Chapter 8.

LAMPS

8.1. General remarks

In chapter 1, the dual nature of light was studied, and in chapter 2, the process of how visible radiations are manifested in light by means of vision was discussed.

As it has already been mentioned, light is a form of energy represented by electromagnetic radiation, which may affect the human eye, and is produced in many ways, depending on the causes that provoke it. If it is due to the radiant body temperature, the phenomenon is called *thermal radiation*. All other examples are considered as *luminiscence*.

Fig. 1 gives a general idea about the main physical agents which intervene in light production and their respective sources.

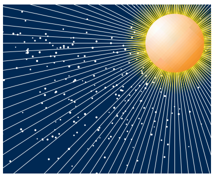
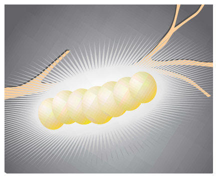
LIGHT PRODUCTION			
	Thermal radiation	Luminiscence	
	Incandescent combustion	Gas discharge	Solid body radiation
Natural	 Sun	 Ray	 Glowworm
Artificial	Flame Gaslight Electric arc Incandescent lamp	Metallic vapor lamp Noble gas lamp Negative glow lamp Xenon lamp	Luminiscent substance Luminous plaque Solid body plaque Radioactive source of light

Figure 1. Physical agents intervening in light production.

8.2. Thermal radiation

It is the radiation (heat and light) emitted by a hot body.

The energy of this radiation depends only on the calorific capacity of the radiant body. In general, the light obtained is always accompanied by a considerable thermal radiation that constitutes a source of energy loss when, in fact, light is trying to be produced. When heating a piece of coal, iron, gold, wolfram or any other material, a visible radiation is obtained. It may be seen in the incandescent colour acquired by the body and it will vary depending on temperature, as shown in Chart 1.

Temperature °C	Incandescent colour
400	red - incipient grey
700	red - grey
900	red - dark
1 100	red - yellow
1 300	red - light
1 500	red - incipient white
2 000 onwards	red - white

Chart 1. Incandescent colours at different temperatures.

All the laws studied and formulated for the ideal radiator may be summarized in a single one: the percentage of visible radiation increases according to radiator temperature.

As it may be seen in Fig. 2, at 6,500 K the maximum performance is obtained. It would be useless to increase temperature of the radiator with the intention of obtaining a performance greater than 40%.

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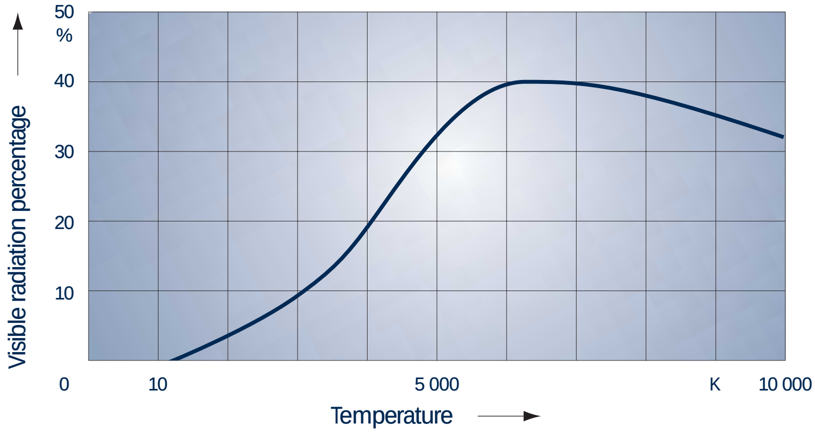

Figure 2. Visible radiation depending on absolute temperature.

8.2.1. Natural thermal radiation

In nature itself, an evident example of light production at a great scale may be found by the thermal radiation offered by the Sun or other stars similar to it. The Sun is an enormous ball of hydrogen in an incandescent state in which nuclear radiation is constantly transforming hydrogen (H_2) into Helium (He). In the process, enormous amounts of energy are expelled to the Universe. From the energy emitted by the Sun, almost 40% of the radiation is transformed into visible light, which corresponds to the maximum optical performance at 6,500 K.

8.2.2. Artificial thermal radiation

Light by artificial thermal radiation is obtained by heating any solid matter or body at a high temperature, either through combustion or incandescence.

Light of the lighting flame

The oldest thermal radiator in history and also the most primitive one was the lighting flame produced by the combustion of a lit torch, followed by the oil lamp, the petroleum one and the wax candle, which were the most widely used lighting sources in the old times.

At the beginning of the 19th century, the mineral coal gas (coal) was used to obtain a lighting flame, instead of the solid substances used until then (wax, grease) and liquid ones (oil, petroleum). At the beginning, light was obtained directly from the flame. Later on, through Auer's incandescent mantle.

Electric arc light

If two coal bars in contact, through which electric current is circulating, are quickly separated up to a certain distance, a permanent and powerful electric arc is produced between its pins.

The electric arc itself only produces 5% of the emitted light. The rest corresponds to the incandescent craters formed in both coal bars. This kind of arc, whose current intensity is quite high, must not be confused with gas discharge arcs.

Light of an incandescent body in the vacuum

When an electric current circulates through an ohmic resistance, this is heated up and, if taking place in the vacuum, it turns incandescent. The colour acquired is red- white at temperatures ranging between 2,000 and 3,000 ºC, in which case it emits light and heat like a perfect thermal radiator. The first person who put this principle into practice was Henrich Goebel who made the first electric incandescent lamps in 1854, using empty perfume bottles in which he hermetically sealed a filament made with carbonized bamboo fibres. However, it was the American Thomas Alva Edison who discovered an incandescent lamp with a coal filament and gave it a practical utility as a series article in 1879. At the same time as Edison, the british Swan also achieved a usual incandescent lamp.

The coal filament: Lamps used from 1880 to 1909, had a coal filament composed of "coked" bamboo or paper fibres.

The point of fusion of this filament was approximately of 3,700 °C, but due to its high vaporization index, lamps could also be made for a temperature in service of about 1,900 °C. Thus, luminous performance was not more than 3 to 5 lm/W.

The metal filament: At the beginning of the past century, a search begun in order to find metals that would be able to substitute the coal filament in a susccessful way. Among metals with a high degree of fusion were osmium, tantalium and wolfram mainly. Wolfram point of fusion is approximately 3,400 °C, with an evaporation index slightly lower than that of coal. The lamp life is approximately 1,000 hours, the filament incandescence temperature reached 2,400 °C and a luminous performance of 8 to 10 lm/W was obtained.

8.3. Luminescence

Those luminous phenomena whose cause does not exclussively obey to temperature of the luminescent substance. Such phenomena are characterized because only some particles of the matter atoms, the electrons, are excited to produce electromagnetic radiations. In order to understand such a study, Börh's atomic model must be studied.

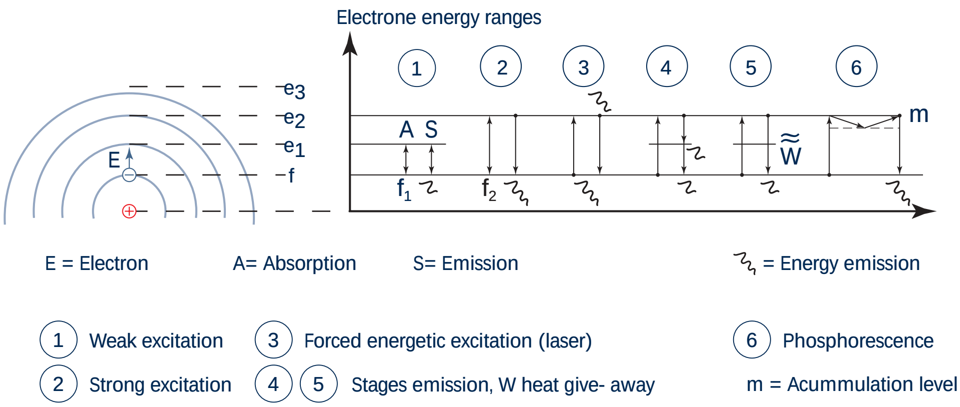

Figure 3. Böhr's atomic model.

According to this model, each atom is formed by a positive atomic nucleus and by a cover of negative electrons. These are distributed in different layers that rotate around the nucleus following certain orbits. Usually there is an electric balance in the atom, that is to say, the number of positive charges is equal to the number of negative charges (electrons). This balance is known as *fundamental state of the electron E,* and for electrons in the most internal orbit, it is identical to the base line *f* (Fig. 3).

