

# Module 2 Lamps

# Lesson 7

## Incandescent Lamps

## Instructional Objectives

- What are Incandescent Lamps?
- State the Components of an Incandescent Lamp.
- Understand need for inert Gas in Incandescent Lamp.
- What is Lamp Darkening?
- State Factors responsible for Performance of an Incandescent Lamps.

## Incandescent Lamps

Natural Illumination due to sun which is 93 million miles away and 865,000 miles in dia, and has temperature  $> 6000^{\circ}\text{C}$ , leads to  $2.3 \times 10^{27}$  cd. Luminance. Moon, 240,000 miles away and 2160 miles dia, is said to have  $I \approx 1.0 \times 10^{27}$  cd. In order to provide artificial Illumination one of the following Physical Properties is employed:

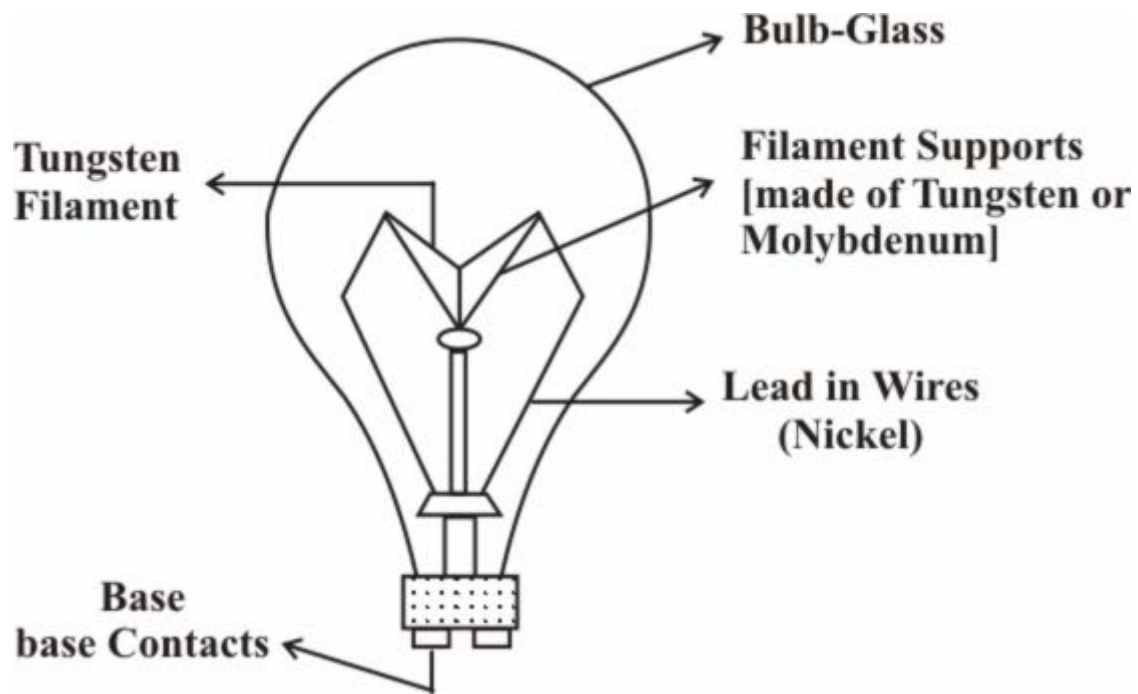
Incandescence depending on thermo luminescence,

Luminescence depending on electrical discharge in a gas or vapor

Fluorescence depending on radiation of visible light by absorbing ultra violet light and Phosphorescence involving radiation at a latter point in time.

