Chapter 7.

LUMINAIRES

INDALUX

General remarks

Due to the high *luminance* of lamps, it is necessary to increase the emission apparent surface in order to avoid visual problems (glare). Also, it is necessary to shield lamps to protect them from external agents and to direct their flux in the most convenient way for visual task.

Thus, different studies and contemporary research place great emphasis on the combination formed by the source of light and the luminaire.

According to the UNE-EN 60598-1* Norm, a luminaire may be defined as a *lighting apparatus which spreads, filters or transforms light emited by a lamp or lamps including all components necessary for supporting, fixing and protecting the lamps, (except for the lamps themselves). Should the need arise, also the auxiliary circuits combined with the media for the connection to the power supply.*

Main components

Independently from other definitions which could be more or less descriptive, a luminaire may be defined as an object formed by a combination of elements designed to give an appropriate luminous radiation of an electric origin. Materialization of these elements is achieved by combining a good formal design and a reasonable economy of materials in each situation.

Formal design solves luminous control depending on needs, which is the main aim: both a thermal control which makes its functioning stable and an electric control which offers adequate guarantees to the user. Economy of materials provides a solid and efficient product, an easily installed luminaire, and minimum maintenance while in use.

Regarding the most fundamental characteristic components, body, control gear, reflector, diffuser, and filter among others, must be mentioned. All of them fall into other classifications shown below.

1. Body: This is the minimum physical element which supports and defines the volume of the luminaire and contains the key components. According to this criterion, several types may be defined:
   - For indoor or outdoor areas.
   - Surface or embedded mounted.
   - Suspended or rail mounted.
   - Wall, bracket or pole mounted.
   - Open or enclosed.
   - For normal or harsh environments (corrosion or explosion).
2. Control gear: Appropriate control gear would be selected to suit different sources of artificial light, according to the following classification:
   - Regular incandescent with no auxiliary elements.
   - High voltage halogene to regular voltage, or low voltage with converter or electronic source.
   - Fuorescent tubes. With reactances or ballasts, capacitors and starters, or electronic combinations of ignition and control.
   - Discharge. With reactances or ballasts, capacitors and starters, or electronic combinations of ignition and control.
3. Reflector: A specific surface inside the luminaire which models form and direction of the lamp flux. Depending on how luminous radiation is emitted, it may be:
   - Symmetric (with one or two axes) or asymmetric.
   - Narrow beam (lower than 20º) or wide beam (between 20 and 40º; greater than 40º).
   - Specular (with scarce luminous dispersion) or non specular (with flux dispersion).
   - Cold (with dicroic reflector) or normal.
4. Diffuser: This forms the cover of the luminaire in the direction of the luminous radiation. The most frequently found types are:
   - Opal (white) or prismatic (translucent).
   - Lamellae or reticular (with a direct influence on the shielding angle).
   - Specular or non specular (with similar characteristics to reflectors).
5. Filters: In possible combination with diffusers, they are used to protect or lessen certain characteristics of luminous radiation.

* The UNE-EN 60598-1 Norm adopts the Internacional Norm CIE 598-1.

7.2. Luminaire classification according to the degree of protection from electric contacts

Luminaires must secure protection of people from electric contacts. Depending on the degree of electric insulation, luminaires can be classified as:

Class 0: Luminaire with basic insulation, lacking double insulation or overall reinforcement as well as an earth connection.

Class I: Luminaire with functional basic insulation and an earth connection terminal or contact.

Class II: Luminaire with double basic insulation and /or reinforced overall insulation lacking provision for earth discharge.

Class III: Luminaire designed to be connected to extra-low voltage circuits, lacking internal or external circuits not working at an extra-low security voltage.

7.3. Luminaire classification according to working conditions

The IP system (International Protection) established by the UNE-EN 60598 classifies luminaires according to their degree of protection from mechanical shock, dust and water. The term mechanical shock includes those elements like tools or fingers that are in contact with energy transmiting parts

The designation to indicate degrees of protection consists in charateristic IP letters followed by two numbers (three in France) which indicate the compliance of conditions established in charts 1., 2. and 3. The first of these numbers is an indication of protection from dust, the second number indicates the degree of protection from water, whereas the third number, in the French system, indicates the degree of protection from mechanical shock.

First characteristic numeral	Brief description	Symbol
0	Non-protected.	No symbol
1	Protected against solid objects greater than 50 mm.	No symbol
2	Protected against solid objects greater than 12.5 mm.	No symbol
3	Protected against solid objects greater than 2.5 mm.	No symbol
4	Protected against solid objects greater than 1 mm.	No symbol
5	Dust- protected.	
6	Dust tight.	

Chart 1. EN-60598 classification according to dust protection degree (1st numeral).

Second characteristic numeral	Brief description	Symbol
0	Non- protected.	No symbol
1	Protected against dripping water.	
2	Protected against dripping water when tilted up to 15º.	No symbol
3	Protected against dripping water when tilted up to 60º.	
4	Protected against spraying water.	
5	Protected against splashing water.	
6	Protected against water jets.	No symbol
7	Protected against the effects of immersion.	
8	Protected against submersion.	-m

Chart 2. EN-60598 classification according to the degree of protection from water (2nd numeral).

Third numeral of the code

This numeral refers to mechanical shock tests. The following chart shows characteristic numerals accompanied by a brief description.

Third characteristic numeral	Brief description	Symbol
0	Non- protected	No symbol
1	Protected against a 0.225 J. mechanical shock	No symbol
3	Protected against a 0.5 J. mechanical shock	No symbol
5	Protected against a 2 J. mechanical shock	No symbol
7	Protected against a 6 J. mechanical shock	No symbol
9	Protected against a 20 J. mechanical shock	No symbol

Chart 3. EN-60598 classification depending on protection from mechanical shock.

Instead of this third numeral, the EN-50102 Norm on “Degrees of protection against external mechanical shock provided by electric material bulb (code IK)” may also be applied.

In the above mentioned Norm, the protection degree from mechanical shock provided by a bulb is indicated by the IK code in the way shown below:

- Code letters (internacional mechanical shock protection): IK
- Characteristic numerals: From 00 to 10

Each characteristic numeral represents a value for impact energy, whose correspondance is summarised in chart 4.

IK Code	IK00	Ik01	IK02	IK03	IK04	IK05	IK06	IK07	IK08	IK09	IK10
Mechanical shock in Joules.	*	0.15	0.2	0.35	0.5	0.7	1	2	5	10	20

Chart 4. Correspondence between the IK code and impact energy.

Generally speaking, protection degree is applied to the bulb as a whole. If several parts of the bulb have different protection degrees, they must be indicated separately.

7.4. Luminaire classification according to the mounting surface flammability

Luminaires cannot be mounted on any surface at hand. The surface flammability and the luminaire body temperature impose certain restrictions. Of course, if the surface is non-combustible, there is no problem.

For classification purposes, the EN-60598 Norm defines flammable surfaces as usually flammable or easily flammable. The *usual flammable* classification refers to those materials whose ignition temperature is, at least, 200 ºC, degrees and do not weaken or deform at that temperature.

