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THE PHOTOMETRY AND GONIOPHOTOMETRY OF LUMINAIRES

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FOREWORD

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THE PHOTOMETRY AND GONIOPHOTOMETRY OF LUMINAIRES

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The Photometry and Goniophotometry of Luminaires

SUMMARY

This technical report provides general requirements for the photometry of luminaires of most types and includes the following information:

- standard test conditions under which the tests should be carried out, with acceptable practical tolerances;
- selection procedures for lamps and luminaires;
- procedures for measurement of the photometric characteristics of luminaires and assessment of the possible sources of error;
- correction factors and service conversion factors;
- presentation of test results.

The report is considered to be sufficiently comprehensive to form a practical guide for industrial laboratories and contains sufficient information to replace publication CIE 24-1973 "Photometry of indoor type luminaires" and CIE 27-1973 "Photometry of luminaires for street lighting". CIE will publish supplementary reports covering these types of luminaires more specifically.

Photométrie et goniophotométrie des luminaires

RESUME

Le présent rapport technique formule les exigences photométriques générales pour différents types de luminaires et comprend les informations ci-après:

- les conditions d'essai normalisées à adopter pour la réalisation des essais, avec les tolérances pratiques acceptables;
- les procédures de sélection de lampes et luminaires;
- les procédures de mesure des caractéristiques photométriques de luminaires et les sources d'erreur possibles;
- les facteurs de correction et les facteurs de conversion en service;
- la présentation des résultats d'essais.

Le rapport est considéré comme une synthèse pouvant constituer un guide pratique pour les laboratoires industriels et contient suffisamment d'informations pour remplacer les publications CIE 24-1973 "Photometry of indoor type luminaires" et CIE 27-1973 "Photometry of luminaires for street lighting". Il est toutefois de l'intention de la CIE de publier des rapports complémentaires couvrant plus spécifiquement ces types de luminaire.

Photometrie und Goniophotometrie von Leuchten

ZUSAMMENFASSUNG

Die allgemeinen Anforderungen in diesem technischen Bericht beziehen sich auf Photometrie vieler Typen von Leuchten. Die folgende Information ist also eingeschlossen:

- die für die Prüfung erforderlichen normierten Bedingungen, zugleich mit den im Betrieb annehmbaren Begrenzungen;
- Auswahlverfahren für Lampen und Leuchten;
- Prozeduren für Messungen der photometrischen Eigenschaften und zugleich mögliche Fehlerursachen;
- Korrekturfaktoren und Umsetzungsfaktoren im Betrieb;
- Darstellung der Prüfergebnisse.

Der Bericht bildet eine Synthese und ist deshalb als praktische Anleitung für industrielle Laboratorien geeignet. Er enthält genügend Informationen, um die Publikationen CIE 24-1973 "Photometry of indoor type luminaires" und CIE 27-1973 "Photometry of luminaires for street lighting" zu ersetzen. Die CIE wird jedoch noch ergänzende Berichte veröffentlichen, die diese Leuchtentypen genauer behandeln.

1. INTRODUCTION

1.1 Scope

This report covers general requirements for the photometry of luminaires which are considered to be applicable to most types of luminaire.

The report sets out to provide specifications for the standard conditions under which photometric tests should be carried out and to recommend testing procedures which will give sufficiently accurate and reproducible results when determining and reporting the photometric characteristics of luminaires. These specifications are intended to provide a basis for uniform national standards and to give guidance to photometric laboratories in the conduct of tests and in the presentation of luminaire performance data. The report also gives specifications for the measurement of correction factors applicable to luminaires operated under practical test conditions different from the standard test conditions.

Detailed descriptions of photometric methods are primarily of value to laboratory personnel and engineers, but are also important to users of the data. Proper interpretation of data often depends on a full knowledge of the testing procedures involved and this report also sets out to provide the user with the information needed to understand photometric testing procedures and data presentation.

