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# INDUSTRIAL PLANTS II

## Chapter seven (part 1): Lighting plants

**DOUBLE DEGREE MASTER IN**

**"PRODUCTION ENGINEERING AND MANAGEMENT"**

**CAMPUS OF PORDENONE**

**UNIVERSITY OF TRIESTE**

## Lighting plants

Generality

The **lighting** is the result obtained by the use of lluminous natural fluxes, mediated by architectural elements, or issued for artificial sources (generally electrical equipment) in order to obtain certain levels of light (illuminances) on the object, on the area etc. to be lit up.

# Lighting plants

## Generality

The **lighting** of a room or an industrial environment has a remarkable influence on the welfare and the safety of the activity of the workers, allowing them to perform their task in the best visual conditions, reducing the accidents percentage and improving the quality and the productivity of the industrial activity or the service, reducing the waste and the inefficiencies.

## Lighting plants

Light and photometric units

The **photometry** one occupies for the measure of the amount of radiant energy emitted by a source or received by a surface in relation to the visual sensations produced in the individual through the eye.

The **colorimetry** one occupies for the chromatic radiation aspect of the measure of the amount of the radiant energy emitted by a source or received by a surface in relation to the chromatic sensations produced in the individual through the eye.

# Lighting plants

## Light and photometric units

The organ of sense deputized to the vision is the eye. The human eye has the property of being not influenced by the amount of radiant energy that invests, him, but from the ratio between this and the time, that is by the power of the incident radiation.

The incident radiation of constant power is such that the visual sensation becomes constant in a time of the order of 0.1 s.

The radiation of the same power efficiency, but characterized by different wavelengths, do not produce the same visual sensation.

The human eye has furthermore the ability to assign the light quality (colour), which depends on the wavelength of the incident radiation.

Light and photometric units

With the term "**light**" one refers to the portion of the visible electromagnetic spectrum to the human eye, and is approximately included between 400 and 700 nanometers in wavelength, or between 750 and 430 THz frequency.

This interval coincides with the center of the spectral area of the light emitted by the sun which is able to be arrived to the ground through the atmosphere.

The limits of the spectrum visible to the human eye are not the same for all the people, but subjectively change and can reach the 730 nanometers, approaching him to the infrareds, and 380 nanometers, approaching to the the ultraviolet ones.

# Lighting plants

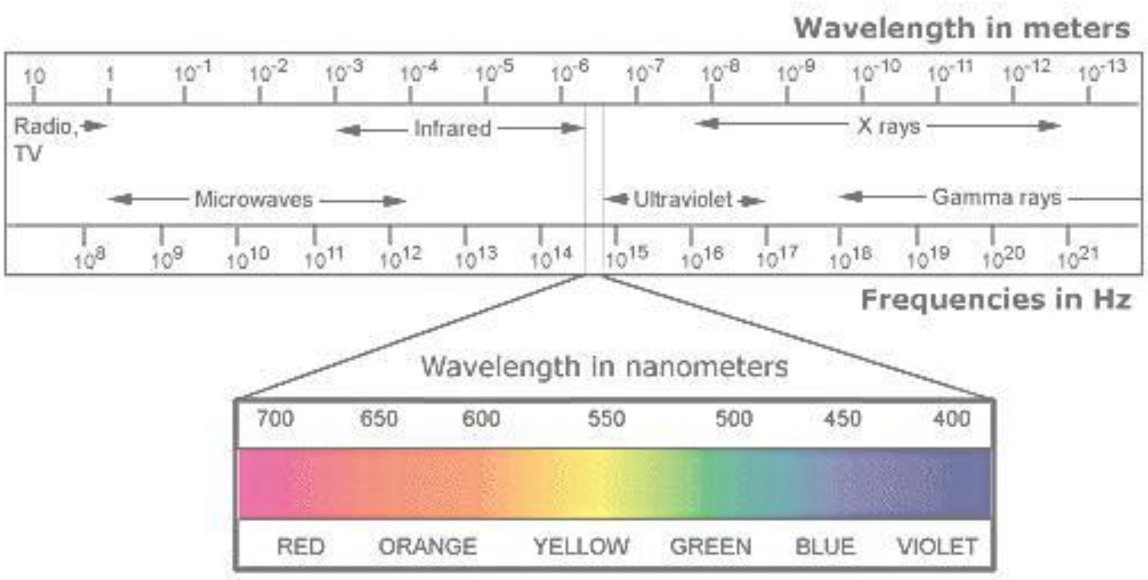
## Light and photometric units

The contemporary presence of all the visible length of wave, in promotional amounts to those of sunlight, form the white light; in fact, the colour of the sources of "white" light is defined for comparison with the light emitted by the black body brought to a determinate temperature (K).

