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INDUSTRIAL PLANTS II

Chapter seven (part 2): Lighting plants

DOUBLE DEGREE MASTER IN

“PRODUCTION ENGINEERING AND MANAGEMENT”

CAMPUS OF PORDENONE

UNIVERSITY OF TRIESTE

Lighting systems

<u>Artificial lighting</u>

The design of a system of **artificial lighting** must be consistent with the characteristics of the environment (size, shape, natural light, windows and their transmission coefficients, walls and floor), its function (commercial, manufacturing, health care) and tasks visual users.

The elements that must be considered are:

- luminance distribution;
- illuminance and uniformity;
- glare;
- color rendition;
- apparent color of light.

Artificial lighting

The UNI EN 12464-1: 2004 recommend for the factors of reflection:

- ceiling: 0,6÷0,9;
- walls 0,3÷0,8;
- work floor: 0,2÷0,6;
- floor: 0,1÷0,5.

You must also follow other criteria for luminance distribution that are:

- minimum ratio of 1:3 between the luminance of the areas immediately surrounding the visual task and the luminance of the visual task;
- minimum ratio of 1:10 between the luminance of the peripheral areas of the visual field and the luminance of the visual task.

Artificial lighting

UNI EN 12464-1 defines the characteristics of artificial lighting appropriate for different work activities, indicating for each of the required values:

- Em: illuminance average maintained (measured before maintenance), which is the value of the average illuminance on a surface to below which one can not go;
- Ra: Color Rendering Index of a light source is a measure of how the colors appear natural objects inspired by it. It measures the difference between how, in general, appear chromatically objects when illuminated by a light source and as they appear when they are illuminated by a black body at the same temperature, which represent the sample source: the smaller this difference, the better the color rendering of the source and, therefore, the greater the value of the index;

Lighting systems

Artificial lighting

UNI EN 12464-1 defines the characteristics of artificial lighting appropriate for different work activities, indicating for each of the required values:

- Ra – Color Rendering Index

  In the design phase it is important to assess the ability of sources to make the colors. The UNI EN 12464-1: 2004 in 5.3 gives limit values of Ra for different environments, tasks and activities. In any work environment should be used lamps with Ra less than 80.

  As for numerical indications artificial sull'illuminamento the same rule sets the following standard :

  - Em illuminance average maintained (in lm);
  - lighting uniformity;
  - UGR unified index of glare;
  - Ra color rendering index;
  - color temperature of the light.

Artificial lighting

UNI EN 12464-1 defines the characteristics of artificial lighting appropriate for different work activities, indicating for each of the required values:

- UGR: unified glare rating. It is an internationally unified index developed by the CIE (Commission International de l'Eclairage) for determination of direct glare relatively to each specific application. Through this index assesses the glare of harassing type in a given environment. The UGR value depends on the arrangement of luminaires, the characteristics of the environment (dimensions, reflection indexes) and observation point of operators who will be inside the space in question. Oscillates between values from 10 (no glare) to 30 (considerable physiological glare) according to a scale of 3 units (10, 13, 16, 19, 22, 25 and 28).

Lighting systems

Artificial lighting

UNI EN 12464-1 defines the characteristics of artificial lighting appropriate for different work activities, indicating for each of the required values :

- UGR - unified glare rating
  Of course, most will lower the value, the lower the direct glare. The UGR factor takes account of the background luminance of the environment and thus the ceiling and walls, and the sum of the effect of dazzle of each device within the space, compared with naturally from a typical position of the observer.

Artificial lighting

UNI EN 12464-1 defines the characteristics of artificial lighting appropriate for different work activities, indicating for each of the required values :

- UGR - unified glare rating

The unified glare rating UGR is expressed by the relation:

$$UGR = 8 \cdot \log_{10}\left(\frac{0,25}{L_b}\sum_i \frac{L_i^2 \cdot W_i}{P_i^2}\right)$$

where:

L_b = background luminance, calculated from E_{ind}/π with E_{ind} = indirect vertical illuminance level of observer's eye (cd/m^2);

L_i = luminance of the luminous parts of each unit i-th in the direction of the observer's eye (cd/m^2);

P_i = position index of Guth, which is a function of the longitudinal distance between the eye and the transverse plane of the i-th source and the transverse distance between the eye and the longitudinal plane of the i-th source;

W_i = solid angle under which is seen the i-th light source.

Lighting systems

Artificial lighting

The table shows some values of the UGR for different types of glare.

Intolerable glare	UGR > 28
Almost intolerable glare	UGR = 28
Annoying glare	UGR = 25
Almost annoying glare	UGR = 22
Just acceptable glare	UGR = 19
Acceptable glare	UGR = 16
Perceptible glare	UGR = 13
Barely perceptible glare	UGR < 10

Artificial lighting

The estimation methods of the glare are:

a) limit curves of luminance

Luminance limit curves A and B (CIE method) are influenced by four factors:

- spatial distribution of the luminance of the source;
- geometry of the system (viewing angle);
- average illuminance on the horizontal work surface (h = 0.90 m);
- type of source.

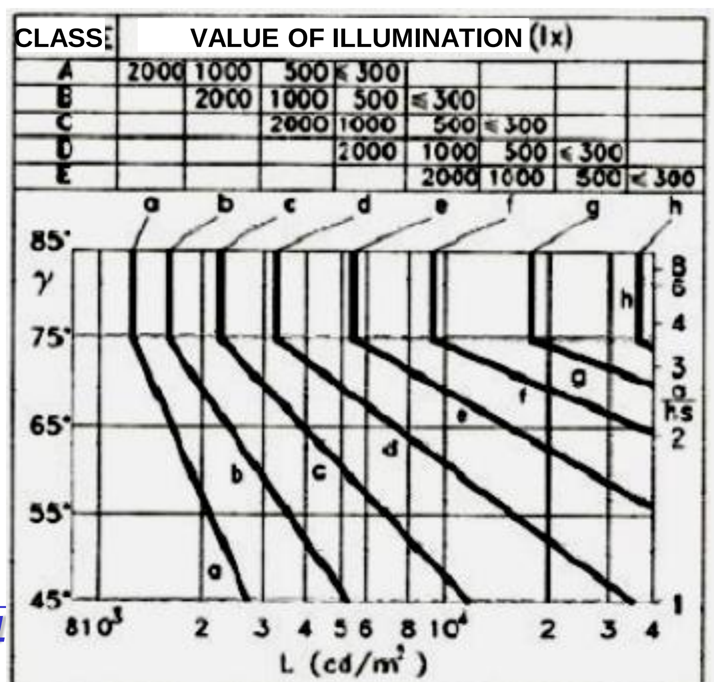
The degree of glare G is evaluated numerically on the basis of a scale from 0 to 6 based on the judgment of a sample of individuals who went from glare null (G = 0) to intolerable glare (G = 6).

