Illumination Engineering and Electric Utility Services
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Lecture No. # 07
Incandescent Lamps

Yeah, welcome to this course in illumination engineering and electric utility services. Continuing with the previous lesson, we go on our next lesson (Refer Slide Time: 00:0:59) are what are incandescent lamps or state the components of incandescent lamps, understand need for inert gas in an incandescent lamp.

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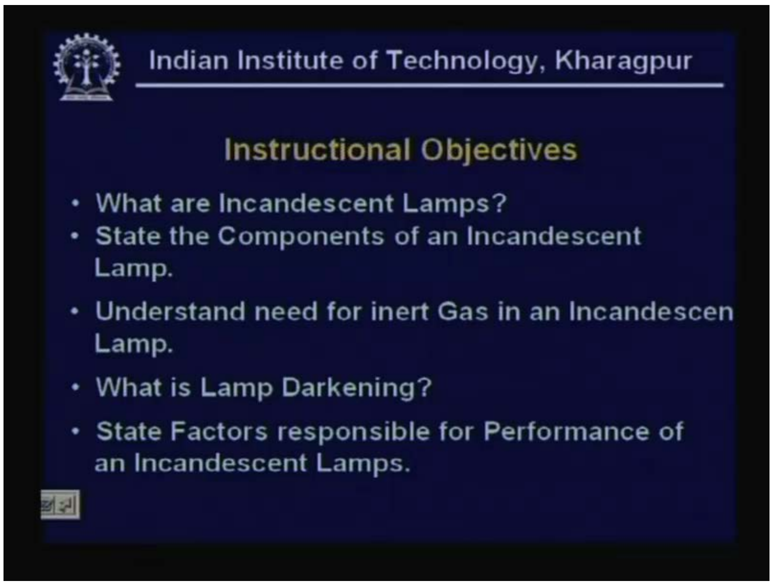

What is lamp darkening? State factors responsible for performance of an incandescent lamp. If we look back till now we have established the need for artificial illumination which has enabled us to extend all our activities round the clock, round the year. And in doing this we have used artificial sources of light. And sources of light have evolved say from oil lamps, wax, candles, vapour lamps to electric lamps. So this is been the thing and today needless to emphasize that most of artificial illumination is in the form of a using some form of an electric lamp. And one of the predecessors of these electric lamps has been the incandescent lamp and that’s the title of this lecture.

Incandescent lamps have been there right from very beginning. In fact we had seen that all our artificial sources are aimed at creating atmosphere close to natural illumination. Remember that the most important source of light and energy in nature has been sun and to some extent moon in the form of a reflected energy from sun. So, we are looking back at the parameters of natural light, we have some which is about 93 million miles away having a diameter of 865000 miles with the temperatures rising much greater than 6000 degree centigrade give rise or it can be said to be having a luminous intensity which is 2.3 into 10 power 27 candela which is remember in the last class we had, I mean earlier class we have standardized what is a standard unit of luminous intensity which is originated from original wax candle and primary standard established based on this was using a good radiator maintained at the freezing or melting temperature of platinum.

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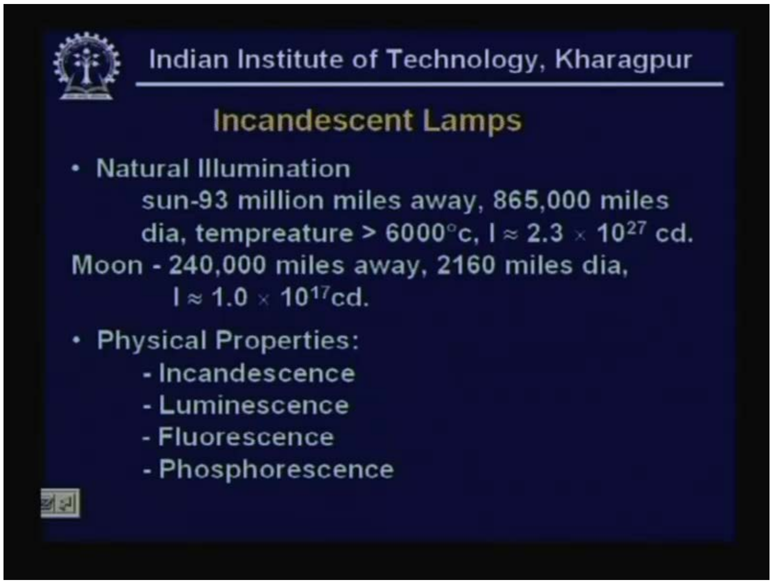

The next most important natural light is been the moon which actually reflects the sun light is around 240,000 miles away from the surface of earth having a diameter of about 2160 miles. Its luminosity can be estimated to be 1 into 10 power 17 candela. Now, we are looking at the application of artificial sources to achieve similar light condition in all our activities to be able to function. In doing this we said we may be employing one of the physical properties and the four physical properties that are often employed have been detailed, none of the earlier lectures is incandescence, luminescence, fluorescence and phosphorescence.

Remember that incandescence is nothing but thermo luminescence working on the principle of a material being maintained at a higher temperature which gives rise to radiation. In this respect we saw the radiation ability can be explained by the wien's law which says that the radiation is proportional to the fourth power of temperature that has to be borne in mind. So the lamps employing these are called incandescent lamps, common naked lamps which we have been using all along are commonly used fall under the category of incandescent lamps and in the sense of a measurement or analysis one could view these lamps as point sources of light.

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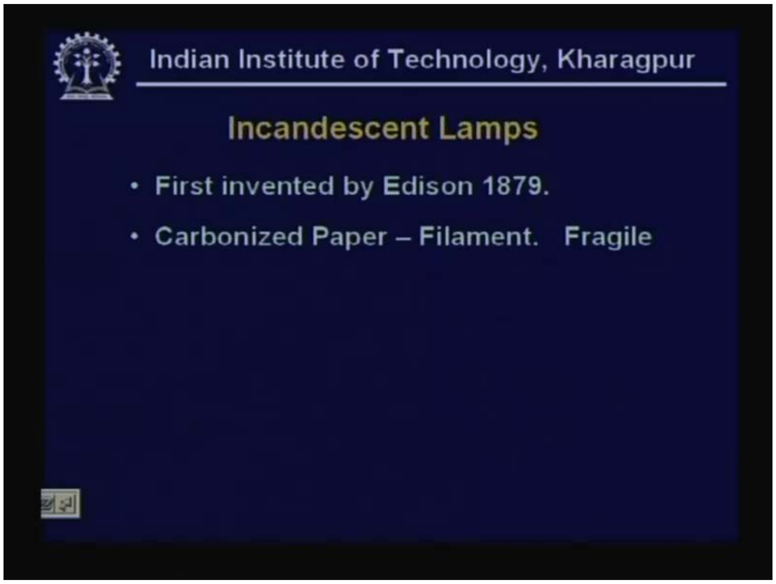

In fact incandescent lamp has been invented by Thomas Edison in the year 1879. This employed essentially a carbonized paper as a filament and carbon paper I mean carbon which was drawn in the form of filament was very fragile, it could not be kept sustained for a longer time. And to have stability it was in fact coated with a hydrocarbon to improve its properties. It was probably in the year 1893 that cellulose filament was developed and this was developed by dissolving and absorbent cotton in zinc chloride. So this is the process through which the lamp went through. As the name implies it calls for having an element maintained at a high temperature on the passage of electricity it develops a heat and gets raised to higher temperature and it radiates.

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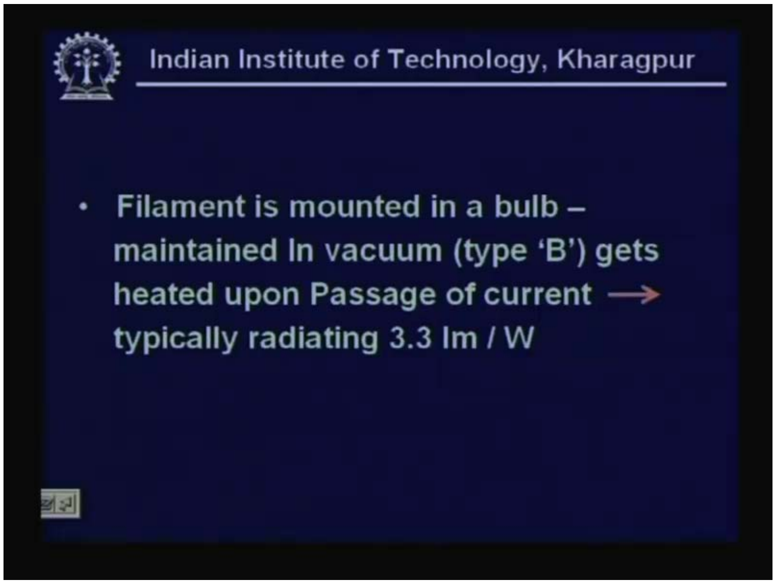

Now to be able to use over the expected life of the lamp, we expect it to be stable without any damage to itself and be able to produce the required light. And one had to go through a series of changes before it was… Now this filament is mounted in vacuum and typically this filament had I mean light output of the order of 3.3 lumens per watt. Recall the light flux we mentioned is talked in terms of the lumens. We did say supposing we have a point source, the light output radiated over a steradian of is what is the light flux due to one source. If the source is of one candela and subtends an area of one meter square that's what is one lumen. Now since the lamps employ electrical energy which consumption of electrical energy is half mentioned in terms of power or watts, the efficacy of a lamp is talked of in terms of the lumens per watt. That is how much of energy is consumed in giving effective light output or light flux.