Such temperature is of 5800 K for the sunlight, 6500 K for the light diffused by the celestial vault and 2700-6500 K for tubular fluorescent lamps.

## Light and photometric units

The figure shows the spectrum of electromagnetic radiations.




http://www.daviddarling.info/encyclopedia/E/emspec.html

## Light and photometric units

The spectrum of light emitted by a source may be continuous, that is, with not null emission in all the field of visible radiation, or discontinuous if the energy is concentrated in a certain number of monochromatic radiation.

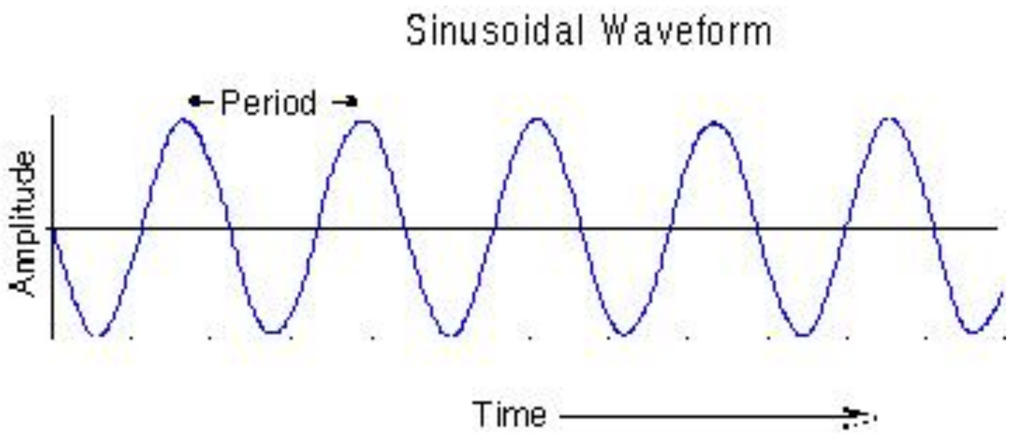
The sunlight and that of the incandescent lamps are to continuous spectrum.

The spectrum of the discharge lamps in rarefied gas is discontinuous; the use of bulbs with fluorescent dusts reduces the discontinuity of emission of these lamps.

# Lighting plants

## Light and photometric units

The factors that influencing the radiant energy, which propagates in the form of electromagnetic waves and to which the visible radiation do a part, are:




http://www.neurophys.wisc.edu/~ychen/textbook/sound_transmission.html

## Light and photometric units

The factors that influencing the radiant energy, which propagates in the form of electromagnetic waves and to which the visible radiation do a part, are:

- the wavelength $\lambda$;
- the period t;
- the frequency f;
- the speed of propagation c.

These three quantities are correlated among them according to the reports:

$$\lambda \cdot f = c \qquad \lambda = \frac{c}{f} \qquad t = \frac{1}{f}$$

The wavelength of a periodic wave is the distance between two crests or between two antinodes of its waveform and is defined by the ratio between the speed of propagation and frequency of the wave.