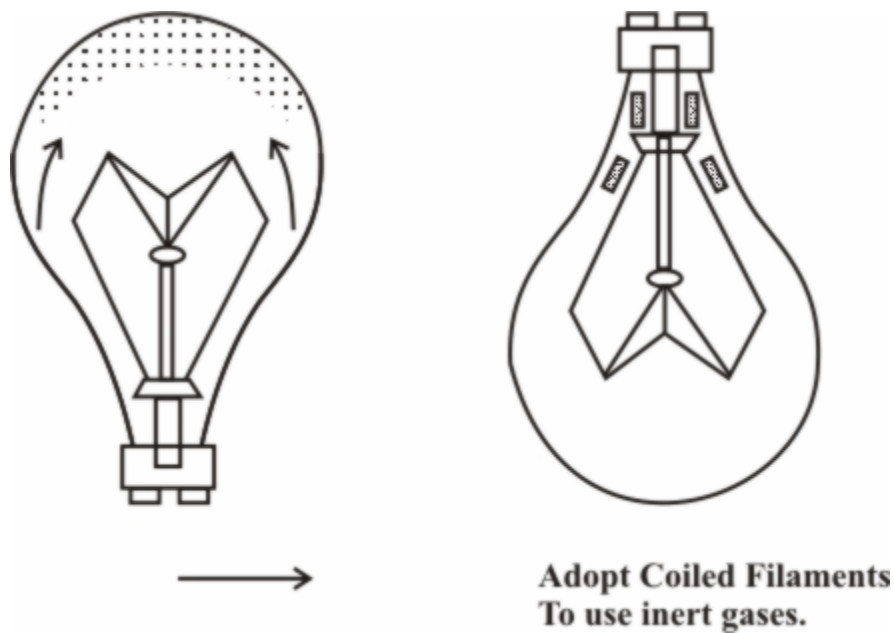
## Incandescent Lamps

Incandescent Lamps were first invented by Edison in 1879. They employed Carbonized Paper as Filament. It was Fragile. Later it was improved by coating with a Hydrocarbon. In 1893 Cellulose Filament was developed from absorbent cotton dissolved in  $\text{ZnCl}_2$ . Normally Filament is mounted in a glass bulb and maintained in vacuum (type 'B') gets heated upon Passage of current and typically radiating 3.3 lm / W. They are called Type 'B' lamps. In 1905, Metallizing by heating Carbon filament at high temperature in an Electric furnace efficiency improved to 4.0 lm/W. In Europe Osmium a Rare & expensive – Fragile filaments were employed with 5 lm/W radiation. It was soon, replaced by Tantalum a Ductile material (1906 - 1913) by crystallizing by application of ac leading to 5 lm/W radiation. In 1907 Tungsten Filaments entered with 7 lm / W radiation. Finely divided Tungsten Powder is mixed with a binder and squirted through a die. In 1911 Coolidge developed Tungsten in ductile form which could result in a Continuous uniform Filament. It was Rugged and had very high efficiency. Langmuir introduced use of inert gases and improved the radiation efficiency – (1913). They were called type 'C'.



**Fig. 1 Incandescent Lamps**

Fig. 1 shows a typical Incandescent Lamp. It has filament made of Tungsten of S. G. 18.81 before drawing, 19.3 – 20.2 after drawing with a high mp of  $3655^{\circ}\text{K}$ . (Osmium with a mp of  $2972^{\circ}\text{K}$  & Tantalum with a mp of  $3172^{\circ}\text{K}$ ). Were other materials Theoretically  $52 \text{ lm / W}$  radiation is possible at m.p but Practically, Highest radiation of  $35.8 \text{ lm / W}$  is achievable. They are available from 250W Flood Light with a life up 3 hours to 1500 W (at 115 V) of 1000 hr life radiating  $22 \text{ lm / W}$ . Smaller lamps being 6 W(at 115 V) with a 1500 hr life radiating  $6 \text{ lm / W}$ . Smallest Lamp being used in Surgical Instruments of 0.17 W of “Grain of wheat” radiation  $0.35 \text{ lm}$ . Largest Lamp being 50,000 W; 1,600,000 Lumens. Equivalent to 1000 - 100 W Lamps. Inert Gases are introduced in the Glass envelope to decrease the vaporizations of Tungsten. The gases Nitrogen and Argon are most suitable. Conduction Losses in a gas are proportional to velocity of gas molecules. Velocity is inversely proportional to square Root of atomic weight. Argon with atomic weight of 39.8 and Nitrogen with atomic weight 28.0 are most suitable. Ionization Potential of Argon is low. Hence a mixture of Argon and Nitrogen in the ratio of 85% Argon – 15% Nitrogen are employed. Concentrate the filament over a small region. To adopt tightly wound helical coil.

