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COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

TECHNICAL REPORT

THE USE OF TUNGSTEN FILAMENT LAMPS AS SECONDARY STANDARD SOURCES

CIE 149:2002

UDC: 53.085.342
535.24

Descriptor: Light sources
Photometry

THE INTERNATIONAL COMMISSION ON ILLUMINATION

The International Commission on Illumination (CIE) is an organisation devoted to international co-operation and exchange of information among its member countries on all matters relating to the art and science of lighting. Its membership consists of the National Committees in 38 countries and one geographical area and of 8 associate members.

The objectives of the CIE are :

1. To provide an international forum for the discussion of all matters relating to the science, technology and art in the fields of light and lighting and for the interchange of information in these fields between countries.
2. To develop basic standards and procedures of metrology in the fields of light and lighting.
3. To provide guidance in the application of principles and procedures in the development of international and national standards in the fields of light and lighting.
4. To prepare and publish standards, reports and other publications concerned with all matters relating to the science, technology and art in the fields of light and lighting.
5. To maintain liaison and technical interaction with other international organisations concerned with matters related to the science, technology, standardisation and art in the fields of light and lighting.

The work of the CIE is carried on by seven Divisions each with about 20 Technical Committees. This work covers subjects ranging from fundamental matters to all types of lighting applications. The standards and technical reports developed by these international Divisions of the CIE are accepted throughout the world.

A plenary session is held every four years at which the work of the Divisions and Technical Committees is reviewed, reported and plans are made for the future. The CIE is recognised as the authority on all aspects of light and lighting. As such it occupies an important position among international organisations.

LA COMMISSION INTERNATIONALE DE L'ÉCLAIRAGE

La Commission Internationale de l'Éclairage (CIE) est une organisation qui se donne pour but la coopération internationale et l'échange d'informations entre les Pays membres sur toutes les questions relatives à l'art et à la science de l'éclairage. Elle est composée de Comités Nationaux représentant 38 pays plus un territoire géographique, et de 8 membres associés.

Les objectifs de la CIE sont :

6. De constituer un centre d'étude international pour toute matière relevant de la science, de la technologie et de l'art de la lumière et de l'éclairage et pour l'échange entre pays d'informations dans ces domaines.
7. D'élaborer des normes et des méthodes de base pour la métrologie dans les domaines de la lumière et de l'éclairage.
8. De donner des directives pour l'application des principes et des méthodes d'élaboration de normes internationales et nationales dans les domaines de la lumière et de l'éclairage.
9. De préparer et publier des normes, rapports et autres textes, concernant toutes matières relatives à la science, la technologie et l'art dans les domaines de la lumière et de l'éclairage.
10. De maintenir une liaison et une collaboration technique avec les autres organisations internationales concernées par des sujets relatifs à la science, la technologie, la normalisation et l'art dans les domaines de la lumière et de l'éclairage.

Les travaux de la CIE sont effectués par 7 Divisions, ayant chacune environ 20 Comités Techniques. Les sujets d'études s'étendent des questions fondamentales, à tous les types d'applications de l'éclairage. Les normes et les rapports techniques élaborés par ces Divisions Internationales de la CIE sont reconnus dans le monde entier.

Tous les quatre ans, une Session plénière passe en revue le travail des Divisions et des Comités Techniques, en fait rapport et établit les projets de travaux pour l'avenir. La CIE est reconnue comme la plus haute autorité en ce qui concerne tous les aspects de la lumière et de l'éclairage. Elle occupe comme telle une position importante parmi les organisations internationales.

DIE INTERNATIONALE BELEUCHTUNGSKOMMISSION

Die Internationale Beleuchtungskommission (CIE) ist eine Organisation, die sich der internationalen Zusammenarbeit und dem Austausch von Informationen zwischen ihren Mitgliedsländern bezüglich der Kunst und Wissenschaft der Lichttechnik widmet. Die Mitgliedschaft besteht aus den Nationalen Komitees in 38 Ländern und einem geographischen Gebiet und aus 8 assoziierten Mitgliedern.

Die Ziele der CIE sind :

11. Ein internationaler Mittelpunkt für Diskussionen aller Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik und für den Informationsaustausch auf diesen Gebieten zwischen den einzelnen Ländern zu sein.
12. Grundnormen und Verfahren der Meßtechnik auf dem Gebiet der Lichttechnik zu entwickeln.
13. Richtlinien für die Anwendung von Prinzipien und Vorgängen in der Entwicklung internationaler und nationaler Normen auf dem Gebiet der Lichttechnik zu erstellen.
14. Normen, Berichte und andere Publikationen zu erstellen und zu veröffentlichen, die alle Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik betreffen.
15. Liaison und technische Zusammenarbeit mit anderen internationalen Organisationen zu unterhalten, die mit Fragen der Wissenschaft, Technik, Normung und Kunst auf dem Gebiet der Lichttechnik zu tun haben.