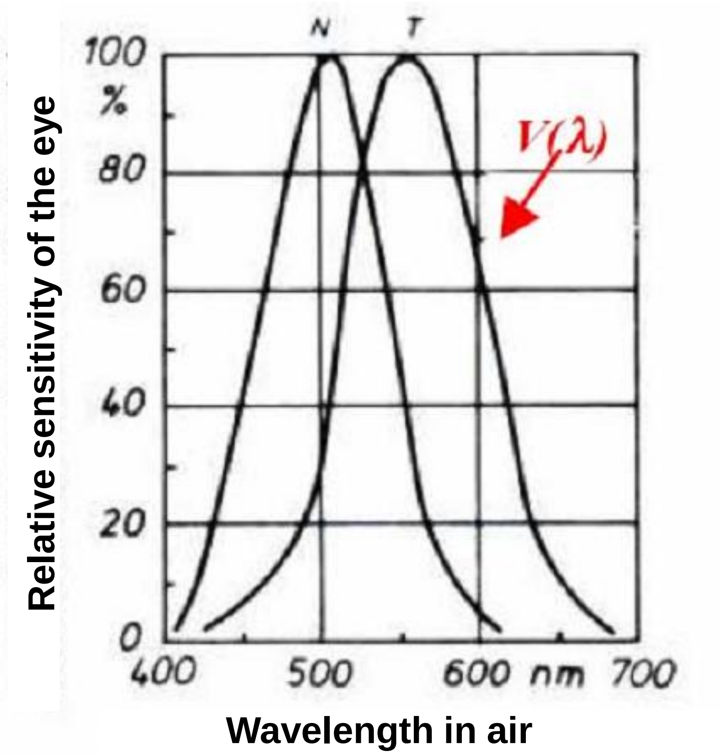
## Light and photometric units

The photometric quantities are the measures defined starting from radiometric quantities by weighing with the spectral response curve of the human eye (photopic luminous efficiency function relative spectral).
They are employed in place of the radiometric quantities as the latter are not directly usable in colour science, while the photometric quantities quantify the light emission in terms of the response of the human visual system, which has non uniform sensitivity to the different wavelength.

The radiometric greatnesses, whose measurement is the task of the radiometry, are those physical quantities related to electromagnetic radiation.

## Light and photometric units

The curve shows the curve of relative visibility V(λ) in conditions of photopic vision (N - corresponding to the daytime vision) and scotopic (T - corresponding to night vision).



Light and photometric units

The photometric quantities are as follows:

- ***luminous energy***

  It is the photometric quantities which corresponds to the radiant energy and is measured in lumens per seconds (lm s);

- ***luminous intensity***

  It is the luminous flux emitted within the unit solid angle steradian (sr) in a given direction and its units of measure is the candela (cd).

  It is also the luminous intensity emitted by a black body at the temperature of solidification of platinum in the direction perpendicular to the exit hole, having an area of 1/600,000 $m^2$, under the pressure of 101,325 Pa.

  It is a photometric quantities that indicating how the luminous flux emitted from a source is distributed between the various directions;

Light and photometric units

The photometric quantities are as follows:

- ***luminous flux***

  It is the amount of luminous energy emitted from a determinate source in the units of time and is measured in lumen (lm).

  It is also the luminous flux emitted by the solid angle of one steradian (sr) from a point source, isotropic, having luminous intensity of one candela (cd):

$$1 \text{ lm} = 1 \text{ cd} \cdot 1 \text{ sr}$$

  The luminous flux is the photometric quantity that measuring the intensity of the visual sensation.

Light and photometric units

The photometric quantities are as follows:

- ***emittance light or luminosity***

  It is the photometric magnitude that corresponds to the radiant emittance. Indicates the ratio of the luminous flux and the emitting surface and one measures in lux, recalling that:

  $$1 \text{ lux} = 1 \text{ lm/m}^2$$

  It is the photometric quantities that expresses the amount of the luminous flux which is emitted from a surface in all the directions

- ***illuminance***

  It is the ratio of the luminous flux received by a surface and the area of the surface itself. It is the illumination produced on a surface area of 1 $m^2$ from the luminous flux of 1 lm incident perpendicularly:

  $$1 \text{ lux} = 1 \text{ lm/m}^2$$

  It is the photometric quantities that expresses the amount of luminous flux incident on a surface and coming from all directions

Light and photometric units

The photometric quantities are as follows:

- ***luminance or brilliance***

  It is the ratio of luminous intensity emitted by a surface in a given direction and the area of apparent surface, as it is seen from an observation point O having an angle α between the direction of the observation point and the normal to the surface itself. It is expressed in nits (nt), recalling that:

  $$1 \text{ nt} = 1 \text{ cd/m}^2$$

  It is the photometric quantities that expresses the luminous intensity of a surface as it appears to the observer.