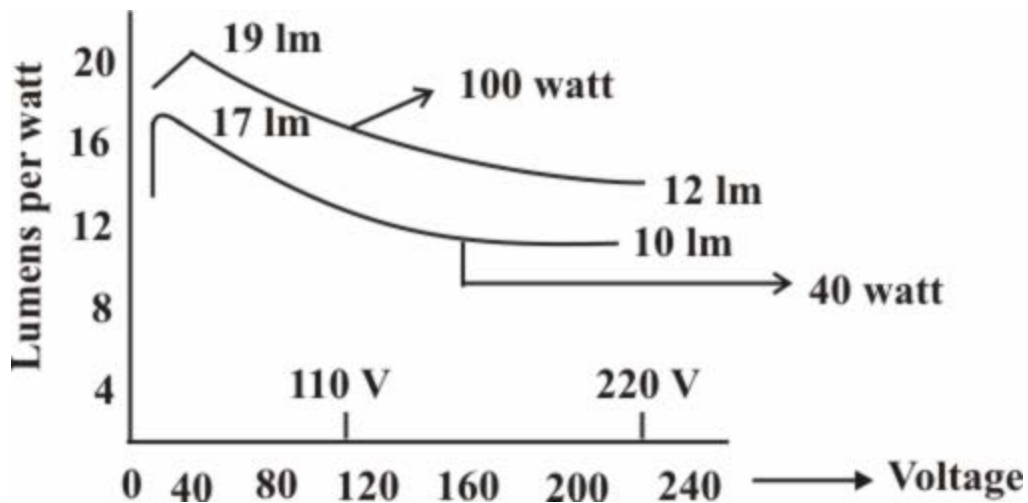


**Fig. 2 Blackening of Glass Bulb**

Fig. 2: shows darkening of Glass bulbs due to vaporization of Tungsten. Hence the lamps are called either

- Type B – Vacuum < 40 W rating or
- Type C – Gas > 40 W using Inert gases

During operation Filament evaporates and Tungsten particles deposit on the interior of Bulb in a Vacuum Lamp. Tungsten Filament cross section of the Filament decides the current Rating and varies as square of dia. The radiation surface varies as dia. With decrease in operating voltage for the same wattage filament becomes larger. If a lamp of 40W were to operate at 115 V and has a cross section  $C/S^1$ , it becomes  $C/S^2$  at 220 V then  $C/S^1 > C/S^2$ .



**Fig. 3 Voltage vs Efficiency**

Fig. 3 shows variations of voltage with luminous efficiency for 40 W and 100W lamps. As may be observed for both the lamps variation in luminous efficacy between 200 – 240V is very little. It implies that small variations in voltage do not effect the light efficiency. Where as in the 110V region variation is significant though one gets higher efficacy compared to 220V region.

