

Australian/New Zealand Standard™

Photobiological safety of lamps and lamp systems



AS/NZS IEC 62471:2011

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Australian/New Zealand Standard™

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee SF-019, Personal Protection Against Laser Radiation.

The objectives of this Standard are as follows:

- (a) To protect people from optical radiation in the wavelength range 200 nm to 3000 nm by introducing a system of classification for all electrically powered incoherent broadband sources of optical radiation, including light emitting diodes (LEDs) but excluding lasers, according to their degree of optical radiation hazard.
- (b) To provide a scheme for evaluation and control of photobiological hazards through specification of exposure limits and reference measurement technique.
- (c) To ensure adequate warnings are provided to individuals of hazards associated with accessible incoherent broadband sources of optical radiation through the use of labels and instructions (refer to next paragraph).

This is the first Standard adopted by Australia/New Zealand relating specifically to the photobiological safety of lamps and lamp systems and is normative. However, additional informative guidance may be found in IEC/TR 62471-2, Edition 1.0 (2009)*, *Photobiological safety of lamps and lamp systems—Part 2: Guidance on manufacturing requirements relating to non-laser optical radiation safety*. The aforementioned IEC technical report provides in the context of classifications defined in AS/NZS IEC 62471, guidance on: requirements for optical radiation safety assessment; allocation of safety measures; and labelling of products.

This Standard is identical with, and has been reproduced from, IEC 62471, Ed.1.0 (2006), *Photobiological safety of lamps and lamp systems*.

As this Standard is reproduced from an International Standard, the following applies:

- (a) Its number appears on the cover and title page while the International Standard number appears only on the cover.
- (b) In the source text ‘This International Standard’ should read ‘This Australian/New Zealand Standard’.
- (c) A full point substitutes for a comma when referring to a decimal marker.

None of the normative references in the source document have been adopted as Australian or Australian/New Zealand Standards.

The term ‘informative’ has been used in this Standard to define the application of the annex to which it applies. An ‘informative’ annex is only for information and guidance.

* To be published as AS/NZS IEC adoption.

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INTRODUCTION

Lamps were developed and produced in large quantities and became commonplace in an era when industry-wide safety standards were not the norm. The evaluation and control of optical radiation hazards from lamps and lamp systems is a far more complicated subject than similar tasks for a single-wavelength laser system. The required radiometric measurements are quite involved, for they do not deal with the simple optics of a point source, but rather with an extended source that may or may not be altered by diffusers or projection optics. Also the wavelength distribution of the lamp may be altered by ancillary optical elements, diffusers, lenses, and the like, as well as variations in operating conditions.

To evaluate a broad-band optical source, such as an arc lamp, an incandescent lamp, a fluorescent lamp, an array of lamps or a lamp system, it is first necessary to determine the spectral distribution of optical radiation emitted from the source at the point or points of nearest human access. This accessible emission spectral distribution of interest for a lighting system may differ from that actually being emitted by the lamp alone due to the filtration by any optical elements (e.g., projection optics) in the light path. Secondly, the size, or projected size, of the source must be characterized in the retinal hazard spectral region. Thirdly, it may be necessary to determine the variation of irradiance and effective radiance with distance. The performance of the necessary measurements is normally not an easy task without sophisticated instruments. Thus it was decided to include reference measurement techniques for lamps and lamp systems in this standard. The measurement techniques along with the described risk group classification scheme will provide common ground for both lamp manufacturers and users to define the specific photobiological hazards of any given lamp and/or lamp system.

Finally, there are well known optical radiation hazards associated with some lamps and lamp systems. The purpose of this standard is to provide a standardized technique for evaluation of potential radiation hazards that may be associated with various lamps and lamp systems.

AUSTRALIAN/NEW ZEALAND STANDARD

Photobiological safety of lamps and lamp systems**1. SCOPE**

This International Standard gives guidance for evaluating the photobiological safety of lamps and lamp systems including luminaires. Specifically it specifies the exposure limits, reference measurement technique and classification scheme for the evaluation and control of photobiological hazards from all electrically powered incoherent broadband sources of optical radiation, including LEDs but excluding lasers, in the wavelength range from 200 nm through 3000 nm.

2. NORMATIVE REFERENCES

The following referenced documents are indispensable for the application 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.