# Lighting plants

Light and photometric units

There are some examples for the luminous flux :

- signaling lamp neon having a luminous flux of 0.6 lm

# Lighting plants

## Light and photometric units

There are some examples for the luminous flux :

- fluorescent tube by 36 W having a luminous flux of 2500-3600 lm

# Lighting plants

## Light and photometric units

There are some examples for the luminous flux :

- high pressure sodium lamp by 400 W with a luminous flux of 50,000-140,000 lm

## Light and photometric units

There are some examples for the luminous flux :

- xenon lamp by 20,000 W with a luminous flux of 500,000 lm

Light and photometric units

With regard to the illuminance you can do the following examples:

- moonlight: 0,2 lx;
- road lighting: 5 – 40 lx;
- industrial lighting: 100 – 1,000 lx;
- solar lighting: 90.000 lx.

As regard luminance you can do the following examples:

- moon: 4,000 cd/$m^2$;
- sun: 1,600,000,000 cd/$m^2$.

## Light and photometric units

The measuring instrument of illuminance is the **luxmeter**. It is composed on one side fixed (tool body) and a mobile that contains the true and own sensor generally constituted of by a transducer (photoelectric or photovoltaic cell) that, under the effect of *luminous energy*, reacts causing an electric current (Photoelectric effect), which is measured by a galvanometer whose scale is calibrated in lux. The luxmeter is used for the verification of the levels of illuminance of the environments and on the workplace.

Light and photometric units

The difficulties of the use of the luxmeter are not different from that of a tester normally used for electrical measure.

The **luminance meter** is a instrument for measure of the luminance.

It is an tool provided with an lens able to focus on the luminous rays coming from a solid angle in circular or rectangular section, which can have a angle of variable opening from 20' to 3° depending on the necessity of the relief.

The luminous rays are focused on a photosensitive cell and, through an electronic control circuit, a digital reading is supplied of the luminance, with varying ranges between 0.0001 and 100,000,000 cd/m$^2$, also through the introduction of neutral filters of attenuation.

# Lighting plants

## Light and photometric units

The luminance meter is equipped with a viewfinder which allows the training, since the luminance depends on the position of the observer.

Light and photometric units

The **goniophotometer** is an instrument used for measuring of the luminous in different directions.

Using a photocell, measurements are made of the luminous intensity of the instrument in all directions.

There are four different techniques measure to each of which corresponds to a type of instrument other than:

- with fixed photocell and rotation lighting instrument around to the longitudinal and transverse axes;
- with mobile photocell along a hemisphere and fixed instrument of illumination fixed;
- with photocell movable along a semicircumference and instrument for illumination on the vertical axis;

Light and photometric units

The **goniophotometer** is an instrument used for measuring of the luminous in different directions.

Using a photocell, measurements are made of the luminous intensity of the instrument in all directions.

There are four different techniques measure to each of which corresponds to a type of instrument other than:

- with photocell fixed and lighting apparatus which, while being movable, always keeps the correct operating position. The emitted light is directed towards the photocell by a rotary mirror.

Light and photometric units

The **flux meter** allows the measure of the luminous flux emitted by a source. The instrument most known is the **Ulbricht of sphere**, which is constituted by a hollow sphere with the internal walls perfectly diffusing that allow the total reflection of light.

The measure is carried out by means of a photovoltaic cell placed behind a small slit practiced on the surface of the sphere. To avoid that the cell directly receives the luminous rays emitted from the source, between the two is placed a diffusing screen.

## Light and photometric units

The **colorimeter** allows to measure the colour of a luminous source according to the chromatic system CIE (Commission Internationale de l'Eclairage). The instrument is fundamentally composed of three photocells, one for each of the three fundamental colours. The data collected are represented by means of response curves that reproduce as faithfully as possible the curves of visibility of the human eye to the three colours. The figure shows a colorimeter with spectroradiometer.

Light and photometric units

The **spectroradiometer** allows to know the spectral distribution of a luminous source by the measure of the flow of energy emitted in the visible range. The flow of energy emitted by the source is detected throughout the range of the visible at intervals Dg constants. The radiometric quantity measures is multiplied by the relative value of the three curves of visibility.

Light and photometric units

The cost of such instrument is quite high and their use requires a certain practice; in the control of lighting features that most interest the visual comfort, there is no doubt that with the operation are obtained data much more significant than the simple relief of illumination with the lux meter.
The measure of the luminous intensity, luminous flux, colour of a luminous source and of the spectral distribution of the same require the illustrated equipments that are complex and such to be used in specialized laboratories.