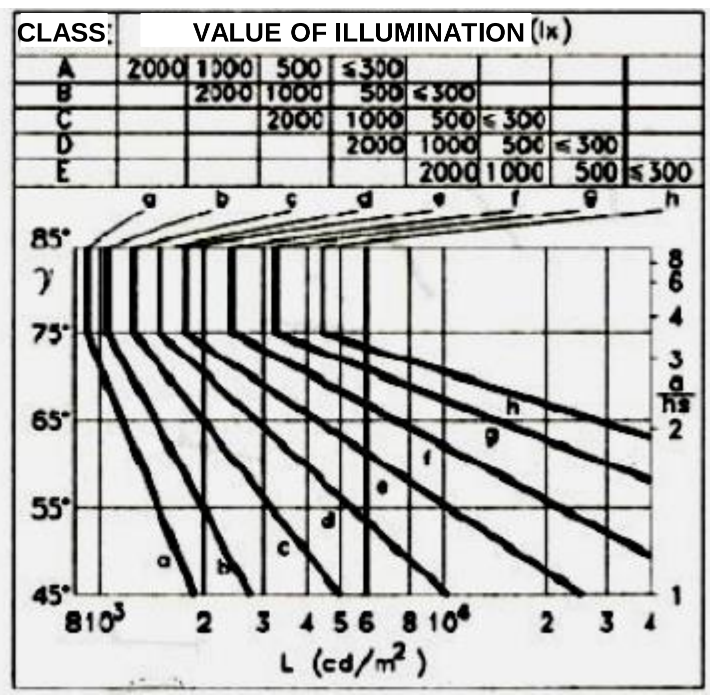
Artificial lighting

The estimation methods of the glare are:

a) limit curves of luminance

The luminance curve A is valid for devices without lateral edges (<30 mm), lighting linear (length/width > 2) linear edges parallel light to the direction of observation. The luminance curve B is valid for devices with lateral edges (figure).





Artificial lighting

The estimation methods of the glare are:

a) limit curves of luminance

The glare can be caused by both bare lamps, both than lighting equipment (direct glare), both with high luminance produced by the shiny surfaces (reflected glare).

The average luminance of each lighting device must not be greater than the values of the limit curves of luminance within the critical angle for the glare $45° < \tau < 85°$.

The extent of the limitation of the luminance of the devices depends on the type and arrangement of the equipment, from their shielding angle, from the class of the required quality of the lighting and illuminance of exercise.

Artificial lighting

The estimation methods of the glare are:

a) limit curves of luminance

The quality class to refer is indicated in the prospectus of the table.

Quality class G	Tasks
A	Visual task very difficult
B	Visual task that requires high performance visual
C	Visual task that requires normal visual performance
D	Visual task that requires modest visual performance
E	For interior, where people are not located in a working position accurate, but they move from place to place dispatching tasks that require visual performance modest

Artificial lighting

The estimation methods of the glare are:

a) limit curves of luminance

The limit of luminance curves you apply to:

- general lighting environment and the general oriented workplace;
- in interior that have the parallelepiped shape;
- in cases where the reflection factor of the surfaces of the room to the ceiling is 0.7-0.8, 0.4-0.6 and 0.1-0.2 for the walls to the floor.

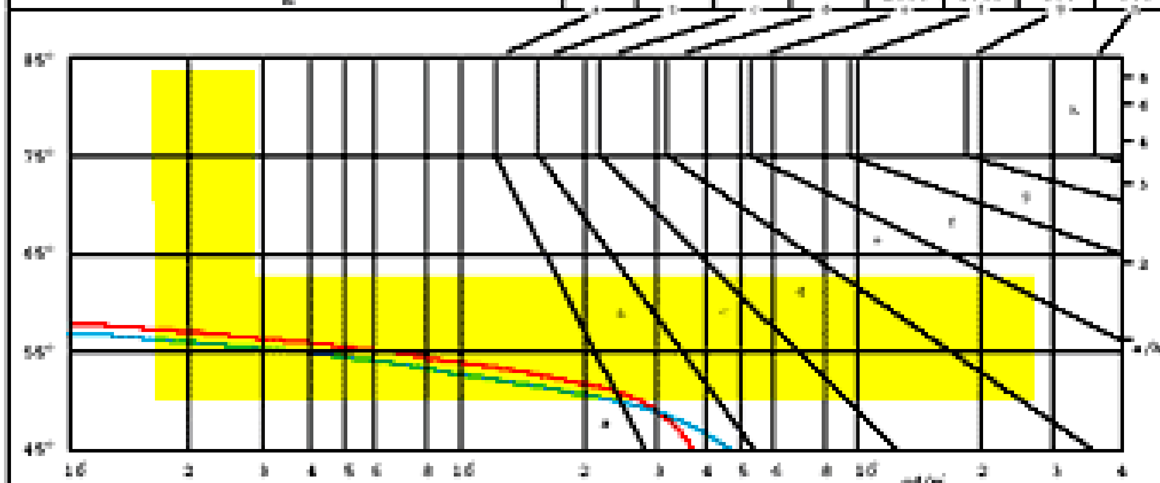
Artificial lighting

The estimation methods of the glare are:

a) limit curves of luminance

The figure is highlighted in yellow must be the area within which the curves of the luminance of the devices DARK 60°.

Quality class	Horizontal illuminance lx							
A	2000	1000	500	300				
B		2000	1000	500	300			
C			2000	1000	500	300		
D				2000	1000	500	300	
E					2000	1000	500	300



Artificial lighting

The estimation methods of the glare are:

a) limit curves of luminance

In particular, it determines the quality class according to the intended use, the average illuminance level, the type and arrangement of the apparatus. Are identified, then, the corresponding limit curves a, b, ..., h that provide the maximum value of the luminance of the devices according to the observation angle γ, i.e. the ratio a/h_s.

Artificial lighting

The estimation methods of the glare are:

b) dayling glare index (CGI)

It is a dimensionless value, which provides a measure of the degree of glare observer procured from all light sources present in an environment. It is expressed by the relation:

$$DGI = 8 \cdot \log_2 \left[\frac{\left(1 + \frac{E_d}{500}\right)}{\left(E_d + E_i\right)} \right] \cdot S \cdot \left(L^2 \cdot \frac{W}{P^2} \right)$$

where: Ed = direct illuminance vertical on the eye of the observer produced by light sources;

Ei = indirect illuminance vertical on the eye of the observer produced by light sources;

L = luminance of the n-th light source;

P = position index observer compared n-th light source;

W = solid angle under which is seen n-th light source.

Artificial lighting

The estimation methods of the glare are:

b) dayling glare index (CGI)

The table shows some values of the DGI for different types of glare.