The *easily flammable* classification refers to those materials which cannot be classified as usually flammable or non-combustible. Materials in this category may be used as mounting surface for luminaires. Suspended mounting is the only option for this type of material.

In chart 5, mounting classification based on these requirements may be observed.

Classification	Symbol
Luminaires suitable for direct mounting only on non- combustible surfaces.	No symbol, but a warning notice is required.
Luminaires suitable for direct mounting only on easily flammable surfaces.	F On plaque.

Chart 5. EN-60598 classification according to the mounting surface flammability.

7.5. Luminaire classification according to service conditions

Depending on their service conditions, luminaires fall into the following types:

7.5.1. Indoor lighting luminaires

Within this group, luminaires to illuminate premises and facilities in shopping areas, industries, offices, educational buildings, indoor sports facilities, etc. are found Therefore, this type of lighting tries to give the adecuate lighting for those working or teaching environments.

Luminaires for general indoor lighting are classified by the C.I.E. according to the total percentage of luminous flux distributed above and below the horizontal plane.

Luminaire type	% Upward flux distribution	% Downward flux distribution
Direct	0 - 10	90 - 100
Semi-direct	10 - 40	60 - 90
Direct-indirect	40 - 60	40 - 60
General diffuse	40 - 60	40 - 60
Semi-indirect	60 - 90	10 - 40
Indirect	90 - 100	0 - 10

Chart 6. C.I.E. classification for indoor lighting luminaires.

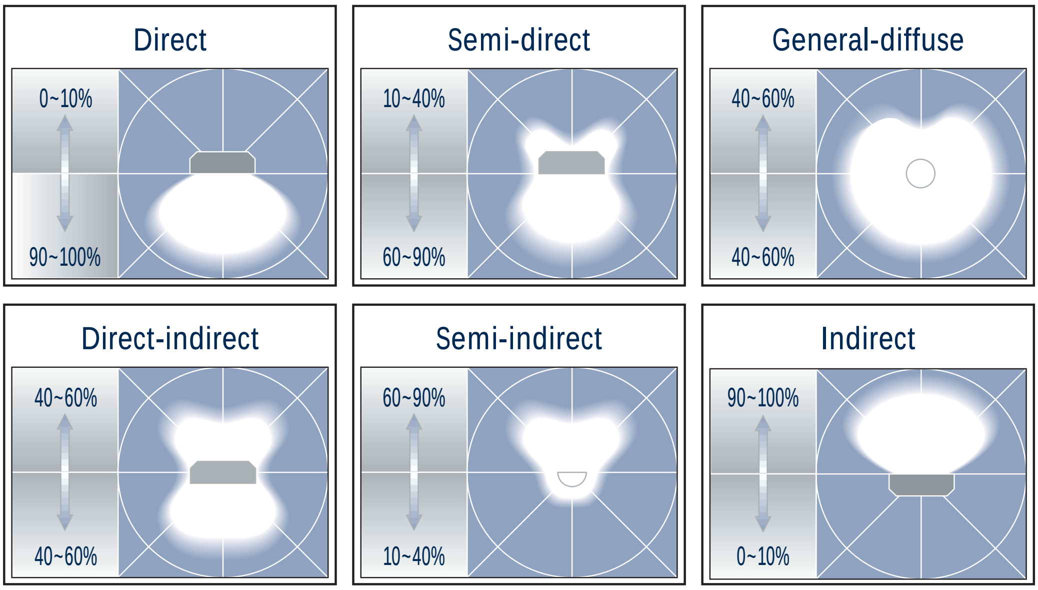


Chart 1. Luminaire classification according to radiation of luminous flux.

In turn, with regards to the symmetric flux emitted, a classification may be considered into two groups:

1) *Symmetrical distribution luminaires:* Those in which the luminous flux is spread symmetrically with respect to the symmetric axis and spatial distribution of luminous intensities. It may be represented as a single photometric curve.

2) *Asymmetric distribution luminaires:* Those in which the luminous flux is spread asymmetrically with respect to the symmetric axis and the spatial distribution of luminous intensities. It may expressed by a photometric solid, or, partially, by a flat curve of such a solid, depending on certain characteristic planes.

Photometric information which accompanies indoor lighting luminaires

Polar distribution curves

These curves are generally represented in the coordinate system C-γ. Since there are infinite planes, in general, three C planes are represented, which are the following:

- Plane C = 0°.
- Plane C = 45°.
- Plane C = 90°.

Polar distribution curves are in the cd units per 1 000 lumens of flux emited by the lamp. They are represented in cd/1 000 lm or cd/Klm. (Fig. 2).

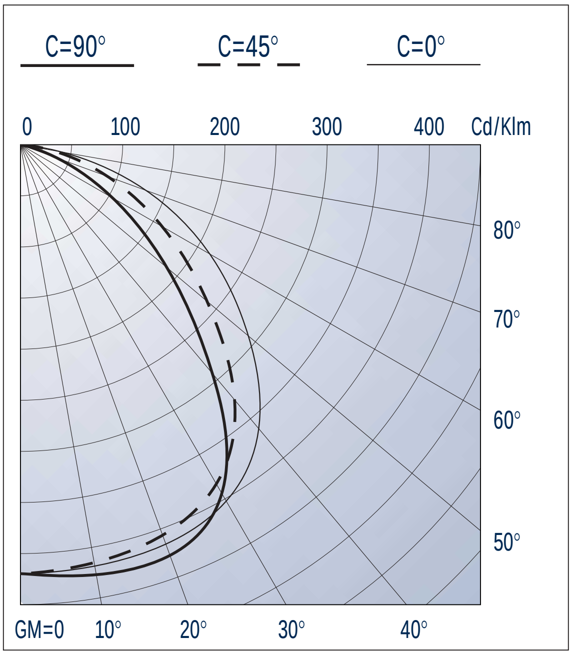


Figure 2. Polar diagram in the C-γ system.

Zone flux diagram

These diagrams indicate the flux received by the surface to be illuminated directly from the luminaire, depending on angle γ. This diagram is obtained by creating cones whose axis coincide with the vertical axis of the luminaire. Generating angles with this axis are γ angles. The percentage of light collected by each of these cones is the image represented in the diagram (Fig. 3).

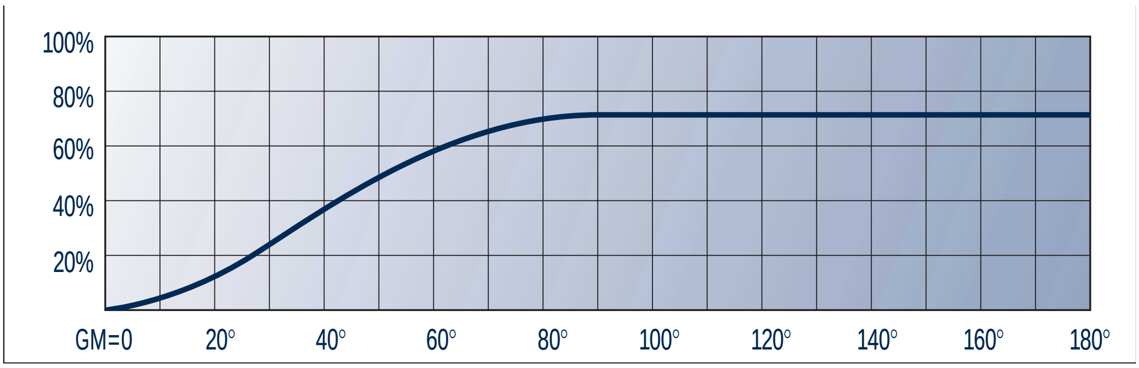


Figure 3. Zone flux diagram.