# Lighting plants

<u>Lighting of the workplaces</u>

In the working environments, lighting plays a fundamental list: it must be to see and recognize the contained objects in hit, besides serves not to tyre the sight and to make perceiving the dangerous situations. The lighting can be artificial, natural or mixed.

The Legislative Decree n. 81 of April 9, 2008 prescribes for the premises used for working activities:

- in case of breakdown have safety lighting of sufficient intensity;
- sufficient natural light and adequate artificial lighting;
- type of lighting that must not represent accident for to workers;
- glass windows and lighting means kept in good condition of cleaning, and efficiency.

# Lighting plants

<u>Lighting of the workplaces</u>

The Decree of the Ministry of Economic Development January 22, 2008, n. 37 imposed that the lighting plants are designed, constructed and maintained to art rule. Are constructed in accordance with to art rule the plants built in compliance with technical standards UNI and CEI.

You also follow the standards:

- UNI EN 1838: 2000, UNI 10819: 2000, UNI EN 12464: 2004 e 2007, UNI 11248: 2007, UNI 10819: 1999, UNI 10840: 2007, UNI EN 12193: 2008
- DIN 5035-1979;
- NF X 35 – 103.

# Lighting plants

## Lighting of the workplaces

Legislative Decree April 9, 2008, n. 81, on "Implementation of Article 1 of Law August 3, 2007, n. 123 concerning the protection of health and safety in the workplace "- OJ of April 20, 2008, n. 101

Decree January 22, 2008 n. 37 "Regulations on the realization of Article 11-quarterdecies, paragraph 13, letter a) of Law no. 248 of December 2, 2005 on the reorganization of the disposition relating to the activities of installation of the plant inside buildings - OJ n. 61 of March 12, 2008

UNI EN 1838: 2000 "Application of lighting - Emergency lighting"

UNI 10819: 2000 "Light and lighting - Lighting plants outside - Requirements for limiting of the dispersion upward of the luminous flux"

UNI EN 12464-1: 2004 "Light and lighting - Lighting of workplaces - Part 1: Work places in interiors"

# Lighting plants

## Lighting of the workplaces

UNI EN 12464: 2008 "Light and lighting - Lighting of workplaces - Part 2: Work places outside“

UNI 11248: 2007 "Street lighting - Selecting of the lighting categories“

UNI 10819: 1999 "Light and lighting - Lighting plants outside - Requirements for the limitation of the dispersion upward of the luminous flux“

UNI EN 12193: 2008 "Light and lighting - Lighting of sports installation“

DIN 5035, Part 1, "Definitions and general requirements for artificial lighting", 1979 and Part 2: "Guideline values for workplaces indoors and outdoors", 1990

NF X 35-103 "Principes ergonomiques visuels applicables à l'éclairage des lieux de travail", 1990

Lighting of the workplaces

In the design phase of a new plant or the restructuring of existing plants it is necessary to put the objective to define the lighting performance that a plant must have in function of its intended use and in consideration of the fact that the plant "affects the visual capacity, the activity, the safety and welfare of the people".

# Lighting plants

<u>Lighting of the workplaces</u>

The furnished indications must regard principally:

- levels and uniformity of illuminance $E_m$
- luminances distribution
- glare limitation
- directionality of light
- light colour or colour temperature

  The colour temperature characterizes the tonality of the light emitted by from a luminous source, for comparison with that one of a black body heated at a temperature ranging between 2,000 and 10,000 K

## Lighting of the workplaces

The provided indications must regard principally:

- colour rendering

  The chromatic rendering of a luminous source expresses the degree of fidelity that it allows in the appreciation of the shading of colour of the objects which it illuminated. Using a set of sample colours, enlightened first from a source (or enlightened) of reference and then from the source of which you want to estimate the color rendering, you can drow up a general index of colour rendering, which can assume values between 0 and 100

- flicker

  The flicker is the phenomenon of visual perception that occurs when the luminous source, powered by alternating current, emits bright lightnings to an opportune frequency

- daylight

# Lighting plants

Lighting of the workplaces

The lighting and the comfort depend on the type and duration of the activities, at design must also take into account qualitative and quantitative aspects.