If a certain amount of energy is administered to the electron from the outside, electron *E* is excited and moved from its regular orbit to the next one or to another more external one. Thus, the energy supplied is absorbed. The electron is located in a superior energy level (level lines e1, e2, e3, etc. of Fig. 3). After a short time in this level, the electron returns again to its regular initial position (line *f* of Fig. 3) and emits the amount of energy absorbed at the beginning, usually in the form of electromagnetic radiation.

If the amount of energy is greater, electron *E* may instantaneously reach a more external orbit. As a consequence of the greater range of energy achieved, radiation emited when the electron returns to base *f* will be richer in energy.

Therefore, the different layers of energy correspond to a perfectly determined level of energy, and, thus, there are not intermediate levels. Thus, it is deduced that in order to excite an atom, an exactly determined amount of energy is necessary. This is emitted in the form of radiation and/ or heat loss when the atom recovers its fundamental shape.

The emission of energy transformed in this process from an atomic point of view takes place in portions or discontinuous parts known as *energy quants* (Böhr postulated that the atom may not rotate at any distance from the nucleus, but in certain orbits only). However, in the field of practical lighting engineering, light emitted in this tranformation is considered to be emitted in a continuous way, in the form of electromagnetic waves, which is acceptable for normal cases of its application.

By means of the theory of *energy quants* formulated by Max Plank, it is proved that different chemical elements, when excited, do not emit a continuous spectrum due to the different structure of their electronic layers, but only very particular wavelengths (lines) within all the electromagnetic spectrum. These spectra are known as *linear spectra*. Each substance has a characteristic linear spectrum and also luminescent gases like, sodium vapor, whose spectrum is composed by a double yellow line whose wavelengths correspond to 589 and 589.6 nm, respectively.

According to the physical technique used to excite atoms, the type of radiation and the form in which it is emitted, several types of luminiscence may be distinguished.

Electric discharge light within a gas

In all gases, especially in those contained in discharge lamps, besides neutral gas atoms, some free electric charges are found (electrons).

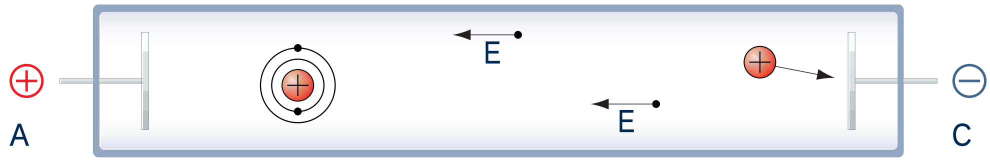

Figure 4. Gas discharge tube.

If a continuous current is applied to the anode A (+) and to the cathode C (-) of the discharge tube (Fig. 4), an electric field is created between A and C which accelerates negative charges (electrons) and hurries them towards the anode. When an electron reaches a certain speed, it has enough kinetic energy to excite a gas atom. If the speed of the electron when crashing against the atom gas is even greater, the impact may even cause the separation of an electron from the atomic cortex, so the atom lacks an electron in its configuration. That is to say, a positive ion is obtained. This phenomenon is known as *impact ionization*. This way, the number of free electrons is even higher. It is even possible that they will increase enormously if the electric current produced by them is not limited by means of an appropriate resistance (stabilizer).

Together with the free or separated electrons, positive ions may be also found moving in the opposite way of electrons. That is to say, towards the cathode. Due to their small speed, they may not produce any excitation of other gaseous particles. On the contrary, after a short period of time, they take an electron again in exchange for an energy emission.

Depending on the noble gas or metal gas with which the discharge container is filled, by means of the previously mentioned atomic excitation, linear spectra or light colours characteristic of the chosen chemical element will be formed. For example, if the gas is neon, the light colour is red- orangish, and if it is mercury vapor, it will be white- bluish.

All these phenomena take place within a volume ranging between two electrodes, and it is limited by the discharge container wall. This volume forms a discharge gaseous column.

If the discharge tube receives an alternating power supply, instead of a continuous one, electrodes change their function periodically, sometimes behaving as a cathode and some other times as an anode. Otherwise, the luminous production phenomenon is exactly the same.

Electric discharge conditions for light production in a gas essentially depend on the gas or vapor pressure inside the discharge tube. So, there are three kinds of discharge, namely:

- Low pressure discharge.
- High pressure discharge.

- Very high pressure discharge.

The higher pressure is, the wider spectral lines, forming even greater bands, so that the chromatic spectrum improves.

Metal vapor lamps need the metal to be vaporized first since it is in a solid or liquid state when cold. This is the reason why these lamps are filled with a noble gas which is the first one to inflame, supplying the heat necessary for metal vaporization.

High voltage electric discharge between cold electrodes (noble gas tubes)

In order to administer enough free electrons in this type of discharge, cold electrodes are used mostly built with a chromium-nickel metal.

The filling of the discharge tube is with noble gases like neon which emits an intense red- orangish light, or helium which emits a light pink coloured light and also with metal vapors, especially mercury vapor which emits a white- bluish light, and when mixed with the neon gas an intense blue light.

Starting and working voltages are high, 600 to 1,000 volts being necessary for half a metre in length. The average voltage consumption also for half a metre in length is of about 33 W, with a luminous performance of 2.5 to 5 lm/W.

Due to this low luminous performance, noble gas tubes have been barely used for indoor lighting, but they really have played an important role in luminous advertisement due to their particular easiness to be modelled in the shape of letters.

Low voltage electric discharge between hot electrodes (metal vapor lamps)

If a certain amount of solid sodium or liquid mercury is introduced inside a glass tube previously evacuated in order to transform metal into vapor through the electric discharge, a metal vapor discharge in gas is obtained. This may be even produced at a regular low voltage (220 V), with prehated or heated electrodes (hot cathodes). Sodium and mercury vapor lamps work according to this principle.

From everything that has been exposed until now, it is deduced that light emitted by metal vapor lamps especially depends on the linear spectrum of the metal vapor chosen. Thus, sodium vapor lamps produce a monochromatic light of a yellow- orangish light and mercury vapor lamps one of a green- bluish characteristic.

Discontinuous spectra of these lamps are improved through different ways:

Mercury lamps:

- Through combination with an incandescent lamp (blended light lamps).
- Through combination with a fluorescent layer (mercury vapor lamps, corrected colour).
- Through addition of metal halides (metal halide vapor lamps).

Sodium lamps:

- Through combination with mercury light in a metal transparent recipient, at high pressure filling (high pressure sodium lamps).

Photoluminescence (low pressure fluorescent lamps)

Photoluminescence is fundamentally understood as the excitation of certain substances to luminescence by means of radiation, usually produced by short wave ultraviolet radiation. The luminescent substances used only emit light while they are being excited by short wave ultraviolet radiation which is transformed into a longer wave radiation (visible spectrum light).

Luminescent substances used are, among others, calcium wolfram, magnesium wolframite, zinc silicate, cadmium silicate, cadmium borate, halophosphates, etc.

Each of these luminescent substances emits a certain light colour. By mixing these substances in an appropriate way, any desired composed light colour may be obtained. If the emission light of each of these chromatic components is achieved to be superimposed, a continuous spectrum is obtained which may also vary from daylight white to warm white.

"Fluorescence" are all those luminescent phenomena in which luminous radiation remains during the excitation. The opposite situation is known as phosphorescence.

Phosphorescence

Phosphorescence takes place when luminous radiation persists in certain luminescent substances even after excitation is over. This phenomenon corresponds to the fact that under certain energy levels (belonging to certain electronic layers) of some chemical components, like sulphures, seleniures or oxides of alkali earth metals, apart from this, there is an “acummulation level” that prevents electrons from quickly returning to their initial position.

Electrons, that because of their excitation reach this acummulation level, can only in a slow fashion recover their fundamental state. It is then when the substance continues emitting light. This phenomenon may last fractions of seconds or months (depending on material type and temperature).

Electroluminance

In order to produce this phenomenon, instead of an exciting radiation, also an electric field may be directly used to “rise“ electrons at a higher level of energy. This is achieved by inserting a luminescent substance between two conducting layers and applying alternating current to the group, as for plaque condensers.

This way to obtain light (manifested by a sparkle of a moderate splendor) has been performed in the so- called *luminous plaques* to be applied in hospital rooms, building numbering, stair lighting, etc.

Injected luminescence

To a certain extent, it is the opposite case to that of the photoelectric principle, in which photometres to measure light are based. Whereas there is a luminous energy transformation in the photometre into electric energy (in the form of a minicurrent), on applying injected luminescence to the so- called solid body lamp of an electric energy, a luminous energy is reciprocally produced (chromatic radiation). This kind of radiation has a very good application for simple procedures of unimportant marking. A solid body lamp is obtained by inlay in the net of a semiconductor certain strange atoms, in such a way, that it will remain divided into two parts, one with an excess of electrons and the other with a defect.