Die Arbeit der CIE wird in 7 Divisionen, jede mit etwa 20 Technischen Komitees, geleistet. Diese Arbeit betrifft Gebiete mit grundlegendem Inhalt bis zu allen Arten der Lichtenwendung. Die Normen und Technischen Berichte, die von diesen international zusammengesetzten Divisionen ausgearbeitet werden, sind von der ganzen Welt anerkannt.

Tagungen werden alle vier Jahre abgehalten, in der die Arbeiten der Divisionen überprüft und berichtet und neue Pläne für die Zukunft ausgearbeitet werden. Die CIE wird als höchste Autorität für alle Aspekte des Lichtes und der Beleuchtung angesehen. Auf diese Weise unterhält sie eine bedeutende Stellung unter den internationalen Organisationen.

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This Technical Report has been prepared by CIE Technical Committee 2-04 of Division 2 “Physical measurement of light and radiation” and has been approved by the Board of Administration of the Commission Internationale de l’Eclairage for study and application. The document reports on current knowledge and experience within the specific field of light and lighting described, and is intended to be used by the CIE membership and other interested parties. It should be noted, however, that the status of this document is advisory and not mandatory. The latest CIE proceedings or CIE NEWS should be consulted regarding possible subsequent amendments.

Ce rapport technique a été préparé par le Comité Technique CIE 2-04 de la Division 2 “Mesures physiques de la lumière et des radiations” et a été approuvé par le Bureau de la Commission Internationale de l’Eclairage pour étude et application. Le document traite des connaissances courantes et de l’expérience dans le domaine spécifique décrit de la lumière et de l’éclairage; il est destiné à être utilisé par les membres de la CIE et tous les intéressés. Il faut cependant noter que ce document est indicatif et non obligatoire. Les derniers comptes rendus de la CIE ou du CIE NEWS devront être consultés pour connaître d’éventuels amendements.

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THE USE OF TUNGSTEN FILAMENT LAMPS AS SECONDARY STANDARD SOURCES

SUMMARY

This publication deals with the selection and operation of tungsten filament lamps intended for use as secondary standard sources.

Secondary standard sources are required to be stable and reproducible. The best performance is obtained from incandescent tungsten filament lamps that have been designed and constructed specifically for this application. The requirements for such lamps and the principles underlying their design, construction and operation are summarized in this report. An indication is given of the levels of performance that can reasonably be expected at the present state of the art.

Because the special, hand-made lamps required for this purpose are only available from a small number of specialist manufacturers, a list of all the known suppliers has also been included.

L'UTILISATION DES LAMPES A FILAMENT DE TUNGSTENE COMME SOURCES ETALONS SECONDAIRES

RESUME

Cette publication a pour objet la sélection et le mode opératoire de lampes à filament de tungstène destinées à être utilisées comme sources étalons secondaires.

Les sources étalons secondaires doivent présenter des caractéristiques stables et reproductibles. Les meilleures performances sont atteintes par des lampes à incandescence à filament de tungstène spécialement conçues et construites pour ce but. Les exigences pour de telles lampes ainsi que les principes de conception, de construction et de fonctionnement sont présentés dans ce rapport. Une indication est fournie quant aux niveaux de performances possibles compte tenu de la technique actuelle.

Au fait que ces lampes spéciales, construites manuellement, sont produites par seulement quelques fabricants spécialisés, une liste de fournisseurs connus est également fournie.

DER GEBRAUCH VON WOLFRAM-GLÜHLAMPEN ALS NORMALLAMPEN

ZUSAMMENFASSUNG

Dieser Bericht behandelt Auswahl und Verwendung von Wolfram-Glühlampen, die zum Gebrauch als Normallampen vorgesehen sind.

Normallampen müssen stabil und reproduzierbar brennen. Beste Ergebnisse werden mit Glühlampen mit Wolfram Leuchtkörper erzielt, die speziell für diese Anwendung entwickelt und gebaut wurden. Die Anforderungen an solche Lampen und die zu Grunde liegenden Prinzipien für Entwicklung, Herstellung und Gebrauch sind in diesem Bericht zusammengefasst. Hinweise werden gegeben, welche Güte vernünftigerweise beim heutigen Stand der Technik erwartet werden kann.

Da die für diese Anwendung erforderlichen speziellen und handgefertigten Lampen nur von wenigen spezialisierten Herstellern geliefert werden, ist eine Liste aller bekannten Lieferanten mit angegeben.

1. INTRODUCTION

An internationally agreed system for the measurement of lamps and lighting would not be possible without the availability of stable secondary standard sources.

National standards laboratories in different parts of the world establish and maintain photometric and radiometric emission scales, but, however good the fundamental accuracy and precision of these scales may be, their wider application depends entirely on the stability and reproducibility of the secondary sources used to maintain and disseminate them. Stable and reproducible lamps that are robust enough to be transported without losing their calibration are the essential key to making the laboratory scales internationally compatible and accessible to the wide range of potential users for whose benefit they were originally created.