So, if we look back Edison's lamp or carbonized filament lamp which of course went through stages of improvement by way of employing hydrocarbon coating and dissolving cellulose filament in the zinc chloride solution could radiate at most what, 3.3 lumens per watt and to have a stability of the filament it was enclosed in a glass envelope. This is what we call as bulb and it was evacuated so that there is no effect, so the atmosphere and therefore and in the lighting terminology these lamps which were maintaining filament in vacuum were called high beam.

Later on we will see there are some requirements that necessitate that this environment is not in vacuum but it consists of certain gas and they are called gas lamps and not the discharge lamp. Discharge lamps are different from gas lamps in a sense these are still incandescent lamps having a gaseous envelope whereas the discharge lamps are one which actually have an arc discharge at the time of a passage of a current. So this let to improvements in the filament. Filament is the heart of the lamp and the efficacy was to be developed and that is how there have been improvements.

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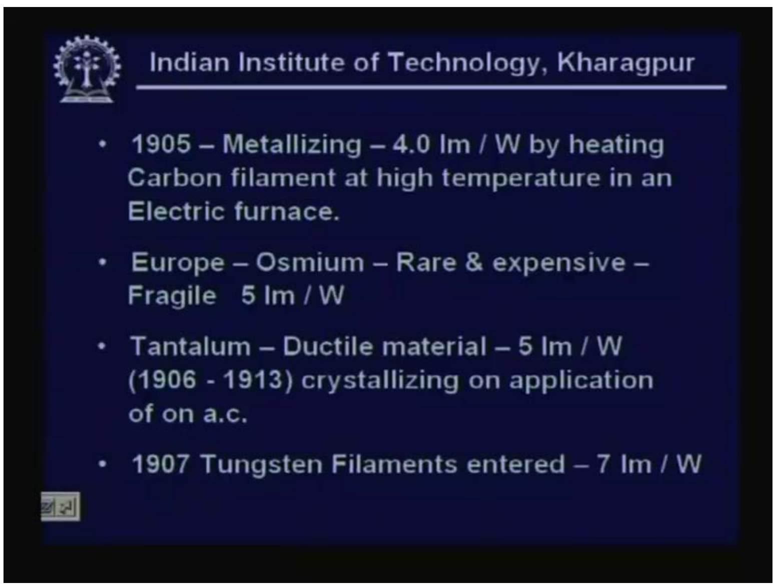

In the year 1905, the metalizing was done and it could be improved say from 3.5 lumens per watt to about 4 lumens per watt. At the same time in the European continent things were been tried out with other materials like osmium. There again no doubt it gave a good light output, efficacy was much better than what it was with the carbon filament lamp it gave about 5 lumens per watt but the fragility was still high and it was rare and expensive. In fact this led to look in for materials which could be ductile and which could be drawn in the forms of wires and at the same time, we able to give good light output. So the efforts were on to increase from the 3.5 lumens per watt to higher and higher levels and it was tantalum was found which was quite ductile but would crystallize an application of ac.

Today we remember although there are two kinds of electric power supplies possible dc and ac, most of our utilization is in the form of ac. For the simple reason ac enables us to step up or step down the voltages quite conveniently and the wonderful device that enables us is the power transformer. The other thing is most applications require some kind of a motion and the induction motors have been the versatile motors. Now all this led to a better materials and it was probably in the year 1907 that the tungsten filaments entered the scene with initial light flux efficacy of 7 lumens per watt.

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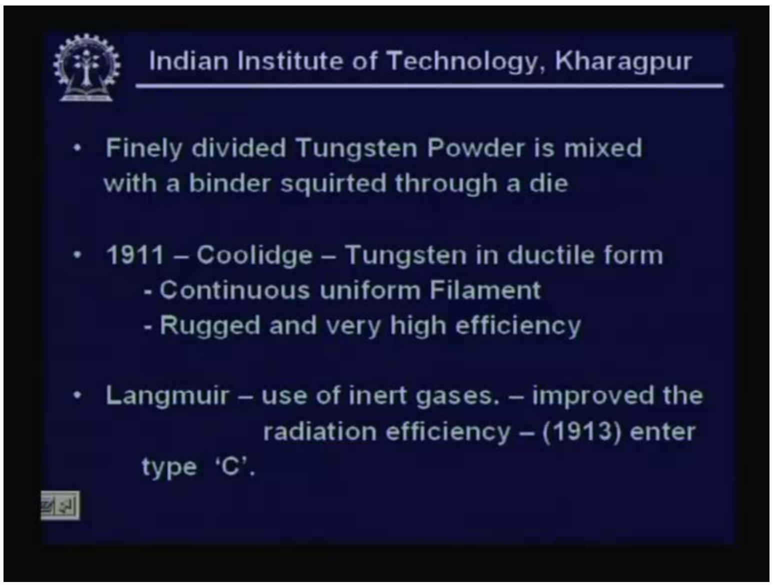

This was obtained by taking finely divided tungsten wire or tungsten powder which is mixed with a binder and squirted through a dye giving rise to a thin conductor. And in the year of 1911 it was Coolidge who could produce tungsten in ductile form. So you had amorphous tungsten which was mixed with a binder and squirted through a dye to draw the filament whereas Coolidge developed the method to get ductile tungsten, in fact even today the incandescent lamps are employing tungsten. The understanding of incandescent lamps becomes very important because be it incandescence, electroluminescence or fluorescence all of them need some form of an initial incandescence to be there.

We will come to know when we look at the discharge lamps that the arc discharge is between two filaments which again are tungsten filaments. So this enables getting a continuous uniform filament which is rugged and very high efficiency. And Langmuir found that with the insertion of inert gases, in fact he developed the properties of inert gases, the radiation efficiency could be improved considerably and possibly in the year 1913 the type c lamps or the gas lamps entered. So we have the filament as the heart of lamp, it has gone through a lot of changes from the days of Edison. We started with carbon and all the time the search was for being able to draw a fine continuous filament of uniform cross section that is what enables good ability. In fact when you talk of a lamp, you talk in terms of a getting nominal light output at the nominal rated voltage.

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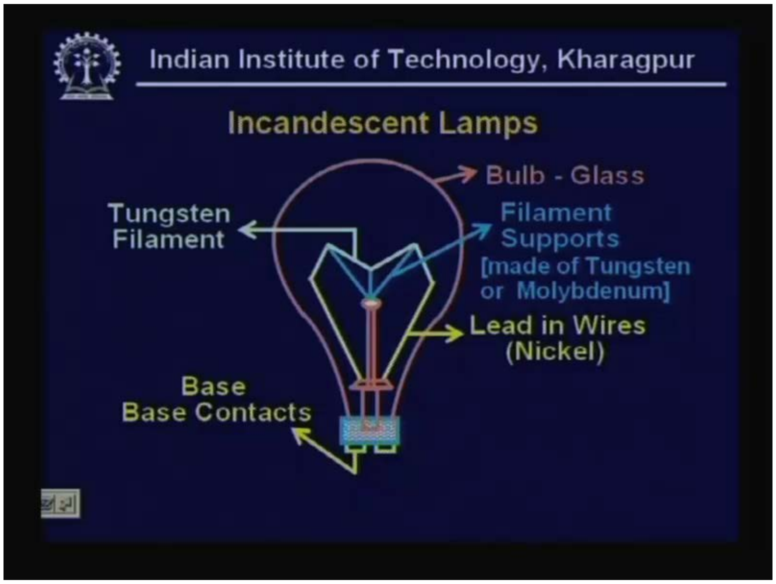

This shows the picture of a lamp all its components are shown. You have here shown the outer envelope which is often made of glass is called bulb which is transparent in its initial thing that these days you have the various types of glasses employed. One is if you have the completely opaque glasses like coated white gives rise to diffusion because we talked about the effect of light radiation falling in the line of vision, what create glare and that will be disabled. And this glass envelope is what we refer as bulb with the green thing that's shown as a basically it's shown as drawn wire placed there is a tungsten filament. As we go along we will find that this at lower watts it could be a wire spread out in the form but at higher wattage levels you will find it is in the form of a coil or a coiled coil that means a coil is recoiled and placed across the two leads, lean wires which are made of nickel.