Radioluminescence (light produced by radioactive substances)

In this case, the luminous emission is based on radiation from a luminescent substance with rays which result from the natural desintegration of radioactive matter, like for example, uranium and its isotopes. This light production principle, the so- called isotope lamp, is applied which does not need power supply at all to work.

Bioluminescence

Bioluminescence is a luminous phenomenon which is weakly manifested in Nature. It consists of a sparkle emitted by light worms, some classes of fishes, marine algae, rotten wood and similar. This phenomenon is due to the oxidation process of some special chemical or organic substances, like the ones glow worms and photogene bacteriae have when in contact with the air or water oxygen.

So far, it has not been possible to reproduce this phenomenon of Nature artificially.

8.4. Conditions to be met by lamps

8.4.1. Total radiation spectral distribution

For lamps as energy transformers to work with a high performance, almost all the energy absorbed should be transformed into visible radiation. Besides, their light should be white like daylight and with a good chromatic reproduction which requires a continuous spectrum containing all main colours from purple to red. But, since eye sensitivity is maximum for yellow- greenish radiation, the best thing to do, as far as luminous performance is concerned, is to obtain the highest percentage possible of radiation in the 555 nm zone.

8.4.2. Luminance

Light lamps preferably used outside must not have a high luminance so that their glare effect is kept within bearable limits. The admissible luminance value depends on the type of application.

On the contrary, lamps used in luminaires may have great luminances, since they trimmer the glare effect. In general, luminance to be obtained from a lamp depends on the system adopted for light production, that is to say, on the physical nature of the source of light and on the fact that it may be pointed, linear or plane.

Lamps luminance may never be increased by means of any optical system but it may be weakened, for example by diffusing layers.

8.4.3. Luminous intensity distribution

Lamp radiation is not equal in all directions in the space. It is affected by the position of the base, the supports of the luminous body, etc. All this determines that each type of lamp possesses a distribution typical of its luminous intensity.

Luminous distribution curves are essential to project lighting installations, as well as for luminaire design, because their optical system must be adjusted in such a way to the lamp luminous distribution curve and light is directed to the place or point where it is needed the most.

8.4.4. Emitted radiation biological effect

Lamps must not emit any unnecessary or harmful radiation for human beings, either immediately or in the long run. With thermal radiators like incandescent lamps, this condition is observed from the beginning (most of the radiation produced is infrared). Some gas discharges, mainly mercury vapor, naturally contain a percentage of ultraviolet radiation that may be classified into:

- UV-A: Sun tanned or long wave (between 315 and 380 nm.).
- UV-B: Anti- rachitic or medium wave (between 280 and 315 nm.). It favours the production of vitamin D in the body.
- UV-C: Bactericide or short wave (between 200 and 280 nm.). It kills germs and organic matter. These effects may increase due to weakening of the atmospheric ozone layer.
- UV-C: Ozonosphere or short wave (between 100 and 200 nm.). This type of radiation is able to create ozone with the same characteristics as that of the atmosphere.

The permanent effect of UV-B or UV-C radiations produces burns on the skin and conjunctivitis in the eyes which are not protected. In general lighting lamps, this may be avoided with the use of appropriate glass classes that absorb critical radiation.

8.4.5. Appropriate colour for each application

The light colour of a lamp is determined by the spectral composition of its radiation. In Chart 2, light groups are established for lamps used in general lighting:

Light colour	Color temperature
Incandescent-fluorescent	2 600-2 700 K
Warm white	2 900-3 000 K
White or neutral white	3 500-4 100 K
Cold white	4 000-4 500 K
Daylight white	6 000-6 500 K

Chart 2

Whereas incandescent lamps, due to their high content in the power supply (with the exception of coloured lamps), may only radiate a warm white colour, light colours of discharge lamps are determined by gases or vapors chosen for them. For example, yellow for sodium vapor discharge, or pale blue for mercury vapor. Other chromatic variants may be used, combining different metallic vapors or modifying vapor pressure. With fluorescent lamps the possibility of achieving any shade that may be desired is offered by means of the selection or mixture of a great amount of well- known luminescent substances, in order to adapt them to each type of application.

8.4.6. Chromatic reproduction quality

Chromatic reproduction refers to the aspect of the colour illuminated surfaces have. Their reproductive quality not only depends on the incident light colour tone, but also on their spectral composition. Therefore, colour temperature technically refers to the colour of light, but not to its spectral composition. Thus, two sources of light may have a very similar colour and have, at the same time, some very different chromatic reproduction properties. Most of the times what is required from a lamp is a good chromatic reproduction, which means a spectral distribution different from the necessary one to obtain a high luminous performance.

8.4.7. Luminous flux constants

In practice, it is not possible to maintain the luminous flux value at a 100% during all the life of the source of light, since physical and technological reasons are against it.

Luminous flux indicated in catalogues refer, as far as incandescent lamps are concerned, to lamps which have not been working yet, and as far as discharge lamps are concerned, to lamps with 100 hours of working, to which this has been stabilized.

8.4.8. Luminous performance

As seen in chapter 5, the maximum luminous performance to be achieved in the most favourable situation is 683 lm/W. Although this value may not be reached, nowadays, lamps with a quite high performance have been achieved that allow the obtaining of high lighting in a relatively economic way.

Nevertheless, in many cases it must be decided which property of the lamp is the most priceless: whether a high luminous performance or an extraordinarily good chromatic reproduction.

8.4.9. Average rated life and service life

Average rated life is an statistical concept which represents the arithmetic means of the duration in hours of each of the lamps of a group representative enough of the same model and type.

Service life is a measurement referred to practice, also given in hours, after which the luminous flux of a certain lighting installation has decreased to such a value that the lamp is not profitable although the lamp may go on working.

8.4.10. Repercussions in power supply

Any modern lamp requires its working not to have an important repercussion in the power supply. With incandescent lamps, this repercussion is limited to an upsurge in the connection moment, due to its small resistance with the cold lamp. Electric discharge lamps generally work in connection with an inductance, representing an apparent resistance for the circuit.

This gives rise to obtaining a low power factor ($\cos \varphi$), which means an additional charge for the power supply and it must be then compensated.

8.4.11. Stabilization of lamps with negative resistance characteristics

Negative resistance is the property some electric resistances have, for example, a discharge arc one, to decrease its value as the intensity of the current circulating through it increases. This obliges to stabilize current in discharge lamps so that it will not acquire excessive values that may destroy it. This is easily done by locating inductive, capacitive and ohmic resistances in the lamp circuit.

8.4.12. Variations in power supply

Variations in power supply influence the lighting engineering data of any lamp. In incandescent lamps, they affect duration and colour temperature very much, and in discharge ones, relations of arc pressure and also discharge conditions.

8.4.13. Time needed until the luminous flux acquires the normal regime

Incandescent lamps ignite immediataly emiting their total flux. Fluorescent lamps may also do it if quick ignition starters are used. If not, ignition will be done later on, after one or several attempts.

The other discharge lamps require some minutes as ignition time, until metal vapor acquires the necessary pressure and the luminous flux reaches it maximum value.

8.4.14. Possibility of immediate reignition

It is the possibility that a lamp, after having been turned off, will be immediately reignited while still hot with full emission of the luminous flux. This condition is only met by incandescent lamps, metal vapor ones present certain differences regarding their immediate reignition possibility, as indicated below:

- High pressure mercury lamps: They need some time (minutes) for cooling down before reignition while still hot, and some more time to reach the total luminous flux.
- Metal halide lamps: They behave exactly like mercury ones. There are some types which may reignite while still hot by means of special devices.
- High pressure sodium lamps: Those types which have a separated ignition device reignite while still hot within a minute and reach their total flux virtually with no delay. Other types without a separate ignition device behave in a similar fashion as mercury lamps.
- Low pressure sodium lamps: They behave like mercury lamps.

8.4.15. Stroboscopic effect

In all artificial sources of light which work with alternating current their emission stops every time current goes through the zero point. This takes place twice per period, so for a 50 Hz. frequency (periods per second) corresponds 100 instants of darkness per second. The filament of incandescent lamps has a lot of thermal inertia. Thus, a slight descend of luminous emission takes place due to such a reason. This is not perceived by the eye except when low power lamps work with a 25 Hz voltage.

For discharge lamps working with 50 Hz. voltages, the eye is not able to appreciate such quick light variations which are produced. It may be the case, too, that lamps illuminate zones in which rapid movements are made, these being observed as if they were made intermittently or even as if they were stationary. This phenomenon is known as the *stroboscopic effect* and it may be reduced to make it unobservable by means of a lamp special power supply mounting, or wherever a three- phased line is available, distributing its connection between the three phases.