The basic requirements that must be met are three:

- visual comfort: the feeling of being perceived by workers indirectly contributes to high levels of productivity;
- visual performance: the workers are able to perform their visual tasks even in difficult circumstances and protracted;
- safety.

# Lighting plants

## Lighting of the workplaces

The field of adaptation of the human eye is very extended by including luminance in the ratio of 1 to 1 million times. Varies, however, the adaptation time, shorter for high illuminance levels and longer for lower ones.

The presence in the visual field of light sources with luminance considerably higher than the average on which is adapted to the eye, it causes a feeling of disorder called **glare**.

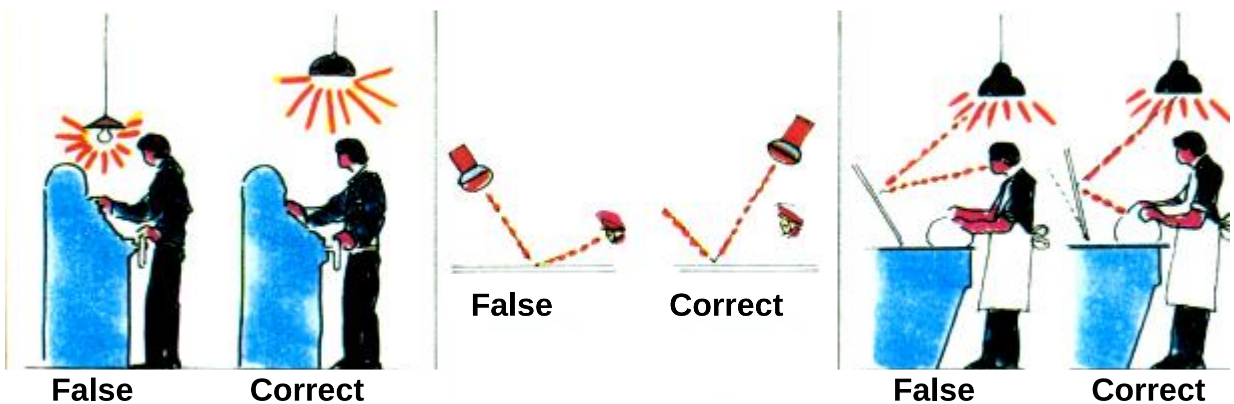
It follows that looking from bright highlights to dark areas, you may have a feeling of temporary blindness and visual affacaticamento with possibility of danger.

# Lighting plants

Lighting of the workplaces

The human eye reacts to overload luminance with glare. The glare can be caused by an excess of luminance of the visual field, from luminance contrasts too high or a combination of these factors.

It is observed that the perception of objects is determined by luminance contrasts. The contrasts limited reduce the visual perception, while those too high contrasts determines effects of glare. If glare is caused by excessive luminance in the direction of a light source, it is called **direct glare**, otherwise we speak of **indirect glare**.




Direct glare

Glare from reflected light

Lighting of the workplaces

In relation to the effect on the person who looks, there are two types of glare:

- **disability glare**, which reduces the ability to clearly see the details or contrasts. It is caused by light sources of high luminance or by reflections on the object to be observed;
- **discomfort glare**, for the presence at the periphery of the visual field areas much less illuminated or of other light sources.

## Lighting of the workplaces

La normativa europea definisce per i vari compiti di lavoro il valore dell’UGR (Unified glare rating) richiesto. Gli angoli minimi di schermatura consigliati in funzione della luminanza delle lampade impiegate sono riportati in tabella.

| Luminance of the lamp ($kcd/m^2$) | Minimum angle of shielding (°) |
|---|---|
| da 20 a 50 | 15° |
| da 50 a 500 | 20° |
| ≥ 500 | 30° |

# Lighting plants

## Lighting of the workplaces

The field of view is the observation of details and objects in relation to the performance of a particular activity or visual elements of the work to be done. The hike of demanding visual tasks is facilitated by several factors mentioned by the European standard implemented in Italy UNI EN12464 are required synthetically:

- adequate luminance of the surrounding surfaces

  It is noted, for example, that the ceiling lighting is especially necessary when work operations often forced to turn his gaze upwards (eg warehouses with stacking by forklift);
- illuminance values in the areas immediately adjacent not less than 0.5;
- adequate shielding against glare;
- measures to avoid veiling reflections on visual task;