In fact when a bulb fuses it is this filament that fuses because of the excess current. There are filament supports which are made of tungsten or molybdenum, the glass envelope is there and you have the two base contacts through which electricity flows into the bulb that is the basic structure of a bulb. Now this envelope in the early stages was completely evacuated, these base contacts are invariably made of tin to be and the base cap is also made of aluminum. So these are the some of the issues.

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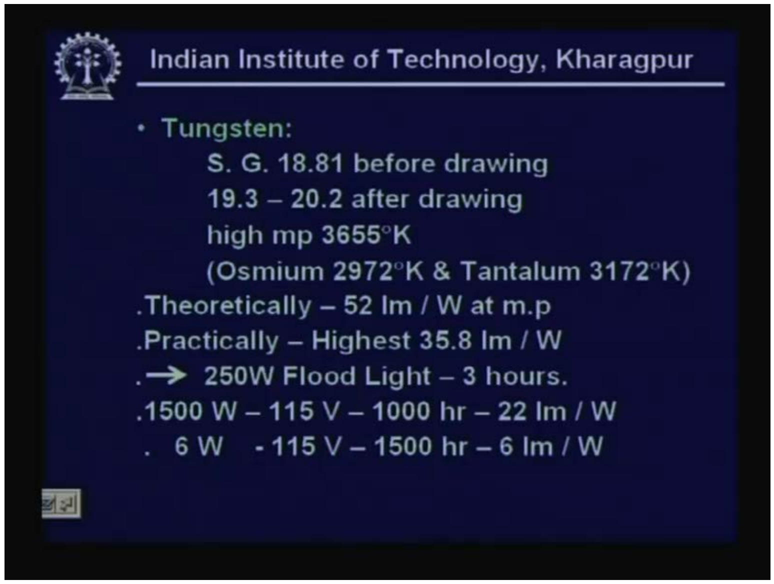

Now the tungsten is known to have a specific gravity of 18.81 before drawing which improves after drawing to 19.3 to 20.2. Incidentally tungsten has a higher melting point with the order of 3655 degree Kelvin. It's a very important issue remember that in the phenomena of incandescence, the temperature at which it is maintained is very important and we have seen that the radiation output is proportional to the fourth power of temperature. We have seen that tantalum and osmium were also experimented in the process of development of filaments and they have temperatures of the order of 2972 degree Kelvin and 3172 degree Kelvin. By shear virtue of having a higher melting point, we are in a position to get higher output from the tungsten filament.

Theoretically the tungsten filament could give up to about 52 lumens per watt at the melting point. And it may be observed or it may be seen practically highest of the order of 36 lumens approximately per watt has been achieved. You have on the high end 250 watt flood lights which have a life of about 3 hours. You could be having that's the lowest life and you do have normal 40 watt lamps which have a life of thousand hours. If you look at the data given here we have a 1500 watt, 115 volt lamp, 115 volts mind you, a 1000 hour life with 22 lumens per watt whereas a 6 watt 115 volt lamp has a higher life of about 1500 hours with a output of 6 lumens per watt. The issues are two fold, in fact you see this even at such low wattage we are having better than what it was in the initial stages.

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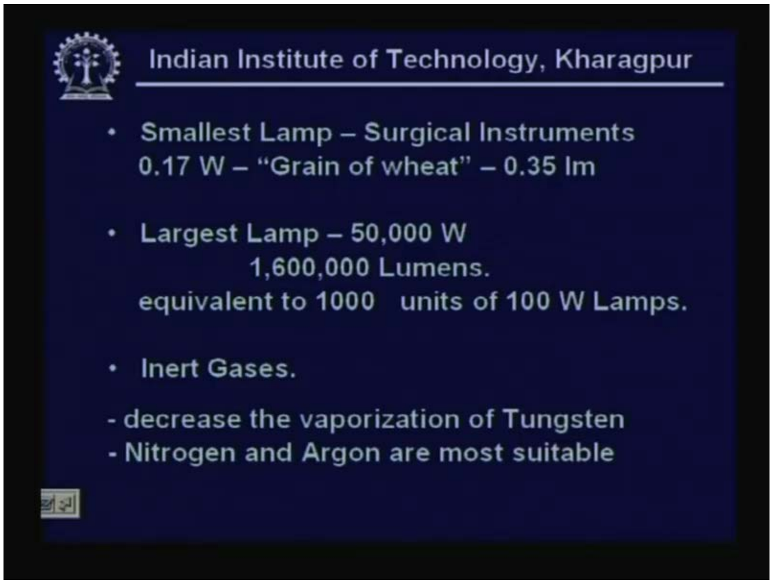

Smallest lamp developed is employed in surgical instruments in fact this is often called grain of wheat which gives consumes about 0.17 watts and delivers about 0.35 lumens is also called sometimes grain of rice or grain of wheat. If you go to a shop, neighborhood shop he may call it rice lamp which is often used for decorative purposes and in fact one of the important festivals around the country where it is used is deepavali and then the Christmas. The largest lamp developed is around 50 kilowatt power which gives out about 1, 600,000 lumens which is equal to our 1000 units of 100 watt lamps that's the kind of a thing. Remember that it consumes lesser power that's the thing.

Now we had initially vacuum lamps which were called type b and later I said the certain properties, stability properties of tungsten necessitated because tungsten remained as the filament to be used. It was the introduction of the gases especially Langmuir study showed that the stability of this filament is more in the presence of gas. Now what happens when the current passes through the filament there is an elevated temperature because of which the radiation takes place but simultaneously there is certain vaporization of the tungsten particles from the surface. So in the process, the amount of element available and the resistant variation takes place in due course and that would change the light output apart from the usual ageing which is associated with any device. So that being the case it was found that once you have a gas in it, think it will reduce this vaporization. The simple thing is that these gases which will get carried in the convection currents combined, they get ionized at a very low temperature and they combine with these tungsten particles which are evaporated and as they cool, they come back and get deposited in the filament. So that is the process and so the inert gases are employed, they decrease the vaporization of the tungsten and the most suitable gases have been found to be nitrogen and argon.

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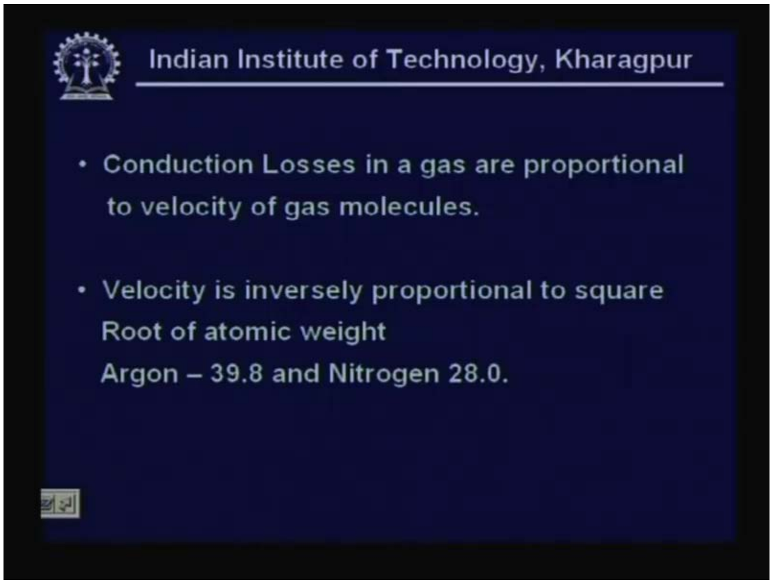

It is said that the losses in a gas are proportional to the velocity of gas molecules and velocity is in turn inversely proportional to the square root of atomic weight and these have been found considering that their atomic weights of 39.8 and 28 respectively for argon and nitrogen that's the thing. And it is as I told you it's the ionization potential which is low that is the reason why it enables a mixture of argon and nitrogen with 85, 15 has been found to be very suitable.