For narrow beam luminaires, a high flux percentage is obtained from small angles. This is the reason why the diagram will initially show a curve with a great slope for the first angles. From a certain angle onwards, it is virtually parallel to the abscissas axis. This is due to the fact that almost all flux is distributed in small angles, that is to say, it is concentrated in a small angle range.

For wide beam luminaires, the diagram will show a curve with a softer slope, since flux varies little by little, as the angle increases.

Glare diagram

These diagrams are based on the C.I.E. Glare Protection System. Curves representing these diagrams are of luminance limitation. Such curves cover a glare index scale (quality classes from A to E established by the C.I.E.) and different illuminance values in standard service.

Two diagrams must be used depending on luminaire type and orientation according to vision.

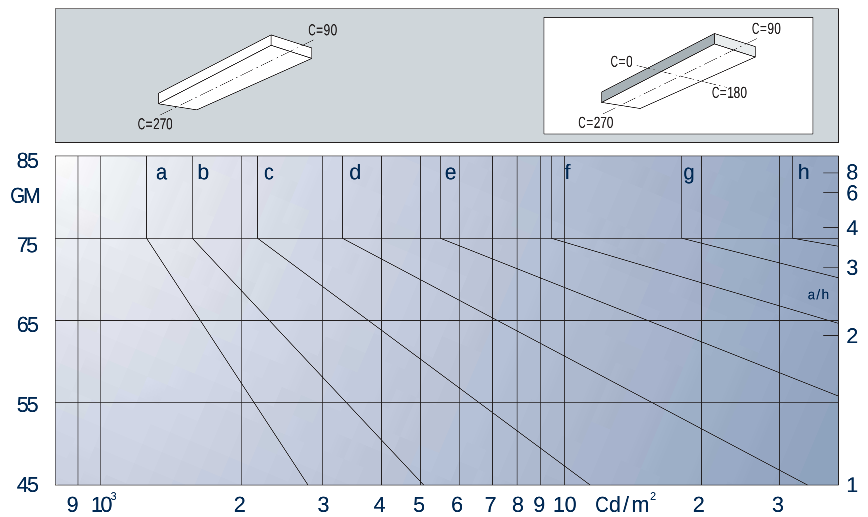
The required limitation of luminance depends on the luminaire type of orientation, shielding angle, acceptance degree or class quality, as well as on the value of the illuminance in service.

In Figs. 4a and 4b, diagrams of luminance curves for the evaluation of direct glare are shown. Diagram 1 is for those directions of vision parallel to the longitudinal axis of any elongated luminaire and for luminaires which lack luminous lateral panels, observed from any direction. Diagram 2 is for those directions of vision in right angles to the longitudinal axis of any luminaire with luminous lateral panels.

It is defined as:

- Luminous laterals: A luminaire has luminous laterals is it possesses a luminous lateral panel with a height of more than 30 mm.

- Elongated: A luminaire is elongated when the ratio between length and width of the luminous area is higher than 2:1.



G	Quality	Illuminance values in service E (lx)							
1.15	A	2000	1000	500	=<300				
1.50	B		2000	1000	500	=<300			
1.85	C			2000	1000	500	=<300		
2.20	D				2000	1000	500	=<300	
2.55	E					2000	1000	500	=<300
		a	b	c	d	e	f	g	h

Figure 4a. Glare diagrams.

G	Quality	Illuminance values in service E (lx)							
1.15	A	2000	1000	500	=<300				
1.50	B		2000	1000	500	=<300			
1.85	C			2000	1000	500	=<300		
2.20	D				2000	1000	500	=<300	
2.55	E					2000	1000	500	=<300
		a	b	c	d	e	f	g	h

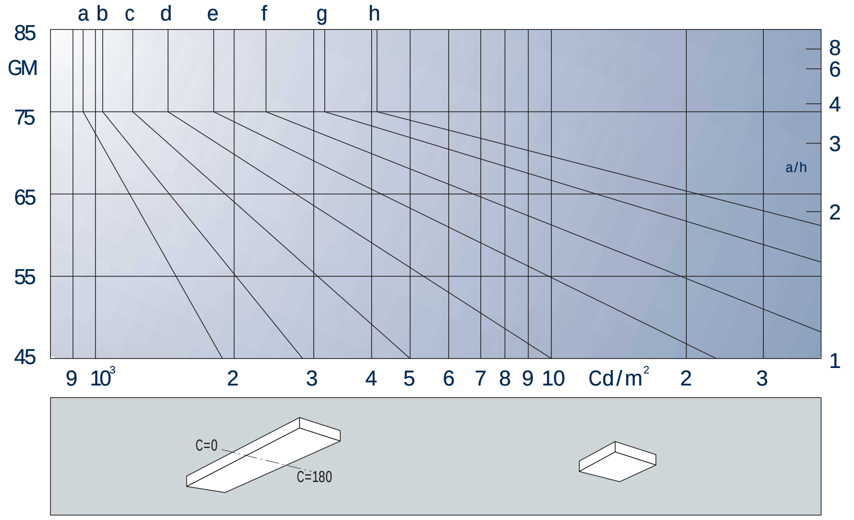


Figure 4b. Glare diagrams.

When using diagrams of Figs. 4a and 4b, luminance distribution of the luminaire in two vertical planes must be considered: the C_0 – C_{180} plane parallel to the inner axis. Luminance distribution of the luminaire in such a plane is used to control glare limitation in the longitudinal direction of the room. Distribution of the luminaire in the C_{90} – C_{270} plane is used to verify glare limitation in the transverse direction to the place to be illuminated.

When luminaires are mounted on the C_{90} – C_{270} plane parallel to the longitudinal inner axis, such a plane must be used to verify glare limitation in the longitudinal direction of the place, and luminance distribution on the C_0 – C_{180} plane to avoid glare limitation in the transverse way of the place.

For elongated luminaires, the C_{90} – C_{270} plane is chosen to coincide with (or parallel to) the longitudinal axis of the lamp/s. When such a plane is parallel to the direction of the perceived vision, it is said to be longitudinal. However, when the C_{90} – C_{270} plane is in right angles to the direction of vision, this vision is considered to be transverse.

These diagrams are generally used for indoor lighting luminaires.

7.5.2. Road lighting luminaires

Within this section, luminaires for parks and gardens as well as public road lighting are included. The first ones are frequently installed, as indicated by their name, in parks, gardens, residential areas, etc. The second ones are installed in urban roads, highways, tunnels, etc.

