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TECHNICAL REPORT

colour inside

Photobiological safety of lamps and lamp systems –
Part 4: Measuring methods

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Photobiological safety of lamps and lamp systems –
Part 4: Measuring methods

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IEC TR 62471-4 has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
76/654/DTR	76/707/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

A list of all the parts in the IEC 62471 series, under the general title *Photobiological safety of lamps and lamp systems*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Most lamps and lamp systems are safe and do not pose photobiological hazards except under unusual exposure conditions, whilst a full photobiological safety assessment requires sophisticated instrumentation and detailed analysis.

In order to provide a framework for the application of detailed measurement only where such is necessary, this document introduces two measurement approaches. Level A encompasses high accuracy, laboratory-based techniques whilst level B represents an estimation of the accessible emission using readily available instrumentation.

PHOTOBIOLOGICAL SAFETY OF LAMPS AND LAMP SYSTEMS –

Part 4: Measuring methods

1 Scope

This part of IEC 62471, which is a Technical Report, provides manufacturers, test houses, safety personnel and others with practical guidance on methods to perform radiometric and spectroradiometric measurements to determine the level of accessible optical radiation emitted by lamps and lamp systems in accordance with IEC 62471.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62471:2006, *Photobiological safety of lamps and lamp systems*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62471 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
accessible emission
level of radiation determined at a given distance and under measurement conditions defined in IEC 62471

Note 1 to entry: The accessible emission is compared with the accessible emission limits to determine the applicable risk group.

3.1.2
angular response
detector output signal as a function of input beam angle

3.1.3
aperture stop
opening that defines the area over which average optical emission is measured

3.1.4
entrance pupil
image of the aperture stop as seen through the object space in an optical system

Note 1 to entry: The entrance pupil defines the acceptance cone in the object space.

Note 2 to entry: If there is no lens in front of the aperture stop, the location and size of the entrance pupil are identical to those of the aperture stop. Optical elements in front of the aperture stop can either magnify or diminish the image and modify the location of the entrance pupil with respect to the physical aperture stop.

Note 3 to entry: The entrance pupil is important since the amount of optical radiation collected from the source depends on this cone angle.

3.1.5
exit pupil
image of the aperture stop as seen through the image space in an optical system

Note 1 to entry: The exit pupil defines the acceptance cone in the image space.

Note 2 to entry: If there is no lens behind the aperture stop, the location and size of the exit pupil are identical to those of the aperture stop.

Note 3 to entry: The exit pupil is important since the amount of optical radiation falling on the detector depends on this cone angle.

Note 4 to entry: The cone angle is held constant in the luminance or radiance measurement at different object distances.

3.1.6
field stop
opening that defines the solid angle over which average optical emission is measured

3.1.7
level A assessment
accurate determination of the accessible emission using sophisticated instruments in laboratory conditions, performed by a trained operator

3.1.8
level B assessment
estimation of the accessible emission using readily available broadband radiometers or photometers with minimum training

Note 1 to entry: Level B assessment can be used as a screening method to determine where further detailed analysis is required without leading to the burden of measuring all sources.

3.1.9
measurement distance
<radiance measurement system> distance between the (apparent) source or the closest point of human access of the source under test and the entrance pupil

Note 1 to entry: If projection optics generate a virtual image of the emitter, the radiance measurement system images the plane of this apparent source and not the plane of the closest point of human access.

3.1.10
measurement distance
<irradiance measurement system> distance between the (apparent) source or the closest point of human access of the source under test and the aperture stop

3.1.11
spectral weighting function
function of the relative spectral effectiveness of optical radiation for a specified photobiological effect in consideration of calculation of a weighted quantity, such as weighted radiance or weighted irradiance

3.1.12
weighted irradiance
radiometric quantity obtained by multiplying spectral irradiance by a spectral weighting function and integrating over the limits of the weighting function

3.1.13
weighted radiance
radiometric quantity obtained by multiplying spectral radiance by a spectral weighting function and integrating over the limits of the weighting function

3.2 Abbreviated terms

CCD charge-coupled device

CCT correlated color temperature

CMOS complementary metal–oxide–semiconductor

CW continuous wave

FOV field of view

GLS general lighting service

HID high-intensity discharge

LED light-emitting diode

NMI national metrology institute

PMT photomultiplier tube

4 Application

4.1 General

This document is intended to be used as a reference guide by (but not limited to) manufacturers, testing laboratories, safety officers and officials of industrial or governmental authorities. It contains interpretations of IEC 62471 and supplementary information relating to the practical realization of radiometric measurements of lamps and lamp systems.