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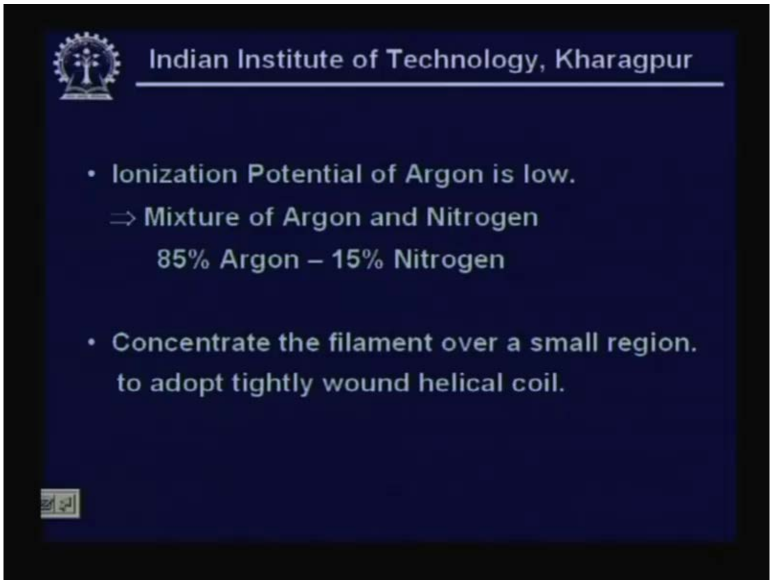

As already said when the current flows, there is elevated temperature. At this elevated temperature surface particles tend to vaporize which go and get deposited by the convection current on the lamp walls that is the interior of the bulb and these because of the ionization of the inert gas present, these ions go and combine with the tungsten filaments in tungsten particles and as a result together they get condensed. And because of the thing as they cool again are known, releases the thing and the tungsten gets deposited. This is the issue and that's how it helps. The other way of avoiding this particle vaporization is to have the filament confined over a small region.

In fact I mention at lower wattages you will have filaments spread out but as you go to higher wattages you tend to coil them. This is the reason why we coil, it's a helical coil. And in fact if you have read the top of a bulb, you will find it is written as coiled coil. That's the reason this coiled coil is placed in fact this vaporization leads the deposition which we call as blackening, this blackening takes place.

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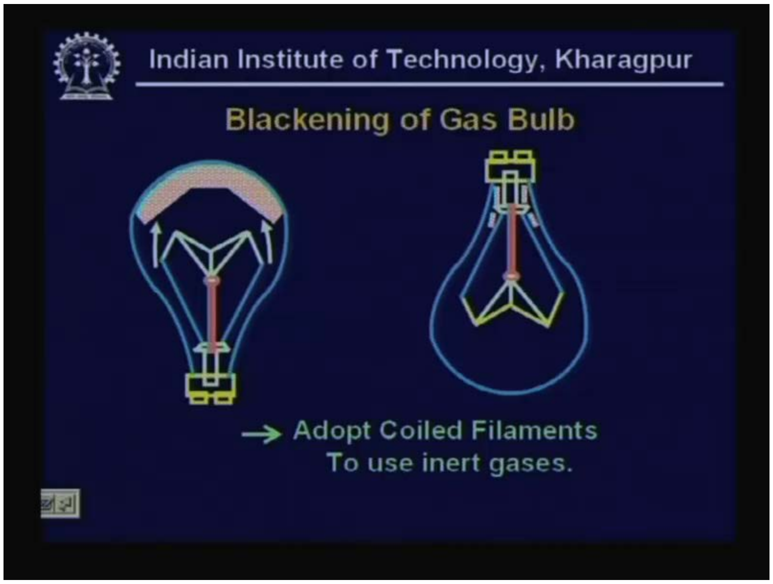

Here are two bulbs which we find are shown. The one is placed in such a way that the base is towards the ground that is as though you have the light pointed towards the ceiling, you could be having a reflector placed which directs the entire light towards ceiling and the reflected light comes on the object to be used. Here we can see some shaded region on top of the bulb in fact that is the reason where you will find there is some deposition of the tungsten. In the absence of inert gas, you will find this region gets blackened and as a result with time, the light is blocked.

In a similar way if you have a bulb mounted with the base on the top that is you have the bulb recessed to the top of the ceiling and the light comes directly towards the object or the table work table, you will find the deposition will be near the cap. Here it was towards the… So these arrows which are marked only on the left hand figure could not be marked because of the space shortage in the diagram on the right hand side, you find these arrows are showing the convection currents established in the presence of an inert gas which has a low ionization potential which gets ionized, combines, gets cool and redeposit's the tungsten particles evaporated on the filament. This is the advantage. So what do we do? To avoid blackening we take two steps. One we try to confine the filament to a concentrate zone by providing in the form of a coil and coiled coils are used. And therefore going by this, we have two categories of lamps, one vacuum lamps which are often called type b, the other gas lamps which are called type c.

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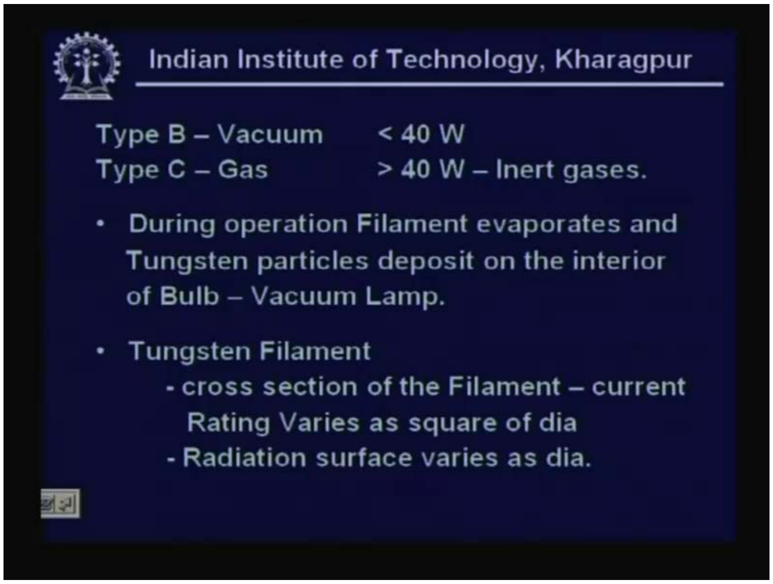

As can be seen type b vacuum lamps are usually around less than 40 watts. All of us have seen 25 watt lamps are there which we use in the areas where which have to lit at a lower level but all the time. It's essential like circulation areas. Type c gas lamps are used beyond 40 watts and they invariably have an inert gases. The inert gas choice depends on the ionization potentials and it's been found argon and nitrogen in a mixture of 85 to 15 is found to be suitable. As already told, during the operation of the filament, filament evaporates and the tungsten particles deposit on the interior of the bulb that's in the case of a vacuum lamp.

Now the tungsten filament remembers that the cross section of the filament require and depends on the current and it varies as a square of the dia, radiation surface again varies as the diameter varies. So these are some of the issues we have to keep in mind. So this is the thing which we look based on the operating voltage. If you are operating in say North America, the standard voltage levels would be around 110. If you operating in the India or Europe, it will be around 220, so these are the some of the issues to be kept in mind, this is what the lamp manufacturers keep in mind.

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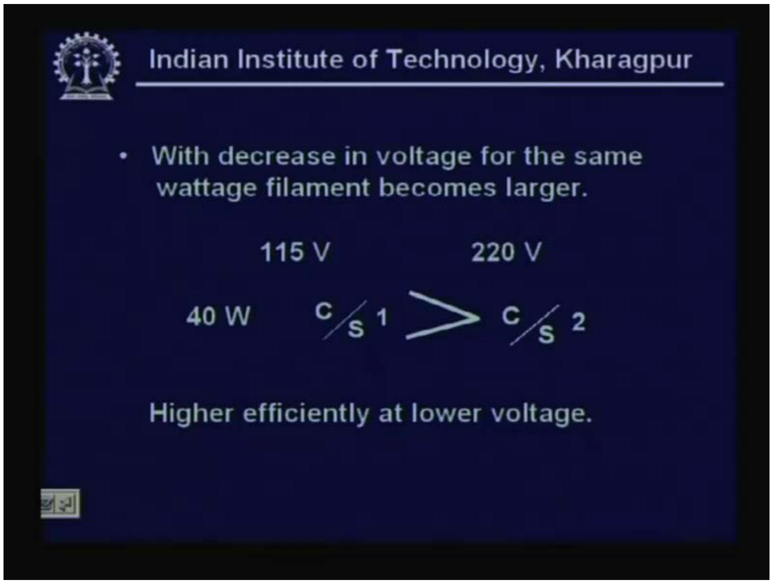

You can see very clearly with the same wattage, decrease in voltage would call for larger cross section filament becomes bulkier. No doubt, there is higher efficiency at lower voltages.