Intolerable glare	DGI > 28
Almost intolerable glare	DGI = 28
Annoying glare	DGI = 26
Aalmost annoying glare	DGI = 24
Just acceptable glare	DGI = 22
Acceptable glare	DGI = 20
Perceptible glare	DGI = 18
Barely perceptible glare	DGI < 16

Artificial lighting

The estimation methods of the glare are:

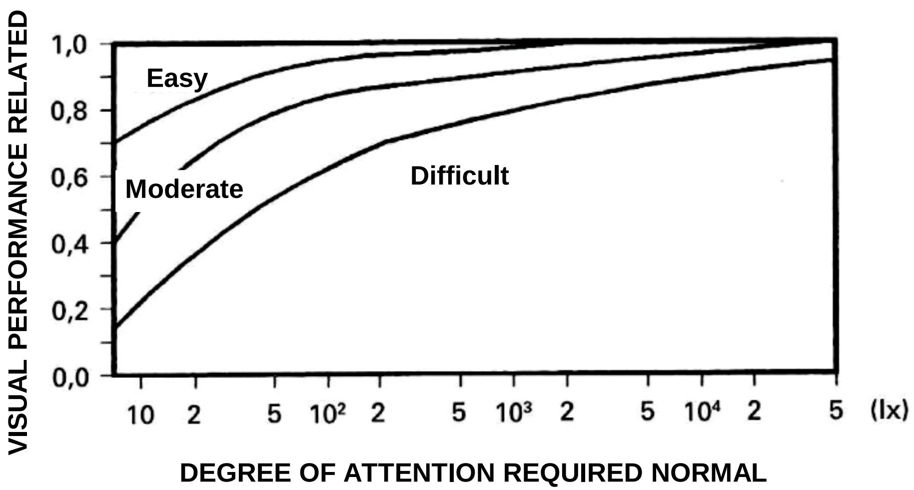
c) ***Visual Comfort Probability (VCP)***

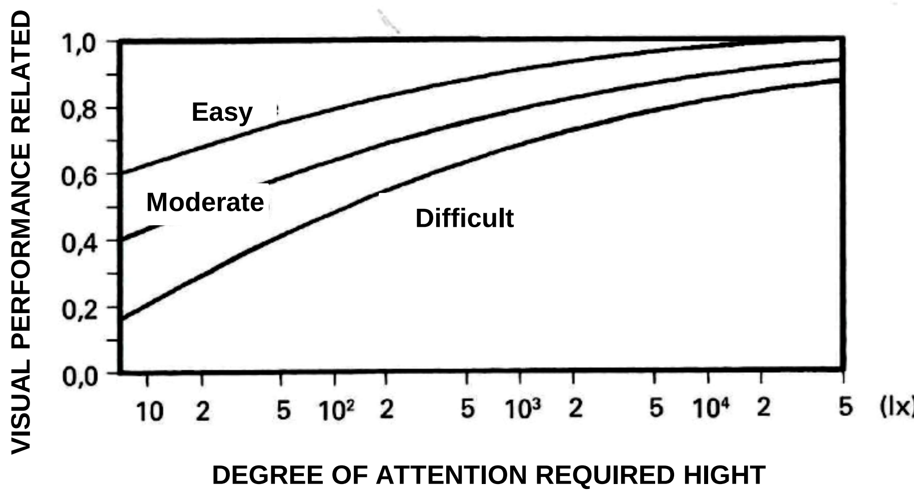
The VCP assesses the percentage of the population that holds the line between the healthy sight and the hassle. The VCP considers the problem of direct glare from data from a single source, and extending later to multiple sources, with exponential algorithms, the concept of discomfort. The calculation algorithm is very complex and the input data are not always determinable with certainty.

The illumination is the physical parameter indicative of the amount of light of an environment, while the visual performance can be defined as the ratio of the work done with a given illumination and the work done in the condition of illuminance ideal. It favors the amount of light impinging on the object (illumination level) rather than the amount of emitted light (luminance).

<u>Artificial lighting</u>

In the graphs of figure is shown the influence of the illumination on visual performance relative (the ratio of work done to a given lighting and work with lighting ideal). It is found that starting from a certain threshold an increase of the illumination does not produce a corresponding increase in visual performance (the curves are crushed).





Lighting systems

Artificial lighting

The visual performance is the ability to react that a person indicates when the details of the object of vision (visual task) enter the space of observation. It is conditioned by three main aspects:

- visual capacity of the subject in terms of visual acuity (accommodation, adjustment of the incident light, the convergence of the visual axis, ocular motility, color sense, the presence of visual defects, adaptation);
- characteristics of the visual task;
- characteristics of the environment.

Lighting systems

<u>Artificial lighting</u>

Important consideration must be made on the contrast, which is the perception of an object is a function of the contrast of luminance and color of the object and the background (or adaptive).

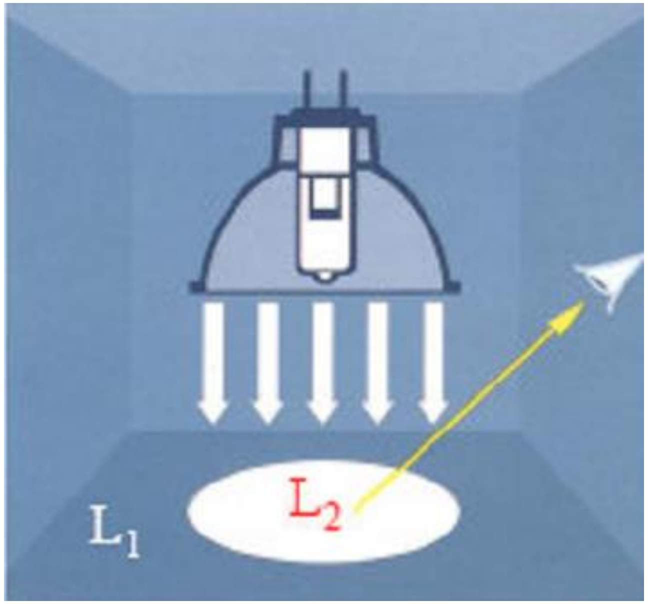
The figure shows different contrast levels of a picture.

Lighting systems

Artificial lighting

The **contrast** C is expressed by the relation (figure):

$$C = \frac{L_{object} - L_{background}}{L_{background}} \qquad \text{with} \quad \text{L = brightness}$$



Artificial lighting

The contrast is, however, also a subjective parameter; it then defines a contrast sensitivity of the observer as the ratio of the luminance of the background and minimum luminance perceived by the eye (subjective parameter).

The **factor of contrast rendition** (UNI EN 12464-1: 2004) is the ratio between the contrast C in a condition of actual lighting and the contrast CR in the reference conditions (perfectly diffused reflection of the background). The optimal value of the factor contrast rendition is not less than 0.7.

It also defines a maintenance factor M as the ratio between the average illuminance on the work surface after a given period and the average illuminance on the same level of work to install new.

Lighting systems

Artificial lighting

The table shows the characteristics of the artificial lighting of workplaces.

Type of business	E_m	UGRL	R_a
Chemical industry: workstations with staff always present in the workings	300	25	80
Chemical industry: areas with occasional manual intervention	150	28	40
Electrical industry: production of cables and conductors	300	25	80
Electrical industry: assembly medium (e.g. final control panels)	500	22	80
Food industry: sorting vegetables and fruit	300	25	80
Food industry: control of glass vessels and final control	500	22	80
Foundries and mergers metals: preparation of the sands	200	25	80
Foundries and metal castings: die casting	300	25	80
Construction of vehicles: painting, retouching and controls	1000	19	90
Construction of vehicles: bodywork and assembly	500	22	80
Production and processing of tissues: finishing and dyeing	300	22	80
Production and processing of tissues: carding, washing, ironing etc.	300	22	80

Lighting systems

<u>Artificial lighting</u>

It will therefore be, for a good project, the identification of the value of average illuminance E_m project and divide it by the maintenance factor M identified according to the maintenance schedule defined by the designer:

$$E = \frac{E_m}{M} \qquad \text{with} \quad M < 1$$

It remember that E = 20 lux is the minimum level of illumination recommended and in areas occupied continuously, and allows the recognition of facial features; other recommended levels are 30, 50, 75, 100, 150, 200, 300, 500, 750, 1000, 1500, 2000, 3000 and 5000 lux.