Where there is felt to be a need for specific recommendations relating to the measurement and data presentation requirements of particular types of luminaire designed for specialist applications, which could not be covered in a general report of this kind, it is intended that the need shall be met by the publication of a number of supplementary technical reports. These supplementary reports will refer back to the appropriate sections in the present report, and will define, where necessary, special requirements and measurement conditions.

For types of luminaire not covered by a specific report, the requirements of the most appropriate report, together with this general report may be used as a guide to the test procedures to be employed.

1.2 Photometric characteristics

Photometric characteristics can be divided into measured characteristics, i.e. those directly measured with laboratory instruments, and derived characteristics, i.e. characteristics which can be calculated from the measured ones. The derived characteristics are more closely related to lighting applications. This report deals mainly with measured photometric characteristics.

2. TERMINOLOGY

Only definitions of immediate interest are included. The terminology used in this report is preferred, but some of the terms may be found in other publications under different names. These other names are given in square brackets.

For other relevant definitions see Publication CIE/IEC 17.4-1987 [1].

2.1 Terms related to the luminaire

2.1.1 Luminaire

Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for supporting, fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electricity supply.

2.1.2 Design attitude (of a luminaire) [also tilt normal in application]

The attitude in which a luminaire is designed to operate (as determined by reference to the manufacturer's instructions or to common practice).

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2.1.3 Measurement attitude (of a luminaire) [also tilt during measurement]

The attitude in which a luminaire is measured.

Note: If not otherwise indicated, assumed to coincide with the design attitude.

2.1.4 Light centre (of a source)

Point used as origin for photometric measurements and calculations.

2.1.5 Photometric centre

The point in a luminaire or lamp from which the photometric distance law operates most closely in the direction of maximum intensity.

Note: This is a term widely used in national standards specifications relating to luminaire photometry. For bare lamps it is equivalent to the International Lighting Vocabulary definition light centre.

2.1.6 First axis (of a luminaire) [also reference axis]

An axis containing the photometric centre, used in photometric measurements as a reference direction to correlate the photometric measurements with the attitude of the luminaire.

2.1.7 Second axis (of a luminaire) [also auxiliary axis]

An axis containing the photometric centre, perpendicular to the first (reference) axis, linked to the luminaire and used together with the first axis for defining the attitude of the luminaire.

Note: The identification of the first axis and the second (auxiliary) axis must be defined by the manufacturer or, if not, by the photometric laboratory.

A third axis is also used in defining the attitude of a luminaire : it is the axis containing the photometric centre and perpendicular to the two first axes.

2.1.8 Practical ballast

A ballast which is representative of the range of production ballasts appropriate to the luminaire and lamp(s) under test.

2.2 Terms related to measured quantities for luminaires**2.2.1 Luminaire data per 1 000 lm (of lamp flux)**

Photometric data of a luminaire relative to a total theoretical luminous flux of 1 000 lm from all the lamps of the luminaire, when these are operated outside the luminaire under reference conditions but with the same ballast(s).

2.2.2 Luminous intensity distribution (of a luminaire)

The distribution of luminous intensity with direction. The luminous intensity distribution may be represented by numerical tables or by graphics and is usually expressed in units of candelas per 1 000 lm of lamp flux.

2.2.3 Ballast lumen factor

Ratio of the luminous flux emitted by a reference lamp when operated with a practical ballast at the rated voltage of the ballast to the luminous flux emitted by the same lamp when operated with its reference ballast.

Abbreviation: BLF

2.2.4 Light output ratio (of a luminaire) [luminaire efficiency (USA)]

The ratio of the luminous flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment under specified conditions.

Abbreviation: *LOR*

Note : Specified practical conditions are normally the standard test conditions as described under 4.2. If different, the practical conditions should be specified.

The luminous fluxes of the lamp(s) outside the luminaire are those obtained with the lamp position and the lamp operating temperature for which the lamp catalogue data are published.

2.2.5 Light output ratio working (of a luminaire)

The ratio of the luminous flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire under reference conditions and with a reference ballast.