8.4.16. Working position

An electric lamp is generally made for a certain working position in which it has optimal working properties. Outside this position, properties worsen, either by an excess of heating of the spiral, the base or the glass outer bulb, by deviation of the discharge lamp arc or by variations of the surrounding heat. This is the reason why tolerances given in the corresponding lamp catalogues must be accepted in order to avoid their premature depletion because of an inadequate working position. Abbreviations used indicate the main working positions and the admissible tilt angle in degrees.

Main working positions:

S (s) = Vertical (standing, base downwards).

H (h) = Vertical (hanging, base upwards).

P (p) = Horizontal (base sideways).

HS (hs) = Vertical (base upwards or sideways).

Universal = Allows any position.

Admissible tilt angles: After the main working position, there is a figure that indicates the admissible tilt in degrees in relation to it.

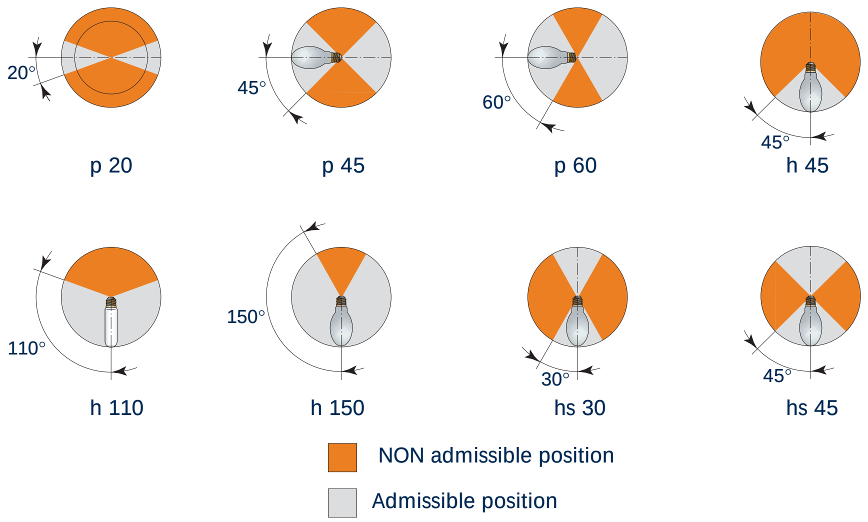

Figure 5. Working position sketch.

8.5. Incandescent lamps

As it has been said before, the incandescent lamp is the oldest source of electric light and, nowadays, the most commonly used one. It is also the one that possesses the widest variety of alternatives and it may be found in almost all installations, specially when a low luminous flux is required. A relatively recent discovery is the halogene incandescent wolfram lamp, which has quickly dominated many lighting application areas.

8.5.1. Conventional incandescent lamps

Incandescent lamps produce light through the electric heating of a wire (the filament) at a high temperature, emitting radiation within the visible field of the spectrum.

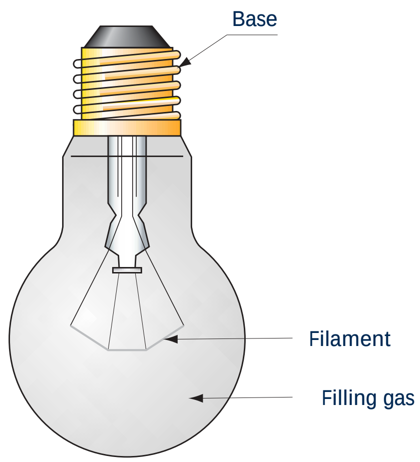

Figure 6. Conventional incandescent lamp.

The main parts of an incandescent lamp are the filament, the filament supports, the glass bulb, the filling gas and the base.

Filament: The one used in modern lamps is made out of wolfram (high fusion point and low evaporation degree). A higher luminous efficiency would be achieved by twisting the filament as an spiral.

Glass bulb: It is a cover of sealed glass which encloses the filament and avoids contact with the air outside (so that it does not burn).

Filling gas: Filament evaporation is reduced filling the glass bulb with an inert gas. The most commonly used gases are argon and nitrogen. In these lamps, luminous energy obtained is very little compared to the heat energy irradiated, that is to say, a great amount of the transformed electric energy is lost as heat and its luminous efficacy is small (it is a waste- energy lamp). The advantage of these lamps is that they are directly connected to the electric current without the need of an auxiliary equipment for their working.

8.5.2. Wolfram halogen lamps

The high temperature of the filament for a normal incandescent lamp makes wolfram particles to evaporate and condense on the wall of the glass bulb, darkening this, as a result. Halogen lamps have a halogen component (iodine, chlorine, bromine), added to the filling gas and work with the halogen regenerative cycle to prevent darkening.

The evaporated wolfram is combined with the halogene to form a halogene wolfram compose. As opposed to wolfram vapor, it is maintained in the form of gas, the glass bulb temperature being high enough as to prevent condensation. When such a gas approaches the incandescent filament, it is decomposed due to the high temperature in wolfram that is again deposited in the filament, and in halogene, which continues with its task within the regenerative cycle (Fig. 7).

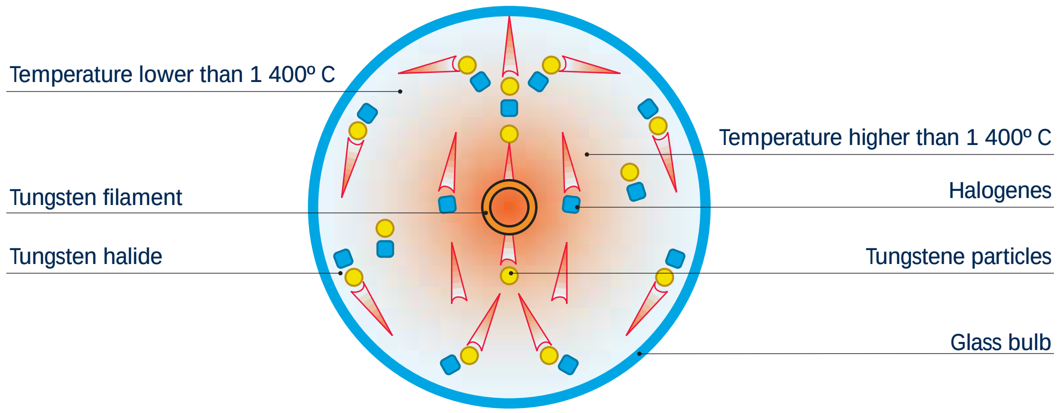

Figure 7. Halogene cycle.

The main difference between an incandescent lamp, apart from the halogene additive mentioned before, is in the glass bulb. Due to the fact that temperature of the glass bulb must be high, halogene lamps are of a smaller size than regular incandescent lamps. Their tubular- shaped glass bulb is made out of a special quartz glass (which must not be touched with the fingers). Since their introduction, wolfram halogene lamps have entered almost all applications where incandescent lamps were used. The advantages of wolfram halogene lamps with regard to regular incandescent lamps are the following: longer duration, greater luminous efficiency, smaller size, greater colour temperature and little or no luminous depreciation in time.

8.6. High pressure mercury discharge lamps

In this section, discharge lamps in whose discharge tube mercury is introduced, are going to be studied. Fluorescent lamps, compact fluorescent lamps, high pressure mercury lamps, blended light lamps and metal halogene lamps are included.

8.6.1. Fluorescent tubes

Fluorescent tubes are a low pressure mercury discharge lamp in which light is produced predominantly through fluorescent powder activated by the discharge ultraviolet energy.

The lamp, generally with a long tubular- shaped glass bulb and a sealed electrode for each terminal, contains low pressure mercury and a small amount of inter gas for ignition and arc regulation. The glass bulb inner surface is covered by a luminiscent substance (fluorescent powder or phosphorous) whose composition determines the amount of emitted light and the lamp colour temperature).

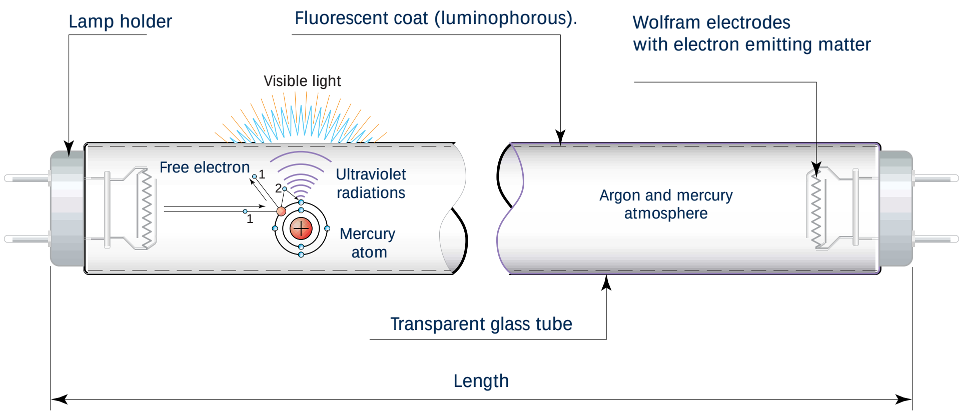

Figure 8. Fluorescent lamp.