Lighting systems

Artificial lighting

Among the area covered by the visual task and the immediate surrounding area (0.5 m), to avoid eyestrain and glare you must have a uniform lighting. In particular, we consider the values in the table.

Average lighting in the area of the task E_{task} (lux)	Minimum illuminance in the surrounding areas E (lux)
> 750	500
500	300
300	200
< 200	$E_{compito}$

Artificial lighting

The relationship between the minimum and average illuminance should not however be less than:

- 0.7 in the area of the task;
- 0.5 in the areas immediately surrounding the task.

The needs for lighting of a visual task increase with difficult visual tasks (close observation and prolonged, frequent changes in vision, objects at different distances, reduced observation time etc.). Other aspects to consider are:

- luminance contrast and luminance of adequate surrounding surfaces;
- color contrast and color appropriate;
- size, shape and surface appearance (distribution of light scattered or concentrated presence of or overshadowed etc.);
- illuminance values not lower than the default values;

Lighting systems

Artificial lighting

Other aspects to consider are:

- illuminance values in the areas immediately adjacent to no less than 0.5;
- adequate shielding against glare;
- measures to avoid veiling reflections on the field of vision;
- any directional light to improve the modeling and the feeling of depth;
- color rendering adequate work to be done;
- elimination of phenomena of flicker (flickering of a lamp filament perceptible by the human eye);
- elimination of stroboscopic effects;
- consideration of energy saving and maintenance costs;
- utilization and integration of daylight.

Lighting in industrial environments

To light the industrial premises you must have sources of high efficiency (see note) and long life, having flow and intensity on the height of installation.

The **luminous efficiency** of a lamp is the variable that describes the relationship between the emitted light flux, expressed in lumens, and the electric power input in watts. The symbol is: η, while the unit is: the lumens per watt (lm / W).

The luminous efficiency is a measure of **energy efficiency**, so the higher the ratio the more light is produced than the energy consumed. The luminous efficiency is very different according to the types of lamps. Examples of values of the luminous efficiency of the various types of lamps expressed in lm/W:

- incandescent lamps:	10 – 20 lm/W
- tubular fluorescent lamps:	45 – 90 lm/W
- lamps at mercury vapor at high pressure:	35 – 55 lm/W
- lamps at sodium vapor at high pressure:	35 – 55 lm/W
- halide lamps (metal halide):	70 – 95 lm/W
- lamps at sodium vapor at low pressure:	65 – 170 lm/W
- halogen lamps:	13 – 25 lm/W
- compact fluorescent lamps:	40 – 60 lm/W

Lighting in industrial environments

The light sources most used are:

a) tubular fluorescent lamps

Fall in the technology of discharge lamps and are commonly known as "neon lights" although the exact wording is that of "mercury vapor lamps at low pressure", since it does contain mercury and not neon.

They consist of a glass tube, linear or circular, sealed and coated internally by photoluminescent powders, which produces an arc of a low-pressure mercury.

Lighting in industrial environments

The light sources most used are:

a) tubular fluorescent lamps

Inside the tube is enclosed in a noble gas (typically argon) and a small quantity of liquid mercury. At the two ends of the tube there are two electrodes which, with the passage of electricity, generate a flow of electrons. The electrons collide with the atoms of mercury contained within the tube, exciting them and causing it to emit ultraviolet. The fluorescent material of the inner liner, in contact with the ultraviolet radiation, produces the emission of visible photons, in other words visible light.

Lighting in industrial environments

The light sources most used are:

a) tubular fluorescent lamps

The unitary powers longer in use go of 18 to 58 W, with a luminous efficiency of about 90 lm/W; average life of 6,000-12,000 hours; correlated color temperature from 2,700 K to 6,500 K depending on the fluorescent powder used. The advantages of this type of lamps are: good efficiency, ability to obtain light with excellent color rendering, long life, low cost, low luminance, ignition time very short. Drawbacks: the need for a power supply and a starter, and limited power, which entails a high number of tubes in order to achieve high levels of illumination.

Lighting in industrial environments

The light sources most used are:

a) tubular fluorescent lamps

The tubular fluorescent lamps (figure), compared to those incandescent, have a high level of luminous efficiency, but typically emit a whiter light and "cold", which have a lower color rendering. But it is a limit exceeded in recent years have been developed models of lamps with shades of "hottest", used in contexts and in various applications;

Detail of tubular fluorescent lamp and power pack

Lighting in industrial environments

The light sources most used are:

b) halide vapor lamps with high-pressure gas discharge of mercury and halides

They consist of a discharge tube, of various lengths and conformations, generally of glass or quartz, in which is present a rarefied gas. At the ends of the discharge tube are placed two electrodes (anode-positive, negative-cathode), which heads, through the attacks, the electrical conductors of the power supply. In the mass of rarefied gas are free electrons and positive ions. If is applied between the two electrodes an electrical potential difference appropriate, the positive ions migrate toward the cathode and the electrons toward the anode. The light emission of a discharge lamp gas. The powers ranging from 70 to 2000 W, with efficiencies from 70 to 95 lm/W and average duration of about 6,000 hours; the luminance varies from 15 · 104 to 14 · 106 cd/m^2.

Lighting in industrial environments

The light sources most used are:

b) halide vapor lamps with high-pressure gas discharge of mercury and halides

The advantages of these lamps are the light emitted and in the high efficiency, while, by contrast, the luminance is high and limited duration (figure);

Lighting in industrial environments

The light sources most used are:

c) sodium vapor lamps at high pressure

In these lamps the discharge occurs in quartz ampoule with sodium vapor.

Increasing the pressure, the sodium vapor moves away from the state of ideal gas and its emission spectrum widens than the typical spectral line monochrome.

Lighting in industrial environments

The light sources most used are:

c) sodium vapor lamps at high pressure

The light produced by these lamps is white to yellow (2,000-2,500 K), a feature that makes them suitable only for applications where the color rendering is not important. Special design features do front the chemical aggressiveness of the sodium. Thanks to high luminous flux you will allow smaller installations of lighting than other lamps, but may not meet the quality of the light emitted. The ideal installation in warehouses without machining or street lighting. The light is not monochromatic, but covers a spectrum quite complete.

You can also say that they are suitable for all industrial applications where color rendering (Ra) does not really matter.

Lighting in industrial environments

The light sources most used are:

c) sodium vapor lamps at high pressure

The unit power ranging from 50 to 1,000 W, with efficiencies of 35-150 lm/W and average life of 16,000 hours; luminance from 15 to 550 cd/cm^2. The advantage of these lamps is essential to the greater efficiency than the mercury vapor. A disadvantage, is the higher cost of the lamp is both feeder, color rendering and less high luminance;

Lighting in industrial environments

The light sources most used are:

d) mercury vapor lamps at high pressure

These lamps produce a discharge within the quartz ampoule protected by glass bulb, mostly coated with fluorescent powders. With the increase in pressure moves the emission in the blue-white light, making the lamp used for illumination.