The C.I.E. has introduced a new system for the classification of road lighting luminaires, thus, substituting the system introduced in 1965, where the classification was cut- off, semi cut- off and non cut- off. Nevertheless, the old system is still being used in certain national recommendations for road lighting. In chart 7, the old system is shown.

Type of luminaire	Allowed value for maximum intensity emitted at an elevation angle of 80°	Allowed value for maximum intensity emitted at an elevation angle of 90°	Direction of maximum intensity inferior to
Cut – off	30 cd / 1 000 lm	10 cd / 1 000 lm*	65°
Semi cut – off	100 cd / 1 000 lm	50 cd / 1 000 lm*	76°
Non cut – off	Any		-

Chart 7. C.I.E. classification from 1965.

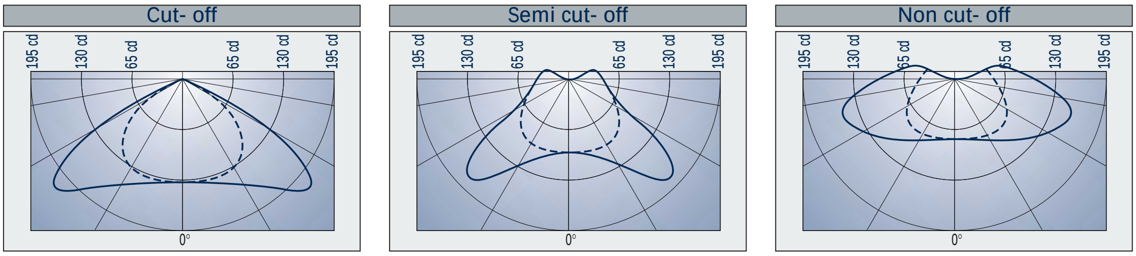


Figure 5. Examples of photometric curves accompanied by their classification.

The new C.I.E. luminaire classification, which substitutes the previous one, is based on three basic properties of luminaires:

1. The extension to which the luminaire light is distributed along a path: the “throw” of the luminaire.
2. The amount of lateral dissemination of light, widthways of a path: the “spread” of the luminaire.
3. The reaching of the installation to control glare produced by the luminaire: the “control” of the luminaire.

The reaching is defined by the angle γ_{max} which forms the axis of the beam with the vertical plane going downwards. The axis of the beam is defined by the direction of the angle bisector formed by two directions of 90% I_{max} in the vertical plane of maximum identity.

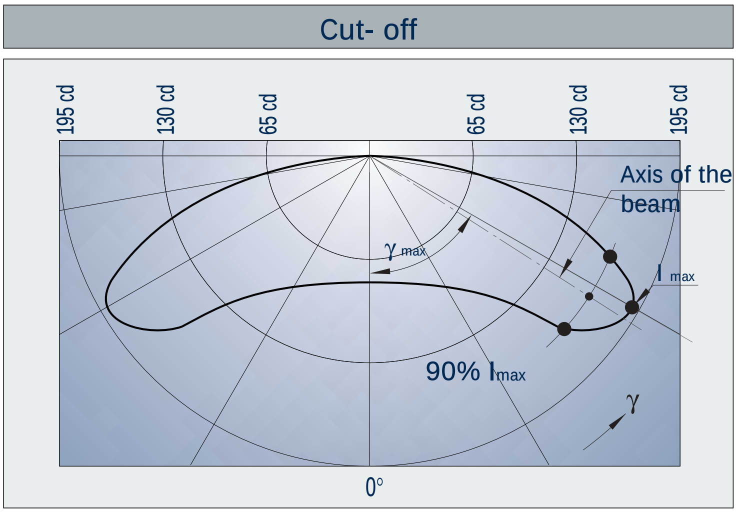


Figure 6. Intensity polar curve in the plane which contains the maximum luminous intensity, indicated by the angle used to determine the throw.

Three levels of throw are distinguished as follows:

$\gamma_{max} < 60°$: short throw.
$70° \geq \gamma_{max} \geq 60°$: intermediate throw.
$\gamma_{max} > 70°$: long throw.

* Up to a maximum absolute value of 1 000 cd.

The **spread** is defined by the positioning of the line, running parallel to the axis of the path. Virtually, it does not touch the furthest side from the 90% I_{max} on its path. The positioning of this line is defined by the γ_{90} angle.

The three levels of spread are defined in the following manner:

$\gamma_{90} < 45°$	: narrow spread.
$55° \geq \gamma_{90} \geq 45°$	: average spread.
$\gamma_{90} > 55°$	: broad spread.

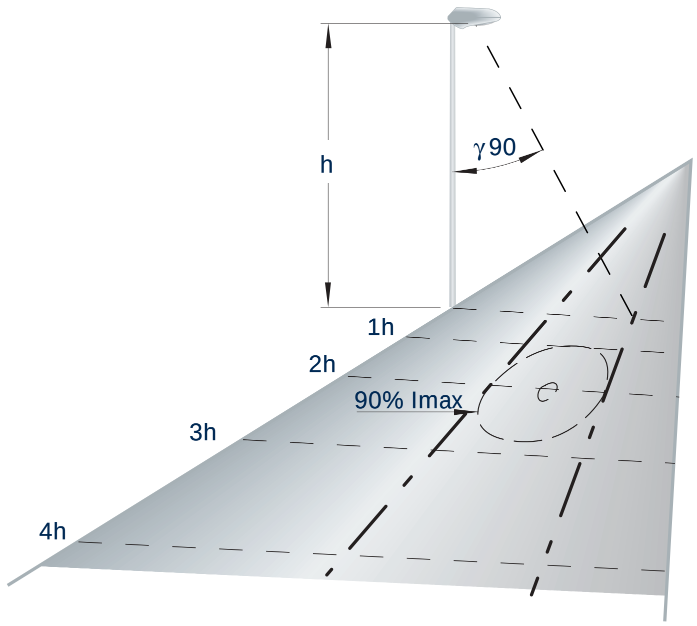


Figure 7. Spread.

Both the luminaire throw and spread may be more easily determined from an isocandela diagram in an azimuthal projection (Fig. 8).

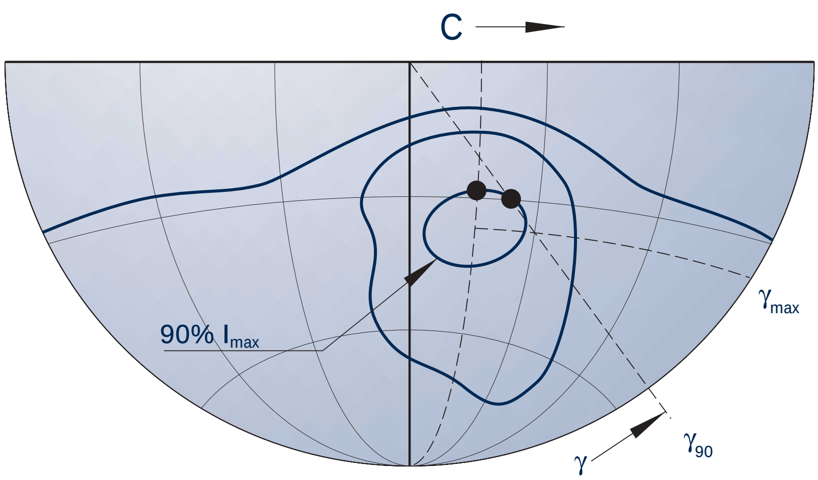


Figure 8. Isocandela diagram related to an azimuthal projection (sine wave) indicated by the γ_{max} and γ_{90} angles used to determine spread and throw.