Abbreviation: *LORW*

Note: $LORW = LOR \times BLF$; *LOR* is preferred to *LORW* as most luminaires can be delivered with different ballasts characterised by their *BLF*.

2.2.6 Upward (downward) flux fraction (of a luminaire)

The fraction of the total luminous flux of a luminaire emitted above (below) the horizontal plane containing the photometric centre of the luminaire.

Abbreviation: *UFF (DFF)*

2.2.7 Upward (downward) light output ratio (of a luminaire)

The product of the light output ratio of a luminaire and the upward (downward) flux fraction. The light output ratio may be the light output ratio or the light output ratio working as appropriate.

Abbreviation: *ULOR (DLOR)*

2.2.8 Average luminance (of a luminaire)

The luminous intensity per unit projected luminous area in a given direction of a luminaire.

2.2.9 Service conversion factor

Factor to convert photometric data related to the standard test conditions to data related to service conditions which differ from the standard conditions.

2.3 Terms related to measurements**2.3.1 Absolute measurement**

A measurement scaled in the appropriate SI units.

2.3.2 Relative measurement

A measurement obtained as a ratio of two quantities of the same type expressed in arbitrary units or a measurement in SI units relative to specified bare lamp flux.

2.3.3 Bare lamp measurement

A measurement in which a lamp is photometered separately from a luminaire in order to determine light output ratio or luminaire data per 1 000 lm of lamp flux.

2.3.4 Reference conditions (luminaire)

The conditions under which photometric measurements on luminaires are performed in accordance with the provisions of chapter 4 of this report.

2.3.5 Reference conditions (lamps)

The conditions under which lamp flux is measured in accordance with the provisions of the appropriate IEC Lamp Specification [5-11].

2.3.6 Reference ballast

A special inductive type ballast designed for the purpose of providing a comparison standard for use in testing ballasts, for selection of reference lamps and for testing regular production lamps under standardised conditions.

Note: The electrical parameters of reference ballasts for each type of lamp are given in the appropriate IEC Lamp Specification [5-11] but the electrical requirements are given in the appropriate IEC Ballast Specifications [12-16].

2.4 Terms related to measuring instruments**2.4.1 Photometer**

Instrument for measuring photometric quantities.

2.4.2 Goniophotometer [also distribution photometer]

Photometer for measuring the directional light distribution characteristics of sources, luminaires, media or surfaces.

2.4.3 Photometer head

That part of the goniophotometer comprising the photometer itself (normally a silicon photodiode with colour filters for the spectral correction of the detector responsivity). It may also contain means for the directional evaluation of the light (e.g. diffusing windows, lenses, apertures). The photometer converts the incident light into an electrical quantity.

2.4.4 Illuminance meter

Photometer for the measurement of illuminance.

3. CO-ORDINATE SYSTEMS FOR THE PHOTOMETRY OF LUMINAIRES**3.1 General aspects**

The basic photometric data of a luminaire consist of a set of values of the luminous intensity in different directions, produced by direct photometric measurements.

Measurements of intensity distribution involve photometric and angular measurements (the goniophotometer), under controlled working conditions of the luminaire (electrical and temperature measurements).

For such photometric measurements involving direction, it is necessary to define a spatial framework around the luminaire (the co-ordinate system).

3.2 Basic goniophotometers

For the measurements of the luminous intensity in different directions, the luminaires are mounted in a goniometer to facilitate the positioning at definite angles. A goniophotometer usually consists of a mechanical device for the support and positioning of the luminaire or lamp and the photometer head, together with associated devices for acquiring and processing data.

Basically, three types of goniophotometer can be distinguished.

- A goniophotometer which rotates the luminaire around two mutually perpendicular axes whose intersection is the photometric centre of the goniophotometer. This type of goniophotometer is normally used with a single photometer head positioned at an adequate distance from the centre.
- A goniophotometer which rotates the luminaire around one axis only, the second rotation being given by a relative movement between the luminaire and the photometer head around a second axis at right angles to the first and crossing it at the photometric centre of the goniophotometer.
- A goniophotometer in which the luminaire does not move at all. The photometer head rotates around two mutually perpendicular axes whose crossing is the photometric centre of the goniophotometer.