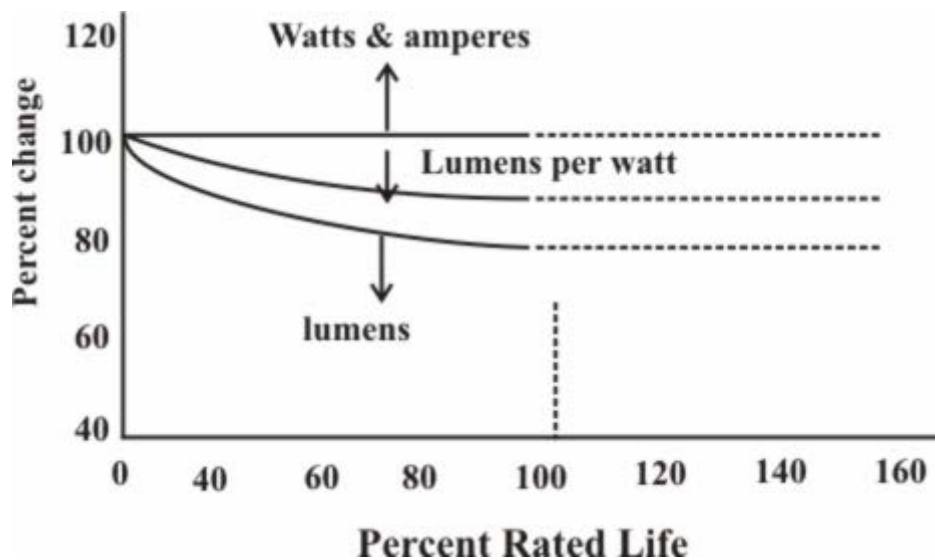


Fig. 4 Performance Curves

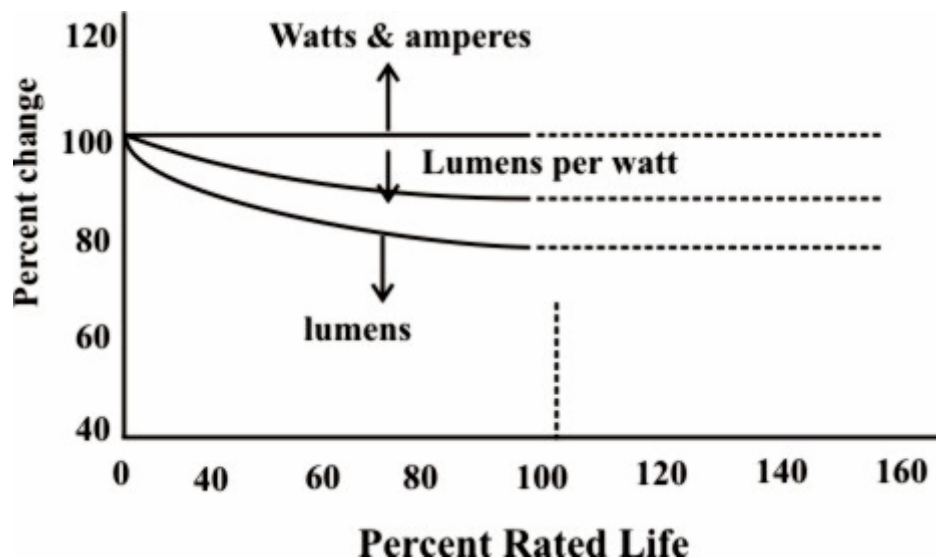
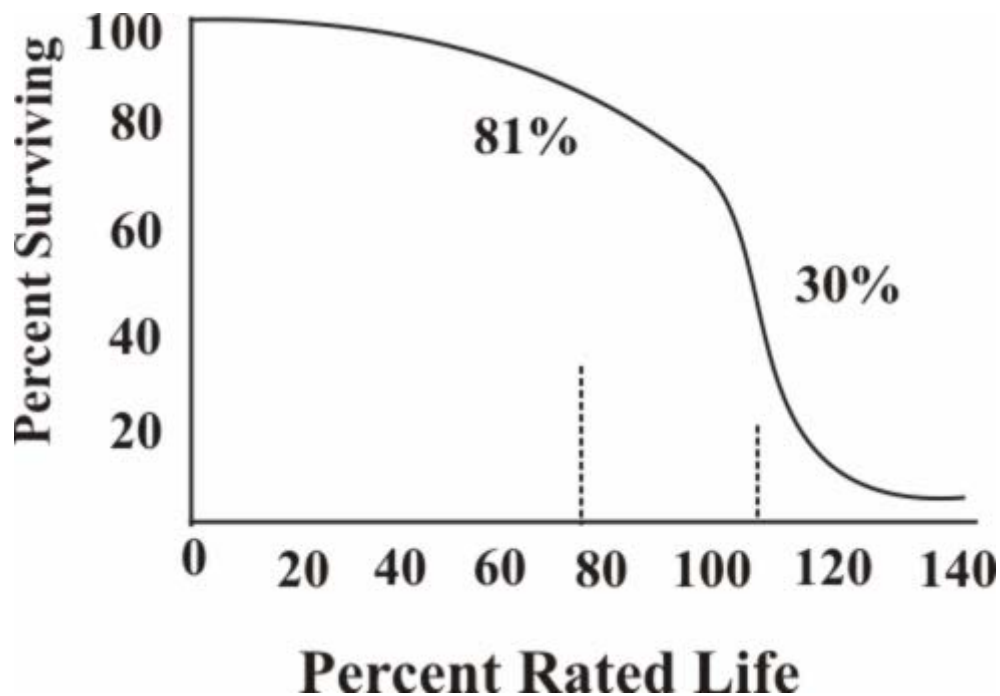