In Fig. 9 the covering given by the three levels of throw and spread of the luminaire mounting height (h) is indicated on a plane of the path.

Control is defined by the specific index, the luminaire SLI. This is part of the G formula of glare control, determined only by the features of the luminaire.

$$SLI = 13.84 - 3.31 \cdot \log(I_{80}) + 1.3 \cdot \log\left(\frac{I_{80}}{I_{88}}\right)^{0.5} - 0.08 \cdot \log\left(\frac{I_{80}}{I_{88}}\right) + 1.29 \cdot \log(F) + C$$

where:

I_{80} = Luminous intensity at an elevation angle of 80°, in a parallel plane to the axis of the roadway (cd).

$\frac{I_{80}}{I_{88}}$ = Ratio between luminous intensities for 80° and 88°.

F = Light emission area for the luminaires (m^2) projected on the direction of the elevation at 76°.

C = Colour factor, variable according to lamp type (+0.4 for low pressure sodium and 0 for the others).

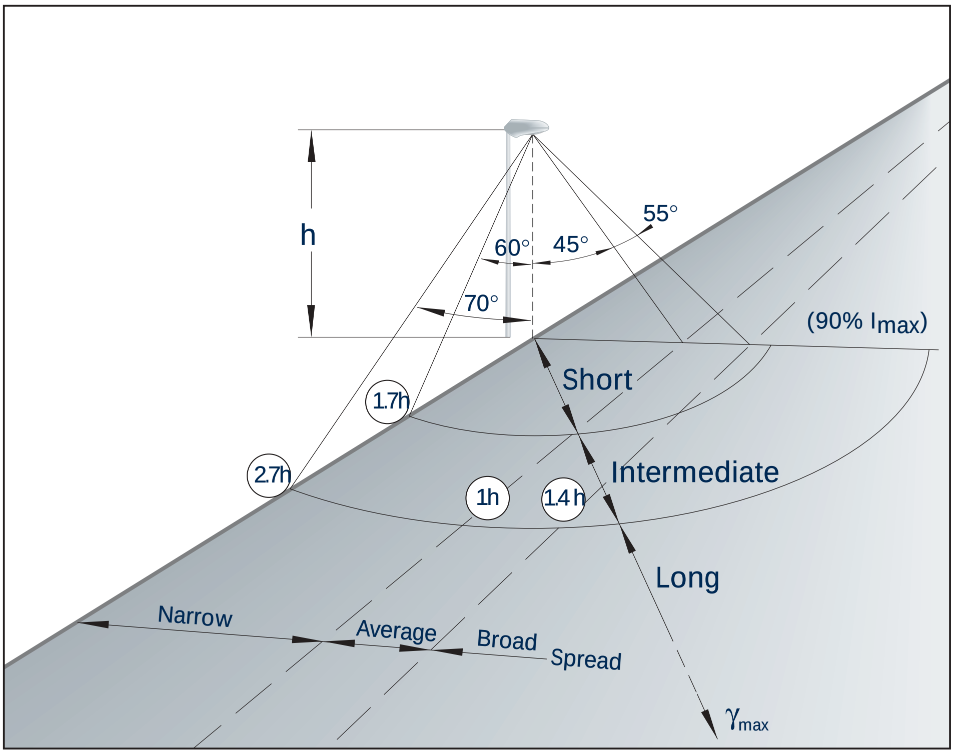


Figure 9. In this figure, the three degrees of throw and spread defined by the C.I.E. are shown, where "h" is the luminaire mounting height.

Control is also classified into three levels, which are the following:

- $SLI < 2$: limited control.
- $4 \geq SLI \geq 2$: moderate control.
- $SLI > 4$: tight control.

In the following chart, the C.I.E. previous definitions are summarised and shown.

Throw	Spread	Control
Short $\gamma_{max} < 60°$	Narrow $\gamma_{90} < 45°$	Limited SLI < 2
Intermediate $70° \geq \gamma_{max} \geq 60°$	Average $55° \geq \gamma_{90} \geq 45°$	Moderate $4 \geq SLI \geq 2$
Long $\gamma_{max} > 70°$	Broad $\gamma_{90} > 55°$	Tight SLI > 4

Chart 8. The C.I.E. classification system depending on luminaire photometric properties.

Photometric information accompanying road lighting luminaires

Diagrams of polar distribution curves

These curves are generally represented for the coordinate system C-γ. Since there are infinite planes, usually there are three C planes represented, which are the following:

- Transverse plane (C = 90° and 270°). This plane would be perpendicular to the axis of the road for a road lighting luminaire.
- Longitudinal plane (C = 0° and 180°). This plane would be parallel to the axis of the road for a road lighting luminaire.
- The plane in which maximum intensity is found. This plane is generally called main vertical plane.

Polar distribution curves are defined in cd by 1 000 lumens of flux emitted by each lamp and it is represented by cd/1 000 lm or cd/Klm.

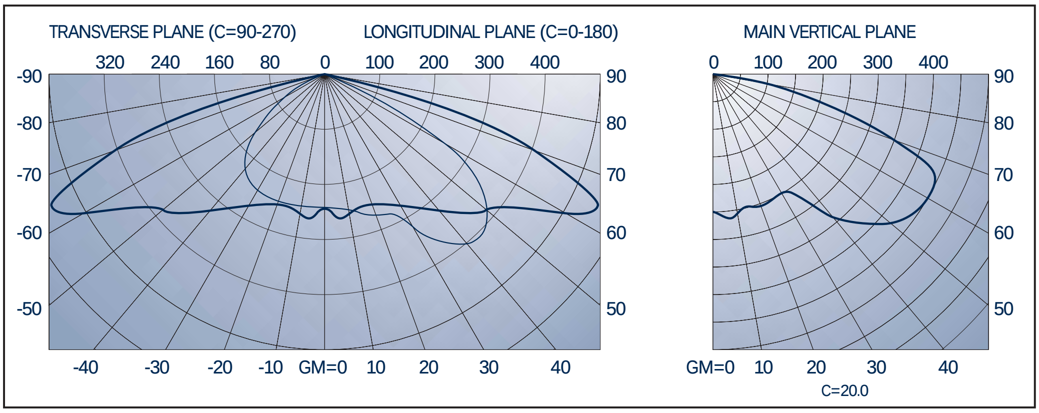


Figure 10. Polar diagram in the C-γ system.

Isocandela diagrams

It consists of imagining that the luminaire is in the center of a sphere; in its exterior surface equal intensity points are joined by a line. Equal surfaces in this diagram represent solid angles. Due to this reason, the diagram may be used to calculate luminous flux for a given area, multiplying the area by the luminous intensity (bearing in mind the scale in which the diagram is represented).