Note : In the first type, the burning position of the lamp changes continuously during measurements which restricts the use of this type of goniophotometer.

In the second type, the burning position of the lamp is the burning position considering the normal use of the luminaire even if the luminaire moves in space or rotates during measurements

Since practical considerations limit the overall dimensions of the two last types of goniophotometer, the use of mirrors to increase the light path between the photometer head and the luminaire, or the use of a luminance meter of appropriate dimensions as a detector, is usually adopted with these types of goniophotometer. Mirrors may also be used to maintain the photometer in a fixed position.

The three basic types of goniophotometer listed above can be used in a variety of configurations, each one fitting a particular purpose. Differences lie in the mounting position of the goniophotometer with respect to the ground, in the orientation of the reference axis with respect to the goniophotometer, and in the way in which the luminaire is mounted in the goniophotometer.

Principles of construction and selection of goniophotometers are covered in publication CIE 70 1987[17].

3.3 The co-ordinate system

The determination of the intensity distribution of a luminaire in space involves the use of a co-ordinate system to define the direction in which the intensity measurements are made. The system used is a spherical co-ordinate system with the centre coincident with the photometric centre of the luminaire.

From a general point of view the co-ordinate system consists of a set of planes with a single axis of intersection. A direction in space is characterised by two angles:

- the angle between one half-plane, taken as an origin, and the half-plane containing the direction considered,
- the angle between the axis of intersection and the direction considered or the complement of this angle.

The orientation of this system with respect to the first (or reference) axis and the second (or auxiliary) axis of the luminaire is chosen with particular regard to the type of luminaire, the type of lamp, the mounting attitude of the luminaire and its application, in order to perform more accurate measurements or to simplify the consequent lighting calculations.

Current practice has limited the possibilities to a finite number of orientations. The axis of the intersection should be either vertical or horizontal; in the latter case the axis may be perpendicular to, or coincident with, the second axis of the luminaire.

3.4 Systems of measurement planes

In general the luminous intensity of a luminaire is measured in a number of planes. From the variety of possible measurement planes three systems of planes have proven specially useful.