Lighting in industrial environments

The light sources most used are:

d) mercury vapor lamps at high pressure

This type of lamp is always more in disuse because of the many disadvantages compared to other technologies: low luminous efficiency, low duration, difficulties and burden of disposal because of the mercury present in the lamp. Precisely because of the high presence of mercury on 13/02/2003 came into force the EU directive 2002/95 / EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (so-called Directive "RoHS“ - Restriction of Hazardous Substances).

Lighting in industrial environments

The light sources most used are:

d) mercury vapor lamps at high pressure

It has the effect of banning mercury lamps high pressure from European territory. The sale and installation of these lamps is prohibited from 1 July 2006.

The unit power ranging from 50 to 1,000 W, with efficiencies of 35-55 lm/W; the average length is about 6,000 hours. Merits unitary powers are high, small footprint, while the disadvantage is has low color rendering, lower efficiency to fluorescent lamps, ignition timing, and in particular relight rather long, high luminance from $4 \cdot 10^4$ to $25 \cdot 10^4$ cd/m^2;

Lighting in industrial environments

The light sources most used are:

e) incandescent lamps

The filament lamp is a light source in which light is produced by heating (up to about 2,700 K) of a tungsten filament through which passes the electric current. During operation, the tungsten sublimates and the filament becomes thinner and thinner, until cracking after about 1000 hours of operation. In addition to the heat energy is converted into light (by between 5 and 10%). In the lamps, the glass bulb is not empty but contains an inert gas at low pressure, usually argon or, more rarely, krypton.

Lighting in industrial environments

The light sources most used are:

e) incandescent lamps

The latter allows a higher yield of about 10% for the same power. These gases reduce the risk of implosion and prolong the life of the filament. Moreover, the presence of these gases reduces the blackening of the bulb due to the deposit of the tungsten that evaporates. When the ignition of the lamp, since the filament is cold and its resistance is low, it results in a peak period of a few tenths of a second and of the value of 10-12 times the current at regime.

Lighting in industrial environments

The light sources most used are:

e) incandescent lamps

They have the power ranging from 25 to 2,000 W, efficiency of 10-20 lm/W, average life 1,000 hours, color temperature 2,900-3,100 K. These features make them unsuitable for use in industrial environments, except for special installations. The advantages are: the light sufficiently white and with continuous spectrum, instant ignition, the lack of auxiliary equipment, the low cost of both the lamp is of the armature. Drawbacks are: the short life, the poor performance, the heat developed.

Lighting in industrial environments

The light sources most used are:

e) incandescent lamps

The European Union has sanctioned the gradual ban on incandescent bulbs second time this series:

- from September 2009 banned the production of incandescent bulbs of 100 W or more and all those bulb frosted or opal;
- from September 2010 to the 75 W;
- from September 2011 to those from 60 W;
- from September 2012 of any power.

Exceptions incandescent bulbs for specific uses (eg fridge, oven, etc.). The stocks of all incandescent bulbs from retailers and stores will still be sold until exhausted.

Lighting in industrial environments

The light sources most used are:

f) halogen lamps

They are a particular incandescent lamp with some fundamental characteristics that differentiate it from the common ones.

At the gas contained in the bulb is added iodine, krypton, and sometimes, xenon to allow the heating of the filament up to more than 3,000 K, in order to increase the luminous efficiency and move upward the color temperature.

Lighting in industrial environments

The light sources most used are:

f) halogen lamps

In halogen lamps, tungsten, that evaporates due to the high temperature, it reacts with the gas to form a halide of tungsten. Subsequently the mixture, coming into contact with the glowing filament, decomposes and re-deposited the tungsten on the filament itself by providing a cycle (halogen cycle). This makes the lifespan of a halogen lamp may be at least the double of a normal incandescent light bulb, although the filament is much hotter. Because the bulb, to allow the chemical reaction between iodine and tungsten, must have a temperature not lower than 250°C, is used a special glass (quartz) with high resistance.

Such lamps are a limited use in industries.

Lighting in industrial environments

It featured in the table the power and the luminous flux of discharge lamps

FLUORESCENT LAMPS		
W	High yield luminous (lm)	High yield chromatic (lm)
18	1350	850
36	3350	2000
58	5200	3300

STEAMS OF MERCURY	
W	Luminous (lm)
125	6300
250	13000
400	22000

Lighting in industrial environments

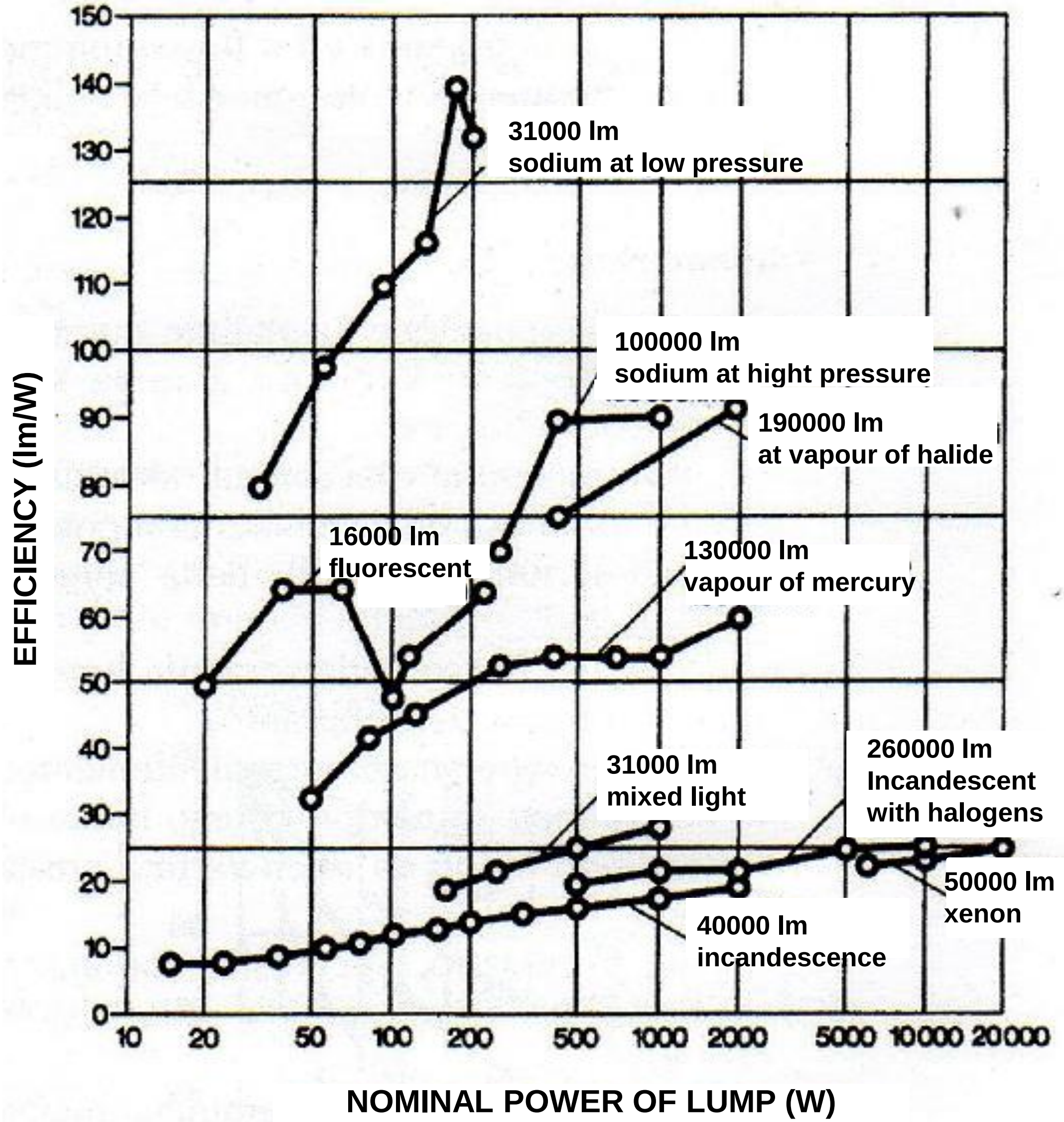
It featured in the table the power and the luminous flux of discharge lamps