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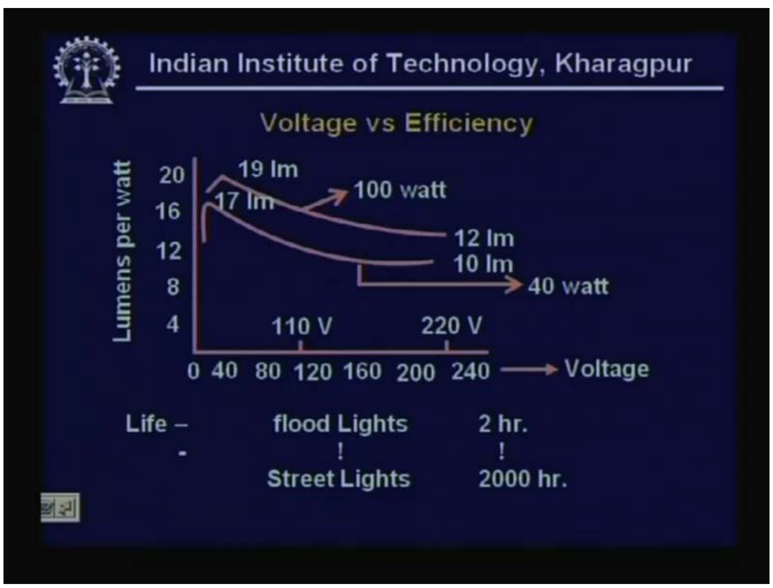

Let us look at some of the characteristics of an incandescent lamp, the typical curves are shown here. This is voltage versus efficiency. Needless to reemphasize that for the light sources, efficiency is talked of in terms of the light flux per unit of electrical energy consumed. That is we talk in terms of lumens per watt. You can see the x axis is in voltage, there are two particular voltages have been marked, one is 110 other is 220, the issue to be noted. No doubt, there are two curves here one for a 40 watt lamp, the other for a 100 watt lamp and you have each of these lamps have a peak close to 40 to 50 volts at 17 lumens per 40 watt lamp and 19 lumens per the this thing, what you call 100 watt lamp. What else do we observe? We observe one thing, possibly for both these lamps we have somewhere around 10 lumens saturation independent of the voltage, as the voltage goes higher for a 40 watt lamp and around 12 lumens for a 100 watt lamp. That is the point to be noted and another thing to be observed is that possibly if you take a 100 watt lamp, the variation in lumen output between 110 to 220 is marginal, it's around 15 lumens to 12 lumens. So this is the some of things which also will determine the life. In fact we do use high wattage lamps to create what we call flood lights.

As the name implies, it is a flood of light. Remember floods are bulky large amounts of water flowing. Similarly if I create a large intensity, large light flux in a particular environment that's the flooding of light and these are used in sports arenas etc which can have a short life of about two hours to the typical street lights which are employed may be having 2000 hours. So the issue one could observe good to operate at a lower voltage, there is no doubt if you operate at a lower voltage you get a higher efficiency but nevertheless the variation between the 110 volts output and 220 volt output is not so much to really warrant that kind of a thing. Remember the thing, the filament size goes on increasing as the voltage goes down. that is equally important from the designer's point of view.

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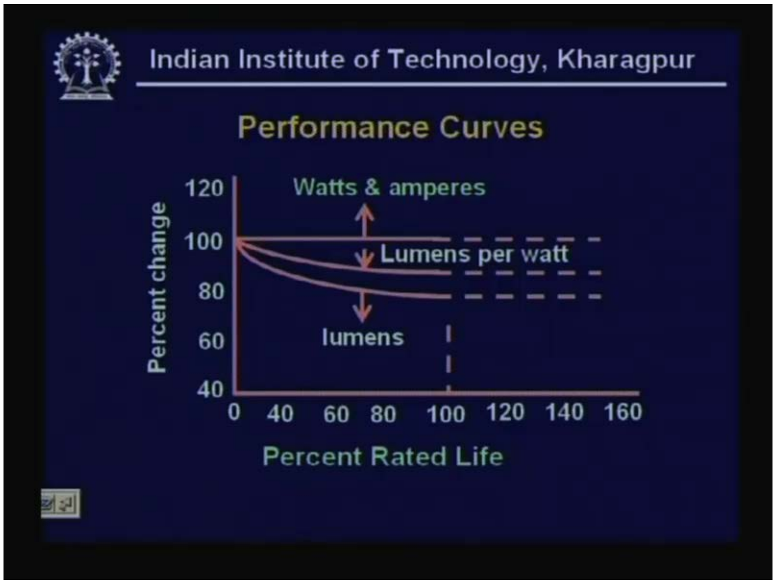

The performance curves which can be seen, it is can be seen is marked in terms of the change in the characteristics with rated life. If I, you can see very clearly the watts and amperes I mean a good lamp that's what we expect is supposed to remain same throughout its life as the virgin lamp. Then the next thing which we find is the light flux and lumens per watt. You can see very clearly, the lumens per watt around 80% of the rated life itself comes down to about 90% of initial of the virgin value and around 100% life, it stabilizes around 85 to 90% of the, so the changes vary little.

On the other hand if you find the light flux itself, you can ensure that if I by design, a design for 1000 lumens I can expect it to give 800 lumens throughout its life. Now the choice of the material, the design lengths and the voltage are such that its resistance is stable over the region and gives the required output. Only when it consumes the required output, you expect it to be of required what you call the light efficiency. However all us know that the system voltage cannot be assured to be same at all times, there is bound to be necessary change in the system voltage. Here it should be mentioned that it is the current flow through the filament that's producing the radiation output but it's the applied voltage that's necessary to produce the required current.

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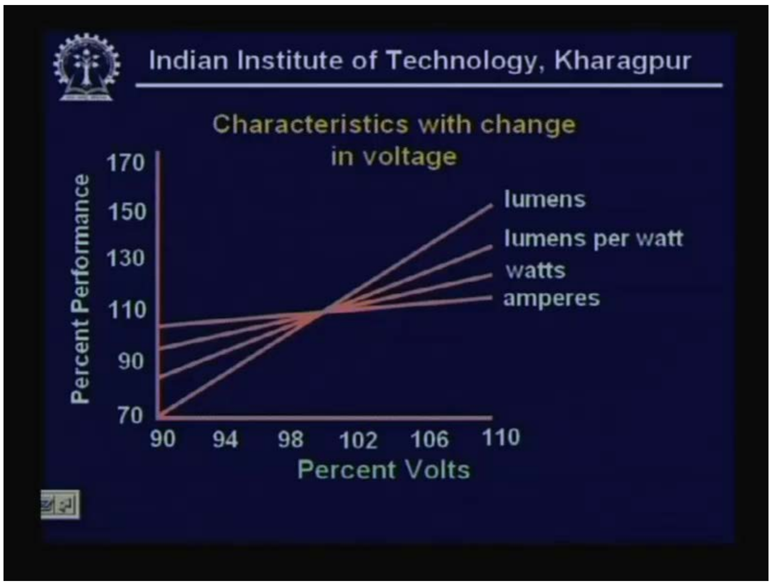

One could see how these characteristics change with change in voltage. There are 4 curves, we have the first curve showing the lumen output, second one lumens per watt third watts and amperes. As you can see lumens per watt does increase but what is not shown in this curve as you can see the point of intersection is corresponding to 100% rate voltage. So, only thing that's not shown is the percent life which we will look at in the next figure. These are representative as we know increase in voltage will certainly give higher output but there is every danger of resistance going very high and as a result because the temperature goes higher, current levels go higher.

See the first thing that happens is you have a fixed length of filament and applied voltage goes higher means you are pumping in a higher current which means i squared r the power, the current, the no doubt the heat increases that means temperature rise increases, therefore light output increases. May be light output, light efficacy also increases, power consumption increases no doubt current increases but there is every possibility of disintegration of the filament because of the high level of the temperatures.