If the luminaire is installed with a δ inclination angle, strokes must be turned around the center in an angle δ to deduce the new C-γ coordinates.

Straight lines from the center represent parallel lines to the roadway axis.

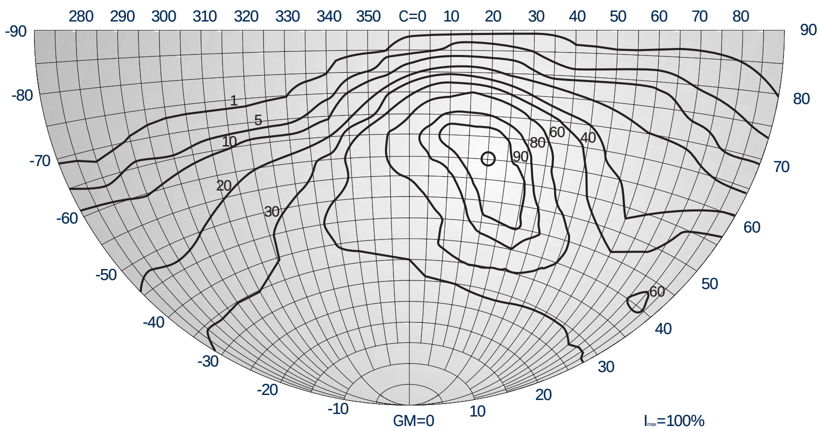


Figure 11. Isocandela diagram in azimuthal projection.

INDALUX

Diagram of isoluminance curves

These diagrams are frequently used for public lighting. This is due to the fact that recommendations for public lighting are not exclusively limited to the average luminance required on the surface of the roadway, but also guidelines for their uniformity (ratio between L_{max} and L_{min}) are provided. Such calculations are possible with the help of the isoluminance diagram (Fig 12).

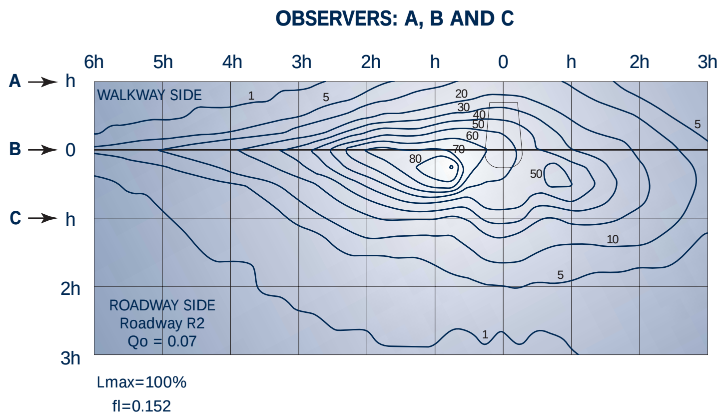


Figure 12. Isoluminance diagram.

In the diagram, letters A, B and C appear, indicating three positions for the observer which are used in luminance performance diagrams.

Diagram of isolux or isoilluminance curves

In practice, illuminances on the road surface and their total distribution are intended to be known in most lighting projects.

In order to ease the determination of these data in an installation, photometric sheets provide us with the isolux relative curves for each luminaire on an illuminated plane.

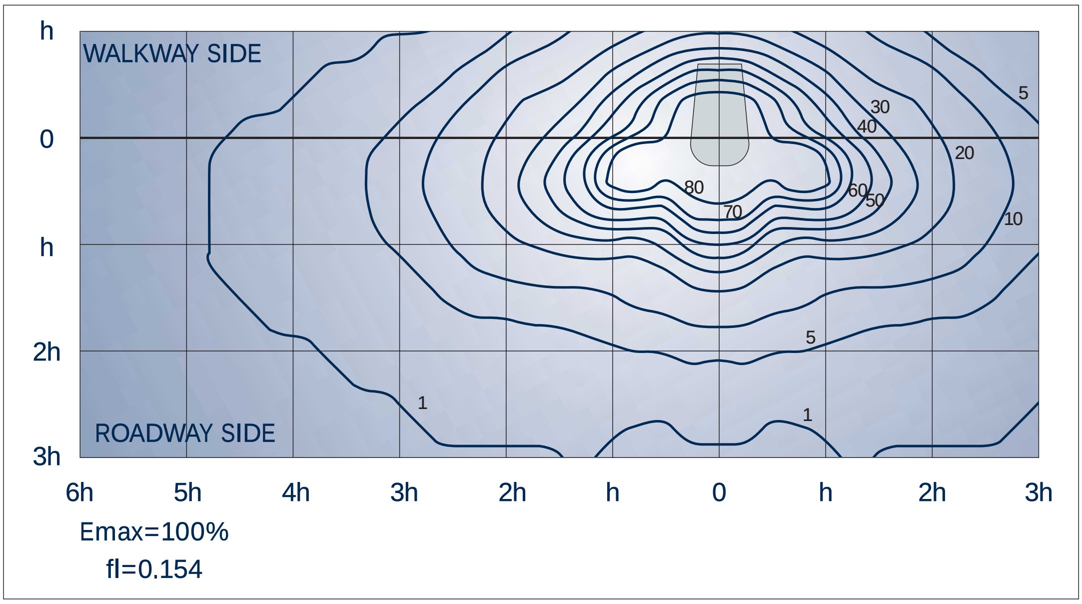


Figure 13. Isolux diagram on the surface to be illuminated.

Values for each isolux line are given in E_{max} percentages, the highest being 100%. The lattice on which isolux lines are drawn is measured in terms of the luminaire mounting height *h*.

Under the diagram, a factor for the luminaire in use (φ) is indicated.
Maximum illuminance is calculated by means of the following formula:

$$E_{max} = \frac{\varphi \cdot \Phi}{h^2}$$

where:

φ = factor for the luminaire in use.

Φ = lamp luminous flux.

h = interdistance between luminaires.

Performance in luminances

These diagrams are used to calculate average luminance on the surface of the roadway of a public lighting installation. If the pavement reflection class is known, the corresponding diagram will be used.

Luminance performance diagrams are drawn in units of luminaire mounting height. Due to this reason, they are very useful for direct graphic uses.