SODIUM AT HIGHT PRESSURE		
W	Luminous (lm)	
	Tubolar	Ellipsoidal
150	14500	14000
250	28000	27000
400	48000	47000

METAL HALIDE		
W	Luminous (lm)	
	Tubolar	Ellipsoidal
150	11250	-
250	17000	17000
400	31500	30600

Lighting in industrial environments

The figure shows the luminous efficiency and the rated power of lamps for lights in general



Lighting systems

Lighting in industrial environments

The table shows for each type of lamp analyzed the type of application.

Type of lamp	Suitable for:
Tubular fluorescent	- Local height of lights less than 7 m (usually 3-3.5 m) - Offices and locals that require the exact color perception
Vapour of halide	- Workshops with installation height above the 9-10 m, in which you request a good color rendering (aeronautical workshops)
Sodium vapour at high pressure	- Workshops with installation height above the 9-10 m (increasing with the lamp power) - Squares and streets with heavy traffic
Mercury vapour at high pressure with fluorescent ampoule	- Workshop with installation height above the 7 m (increasing with the lamp power) - Roads and fences
Incandescent	- Small lights, projectors and explosion-proof equipment ponds with a few hours of operation

Lighting in industrial environments

It should be borne in mind that all gas discharge lamps (sodium, mercury, halides, fluorescent) require a ballast to limit the current. It should be an initiating device of the arc, formed by a generator of electronic overvoltages (igniter) for sodium vapor lamps or metal halide and by the starter for fluorescent lamps.

The power factor (the ratio between the active power (kW) and the apparent power (kVA)) is between 0.5 and 0.65 in the case of mercury lamps and fluorescent lamps, and 0.22 to 0.36 for those using sodium. It becomes necessary to re-phase the system using capacitors alone or centralized $\cos\varphi$ of 0,9.

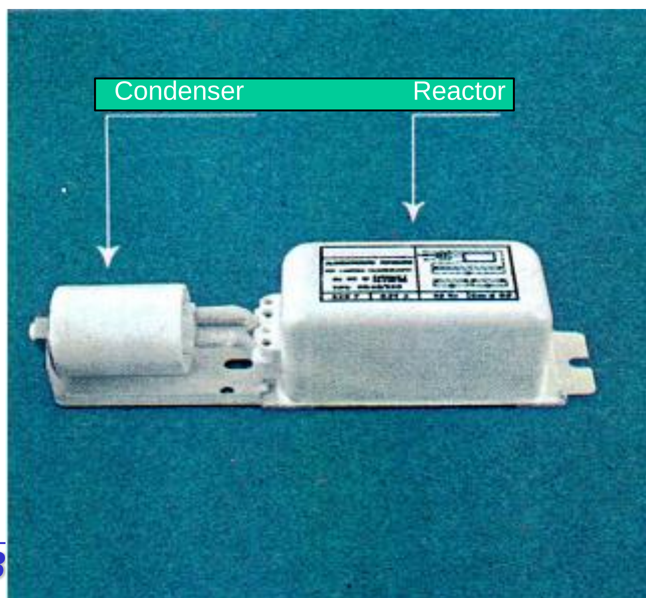
The mercury vapor lamps and sodium does not light up instantly, but require, at first power, about 5 minutes for mercury and 8 minutes for the sodium.

Lighting in industrial environments

The circuits of the lamps and their accessories

a) **incandescent lamps**, both normal that halogen, that do not require other accessories and the lamp holder;

b) **fluorescent lamps** require power supply, capacitor, and, in most cases, the starter switch or trigger. The capacitor serves to re-phase the electric power supply circuit (see figures).

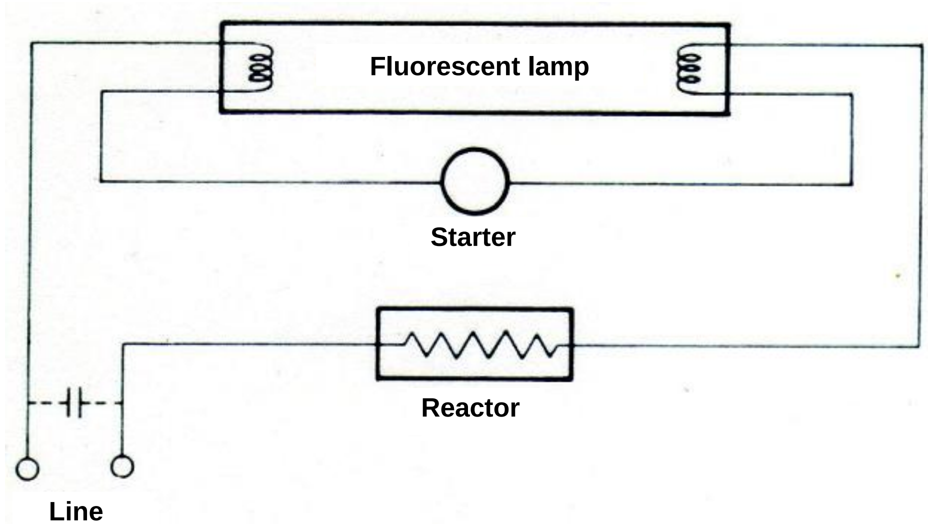


The starter is a device which inserts the circuit at the moment of preheating of the cathodes and then excludes causing a surge that triggers the arc

Lighting in industrial environments

The circuits of the lamps and their accessories

b) **fluorescent lamps** require power supply, capacitor, and, in most cases, the starter switch or trigger. The capacitor serves to re-phase the electric power supply circuit (see figures).