3.4.1 A-planes

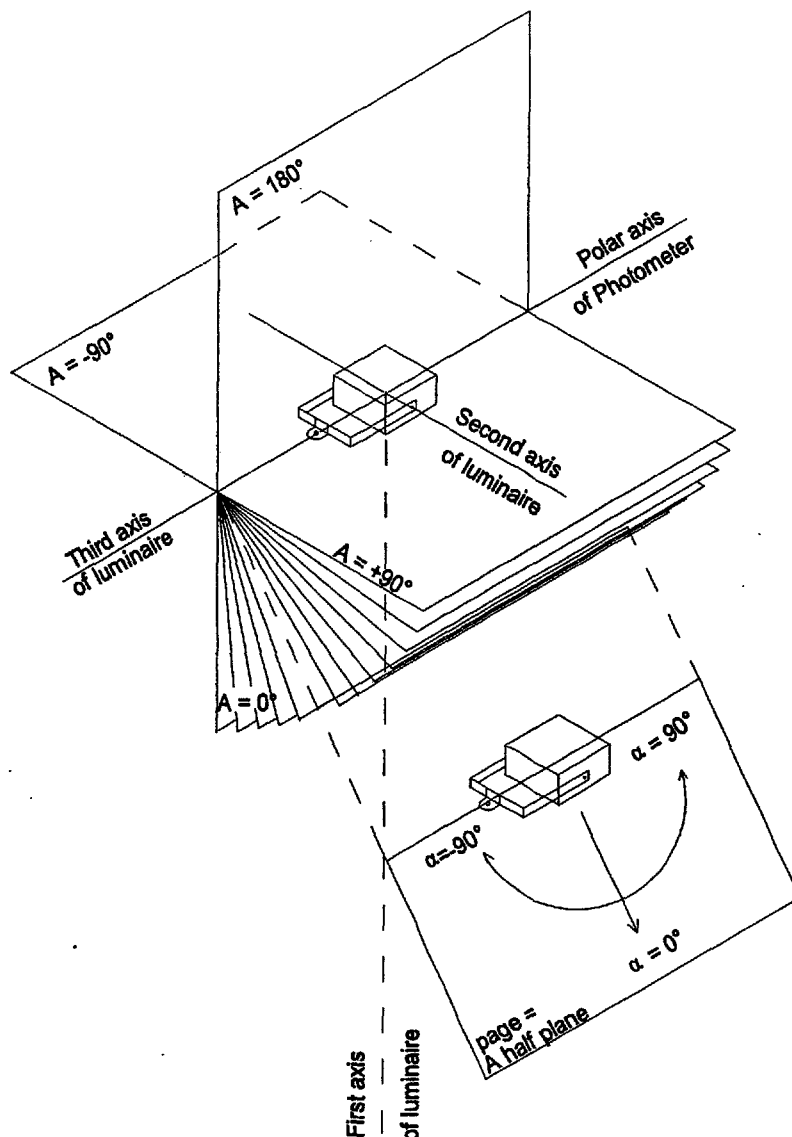


Figure 1. Luminaire orientation for A, α goniophotometry.

The system of A-planes is the group of planes for which the line of intersection (polar axis) goes through the photometric centre and is perpendicular to the plane containing the first and the second axes of the luminaire.

The system of A-planes is coupled rigidly to the luminaire and follows its tilt if the luminaire is tilted. The first axis is the axis going through the photometric centre and perpendicular to the light emitting area. It lies in the $A = 0^\circ$ half-plane, usually in the direction $\alpha = 0^\circ$. The second axis also passes through the photometric centre of the luminaire and is perpendicular to $A = 0^\circ$ plane.

Some types of goniometer provide data in this system and are used in the photometry of interior lighting luminaire. The conversion formulas given in 3.4.4 are applicable if the third axis of the luminaire (coincident with the polar axis) is the long axis of the luminaire.