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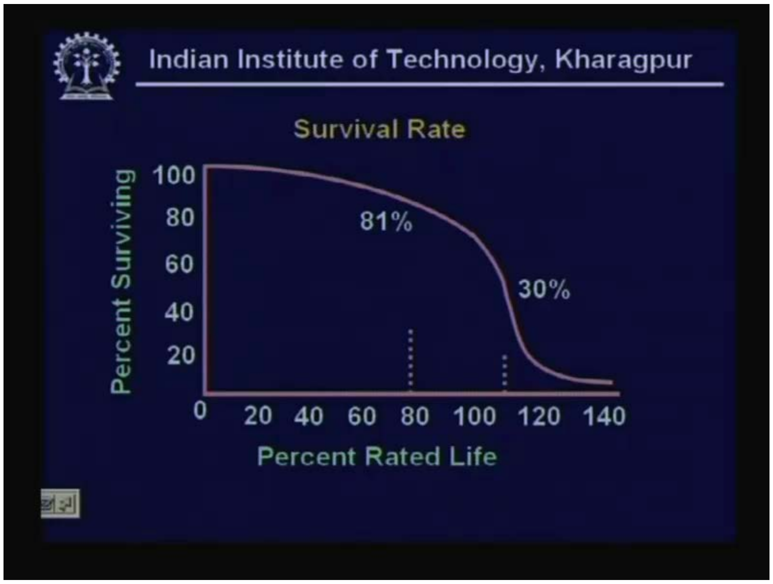

Stability of the filament is at stake therefore you have the survival curve which is very important. As you can see supposing I have produced about 100 lamps and you see it is about 81% of them which survive more than 80% of the rated life and it's less than 30% which survive at about 110%, this is a very important issue. So if I have 100 units developed, it's only 80 units that can be really expected to give full life. In fact this does tell us in a system what kind of a replacement schedules one has to adapt. So there are two ways to do it.

What we do at home? A lamp fuses then we replace because we have few lamps, it's quite easy for us to keep track and allow it to go till the end of life. But when you think of a workshop which is a very large workshop with large number of lamps, it may not be feasible to do hundreds of lamp. To do this every now and then one has to really do it in a planned manner. So this particular such data from the manufacture enables us to have our maintenance schedules and replacement schedules. So having known this, it is necessary for us to know on what does filament characteristics depend.

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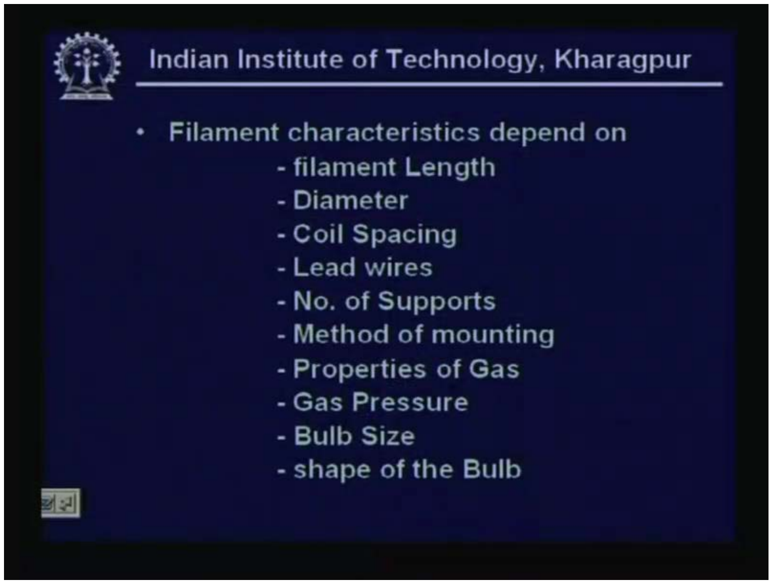

Filament characteristics when I mean the most important characteristic as far as illumination engineer goes is the resistance because it is the thermo luminescence that's giving us the output. And that depends on the length of the filament diameter, since the coils are involved, the coil spacing. Now the kind of lead wires, kind and number of supports method of mounting, there is no doubt number of supports and method of mounting only effect the mechanical stability, properties of gases, gas pressure, size of the bulb and shape of the bulb. No doubt in most natural systems, the spherical system is the or spherical size, a spherical shape is the most suitable and in fact that's why we find most bulbs have a spherical ended shape though it may be somewhat conical at the base cap side, this is the thing.

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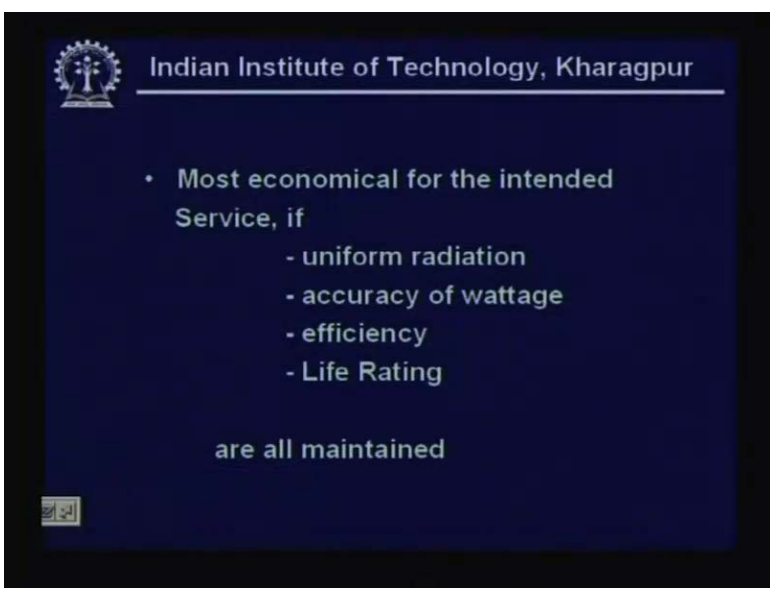

And in order to have economic service for the intend application, we try to design the filaments for uniform radiation with reasonably good accuracy of wattage and light efficiency and life rating. All are to be maintained and that is why we saw how the survival rate comes and in fact I told you, if you design 100 units it's possible to have about 80 of them to give you the required this thing. Now all this has led researches to look at the variation in these characteristics by the change in the lamp characteristics from the nominal ones. How do we specify a lamp? We specify in terms of two things, one is the wattage the other is the voltage.

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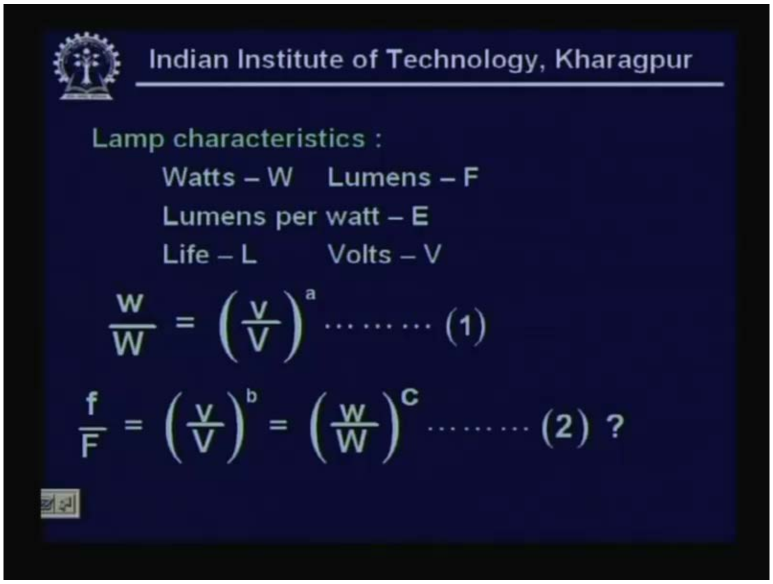

And let us say we have a lamp rated for 100 watts and then you can. The nominal lumen output is if it is called capital F and the lumens per watt, the efficacy as capital E life at this wattage or at this light output be L and volts be V, it's found that the variation in voltage with variation in wattage can be exponentially related through a relation V_o or V_e by A. In fact we know if assuming the resistance to be same, if the voltage reduces wattage reduces hence the light output reduces.

Remember one thing we saw, life may improve if you operate at a lower voltage but light output also reduces which means you are going to strain your eyes which means you are going to pay higher bills to the doctor. The other alternative, in fact the lumen output beside this voltage and the wattage is related through equation two which is raised to the power b and c. So we have come across three exponents, exponent a relating the power of consumption besides the applied voltage. The two b and c relating life to the voltage and wattage. This will be very useful in the sense that once you have these exponents, depending on the operating conditions you can arrive at the possibility of the performance of your lamp with the manufacturers guaranteed specifications. Here the uppercase W F E L V are the nominal ratings where the lower case corresponds to the operating conditions.