Lamp at ignition with starter

Lighting in industrial environments

The circuits of the lamps and their accessories

c) the **mercury vapor lamps** require power and power factor correction condenser. Their attack is normal lives

d) the **halide vapor lamps** require, in addition to the power supply and the condenser, even an ignite;

e) the **sodium vapor lamps at high pressure** require, in addition to the power supply and the condenser, even an igniter of which there are various types. Some lamps have the igniter placed inside the bulb.
The attack is at screw normal, except for lamps with a tubular bulb at 2 attacks.

Lighting in industrial environments

For lighting fixture is commonly understood the container of the light source, which is in charge of two functions:

- provide adequate mechanical protection, thermal and electrical at light source and at related electrical components necessary for the operation of the source;
- modify the emission flux of the light source, adapting it to the needs of the plant.

The latter function is implemented in certain directions concentrating the light flux emitted by the lamps, so as to obtain a predetermined distribution or attenuating, when necessary, the excessive luminance of the source or even removing it from the direct vision.

Lighting in industrial environments

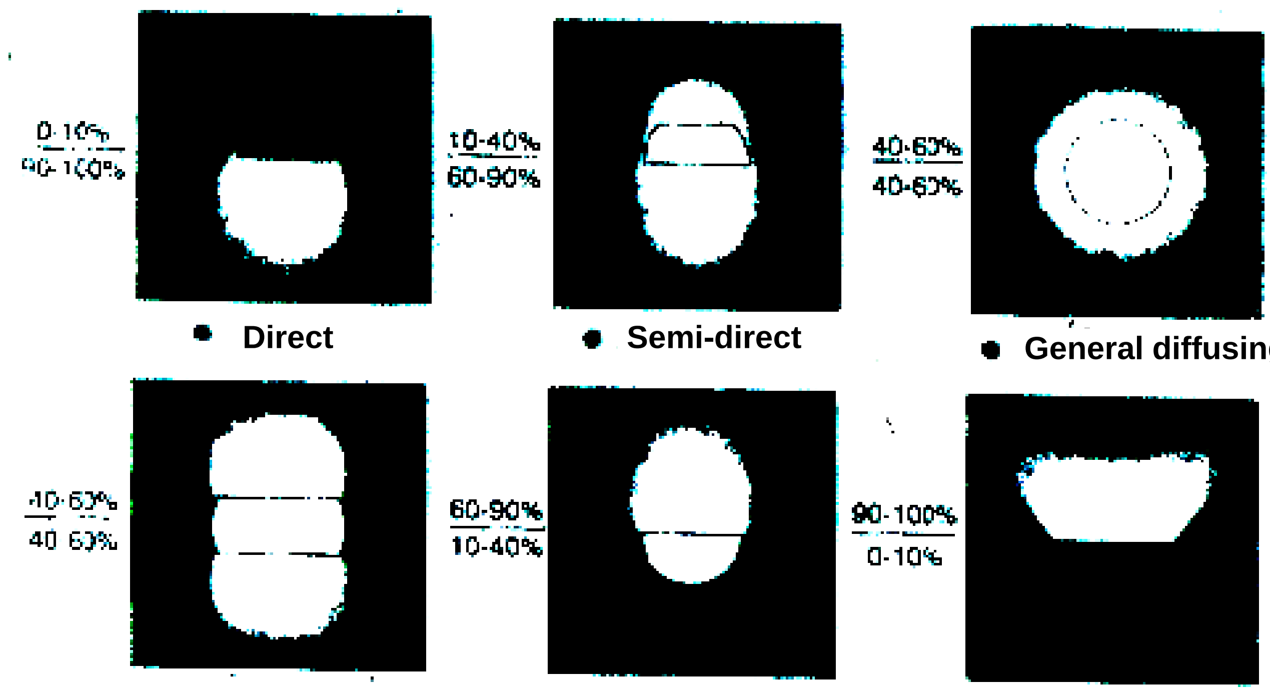
According to the percentage of light flux sent upwards, the devices can be divided into:

- direct (upward flow 0-10%);
- semi-direct (upward flow 10-40%);
- diffusing (upward flow 40-60%);
- semi-indirect (upward flow 60-90%);
- indirect (upward flow 90-100%).

In the industrial field are applied apparatus of the first three types (figure below).

Lighting in industrial environments

Classification of luminaires in relation to the luminous flux sent upwards



- Direct
- Semi-direct
- General diffusing

Direct-indirect

Semi-indirect

Indirect

Lighting in industrial environments

The efficiency of the apparatus is usually defined as the percentage ratio between the flux emitted outside from the apparatus and that emitted by the lamp, both measured with appropriate instruments. On industrial equipment direct or semi-indirect, such performance can be considered comprised between 65% and 85%.

The level of light in the interior of the buildings gradually decreases due to the accumulation of dust and other substances on the reflective surfaces of luminaries, as well as walls and ceilings of the premises; furthermore, the luminous flux emitted by the lamps gradually decreases with time of use.

The efficiency of the system over time illuminating is met by the following actions:

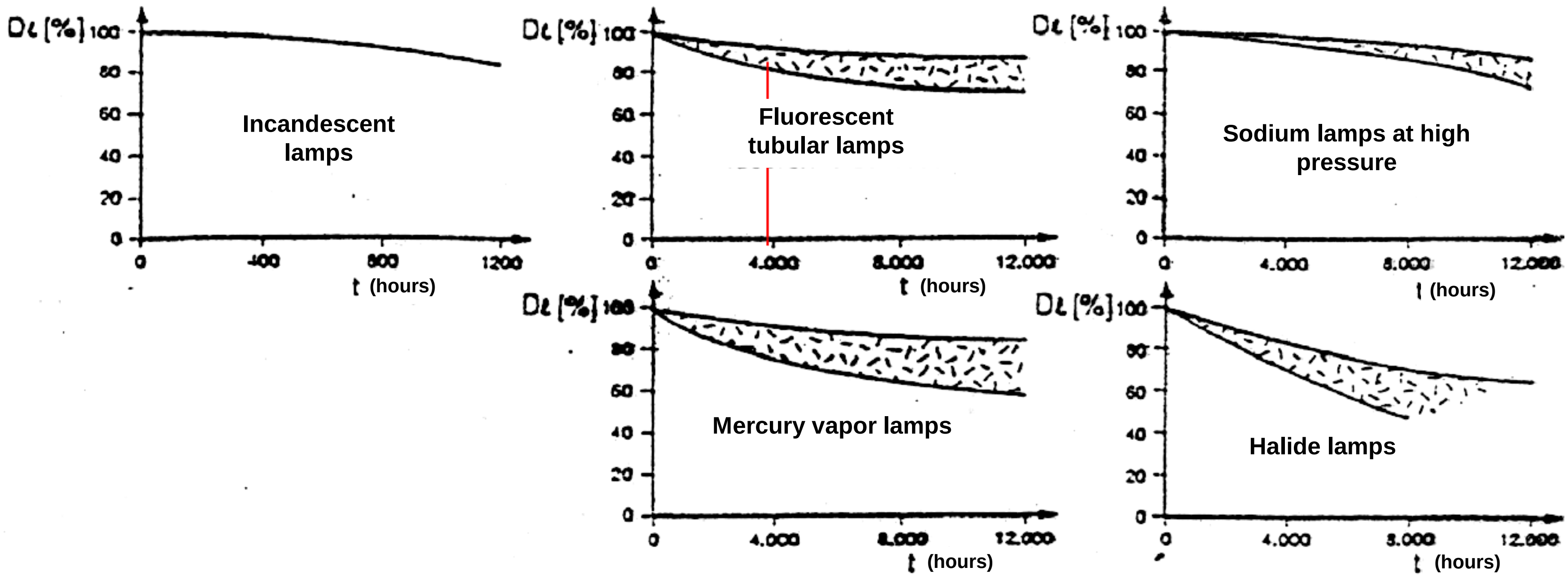
- cleaning of lighting fixtures;
- decoration of walls and ceilings;
- replacement of light sources.