3.4.2 B-planes

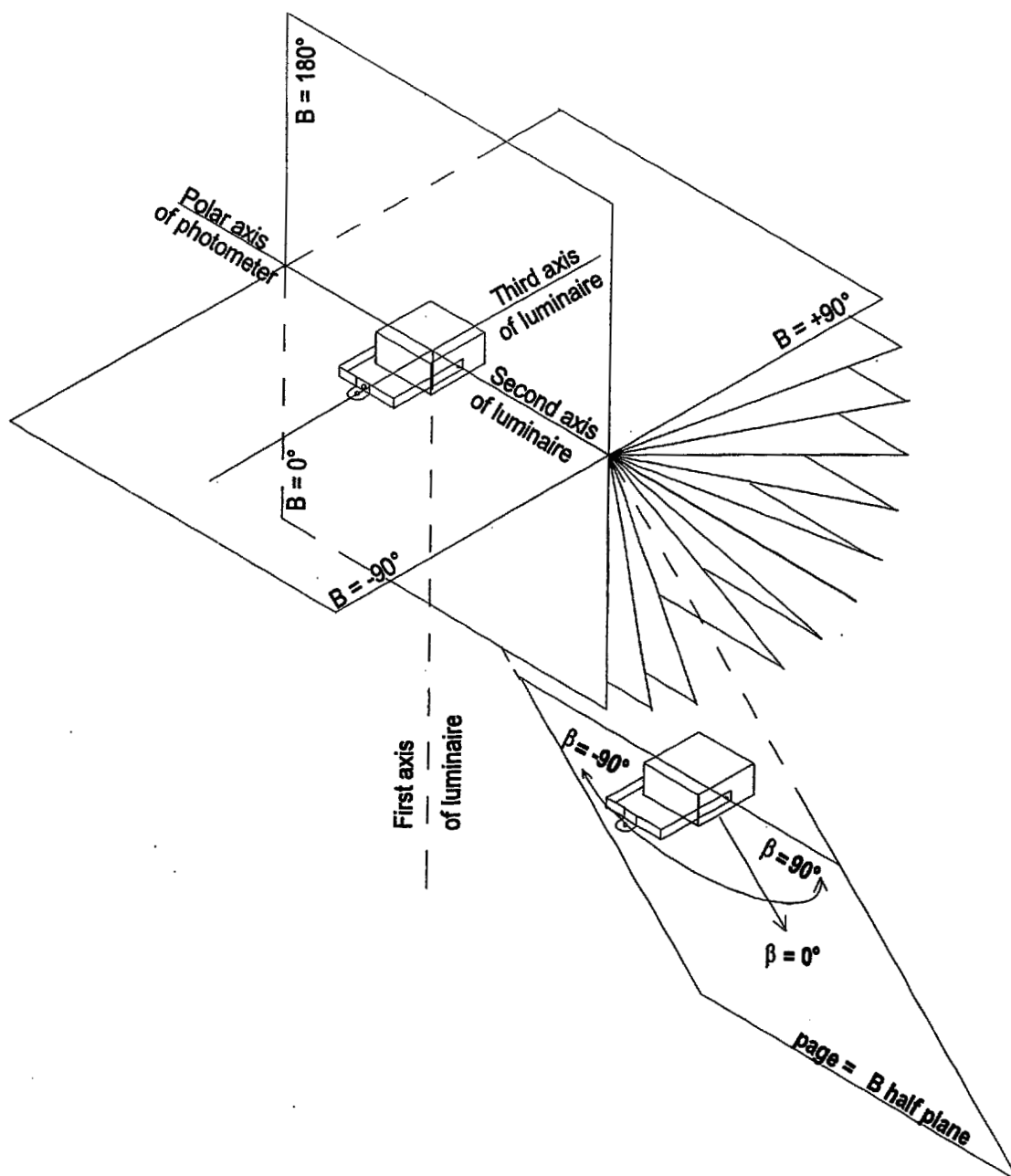


Figure 2. Luminaire orientation for B, β goniophotometry.

The system of B-planes is the group of planes for which the line of intersection (polar axis) goes through the photometric centre and is parallel to the second axis of the luminaire.

The system of B-planes is coupled rigidly to the luminaire and follows its tilt if the luminaire is tilted. The first axis is the axis going through the photometric centre and perpendicular to the light emitting area. It lies in the $B = 0^\circ$ half-plane, usually in the direction $\beta = 0^\circ$. The second axis is coincident with the line of intersection of the B-planes.

The system is commonly used in the photometry of floodlights. However the reference axis, perpendicular to the light emitting area, is often set horizontal and a variant of this system (V,H system) may be used. See Publication CIE N° 43, 1979 [18].