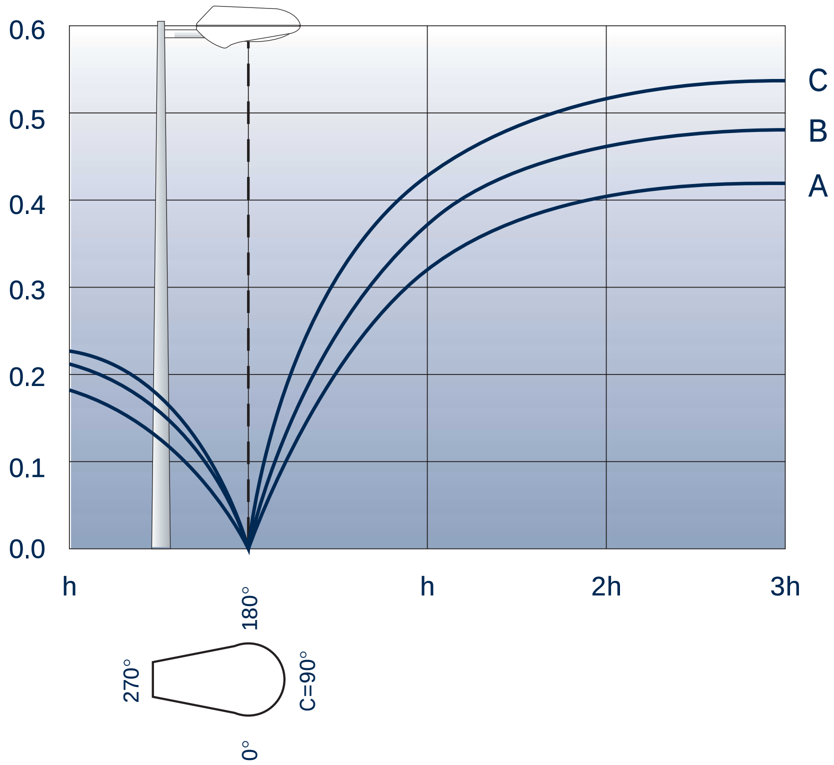


Figure 14. Performance in luminances with respect to three observers.

Their reading is equal to that of utilization factor curves, except that the observer's position is important. Hence, curves are given for three observer's positions: A, B and C.

- A: Observer located on a side of the sidewalk at a distance h of the row of luminaires.
- B: Observer located in line with the row of luminaires.
- C: Observer located on a side of the road at a distance h of the row of luminaires.

For other positions, it is necessary to interpolate.

Average luminance is calculated with the following formula:

$$L_{max} = \frac{\eta_L \cdot \Phi \cdot Q_o}{w \cdot s}$$

where:

- η_L = luminance performance factor.
- Φ = lamp luminous flux.
- Q_O = average luminance coefficient.
- w = road width.
- s = interdistance between luminaires.

Utilization factors

In road lighting, utilization factor (h) is defined as the fraction of the luminous flux coming from a luminaire which, in fact, reaches the road. Utilization factor curves found on the photometric information sheets offer a simple method to calculate average illumination, which may be determined for a certain transverse section of the road.

$$\eta = \frac{\Phi_{used}}{\Phi_{lamp}}$$

Utilization factor curves for a luminaire are understood as a function of transverse distances, measured in terms of h (mounting height) on the road surface, from the center of the luminaire up to each of the two curves (Fig. 15).

Figure 15. Utilization factor as a function of h.

The easiest and quickest way to calculate average illuminance of a straight road of infinite length is by using utilization factor curves:

$$E_{med} = \frac{\eta \cdot \Phi \cdot n}{w \cdot s}$$

where:

- η = utilization factor.
- Φ = lamp luminous flux.
- n = number of lamps per luminaire.
- w = width of the road.
- s = interdistance between luminaires.

Polar diagrams are frequently used for luminaires in:

- Public lighting.
- Lighting of parks and gardens.

7.5.3. Floodlight luminaires

Within this section, those luminaires designed for installation in indoor and outdoor sports facilities, facades, working areas, invigilance areas, etc.

A *floodlight* is a luminaire which concentrates the light in a solid angle determined by an optical system (mirrors or lenses), in order to achive a high luminous intensity.

Lamps suitable for floodlights range from pressed glass lamps and halogen lamps and even high pressure mercury lamps, metal halide lamps and low pressure and high pressure sodium lamps. They all have different voltages and each provides a kind and special type of light, colour effects and efficiency.

Mounting, relamping and cleaning must be done at a considerable height from the ground. Thus, an ergonomic design of the luminaire is required so that these tasks are easily taken care of.

From the point of view of light distribution, floodlights are grouped in three basic types: symmetric, asymmetric and symmetric rotation.

Floodlights are also classified according to the opening of the beam, as shown in chart 9. The opening of a floodlight beam (or beam angle) is defined as the angle, in a plane which contains the axis of the beam, on which luminous intensity decreases to reach a certain percentage (generally 50% or 10%) of its peak value (Fig. 16).

Description	Opening of the beam (at 50% I_{max})
Narrow beam	< 20°
Medium beam	20° to 40°
Wide beam	> 40°

Chart 9. Classification of the beam opening.

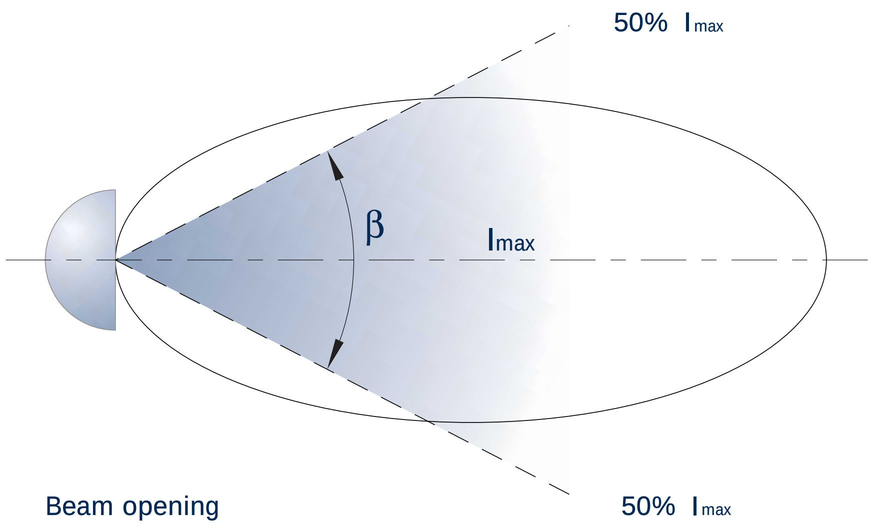


Figure 16

For a floodlight with an intensity distribution of light in a symmetric rotational way (that is to say, distribution remains unchanged independently from the plane containing the axis of the beam under consideration), a figure for the opening of the beam may be established, for example 28° at both sides of the axis of the beam.

For asymmetric distribution, as that given by rectangular fllodlights, two figures are given: for example 6°/24°, since the beam is spread into two symmetric perpendicular planes (vertical and horizontal, respectively). Sometimes, distribution in the vertical plane of such floodlights is asymmetric in relation to the beam axis. In this kind of situation, two figures are given for the opening of the beam in this plane: for example, 5º - 8º/24º, that is to say, 5º above and 8º below the axis of the beam; and, in the horizontal plane, 12º to the left and 12º to the right of the beam.

Photometric information accompanying floodlights

Cartesian diagram

These diagrams are obtained in photometries performed on floodlights, since they provide us with information to be able to classify them according to beam opening They are generally represented under the coordinate system B-β.

Three lines representing the vertical plane, the horizontal plane and 50% of the maximum intensity (line parallel to the abscissas axis) are represented.