The main parts of the fluorescent lamp are the glass tube, the fluorescent layer, the electrodes, the filling gas and the base.

Glass tube: The glass tube of a regular fluorescent lamp is made out of sodium- calcium glass softened with iron oxide to control short wave ultraviolet transmission.

Fluorescent covering: The most important factor to determine the characteristics of the light of a fluorescent lamp is the type and composition of the fluorescent powder (or phosphorous) used. This establishes colour temperature (and, as a consequence, colour appearance), colour reproduction index (R) and, lamp luminous efficiency, to a great extent.

Three groups of phosphorous are used to produce different series of lamps with different colour qualities (standard phosphorous, tri- phosphorous and multi- phosphorous).

Electrodes: Electrodes of a lamp which possesses an adequate layer of material emitter serve to drive electric energy to the lamp and provide the necessary electrons to maintain discharge.

The majority of fluorescent tubes have electrodes that are preheated by means of an electrical current just before ignition (they are given the name of preheating electrode lamps; this preheating is begun by an independent starter).

Filling gas: Filling gas of a fluorescent lamp consists in a mixture of saturated mercury and an inert gas trimmer (argon and krypton).

Under normal working conditions, mercury is found in the discharge tube both as a liquid and as vapor. The best performance is achieved with a mercury pressure of about 0.8 Pa., combined with a pressure of the trimmer of about 2 500 Pa. (0.025 atmospheres). Under these conditions, about 90% of the radiated energy is emitted in the ultraviolet wave of 253.7 nm.

In fluorescent lamps, colour temperature ranges between 2 700 K and 6 500 K., with a discontinuous spectral distribution curve reproducing colours depending on the composition of the fluorescent substance that covers the inner wall of the tube.

Each resulting total luminous radiation is the sum of the radiation of discontinuous spectrum plus that of a continuous spectral distribution, more efficient each time, with the use of special phosphorous.

Thus, fluorescent tubes with several light tones and chromatic reproduction indexes are manufactured. According to the C.I.E. norms, these are divided into three main groups:

- Daytime white light: $T_C > 5\ 000$ K.
- Neutral white: $5.000\ K \geq T_C \geq 3\ 000$ K.
- Warm white: $T_C < 3\ 000$ K.

There are several tones for each group, with a wide range of colour temperatures and chromatic reproduction indexes, depending on each manufacturer. These cover the needs for a wide range of applications.

These lamps require an auxiliary equipment formed by a ballast and an igniter (starter), besides a compensation condenser to improve the power factor.

Working nominal values are reached after five minutes. When the lamp is turned off, due to a great pressure in the burner, it is necessary to cool down between four and fifteen minutes before it is turned back on.

8.6.2. High pressure mercury lamps

Since their introduction, high pressure mercury lamps have been developed to a point that lighting technology cannot be thought of without it.

In these lamps, discharge takes place in a quartz discharge tube containing a small amount of mercury and an inert gas filling, usually argon, to help ignition. One part of the discharge radiation occurs in the visible region of the spectrum as light, but some part is also emitted in the ultraviolet one. Covering the inner surface of the blister, in which the discharge tube is located, with a fluorescent powder which will transform this ultraviolet radiation into visible radiation. The lamp will offer higher lighting than a similar version without such a layer.

Working principles

When the working of the high pressure mercury lamp is examined, three well differentiated phases must be distinguished: ignition, turn-on and stabilization.

Ignition

Ignition is achieved by means of an auxiliary electrode, placed very close to the main electrode and connected to the other through a high value resistance (25 kΩ). When the lamp is turned on, a high voltage gradient takes place between the main and the ignition electrodes, which ionizes the filling gas in this area as a luminescent discharge, the current being limited by a resistance. Luminescent discharge is then expanded through the discharge tube under the influence of the electric field between the two main electrodes.

When luminescent discharge reaches the most distant electrode, current increases in a considerable way. As a result, the main electrodes are heated until the emission increases enough to allow the luminescent discharge to change completely to an arch discharge. The auxiliary electrode lacks another function in the process as a consequence of the high resistance connected serially to it.

During this stage, the lamp works as a low pressure discharge (similar to that of a fluorescent lamp). The discharge fills the tube and gives it a bluish appearance. la corriente limitada por una resistencia. La descarga luminiscente luego se expande por todo el tubo de descarga bajo la influencia del campo eléctrico entre los dos electrodos principales.

Turn- on

The inert gas having been ionized, yet, the lamp does not burn in the desired way and does not offer its maximum production of light, until mercury present in the discharge tube is completely vaporized. This does not happen until a certain amount of time has elapsed, called turn-on time.

As a result of the arch discharge in the inert gas a heating is generated providing a quick increase of temperature inside the discharge tube. This causes mercury gradual vaporization, increasing vapor pressure and concentrating discharge towards a narrow band along the axis of the tube. With an increase in pressure, radiated energy progressively concentrates along the spectral lines of greater wavelengths and a small portion of continuous radiation is introduced. This way, light turns whiter. With time, the arc achieves a stabilization point and it is said that the lamp reaches the total thermodynamic balance point. All mercury is then evaporated, and discharge occurs in non- saturated mercury vapor.

The turn- on time, defined as the necessary time for the lamp since the ignition moment to reach an 80% of its maximum production of light, is approximately four minutes.

Stabilization

The high pressure mercury lamp, like most discharge lamps, has a negative resistance and, thus, it cannot work on its own in a circuit without an adequate ballast to stabilize the flux of the current through it.

Main parts

In Fig. 9 the main parts of a high pressure mercury lamp may be observed.

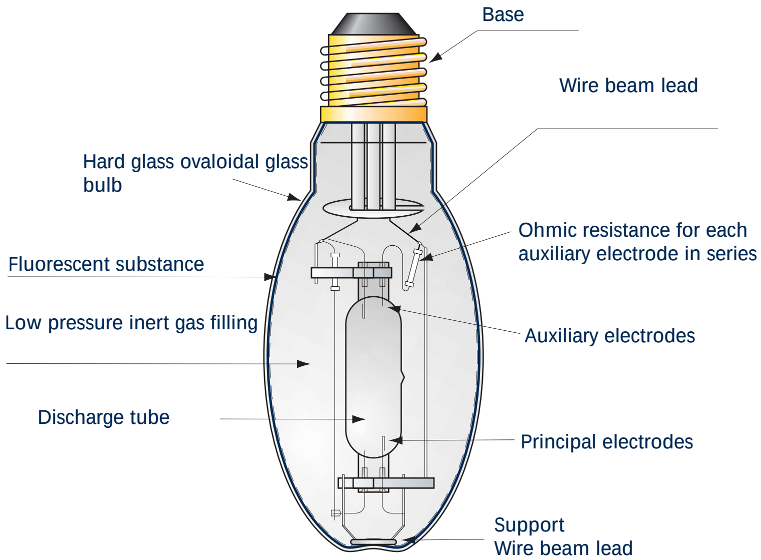

Figure 9. High pressure mercury lamp.

Discharge and support tube: The discharge tube is made out of quartz. It has a low absorption of ultraviolet and visible radiation. Also, it stands high temperatures of the work involved.

Electrodes: Each main electrode is composed of a wolfram bar, whose extreme is covered by wolfram serpentine impregnated with a material that favors the emission of electrons. The auxiliary electrode is simply a piece of wire of molybdenum or wolfram located near one of the main electrodes and connected to another one by means of a resistance of 25 kΩ.

Blister: For lamps up to 125 W of potency, the blister may be of glass sodium- calcium. However, lamps with higher potencies are manufactured, generally, with hard glass of borosilicate, since higher working temperatures and thermal shock are tolerated. The blister, which normally contains an inert gas (argon or a mixture of argon and nitrogen), protects the discharge tube from changes in the room temperature and protects lamp components from corrosion.

Glass covering: In most high pressure mercury lamps, the inner surface of the blister is covered by white phosphorous to improve lamp colour reproduction and to increase its luminous flux. Phosphorous transforms a great amount of ultraviolet energy radiated by the discharge into visible radiation, predominantly in the red extreme of the spectrum.