# Lighting plants

Lighting of the workplaces

Are required synthetically:

- illuminance values not lower than the values specified in the table with a uniformity of 0.8 on the area of the visual field;

| 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 plants

Lighting of the workplaces

Are required synthetically:

- eventuale luce direzionale per migliorare il modellato e la sensazione di profondità;
- any directional light to improve the modeling and the feeling of depth;
- color rendering adequate work to be done;
- elimination of flicker phenomena (for example of electrical networks that feed the welding);
- elimination of stroboscopic effects (eg use of discharge lamps);
- consideration of energy saving and maintenance costs;
- utilization and integration of daylight.

## Natural lighting

The natural lighting is a key element in lighting design. The contribution of natural light should be privileged, since, in addition to the benefits of energy type, involves psychological benefits on people.

The ratio of the average illuminance of the environment and the illumination that would be obtained in the same conditions on a horizontal surface that receives light from the entire outer sky without direct radiation is called average factor daylighting ($FLD_m$).

# Lighting plants

Natural lighting

The level of illumination by natural light in confined depends :

- locality;
- orientation of the building;
- orientation and characteristics of the glass surfaces;
- neighboring buildings and natural elements of the landscape.

Natural lighting

The average factor daylighting $FLD_m$ is defined by the relationship:

$$FLD_m = \frac{t \cdot A \cdot \varepsilon \cdot \psi}{S \cdot (1 - r_m)}$$

where:

t = transmission coefficient of the glass; is obtained from tables (0,80 ÷ 0,90)

A = surface of the transparent windows ($m^2$);

ε = factor window, which takes into account the location and the presence of obstructions. It is calculated by means of graphs and tables;

ψ = factor retreat of the window relative to the wire of the facade of the building (by graphs and tables)

S = the inner surface of the environment (walls, ceiling and floor, including glass surfaces ($m^2$);

$r_m$ = average factor of reflection of the inner surfaces of the environment (ranging from 0.1 - dark brick, rough concrete - 0.8 ÷ 0.9 - white plaster, aluminum)

# Lighting plants

## Natural lighting

The optimal values of $FLD_m$, detectable by existing standards, are comprised of a minimum of 0.7% for the occupied areas in a non-continuous by workers up to values greater than 2%.

The ratio between the surface and the windowed paved surface of an environment is called illuminating ratio (RI), which depending on the type and size of the room takes the values shown in the table

| Type of local | Size | RI minimum |
|---|---|---|
| Offices, meeting rooms, clinics, canteens, rest rooms, classrooms, local hospital | - | 1/8 |
| Locals used for business activities other than the above, including bonded warehouses and archives, permanently occupied by workers | < 1.000 $m^2$ | 1/10 |
| | 1.000 – 3.000 $m^2$ | 1/12 |
| | > 3.000 $m^2$ | 1/15 |
| Locals occupied by temporary workers* | - | 1/20 |
| * In these locals can also be permitted for natural lighting reduced respect to the relationship illuminating RI indicated in cases where there are technical difficulties (structural and / or planning restrictions) or other obstacles that make it particularly complex implementation of transparent surfaces. | | |

# Lighting plants

Natural lighting

There are some correction factors for the relationship illuminating RI and concerns:

- surfaces with low transmission (t <0.7) increases the glass surface;
- excluding glass surfaces with h <0.60 m;
- environment depth <2.5 times $h_{max}$ of the glass surface;
- presence of canopies, balconies etc.

## Natural lighting

The glare is the phenomenon of interference due to excessive luminance contrast between the visual task and background, the excessive brightness of the source or something fits in the field of observation with a light source luminance significantly greater than the average of the real sources or apparent present in the field (figure); it creates a temporary loss of visibility.

# Lighting plants

## Natural lighting

According to the International Commission on Illumination, the glare is seen as a condition of vision that creates discomfort or reduced ability to perceive the details of an object as a result inadequate distribution or direction of light or excessive contrast. The glare depends on the size, position and luminance of the source (for example glass surface), from the luminance level at which the eye of the observer is used and the number of sources, and then the luminance of the portion of sky framed by glass surface, from the luminance contrast between the internal surfaces and the presence of reflective surfaces.