La Sapienza
Università degli Studi di Roma

Safety of Industrial Plants

Lecture 14

Ergonomis

Lighting

Contents and Goals

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  - bright environment
  - Ergonomic design criteria of a bright environment criterio del flusso totale
    - Total flow criterion
    - point to point criterion

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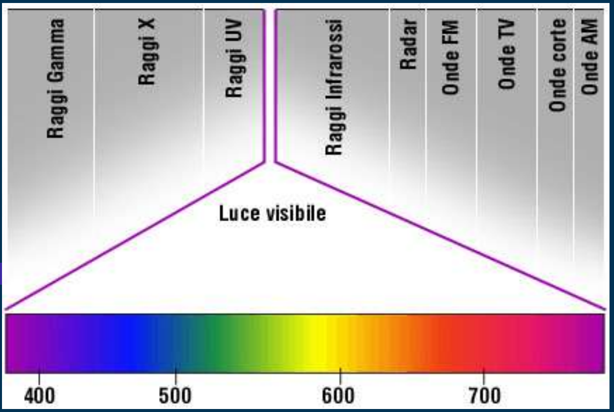
Bright environment

- Design in a suitable way a bright environment requires compliance with at least two main requirements:
  - A suitable visibility
  - visual comfort
- To define a bright environment, what follows has to be considered:
  - the organ responsible for the vision and, therefore, the behavior of the eye
  - Light features

Bright environment

- The eye is an optical system with two lenses:
  - the **cornea**
    - is a fixed focus lens that represents the front of the eye
  - the crystalline lens
    - is a variable focus lens, adjusted by means of the musculature of the visual
- In the back of the eye, there is the retina, tissue of cells particularly sensitive to light of two types
  - The cones
    - They are mainly present in the central part of the retina where there is the optic nerve, in general , these cells are not very sensitive to light, however, they can distinguish the colors
  - The rods
    - The Rods are cells much more sensitive to light, but they cannot distinguish colors
- When the eye is stopped, the field of view corresponds to an angle of three ten-thousandths of steradians
  - That is to say a plane angle approximately equal to 1 degree
- The field of view extends for much wider corners
  - vertically, from about 55 ° above the horizontal up to about 70-80 ° below
  - horizontally, it can exceed 180°

Bright environment



- Light is an electromagnetic wave characterized, as in the case of elastic waves of the sounds, by a wavelength and a frequency.

- Human eye can perceive electromagnetic radiation of a wavelength between 380 and 780 Nm:
  - below 380 Nm we have the so-called ultraviolet radiations
  - above 780 Nm, we have the infrared radiations

- beyond the diversity of the wavelength, the vision is affected by the particular sensitivity of the eye:
  - There is a standard curve, the curve of visibility, which is representative of the visual capacity of an average man: it takes into account the degree of sensitivity of the eye to the radiation depending on the wavelength
  - it can be observed that the sensitivity of the human eye is maximum around 550 Nm

Bright environment

- The phenomena to consider speaking of visual perception are:
  - chromatic aberration
    - It consists in the fact that electromagnetic radiation of different wavelengths have different optical paths and, consequently, the eye is unable to focus perfectly all the components of the image. The consequence is the loss of image definition, which may represent a problem if the working activity requires a good perception of colors and images.
  - adaptation
    - when human eye is suddenly hit by a discrete light dose, it is necessary to adapt, through a biological regulation, the amount of light that can actually invest the retina. This phenomenon can lead to eyestrain. The sight , if subjected to frequent variations in amount of light, regulates itself constantly on occurring variations
  - dazzling
    - It consists in the saturation of the sensitive cells of the eye due to which, the visual apparatus is rendered almost blind, usually in a temporary way (relative dazzling)
    - We may also have dazzling phenomena whose consequences are very serious, as, indeed, permanent blindness. In these cases, we speak of absolute dazzling .

Bright environment

- The appropriate analysis of the luminous environment requires technical knowledge of the magnitudes involved :
  - radiant power **(W), w (λ)**
  - coefficient of visibility**, 0 < v(λ) < 1**
  - Light flow (lumen), $$\phi(\lambda) = \int_{380}^{780} w(\lambda)\cdot v(\lambda) d\lambda$$
  - light intensity **(cd),** $$I = \frac{d\phi}{d\omega}$$
  - **illuminance** (lux), $$E = \frac{d\phi}{dS_{inc}}$$
  - **luminance** (cd/m^2), $$L = \frac{dI}{dS_{em}\cdot \sin\vartheta}$$

Bright environment

- The design of bright environments also requires some derived magnitudes:
  - luminance ratio,

$$R_L = \frac{L_1}{L_2}$$

  - contrast factor,

$$F_C = \frac{L_2 - L_1}{L_1}$$

  - reflectance,

$$\rho = \frac{\phi_r}{\phi_i} = \frac{E_r}{E_i}$$

Bright environment

- Types of lamps :
  - incandescent lamps have an operating temperature approximately equal to 2700 K; the tungsten filament, in fact, to higher temperatures tends to sublimate. Consequently, the filament thins slowly over time, resulting in an increase of electrical resistance and, hence, an increase in temperature which leads to melting the filament
  - using a particular atmosphere, for example a iodine atmosphere, tungsten that sublimates is "captured" by iodine and reported on the filament: the operating temperature, in consequence, can be increased up to about 3,200 K, also bringing an increase of luminous efficiency
  - More lamp types, such as fluorescent and sodium lamps, work by establishing an electric arc between two electrodes. These types of lamp, in consequence, are characterized by high luminous efficiency, even if the light emitted tends to yellow and, therefore, it makes little use for the closed places (usually these lamps, especially sodium lamps, are used to street lighting)

Bright environment

- The choice of lamps depends on :
  - Luminous efficiency, which expresses the ratio between the luminous flux emitted by the lamp and the power consumed to generate it (lumen/W)
  - Length in hours
  - Consumption , in kWh
  - Color of the light (depending on the color temperature, i.e. the temperature which should have the black body to emit radiation of the same hue than those of the lamp considered).

Design of a Bright environment

- Standard ISO 8995:2006 underlines that the correct level of lighting should be fixed on the basis of visual requirements required by the operator to perform a very specific task.
- The dimensioning of lighting systems can be done according to two main criteria or methodologies:
  - the total flow method or the utilization factor
  - The point to point method

Design of a Bright environment

- The total flow method derives from the application of the report of the illumination:

$$E = \frac{\phi}{S} = \frac{n \cdot \phi_L}{S}$$

$$n = \frac{S \cdot E}{\phi_L}$$

$$n = \frac{S \cdot E}{\phi_L \cdot u \cdot m \cdot d}$$

n, number of lamps

u, utilization factor

m, maintenance or dirtying factor

d, decay factor

Design of a Bright environment

- The total flow method requires checks, often accomplished by the other method which has been mentioned, the point to point method:

$$E = \frac{d\phi}{dS} = I \cdot \frac{d\Omega}{dS} = \frac{I \cdot dS \cdot \cos\alpha}{dS \cdot r^2} = \frac{I \cdot \cos\alpha}{r^2}$$

$$E = I \cdot \frac{\cos\alpha^3}{h^2}$$