Gas filling: The discharge tube is filled with an inert gas (argon) and a precise dosis of distilled mercury. The first is necessary to help originate the discharge and to secure a reasonable life for the covered emission electrodes.

The blister is filled with argon or with a mixture of argon and nitrogen at atmospheric pressure. The addition of nitrogen serves to avoid an electronic arc between the wire supports of the glass.

These lamps require an auxiliary equipment which is normally a ballast with an inductive resistance or transformer of the dispersion field, besides a compensation condenser.

When the lamp is turned off, it will not start again until it has cooled off enough to lower vapor pressure to the point where the arc will be turned on again. This period lasts about minutes.

8.6.3. Blended light lamps

Blended light lamps are a combination of the high pressure mercury lamp and an incandescent lamp. They are a result of one of the tries to correct bluish light of mercury lamps, which is achieved by inclusion within the glass itself, of a mercury discharge tube and a wolfram incandescent filament.

Mercury discharge light and that of the fired filament are combined, or mixed, to achieve a lamp with totally different operative characteristics compared to those which have both pure mercury lamp and an incandescent lamp.

Main parts

With the exception of the filament and the gas used in the blister, parts of a blended light lamp are the same as those described for high pressure mercury lamps (Fig. 10).

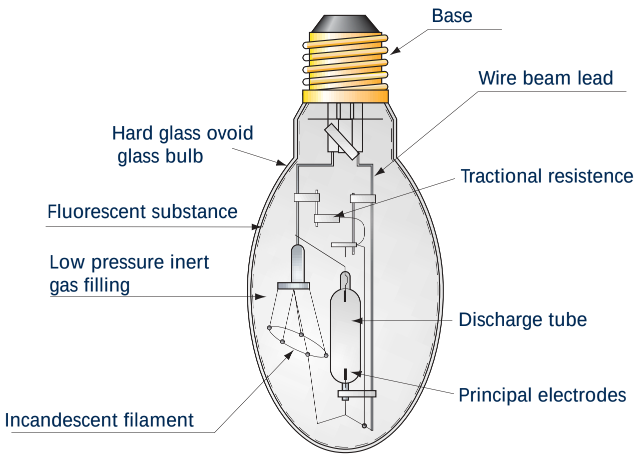

Figure 10. Blended light lamp.

INDALUX

Filament: The filament, which also acts as a resistance ballast for the discharge tube, is a coiled wolfram wire the same as that of the incandescent lamp. It is connected with the discharge tube in series and located next or around it, to obtain a good blended light and to favour a quick ignition of the tube.

Filling gas blister: As for incandescent lamps, the filling gas in blended light lamps is made out of argon but adding a percentage of nitrogen to avoid an arc in the filament. Compared with the standard high pressure mercury lamp, a greater filling pressure to keep evaporation of wolfram to the minimum is used.

Blended light lamps have the advantage of being connected directly to the power supply system (ballast and starter for is not required their working). Ignition takes about two minutes and re- ignition is not possible before cooling- down.

8.6.4. Metal halide lamps

High pressure mercury lamps also contain rare earths like Dysprosium (Dy), Holmium (Ho) and Thulium (Tm). These halides are partly vaporized when the lamp reaches its normal working temperature. Halide vapor is later on dissociated, within the hot central zone of the arc, into halogene and metal, achieving a considerable increase of luminous efficacy and approaching colour to that of daylight. Different halide combinations (sodium, iodine, ozone) are used to which scandium, thallium, indium, lithium, etc. is added.

Main parts

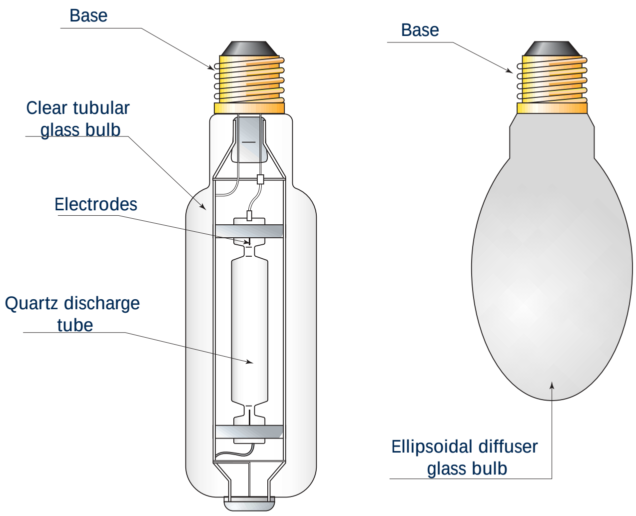

Figure 11. Metal halide lamps.

Discharge tube: It is made out of pure quartz. Sometimes, a white layer of zirconium oxide is applied to the outer part of the electrode cavities, to increase wall temperature at that point.

Electrodes: They are similar to those of the high pressure mercury lamp.

Blister: The blister of metal halide lamps is made out of hard or quartz glass. Some do not even have an blister.

The inner surface of blisters with an ovoid shape has a phosphorous layer to transform discharge ultraviolet radiation into visible radiation. However, halides used for the metal halide lamp produce only a small amount of ultraviolet, and mainly, it is radiated in the ultraviolet spectrum wavelength zone, where conversion into visible radiation is poor.

Filling gas in the discharge tube: The discharge tube is filled with a mixture of inert gases (neon and argon or krypton- argon), a dosis of mercury and appropriate halides, depending on the type of lamp.

Filling gas of the blister: The blister of a metal halide lamp whose discharge tube is filled with a mixture of neon- argon, must also be filled with neon so that neon pressure inside and outside the tube is the same. In case the discharge tube is filled with a mixture of krypton- argon, nitrogen may be used in the blister, or else, the latter may be eliminated, too.

Working conditions of metal halide lamps are very similar to those of conventional mercury vapor. They are prepared to be connected in series with a ballast to limit current, a compensation condenser being necessary.

Due to metal halides, the ignition voltage for these lamps is high. The use of a starter or ignition device with shock voltage of 0.8 to 5 KV is needed.

Most lamps allow for immediate re- ignition with hot lamps (right after being turned- off), by using shock voltage of 35 to 60 KV. If not, they must cool- down between four and fifteen minutes before being turned back on.

8.7. High pressure sodium discharge lamps

This section deals with those lamps with a discharge tube where sodium vapor is introduced. Low pressure sodium lamps and high pressure sodium lamps are included.

8.7.1. Low pressure sodium lamps

There exists a great similarity between the working of a low pressure sodium lamp and a low pressure mercury lamp (or a fluorescent one). However, while light in the latter is produced by transforming ultraviolet radiation of the mercury discharge into visible radiation, using fluorescent powder in the inner surface, visible radiation in the former is produced by direct discharge of sodium.

Working principle

The discharge tube of a low pressure sodium lamp is usually U- shaped and is located inside an empty tubular glass cover, with indio oxide coat on the inner surface. The empty part, together with the layer, which behaves as an infrared selective reflector, helps keep the discharge tube wall at an adequate working temperature. Such measurements are necessary for the sodium, which is deposited in slits of the glass when condensed, and it evaporates with a minimum heat loss. Due to this fact, the most luminous efficiency possible is achieved.

The neon gas inside the lamp is used to begin the discharge and to develop enough heat to vaporize the sodium. This responds for the red- orangish luminescence during the firsts few working minutes. The metallic sodium is gradually evaporated, producing the characteristic monochromatic yellow light, with 589 nm. and 589.6 nm. lines in the spectrum. The red colour, initially produced by the neon discharge, is energetically suppressed during the working because sodium excitation and ionization potentials are much lower than those of neon.

The lamp reaches its luminous flux established in approximately ten minutes. It will re- ignite immediately in case power supply is momentarily interrupted, since vapor pressure is quite low and the voltage applied enough to reestablish the arc.

The lamp has a luminous efficiency up to 200 lm/W and a long life.

Therefore, this lamp is applied to those places where colour reproduction is of less importance and mainly where contrast recognition matters, for example: motorways, ports, beaches, etc. Low pressure sodium lamps range from 18 W to 180 W.

Main parts

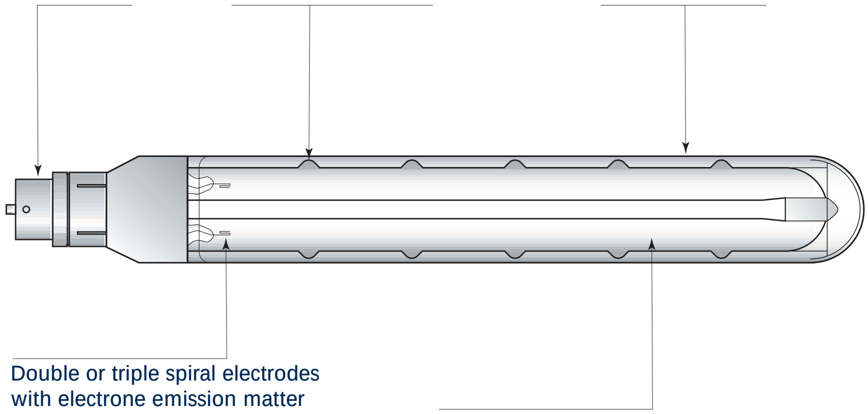

Figure 12. Low pressure sodium lamp.