The procedures described in this document are adequate to meet the measurement requirements of IEC 62471 where measurements are deemed to be required. The existence of other equivalent measurement techniques, yielding results as valid as those described in this document, is acknowledged.

In many cases, measurement may not be necessary. Compliance with the requirements of IEC 62471 can be determined from an analysis of reported characteristics of the source and the design of the product.

4.2 Safety precautions

Optical radiation emitted from a test lamp or lamp system may be potentially hazardous to the operator's eyes and skin during the measurement. The existence of these hazards may be unknown in advance of the measurement results, especially for UV and infrared sources. If in doubt, it is recommended that the operator wear personal protection equipment to avoid damage to eye or skin during measurement, e.g. gloves, goggles, protective clothing or masks.

In the special case of vacuum-UV sources, the formation of ozone in the measurement path may produce additional hazards, so the test room should be appropriately ventilated.

It should be noted that the optical emission from the lamp or lamp system may be sufficiently intense to cause damage to instrumentation and black (absorbing) material in the laboratory. The risk of deterioration of non-metallic safety critical components, such as electrical wires, due to long term exposure to UV, should be assessed.

4.3 Hazard assessment overview

IEC 62471 provides an assessment and classification scheme for the photobiological safety of all electrically powered lamps and lamp systems emitting optical radiation in the wavelength range from 200 nm to 3 000 nm. The assessment of optical radiation hazards considers exposure of the skin, the anterior elements of the eye (cornea, conjunctiva and lens) and the retina as detailed in Table 1. Lasers are excluded from this scope except laser products designed to function as conventional light sources that meet the relevant criteria in IEC 60825-1:2014, Clause 4.4.

Each hazard is accompanied with a measurement type, spectral range and, where applicable, a hazard weighting function to account for the wavelength dependence of the hazard.

Table 1 – Optical radiation hazards considered by IEC 62471

Hazard	**Action spectrum**	**Wavelength range** (nm)	**Measured quantity**	**Symbol for emission level**	**Units**
Actinic UV	$S_{UV}(\lambda)$	200 to 400	Irradiance	E_s	$W \cdot m^{-2}$
Near UV	N/A	315 to 400	Irradiance	E_{UVA}	$W \cdot m^{-2}$
Blue light	$B(\lambda)$	300 to 700	Spatially-averaged radiance	L_B	$W \cdot m^{-2} \cdot sr^{-1}$
Blue light, small source	$B(\lambda)$	300 to 700	Irradiance	E_B	$W \cdot m^{-2}$
Retinal thermal	$R(\lambda)$	380 to 1 400	Spatially-averaged radiance	L_R	$W \cdot m^{-2} \cdot sr^{-1}$
Retinal thermal, weak visual stimulus	$R(\lambda)$	780 to 1 400	Spatially-averaged radiance	L_{IR}	$W \cdot m^{-2} \cdot sr^{-1}$
IR radiation, eye	N/A	780 to 3 000	Irradiance	E_{IR}	$W \cdot m^{-2}$

NOTE The naming of hazards differs between IEC 62471 and IEC 62471-5.

The methods employed to measure these quantities (described in Clause 5) are designed to account for biophysical phenomena, including averaging over apertures or fields of view (FOVs) which may be considered inappropriate for general radiometric measurements. Without taking these measurement conditions into account, hazards may be overestimated.

This assessment may be performed on both lamps and lamp systems. IEC 62471 provides guidance on the conditions under which the risk group classification may be transferred from lamps to lamp systems.

4.4 Selection of hazards

Given prior knowledge of the source type, one can select which of the hazards presented in Table 1 should be assessed for a particular product. The potential hazard categories relating to a range of typical sources are listed in Table A.1 in Annex A.

If in doubt, the full spectral range of emission can be measured before performing more detailed analysis.