3.4.3 C-planes

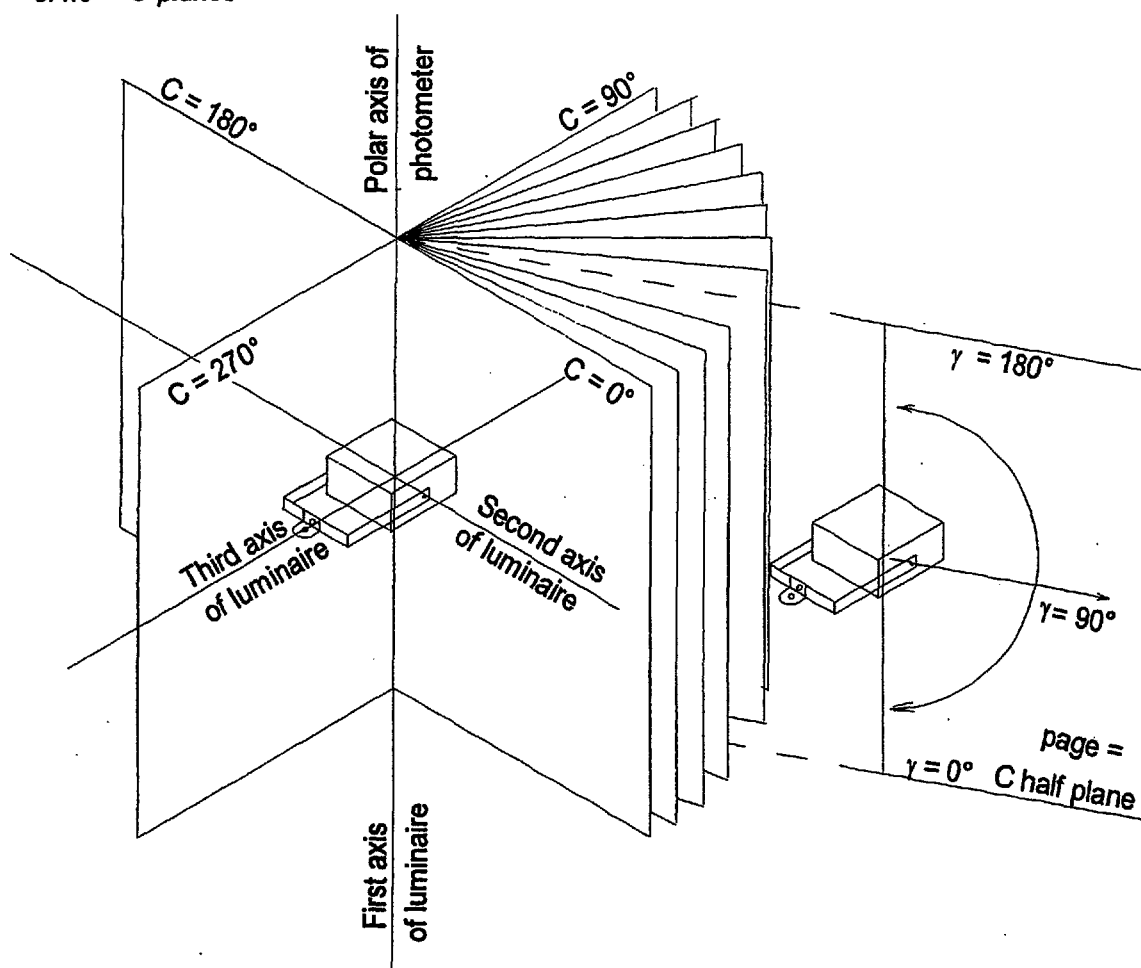


Figure 3.3. Luminaire orientation for C, γ goniophotometry.

The system of C-planes is the group of planes for which the line of intersection (polar axis) is the vertical line through the photometric centre.

The system of C-planes is generally oriented rigidly in space and does not follow the tilt of the luminaire. The line of intersection of the C-planes is only perpendicular to the lines of intersection of the A- and B-planes for zero tilt of the luminaire. It does not necessarily coincide with the first axis of the luminaire except in case of zero tilt. This first axis is usually the axis going through the photometric centre and perpendicular to the light emitting area. The second axis lies within the plane $C = 0$.

The system is commonly used in the photometry of interior and street lighting. In interior lighting, the third axis of the luminaire is the long axis, while in public lighting (see Publication 34-1977 [19]) the second axis of the luminaire is usually parallel to the road axis.

3.4.4 Relationships

A certain direction in each system of planes is characterised respectively by two angles:

- an angle A, B or C for the tilt of the plane A, B or C ;
- an angle α, β or γ in the associated A, B or C half-plane.

The angles α (or β) in an A-plane (or a B-plane) are measured up to $\pm 90^\circ$ from the direction of the perpendicular to the axis of intersection of the A (or B) planes. The A (or B) half-plane, taken as 0° plane, contains the first axis and is normal to the second axis of the luminaire (A-plane) or contains the second axis (B-plane). A and B-planes are taken from 0° to $\pm 180^\circ$.

The angles γ in a C-plane are measured up to 180° from the direction of the perpendicular to the axis of intersection of the C-planes. This axis does not necessarily coincide with the first axis of the