Fig. 5 Characteristics with change in voltage

Figures 4 and 5 show the performance of Incandescent Lamps. As may be seen from Fig. 4 both luminous efficacy lm/W and light flux lumenes reduce to 20% of Virgin values. Fig 5 shows the effect of variation of voltage from rated value. From this it may be said that although light output may reduce marginally when voltage reduces, one can get near 90% performance at about 95% rated voltage. Fig 6 shows the survival rate. More than 81% survive 80% stated life. Only 30% survive beyond 100% stated life.



**Fig. 6 Survival Rate**

- Filament characteristics depend on Filament Length, Diameter, Coil Spacing, Lead wires, No. of Supports, Method of mounting, Properties of Gas, Gas Pressure, Bulb Size and Shape of the Bulb.

The lamp is said to be most economical for the intended Service, if uniform radiation is there at stated wattage with guaranteed efficiency and Life Rating. Lamp characteristics may be quantified interest of

Watts – W, Lumens – F, Lumens per watt – E, Life – L, and Volts – V

Equations (1) to (4) give the characteristics. They all show dependence on exponents a, b, c, d, e, f, g and h.

Table I shows the typical values for Gas Lamps and Vacuum Lamp

$$\frac{W}{F} = \left( \frac{V}{V} \right)^a \dots\dots\dots(1)$$

$$\frac{f}{F} = \left( \frac{v}{V} \right)^b = \left( \frac{W}{F} \right)^c \dots\dots\dots(2)?$$

Typical cal values of Exponents

$$\frac{E}{e} = \left( \frac{v}{V} \right)^d = \left( \frac{F}{f} \right)^e \dots\dots\dots(3)$$

$$\frac{1}{L} = \left( \frac{V}{v} \right)^f = \left( \frac{F}{f} \right)^g = \left( \frac{E}{e} \right)^h \dots\dots\dots(4)$$

**Table I: Typical Constants**

	<b>a</b>	<b>b</b>	<b>c</b>	<b>d</b>	<b>e</b>	<b>f</b>	<b>g</b>	<b>h</b>
<b>G</b>								
<b>A</b>	1.54	3.38	2.19	1.84	0.544	13.1	3.86	7.1
<b>S</b>								
<b>V</b>								
<b>A</b>								
<b>C</b>	1.58	3.51	2.22	1.93	0.540	13.5	3.85	7.0
<b>U</b>								
<b>U</b>								
<b>M</b>								

This lecture covered the characteristics of Incandescent Lamps. One important specifications of any light source is power consumed in watts. Any lamp is guaranteed to give radiation at stated efficiency, if operated around rated voltage.

## Lecture Summary

- Incandescence – radiation at high temp.
- Incandescent Lamps:
  - Type-B : tungsten / osmium / tantalum filament, in vacuum
  - Type-C : tungsten filament, in inert gas (generally a mixture of Ar & N<sub>2</sub>)
- Tungsten is ductile in nature, has high MP & high efficiency which makes it suitable for use as filament
- Use of inert gas in incandescent lamps helps in decreasing the rate of evaporation of tungsten & improves efficiency
- Higher efficiency is obtained when incandescent lamps are operated at low voltages
- Filament characteristics depend on
  - filament length
  - filament diameter
  - coil spacing
  - lead wires
  - method of mounting
  - no. of supports
  - properties of gas employed
  - gas pressure
  - bulb size
  - shape of bulb
- Bulbs are designed for :
  - uniform radiation



- accurate consumption of power
- efficiency
- life rating

## Tutorial Questions

- What are the methods employed to tackle evaporation of tungsten filament in an incandescent bulb?
  - use of inert gases in the bulb
  - adopt coiled filament.
- Why is it not feasible to operate bulbs at low voltages although it amounts to high efficiency?

With decrease in voltage current increases & it becomes difficult to handle large current

- What properties of tungsten make it a better material to be used as filament of a bulb?  
High melting point, high efficiency, ready availability & ductility.