4.5 Assessment levels

Most lamps and lamp systems are safe and do not pose photobiological hazards except under unusual exposure scenarios. There remain, however, some lamps and lamp systems for which the emitted optical radiation has the potential to pose adverse health effects. It follows that the most detailed measurement need only be performed in the latter case. The assessment approach recommended in this document is based on two assessment levels, termed level A and level B.

Level A represents the most accurate determination of the accessible emission using sophisticated spectroradiometric equipment and can be used in all cases. The instrumentation description is given in Annex B.

Level B measurements are made with readily available instruments, such as broadband radiometers or photometers with minimum training. Level B may then be considered as an initial screen to determine where detailed analysis is required. The application of level B is not suitable for those sources known to be potentially hazardous (including UV lamps) nor for consideration of the retinal thermal hazard, where required.

As with all measurements, a consideration of measurement uncertainty is important, particularly in the case of a level B assessment if the estimated accessible emission is close to the accessible emission limit. If a level B assessment does not clearly designate the risk group, then proceeding to a level A assessment is recommended.

Examples of the risk group determination of several lamps are shown in Annex F.

4.6 Initial filtering

In the case of sources emitting white light, if the luminance of the source is below 10^4 cd·m^{-2}, detailed analysis is not required. The luminance of the source can be obtained by measurement or calculation of reported parameters.

A luminance meter, with the FOV selected to be smaller than the emission area of the source, will report the value directly.

Luminance can be estimated from the illuminance, E_v, measured at a distance, D, from the source and the estimated luminous area of the source, A.

$$L_\mathrm{v} = \frac{E_\mathrm{v} \cdot D^2}{A} \tag{1}$$

Using data sheet values, luminance can be computed from luminous intensity, I_v (cd) by Equation (2) and from luminous flux, Φ_v (lumen), luminous area, A and beam half emission angle, θ, from Equation (3).

$$L_\mathrm{v} = \frac{I_\mathrm{v}}{A} \tag{2}$$

$$L_\mathrm{v} = \frac{\Phi_\mathrm{v}}{2\pi \cdot A \cdot (1-\cos\theta)} \tag{3}$$

4.7 Measurement quantities

4.7.1 Emission wavelengths

Given the wide spectral range over which photobiological safety hazards are considered and the wavelength dependence of those hazards, spectral analysis of the emission of lamps and lamp systems is recommended. In the case of the UV, blue light and retinal thermal hazards for which the spectral weighting functions are strongly wavelength dependent, detailed spectral measurements may be required.

Whilst the spectral range of application of IEC 62471 is 200 nm to 3 000 nm, spectral measurements beyond 1 400 nm are not required, but may be used.

The range of hazards considered for a particular product can be reduced given prior knowledge of the source type.

The potential hazard categories relating to a range of typical source types are listed in Table A.1.

4.7.2 Irradiance

The following description applies both to broadband irradiance and spectral irradiance measurements.

Measurement of the irradiance produced at a given distance by a lamp or lamp system is required to assess the following hazards:

- actinic UV hazard, E_{S};
- near UV hazard, E_{UVA};
- retinal blue light hazard (small source), E_{B};
- IR radiation eye hazard, E_{IR}.

The instrument should:

a) have a plane circular entrance aperture of diameter between 7 mm and 50 mm;
b) accept radiation within a circular cone whose centreline is normal to the plane of the entrance aperture;
c) have an angular spatial response varying as the cosine of the angle (up to the acceptance angle) from the normal to the detector area.

Whilst in general radiometry, the irradiance geometry requires a hemispherical cosine response, in consideration of biophysical phenomena the full acceptance angle (γ) is limited to 1,4 rad.

Where a source subtends an angle greater than 1,4 rad at the measurement distance, a field stop should be placed at the source to ensure measurement under 1,4 rad. Where the source cannot be accessed, the aperture can be moved toward the entrance aperture, as in Figure 1.

The entrance aperture of the optic serves as an averaging aperture and should be selected in consideration of the spatial uniformity of irradiance in the measurement plane. For sources that do not produce a spatially uniform irradiance, for example narrow beam reflector lamps, the peak irradiance may be significantly higher than that obtained by measurement using a wide entrance aperture. In such cases, a 7 mm entrance aperture diameter should be used.