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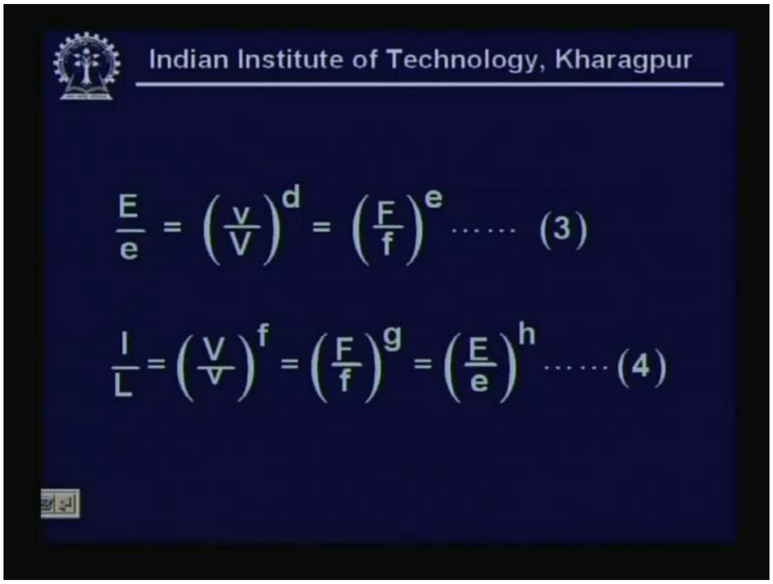

Now this shows the variation for the light efficacy is somewhat inversely proportional to the voltage and directly proportional to the life. And the last one, you have is the, just a moment you have the light versus efficacy was the third equation which related to the life as well as lumen output and this thing and life with a respect to the lumen output, voltage and efficacy. So you have how many exponents? You have a b c d e f g h that is about 8 exponents.

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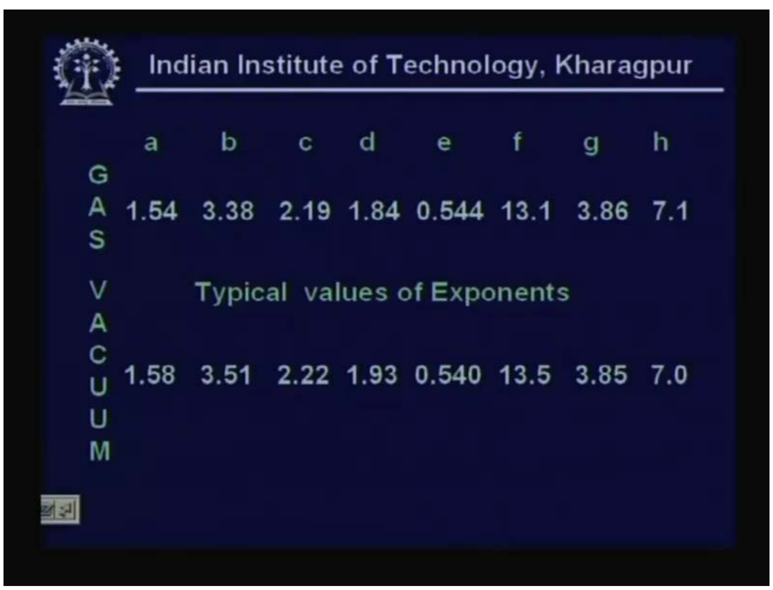

Now let us look at some typical values. There are typical values for all these are given a b c d e f g h for a typical gas lamp. What is a gas lamp? Gas lamp is a tungsten lamp with an inert gas and closed in the envelope. What does the gas do there? It avoids vaporization of tungsten in turn which could cause blackening of the bulb and blackening of the bulb is totally a void. Now the similarly what's a vacuum lamp? A vacuum lamp is a normal incandescent lamp. Now what did we see? The vacuum lamps are called type b, gas lamps are called type c and below 40 watts we have vacuum lamps, above 40 watts we have gas lamps. So what did we observe? We observe the process of application of the phenomena of incandescent for having an artificial light source which we call incandescent lamps and this depends on essentially the characteristics of the filament. So, filaments if you recall the Edison's bulb had carbon filament which grew through several stages and finally tungsten was found to be suitable and this is how… And then how do we specify the characteristics?

We specify the characteristics in terms of the, what is the energy consumed by this filament at a operating or a nominal voltage. We have seen that these exponents a b c d e f g h essentially relate your performance of the lamp when there is a deviation from the rated voltage or rated wattage. What are the various characteristic which we are looking here? We are looking here the light flux output or the lumen, light efficacy in terms of lumens per watt and as already said we have the smallest lamp is the grain of wheat or grain of rice used in surgical instruments and the largest lamps could be as large as 50 kilowatt lamp which could in principle be radiating flux corresponding to 1000 units of 100 watt lamps.

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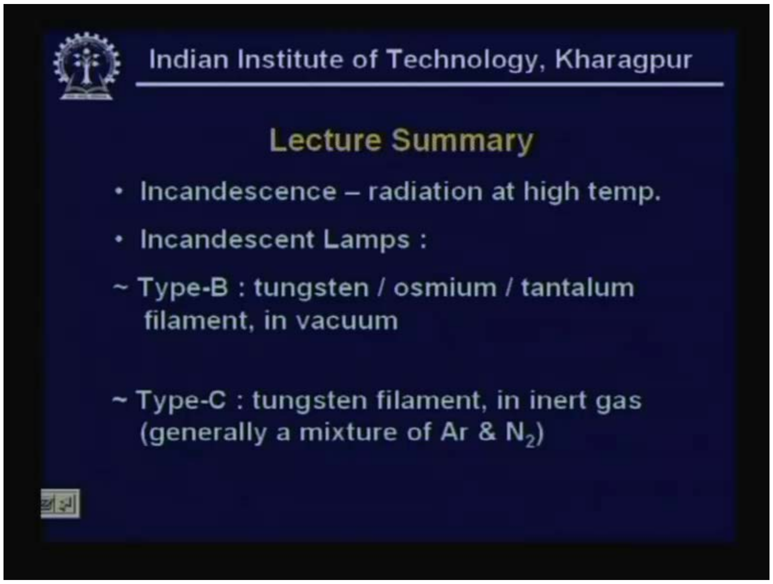

Having said this, the summary of this lecture could be summarized that the incandescent is a phenomena which is thermal luminescence is a radiation at high temperature which is being adapted incandescent lamps. And mind you we have other effects that are used in artificial sources like electroluminescence and fluorescence. Electroluminescence is the discharge giving rise to radiation in a gas or a vapour, it could be gas, a metalized vapour or a gas. And all these in fact are also depended on certain filaments which are using thermo luminescence and thermo luminescence depends on the temperature.

Now we had type b lamps which are in fact using tungsten, they have started with carbon, osmium, tantalum and finally zeroed (Refer Slide Time: 00:45:57) on tungsten and it maintained in vacuum whereas type c in inert gas. As said the inert gas enables avoiding vaporization in the filament. The vapourization in the filament does give rise to the blackening of the bulb and this gas employed is a mixture of argon and nitrogen. What are the properties we are looking for in the gases? They should have low ionization potentials. What happens? Because of the low ionization they get easily ionized and the convection current setup because of the temperature. Due to the filament they go and interact with the particles that are deposited in the interior of the bulb and they combine in the process they cool and get redeposited on the filament, this is the process.

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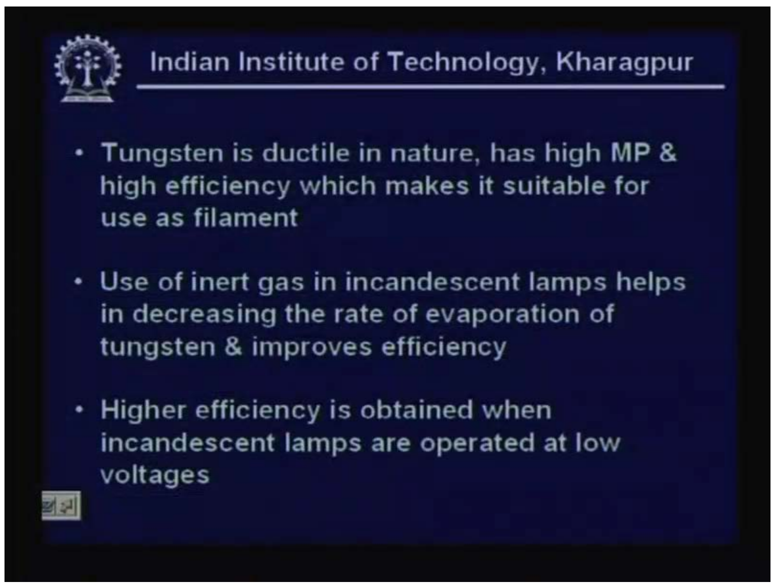

Tungsten is ductile in nature and therefore it is highly suitable because it enables you to draw uniform conductor of long lengths. It’s got a high melting point that’s a very good thing that over the life or over the rate of operation, it does not melt and gives rise to good light output. And hence has been zeroed in as the filament material. As already told inert gases in incandescent lamps help in decreasing the rate of evaporation and add to the efficiency of the lamp. Higher efficiency is obtained when lamps are operated at low voltages. Yes, when you operate at a lower voltages the life may be there that is what we are talking about but remember lower the voltage, lower is the light output. And therefore it is very very important to know that it may not, though you get a longer life from the lamp life point of view but efficacy of the individuals may be at stake, that’s the thing to be borne in mind. So it is preferable not to reduce the voltage below 90% of the nominal rating rated voltage, that’s thing to be borne in mind.