Discharge tube and supports: The discharge tube of a high pressure sodium lamp is U- shaped, to make the most out of space and provide a better thermal isolation. It is made out of sodium- calcium glass, and has an inner surface covered with borate glass to form a protective layer against sodium vapor.

The tube also contains a number of small slits or holes, where sodium is deposited during manufacturing.

Discharge tube filling: The discharge tube filling consists of metallic sodium of high purity and of a mixture of neon and argon, which behaves as an ignition and trimmer gas.

Electrodes: Low pressure sodium lamps possess cold ignition electrodes. These consist of a triple wolfram wire, in such a way that a great amount of emitter material may be maintained.

Blister: It is empty and covered by a thin film of infrared material reflector in its inner surface. The infrared reflector serves to reflect most part of the heat radiation which returns to the discharge tube, keeping it, at the desired temperature, this way, while visible radiation is transmitted.

These lamps precise an auxiliary equipment formed by a power supplier with an autotransformer or ballast and igniter with impulse voltage depending on type. A compensation condenser is required.

Nominal values are reached after fifteen minutes after re- ignition. When the lamp is turned off, a few minutes are necessary before re- ignition.

8.7.2. High pressure sodium lamps

Physically speaking, high pressure sodium lamps are quite different from low pressure sodium lamps, due to the fact that vapor pressure is higher in the former. This pressure factor also causes many other differences between the two lamps, including emitted light properties.

Discharge tube in a high pressure sodium lamp contains an excess of sodium to produce saturated vapor conditions when the lamp is working. Besides, it has an excess of mercury to provide a trimmer gas, xenon excluded, to ease ignition and limit heat conduction from the discharge arc to the tube wall. The discharge tube is housed in an empty glass cover.

High pressure sodium lamps radiate energy through a good part of the visible spectrum. Therefore, when compared to the low pressure sodium lamp, they offer a quite acceptable colour reproduction.

Main parts

The main parts of a high pressure sodium lamp are the following:

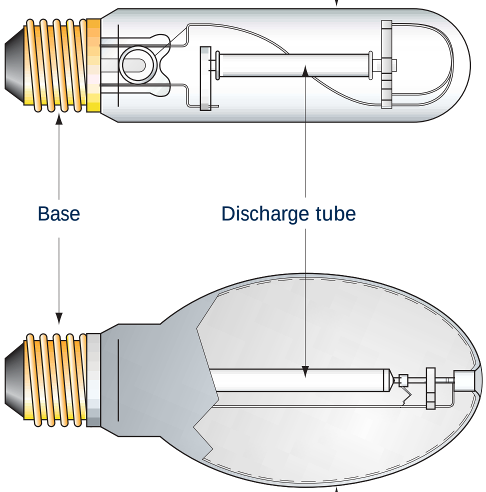

Figure 13. High pressure sodium lamp.

Discharge tube: The discharge tube is made out of aluminium oxide ceramics (sintered aluminium) very resistant to heat and to chemical reactions with sodium vapor.

Electrodes: Electrodes, covered by a layer of emitter material, consist of a twisted serpentine wolfram rod around it.

Filling: In the inside of the discharge tube are sodium, mercury and noble gases (xenon or argon) out of which sodium is the main producer of light.

Blister: This glass is generally empty.

The shape must be either ovoid or tubular. The first one has an inner covering. However, since the discharge tube of the high pressure sodium lamp does not virtually produce any ultraviolet radiation, the covering is simply a diffused layer of white powder, to decrease the high brightness of the discharge tube. The tubular glass is always made out of clear glass.

Starters and auxiliary starters: Many of the high pressure sodium lamps have an incorporated auxiliary starter, which helps reduce the measure of the ignition peak voltage needed for the lamp ignition. Sometimes, both the incorporated starter and the auxiliary starter are in the lamp itself.

These lamps precise of an auxiliary equipment formed by a ballast and an igniter with impulse tension depending on type. A compensation condenser is also needed. Nominal values are reached five minutes after ignition. When a lamp is turned off, due to a great pressure of the burner, it needs to cool down between four and minutes before turning it back on.

8.8. Induction lamps

The most vulnerable parts of all discharge lamps are the electrodes. During their average rated life, lamps reduce and lose their emitting voltage by the impact of quick ions or by chemical reactions with energetic vapors in the discharge tube. Electrodes in high pressure discharge lamps also produce a great amount of infrared wasted radiation, which decreases efficiency of the lamp.

The induction lamp introduces a completely new concept in light generation. It is based on the low pressure discharge gas principle. The main characteristic of the new lamp system is that it does not need electrodes to originate gas ionization. Currently, there are two different systems to produce this new ionization of gas without electrodes.

8.8.1. High power fluorescent lamps without electrodes

Discharge in this lamp does not begin and end in two electrodes like in a conventional fluorescent lamp. The shape of close ring of the glass of the lamp allows to have a discharge without electrodes, since energy is supplied from the outside by a magnetic field. Such magnetic field is produced in two ferrite rings, which constitutes an important advantage for lamp duration.

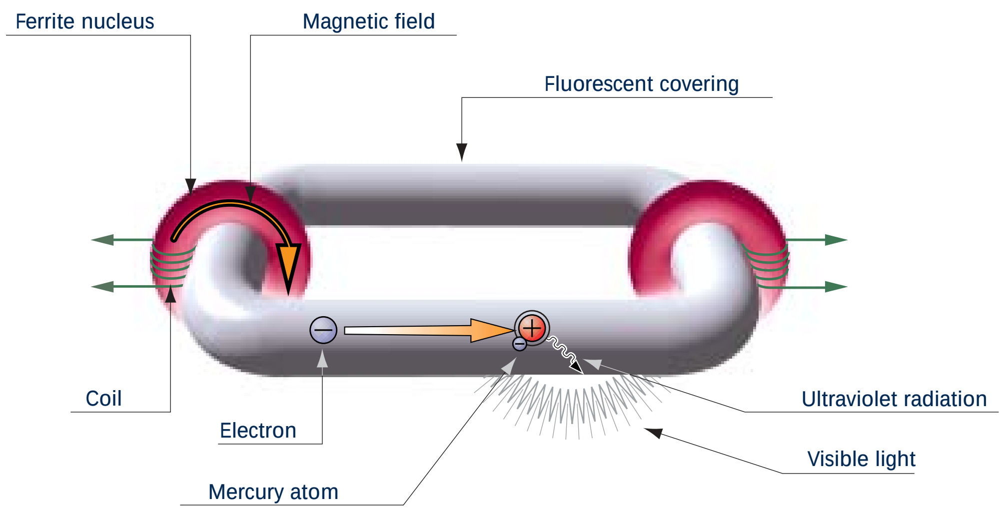

Figure 14. High voltage fluorescent lamp without electrodes.

The system has an electronic equipment (at a frecuency of approximately 250 kHz) separated from the lamp besides a fluorescent tube without electrodes. This allows to preserve optimal energy of discharge in the fluorescent lamp and reach a high luminous potency with a good efficacy.

The main advantages of this lamp are:

- Extremely long life: 60 000 hours.
- Lamp potency 100 and 150 W.
- Luminous flux up to 12 000 lumens.
- Luminous efficacy of 80 lm/W.
- Low geometric profile that allows the development of flat luminaires.
- Comfortable light without oscillations.
- Start without flickers or sparkles.

These lamps are essentially indicated for those applications where relamping increases maintenance expenses excesively, like for example, illumination of tunnels, industrial premises with very high ceilings and difficult access, etc.

8.8.2. Low pressure gas discharge lamps by induction

This type of lamps consists of a discharge recipient which contains the low pressure gas and a voltage coupler (antenna). Such a potency coupler, composed by a ferrite cylindrical nucleus, creates an electromagnetic field within the discharge recipient inducing an electrical current in the gas generating its ionization. Enough energy to begin and maintain discharge is supplied to the antenna by a high frequency generator (2.65 MHz) by means of a coaxial cable of a determined length, since it forms part of the oscillating circuit.