Lighting systems

Lighting in industrial environments

The figure shows the trend of the decay factor D_l in function of operating hours for the main light sources. For discharge lamps shall be understood as the initial luminous flux that detected after the first 100 hours of operation. For the tubular fluorescent lamp for 4000 hours of operation, equal to half the value of the average life of the decay facto D_l = 80%.

Lighting in industrial environments



Lighting in industrial environments

The cadences of the actions mentioned above depend on the type of device, the environment in which it is located and the type of light source adopted.

Among the factors that contribute to facilitate maintenance, remember standardization, portability and accessibility of the fixture and programming assistance.

Experimental data show that the trend of the decay curve of the light source follows a multi exponential law, with a tendency to become approximately linear.

Lighting in industrial environments

Experimentally were determined efficiencies of the various lighting fixtures, their decays and those of environmental surfaces and results are summarized as follows:

a) decay of the lamps after a predetermined number of hours;

Decay of the lamps after x hours	100	1.000	5.000	10.000
A cycle of iodine	1	1,00	-	-
Incandescent from 40 to 220 W	1	0,98	-	-
Fluorescent tube from 40 to 65 W	1	0,95	0,85	0,75
Mercury with fluorescent bulb	1	0,96	0,88	0,78
Sodium at hight pressure	1	0,98	0,95	0,87

Lighting in industrial environments

Experimentally were determined efficiencies of the various lighting fixtures, their decays and those of environmental surfaces and results are summarized as follows:

b) decay of the devices of lighting

The decay of the light emitted by these devices is mainly due to the presence of dust, oils suspended in the air and smog, which is deposited on reflective surfaces. The phenomenon can be accelerated or delayed by the inclination of these surfaces, ventilation, dust and the possible treatment more or less polluted atmosphere that surrounds the luminaire (table)

Lighting in industrial environments

Experimentally were determined efficiencies of the various lighting fixtures, their decays and those of environmental surfaces and results are summarized as follows:

c) decay of the surfaces of the environment

The color of the walls, ceiling and floor determines a different reflection of the luminous flux incident. The performance of their decay is similar to that of the lighting bodies.

Lighting in industrial environments

The replacing of lamps can be made using three different criteria:

a) changes of the lamps when you "burn”
   This criterion is valid for systems with few lamps, while in all other cases it is expensive and excessive disturbance to machining;

b) change of the lamps in small groups, when a number of the same is "burned”

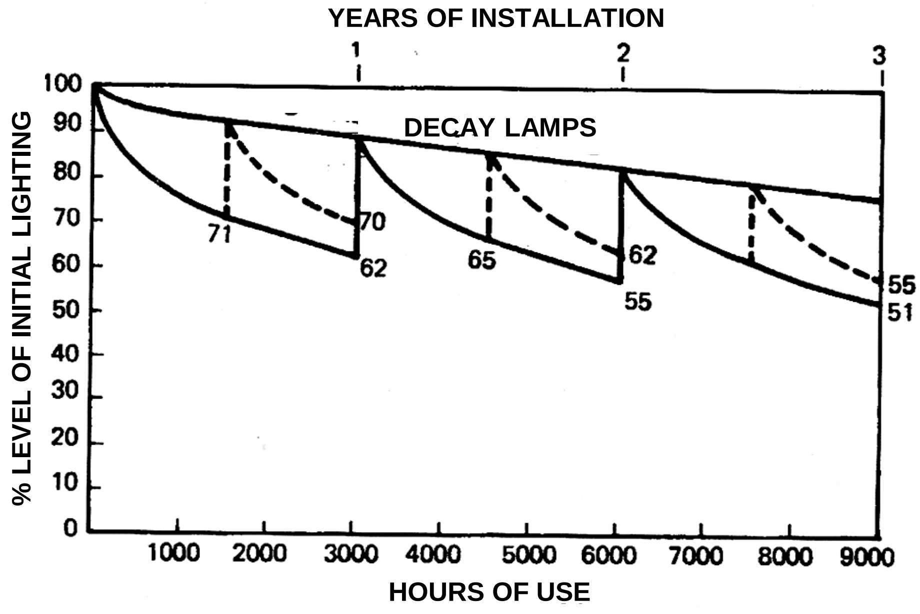
c) change total of the lamps when it has reached 70-80% of the useful life, that corresponds to the MTBF, or when the light flux is reduced approximately 80-90% of the initial one: this system is the only valid for industrial installations.

The MTBF is the expected value of the time between a fault and the next. It is the average time between failures (mean time between failures) and is a parameter of reliability applicable to mechanical, electrical and electronic, and software applications.

Lighting in industrial environments

The frequency of cleaning of the lighting fixtures and walls depends of the work performed and the type of industrial building. In rooms with air conditioning, is normal a range of 1-2 years; in a foundry you should get to cleaning monthly. When you adopt the system of the total change, it coincides the cleaning of the reflectors with a change of the lamps.

The figure shows an example of the application of the maintenance cycles to luminaries in fluorescent tubes in a machine shop.



Lighting in industrial environments

The equipment used for maintenance depend on the environment, the mounting height and the type of luminaries.

In order to guarantee, for the duration of the maintenance period, the illuminance required in an environment, it is necessary to consider a higher illuminance level: this is obtained by dividing the average illuminance maintained for a maintenance factor, which takes into considerations above, unless otherwise specified in designs indoors with artificial light, assumes a maintenance factor of 0.8.

Lighting in industrial environments

The maintenance factor m is defined as:

The ratio between the average illuminance and illuminance initial relative to the lighting made.

For this factor the aforementioned UNI 10380 suggests a value of 0.8.

The maintenance factor takes account of:

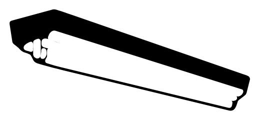
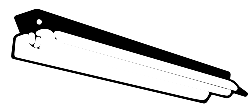
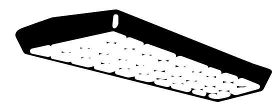
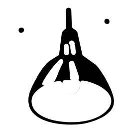
- depreciation of the photometric characteristics of the light fittings;
- aging of the light sources.

Varies according to:

- the environmental conditions;
- as the maintenance is carried out.

Lighting in industrial environments

The table shows the values to be taken for the devices currently used

Type of maintenance	Maintenance factors in relation to the type of device			
				
Good	0,80	0,75	0,75	0,75
Average	0,70	0,65	0,70	0,65
Slack	0,60	0,55	0,65	0,55