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Filament characteristics are important and they are dependent on the length of the filament and we told the other technique apart from using inert gases is to coil the filament. If you coil the filament, you are concentrating over a small region. What happens if there is a coil? If there is any particle from the surface that's evaporated and trying to move away, gets re deposited on the coil within it gets confined in that space, that's what helps. The method of mounting does look at the mechanical stability, the gas employed of course we said normally it should be argon and nitrogen. Bulb size naturally it depends whether it's going to create any explosion or not. Filament diameter decides the ability of carrying the current to give the required output.

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Lead wires if you have a filament which can carry higher current than the lead wires, no use because the life of the lamp is at stake, the gas pressure and shape of the bulb, shape as you know when the stability point of view the best shape for all natural I mean all the things is to have a spherical shape. Now keeping all this in mind, we design here it says bulbs. Bulbs means incandescent lamps are designed for uniform radiation, we like to have uniform radiation that is from unit to unit we should have uniform radiation. Supposing a portion of the filament radiates much higher than the other portion, it will again create non-uniform flux output and then it will not be productive in the sense. The accurate consumption of power because that will enable the engineer to estimate actual requirements comfortably and efficiency no doubt, every system should be efficient and the life rating enables in us to decide when to replace the lamp, may be its easy at home for you to replace whenever the lamp fuses. But in a large setting like industrial setting or office setting, it becomes very important to have an idea of the life rating. What did we see? Survival rate is around if you have 100 units bill about 80% do survive for more than 90% of an expected life.

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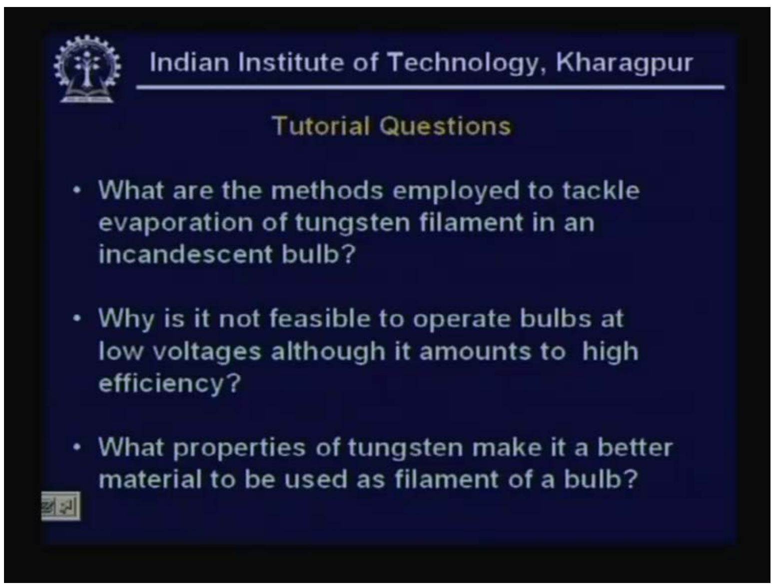

So the questions that may be addressed from this lesson are what are the methods employed to tackle evaporation of tungsten filament in an incandescent lamp. Why is it not feasible to operate bulbs at low voltages, although it amounts to high efficiency? What properties of tungsten make it a better material to be used as a filament of a bulb?

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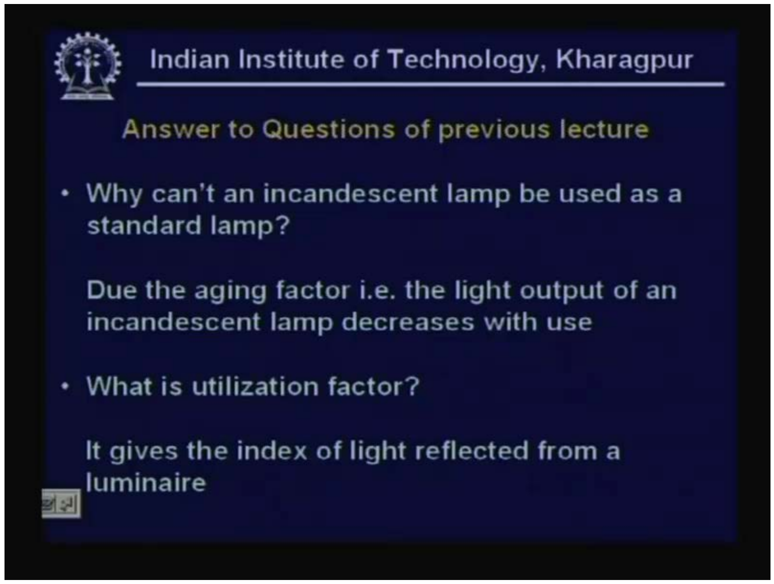

And, coming back to some of the questions which have been asked in the last lesson on photometric, why can't an incandescent lamp be used as a standard lamp. Due to the aging factor the light output of an incandescent lamp decreases with use. This is one reason why though when shifting from wax candle, for some time incandescent lamp was thought of a standard but there are two issues its age is one factor. The other factor that is stability of the voltage is very important. The light output is guaranteed only at that particular rated or nominal voltage. What is a utilization factor; it is the index of light reflected from a luminaire.

Now supposing we said a particular lamp has say 100 watt lamp radiating 10 lumens per watt would amount to meaning 1000 lumens of flux but all 1000 lumens may not be usable based on the accessories that are employed along with the lamp and this is what it gives. Typically we said it is around 0.85 to 0.9.

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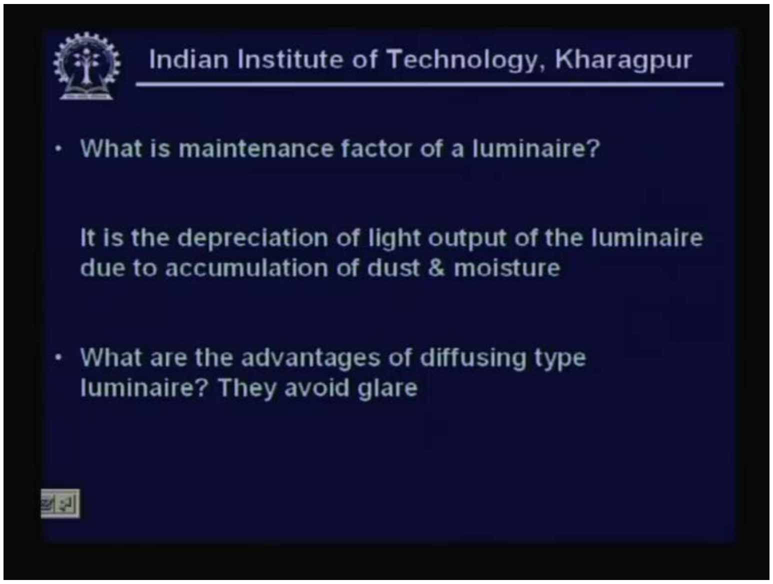

What is a maintenance factor of a luminaire? It is the depreciation of light output of the luminaire due to accumulation of dust and moisture. What are the advantages of using diffusing type of luminaire? They avoid glare. So having said so much about the incandescent lamps and having addressed the various aspects of a measurement, effect of importance of illumination, the way eye is affected.

The next issue to be taken up is to consider the second effect that's the electroluminescence which is used in the artificial sources that would be the topic of next lecture which is titled discharge lamps one because I told you the electroluminescence is producing light radiation by a discharge in a gas or a metal vapour at high, I mean by creating an arc. And in creating this discharge, we use filaments which have been studied today in incandescent lamps. Thank you.