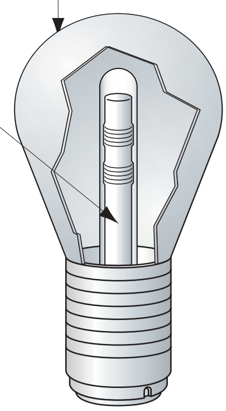

Figure 15. Gas discharge lamp by induction.

The main advantages of these lamps are:

- Extremely long duration: 60 000 hours.
- Voltage lamps with 55, 85 and 165 W.
- Luminous flux up to 12 000 lumens.
- Luminous efficacy between 65 and 81 lm/W.
- Instantaneous ignition free of flickers and stroboscopic effects.
- Light for a great visual comfort.

These lamps are used for many general and special lighting applications, mainly to reduce maintenance expenses, like in public buildings, outdoor public lighting, industrial applications, etc.

8.9. Charts with characteristics

8.9.1. Fluorescent lamps

TL linear fluorescent

Average rated life : 7 500 hours

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder	R.I. Ra	Chromatic degree
18	1350	75.00	26	590	G 13	85	1 B
18	1150	63.88	26	590	G 13	62	2 B
18	1100	61.11	26	590	G 13	75	2 A
18	1000	55.55	26	590	G 13	98	1 A
36	3350	93.05	26	1200	G 13	85	1 B
36	2850	79.16	26	1200	G 13	62	2 B
36	2600	72.22	26	1200	G 13	75	2 A
36	2350	65.27	26	1200	G 13	98	1 A
58	5200	89.65	26	1500	G 13	85	1 B
58	4600	79.31	26	1500	G 13	62	2 B
58	4100	70.68	26	1500	G 13	75	2 A
58	3750	64.65	26	1500	G 13	98	1 A

Compact fluorescent TC-D of 2 pins

Power supply voltage: 230 V.

Average rated life: 10 000 hours.

Nominal power	Flux ϕ (lm)	Performance Lm/W	Width in mm	Length L in mm	Lamp holder	R.I. Ra	Chromatic degree
13	900	69.23	27	138	G24d-1	85	1 B
18	1200	66.66	27	153	G24d-2	85	1 B
26	1800	69.23	27	172	G24d-3	85	1 B

Compact fluorescent TC-D of 4 pins

Power supply voltage: 230 V.

Average rated life: 10 000 hours.

Nominal power	Flux ϕ (lm)	Performance Lm/W	Width in mm	Length L in mm	Lamp holder	R.I. Ra	Chromatic degree
13	900	69.23	27	131	G24q-1	85	1 B
18	1200	66.66	27	146	G24q-2	85	1 B
26	1800	69.23	27	165	G24q-3	85	1 B

Compact fluorescent TC-L of 4 pins

Power supply voltage: 230 V.

Average rated life: 10 000 hours.

Nominal power	Flux ϕ (lm)	Performance Lm/W	Width in mm	Length L in mm	Lamp holder	R.I. Ra	Chromatic degree
18	750	41.66	38	225	2G11	95	1 A
24	1200	50.00	38	320	2G11	95	1 A
36	1900	52.77	38	415	2G11	95	1 A
40	2200	55.00	38	535	2G11	95	1 A
55	3000	54.54	38	535	2G11	95	1 A

8.9.2. High pressure mercury lamps

Average rated life: 14 000 hours.

Colour temperature: 3 500 K ÷ 4 200 K

Colour reproduction index (R): 50

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
50	1800	36.00	55	130	E-27
80	3800	47.50	70	156	E-27
125	6300	50.40	75	170	E-27
250	13000	52.00	90	226	E-40
400	22000	55.00	120	290	E-40
700	38500	55.00	140	330	E-40
1000	58000	58.00	165	390	E-40

8.9.3. Blended light lamps

Average rated life: 6 000 hours.

Colour temperature: 3 500 K ÷ 4 200 K

Colour reproduction index (R): 50

Power suuply voltage: 230 V.

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
160	3100	19.37	75	180	E-27
250	5600	22.40	90	226	E-40
500	14000	28.00	125	275	E-40

8.9.4. Metal halide lamps

Average rated life: 2 500 ÷ 14 000 hours.

Colour temperature: 3 000 K ÷ 6 000 K

Colour reproduction index (R): 60 ÷ 93

Compact metal halide lamps

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
35	3400	97.14	19	100	G12
75	5500	73.33	25	84	G12
150	12500	83.33	25	84	G12

Double- based metal halide lamps

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
70	5500	78.57	20	114	RX7s
150	13500	90.00	24	132	RX7s
250	20000	80.00	25	163	Fc2
400	38000	95.00	31	206	Fc2
1000	90000	90.00	≈40	-	Cable
2000	220000	110.00	≈40	-	Cable

Metal halide lamps with a clear base and a clear tubular shape

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
250	20000	80.00	45	225	E-40
400	42000	105.00	45	275	E-40
1.000	80000	80.00	75	340	E-40
2.000	240000	120.00	100	430	E-40
3.500	320000	91.42	100	430	E-40

Metal halide lamps with a base in an ellipsoidal form with a diffusing layer

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
70	4900	70.00	55	140	E-27
100	8000	80.00	55	140	E-27
150	12000	80.00	55	140	E-27
400	43000	107.50	120	290	E-40
1000	90000	90.00	165	380	E-40

8.9.5. Low pressure sodium lamps

Average rated life: 14 000 hours.

Colour temperature: 1 800 K

Colour reproduction index (R): NULL.

Low pressure sodium with a clear tubular shape and an infrared reflecting layer

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
18	1800	100.00	55	215	BY-22d
35	4600	131.42	55	310	BY-22d
55	8100	147.27	55	425	BY-22d
90	13000	144.44	70	530	BY-22d
135	22500	166.66	70	775	BY-22d
180	32000	177.77	70	1120	BY-22d

Low pressure sodium with a light tubular shape

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
26	3500	134.61	55	215	BY-22d
36	5750	159.72	55	310	BY-22d
66	10700	162.12	55	425	BY-22d
91	17000	186.81	70	530	BY-22d
131	25000	190.83	70	775	BY-22d

8.9.6. High pressure sodium lamps

Average rated life: 12 000 ÷ 18 000 hours.

Colour temperature: 2 000 K ÷ 2 200 K

Colour reproduction index (R): 20 ÷ 65

High pressure sodium lamps with a tubular shape

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
50	4000	80.00	40	155	E-27
70	6500	92.85	40	155	E-27
100	10000	100.00	45	210	E-40
150	17000	113.33	45	210	E-40
250	33000	132.00	45	255	E-40
400	55500	138.75	45	285	E-40
600	90000	150.00	55	285	E-40
1000	130000	130.00	65	400	E-40

High pressure sodium lamps with an ellipsoidal shape and a diffusing layer

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
50	3500	70.00	70	155	E-27
70	5600	80.00	70	155	E-27
100	10000	100.00	75	185	E-40
150	14000	93.33	90	225	E-40
250	25000	100.00	90	225	E-40
400	47000	117.50	120	290	E-40
1000	128000	128.00	165	400	E-40

High pressure sodium lamps with two bases

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
70	7000	100.00	20	115	RX7s
150	15000	100.00	25	130	RX7s-24
250	25500	102.00	25	205	Fc2
400	48000	120.00	25	205	Fc2

Luxurious high pressure sodium lamps with a tubular shape

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
150	12.500	83.33	45	210	E-40
250	23.000	92.00	45	255	E-40
400	39.000	97.50	45	285	E-40

Luxurious high pressure sodium lamps with an ellipsoidal form and a diffusing layer

Nominal power	Flux ϕ (lm)	Performance Lm/W	Diametre Ø in mm	Length L in mm	Lamp holder
150	12.000	80.00	90	225	E-40
250	22.000	88.00	90	225	E-40
400	37.500	93.75	120	285	E-40

8.9.7. High powered fluorescent lamps without electrods (induction)

Power supply voltage: 230 V.

Average rated life: 60 000 hours.

Nominal power	Flux ϕ (lm)	Performance Lm/W	Width in mm	Length L in mm	Lamp holder	R.I. Ra	Chromatic degree
100 W	8000	80.00	139	313	-	80 (840/835)	1 B
150 W	12000	80.00	139	414	-	80 (840/835)	1 B

8.9.8. Low pressure discharge gas lamps by induction

Power supply voltage: 230 V.

Average rated life: 60 000 hours.

Nominal power	Flux ϕ (lm)	Performance Lm/W.	Diametre in mm.	Height in mm.	Lamp holder	R.I. Ra
55 W	3500	65	85	140.5	-	80 (840/830/827)
85 W	6000	70	111	180.5	-	80 (840/830/827)
165 W	12000	70	130	210	-	80 (840/830/827)