Although light sources of many new types have been developed in recent years, incandescent tungsten filament lamps are still by far the most stable and reproducible of the sources available and, therefore, the most widely used as secondary standards. The tungsten filament lamp is an extremely versatile source, available in a wide range of power ratings and filament geometries. Most tungsten lamps, however, are designed and manufactured for purposes of illumination and the main factors that control the development and manufacture of commercial light sources, such as cheapness, efficacy and easy operation from the mains supply, are not consistent with the requirements for the construction of good stable secondary standard sources.

The high levels of stability and reproducibility essential in lamps that are intended for use as secondary standard sources can only be obtained from lamps that have been designed and built specifically for that purpose. The lamps have to be built by hand, a time consuming process that demands special skills, and they are required to meet very tight production tolerances. It is inevitable that the cost of lamps produced in this way will be high. The market for them is small and highly specialized and, as a consequence, they can only be obtained from a restricted number of specialist manufacturers. Because of this exceptional situation, the decision was taken to provide a list, in this report, of all the manufacturers at present known to be offering for sale lamps designed and manufactured specifically for use as secondary standard sources.

The purpose of this technical report is to explain the various features that contribute to the design of the special tungsten filament lamps required for use as secondary standards and to show what level of performance can reasonably be expected at the present state of the art. It also offers guidance on the selection of the most suitable lamp for a particular task and the best method of operating it.

2. APPLICATIONS

Secondary standard sources can be classified and divided into groups, based on the way in which they are used, that is, on the way in which the radiation from the source is collected. The different spatial and directional characteristics of the radiant flux in these groups relate to particular radiometric quantities and their geometrically equivalent photometric quantities [1] [2].

- 1) Sources that are used in a specified single direction, without imaging optics. These can be divided into two sub-groups;
 - (i) standards of radiant or luminous intensity, the radiant or luminous flux emitted per unit solid angle by the source,
 - (ii) standards of irradiance or illuminance, the radiant or luminous flux incident on a surface or a detector at a specified distance from the source.
- 2) Sources also used in a specified single direction but with an imaging system to isolate a specific radiant area. These provide standards of radiance or luminance.
- 3) Sources used as standards of geometrically total flux for which measurements are made of the radiant or luminous flux emitted in all directions over the full solid angle of 4π steradians.

2.1 Radiant and luminous intensity

Radiant and luminous intensity are quantities that characterize the flux from the source in a specific direction.

The radiant intensity I_e of a source in a given direction is the quotient of the radiant flux $d\Phi_e$ leaving the source propagated in an element of solid angle $d\Omega$ containing the given direction, by the element of solid angle.

$$I_e = d\Phi_e/d\Omega$$

The unit is watt per steradian, $\text{W}\cdot\text{sr}^{-1}$.

Similarly, the luminous intensity I_v of a source in a given direction is the quotient of the luminous flux $d\Phi_v$ leaving the source propagated in an element of solid angle $d\Omega$ containing the given direction, by the element of solid angle.

$$I_v = d\Phi_v/d\Omega$$

The unit is the candela, cd. A luminous intensity of one candela is equal to a luminous flux of one lumen per steradian ($1 \text{ cd} = 1 \text{ lm}\cdot\text{sr}^{-1}$).

The concept of radiant/luminous intensity involves an implicit assumption of a point source and conformity with the inverse square law.

For measurement purposes, a source is required that provides a uniform intensity into a cone of semi-angle 2° or 3° in a specified direction about a precisely defined reference axis.

2.2 Irradiance and illuminance

Irradiance and illuminance are quantities related to the flux incident at a point on a surface irradiated or illuminated by the lamp.

The irradiance E_e at a point of a surface is the quotient of the radiant flux Φ_e incident at an element of the surface containing the point, by the area of that element dA .

$$E_e = d\Phi_e/dA$$

The unit is watt per square metre, $\text{W}\cdot\text{m}^{-2}$.

Similarly, the illuminance E_v at a point of a surface is the quotient of the luminous flux Φ_v incident at an element of the surface containing the point, by the area of that element dA .

$$E_v = d\Phi_v/dA$$

The unit is the lux, lx. An illuminance of one lux is equal to a luminous flux of one lumen per square metre ($1 \text{ lx} = 1 \text{ lm}\cdot\text{m}^{-2}$).

In this case the calibration applies to the radiation from the source incident on a surface. Although the same lamps can often be used either as radiant/luminous intensity standards or as irradiance/illuminance standards, the latter concept does not involve the assumption of an effective point source and obedience to the inverse square law. Both these concepts are implicitly assumed in the case of a standard of radiant/luminous intensity.

A source is required that provides a uniform field of irradiance/illuminance over a surface at a specified distance from the source, in a given direction. The distance is measured from a precise reference point on the source, but, in the case of an irradiance/illuminance standard, the reference point does not necessarily have to be in the same plane as the radiant centre of the source.

2.3 Radiance and luminance

Radiance and luminance are quantities defining the flux emitted in a specific direction from a specific area of the surface of a source.

The radiance L_e at a given point on the surface of a source, in a given direction, is the quantity defined by the formula

$$L_e = d^2\Phi_e/(dA\cdot\cos\theta\cdot d\Omega)$$