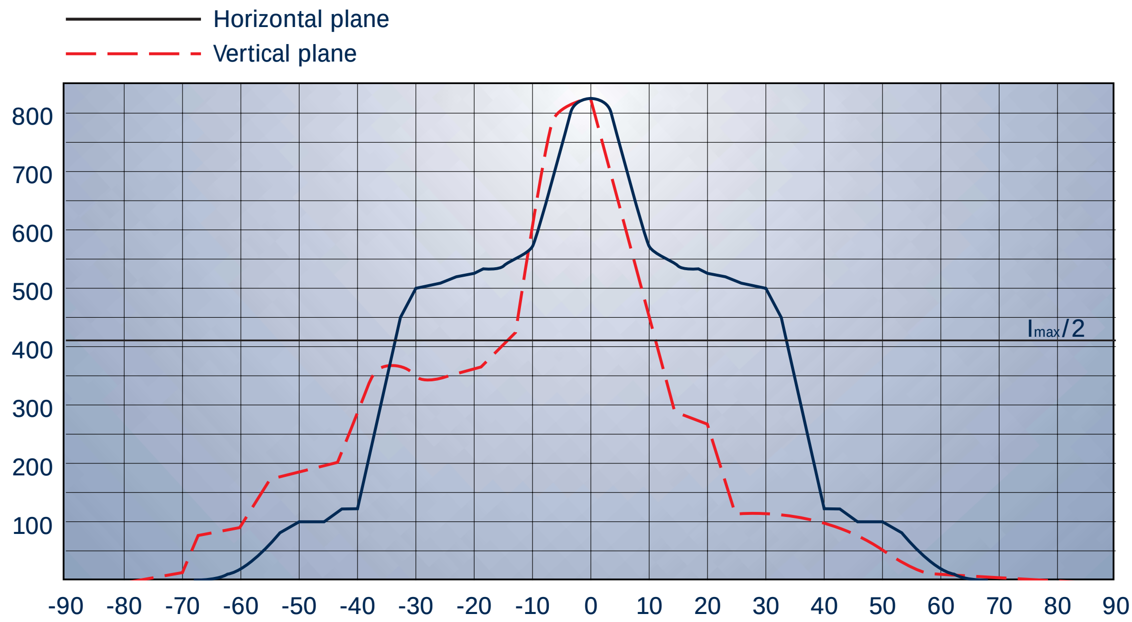


Figure 17. Cartesian diagram.

Isocandela diagram

In order to avoid coordinate curves, as it happens with solid angle systems, and ease the reading of coordinates, these are drawn in a rectangular system.

The angles of C and B planes are on the horizontal axis, γ and β angles on the vertical one.

The diagram may be compared with that of azimuthal projection, but, it must be taken into account that:

- There is no linear ratio between rectangles in the diagram and solid angles.
- The line γ = 0 or β = 0, in fact, represents a point.

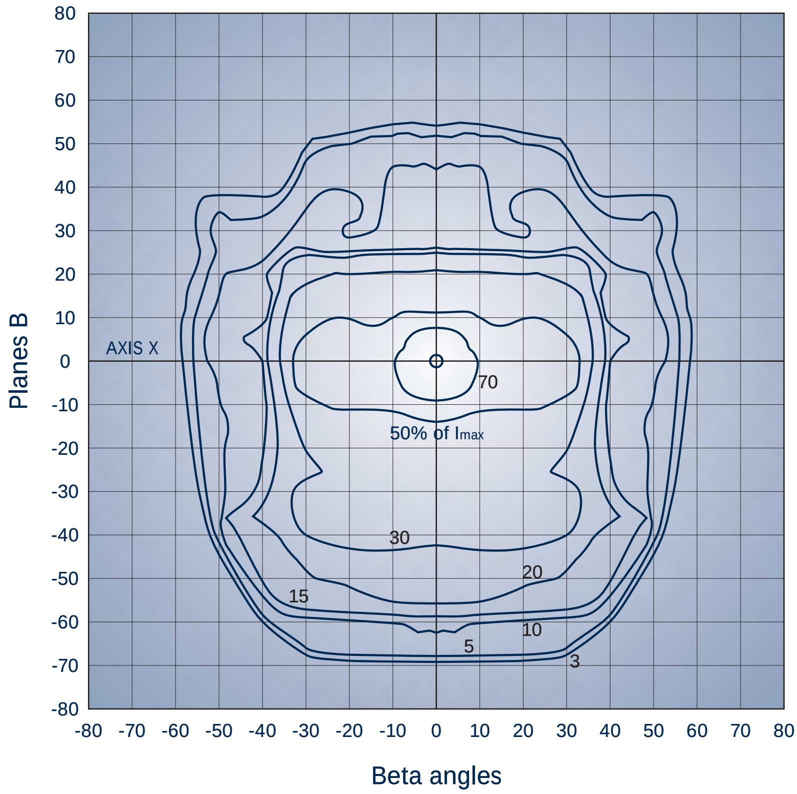


Figure 18. Isocandela diagram for the B-β system.

7.6. Basic photometric data

Luminaire information sheets show a series of diagrams which indicate their photometric peculiarities. In this section two terms associated to the obtention of such curves are going to be studied.

7.6.1. Photometric center

Most calculations are done under the supposition that luminaires are specific sources of light. Thus, there is the need to search for a point in space limited by the luminaire which will place the specific equivalent and imaginary luminous source.

For angles close to the nadir, there are virtually no differences between photometric data of the same luminaire given by different measurement laboratories. For big angles, there could be differences, for example 80º and 88º, if the photometric center of a luminaire is not clearly established.

The photometric center is a point of a luminaire or a lamp from which the Law of the inverse square of the distance in the direction of maximum intensity is best complied. Or what is the same, it is the point where the imaginary and specific luminous source, with the same spatial distribution of luminous intensities of the luminaire is located. The only goal is to simplify photometric calculations.

The C.I.E. has established in its publications the rules to locate such a photometric center for different types of luminaires.

7.6.2. Photometric coordinate systems

Each and every one of the directions in the space through which luminous intensity is radiated is determined by two coordinates. On photometric information sheets for indoor luminaires, public lighting and floodlights, representations obtained by means of three coordinate systems, the most frequently used, are utilized. Such systems are A-α, B-β and C-γ.

The C-γ coordinate system is defined in the C.I.E. publications. However, there is no international agreement on the definition of the systems A-α and B-β. Tests for obtaining the last two differ depending on the country that conducts them.

When applied to the photometry of these types of luminaires, the reference axis is always vertical and directed towards the lowest point (nadir).

All systems have a beam of planes with an intersection axis, sometimes called “rotation axis”.

In each case, a direction in space is characterized by an angle measured between two planes and an angle measured in one of the planes.

Systems differ between themselves with regards to axis orientation of the intersection in space in relation to the luminaire axis.

To test floodlights, systems adapted to the horizontal axis are used, but their name varies in different countries.

7.7. Luminaire efficiency

Luminaire efficiency is expressed in terms of its *Light Output Radio* – l.o.r.)*. This radio is defined as the portion of light output of the luminaire with regard to the sum of light individual exits of lamps when they are used outside the luminaire.

The light output radio defined this way is the total “l.o.r.” of the luminaire, and is equal to the sum of the “l.o.r.” upwards and downwards.

* The term used in the U.S.A. is “luminaire efficiency”.