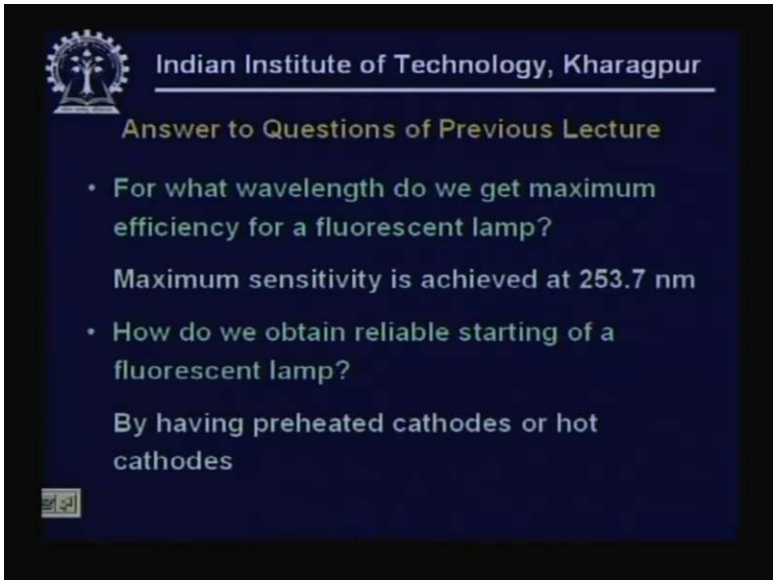

For what wave length do we get maximum efficiency of a fluorescent lamp? The maximum sensitivity is around 253.7 nanometers. How do we obtain reliable starting of a fluorescent lamp? By having preheated cathodes or hot cathodes.

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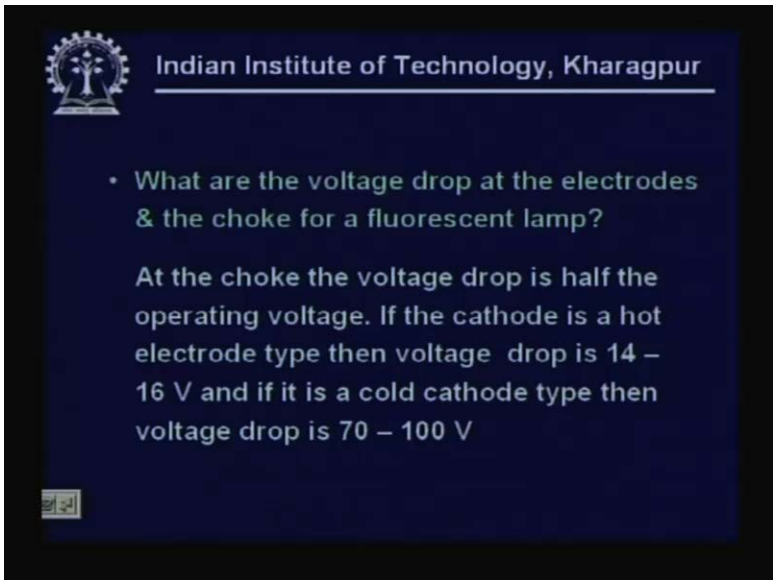

What are the voltage drop at the electrodes and the choke for a fluorescent lamp? At the choke the voltage drop is half the operating voltage of the cathode is a hot electrode type then the voltage drop is around 14 to 16 and if it is a cold cathode type it's around 70 to 100 volts.
Thank you.