CIE 17.4-1987	<i>International lighting vocabulary (ILV)</i> – Joint publication IEC/CIE
CIE 53-1982	<i>Methods of characterizing the performance of radiometers and photometers</i>
CIE 63-1984	<i>The spectroradiometric measurement of light sources</i>
CIE 105-1993	<i>Spectroradiometry of pulsed optical radiation sources</i>
ISO	<i>Guide to the expression of uncertainty in measurement</i> , ISO, Geneva, 1995.

3. DEFINITIONS, SYMBOLS AND ABBREVIATIONS

For the purposes of this standard, the following definitions, symbols and abbreviations apply.

3.1 actinic dose (see ILV 845-06-23)

Quantity obtained by weighting spectrally the dose according to the actinic action spectrum value at the corresponding wavelength.

Unit: $\text{J}\cdot\text{m}^{-2}$

Note: This definition implies that an action spectrum is adopted for the actinic effect considered, and that its maximum value is generally normalized to 1. When giving a quantitative amount, it is essential to specify which quantity dose or actinic dose is meant, as the unit is the same.

3.2 angular subtense (α)

Visual angle subtended by the apparent source at the eye of an observer or at the point of measurement. In this standard subtended angles are denoted by the full included angle, not the half angle.

Unit: radian

Note: The angular subtense α will generally be modified by incorporation of lenses and mirrors as projector optics, i.e. the angular subtense of the apparent source will differ from the angular subtense of the physical source.

3.3 aperture, aperture stop

Opening that defines the area over which average optical emission is measured. For spectral irradiance measurements this opening is usually the entrance of a small sphere placed in front of the radiometer/spectroradiometer entrance slit.

3.4 blue light hazard (BLH)

Potential for a photochemically induced retinal injury resulting from radiation exposure at wavelengths primarily between 400 nm and 500 nm. This damage mechanism dominates over the thermal damage mechanism for times exceeding 10 seconds.

3.5 continuous wave (CW) lamp

Lamp that is operated with a continuous output for a time greater than 0,25 s, i.e., a non-pulsed lamp.

Note: In this standard, General lighting service (GLS) lamps are defined to be Continuous wave lamps.

3.6 erythema (see ILV 845-06-15)

Reddening of the skin; as used in this standard the reddening of the skin resulting from inflammatory effects from solar radiation or artificial optical radiation.

Note: The degree of delayed erythema is used as a guide to dosages applied in ultraviolet therapy.

3.7 exposure distance

Nearest point of human exposure consistent with the application of the lamp or lamp system. For lamps radiating in all directions the distance is measured from the centre of the filament or arc source. For reflector-type lamps the distance is measured from the outside edge of the lens or the plane defining the end of the reflector in a lens free reflector.

Unit: m

3.8 exposure limit (EL)

Level of exposure to the eye or skin that is not expected to result in adverse biological effects.

3.9 eye movements

The normal eye, when focused on an object, moves slightly in a random motion with a frequency of a few hertz. This rapid eye movement causes the image from a point source to be spread over an area of the retina equivalent to an angular subtense of about 0,011 radians. Furthermore, for times greater than about 100 seconds the focused stare capability breaks down causing further spreading of the radiant power over the retina due to task determined eye movements, e.g. as in reading.

3.10 field of view

Solid angle as "seen" by the detector (acceptance angle), such as the radiometer/ spectroradiometer, out of which the detector receives radiation.

Unit: sr

Note 1: The field of view should not be confused with the angular subtense of the apparent source α .

Note 2: A plane angle is sometimes used to describe a circular symmetric solid angle field of view.

3.11 general lighting service (GLS) lamps

Term for lamps intended for lighting spaces that are typically occupied or viewed by people. Examples would be lamps for lighting offices, schools, homes, factories, roadways, or automobiles. It does not include lamps for such uses as film projection, reprographic processes, "suntanning", industrial processes, medical treatment and searchlight applications.

3.12 hazard distance

See skin hazard distance or ocular hazard distance.

3.13 illuminance (at a point of a surface) (E_v) (see ILV 845-01-38)

Quotient of the luminous flux $d\Phi_v$ incident on an element of the surface containing the point, by the area dA of that element.

$$E_v = \frac{d\Phi_v}{dA} \quad (3.1)$$

Unit: lx

3.14 infrared radiation (IR) (see ILV 845-01-04)

Optical radiation for which the wavelengths are longer than those for visible radiation.

Note: For infrared radiation, the range between 780 nm and 10^6 nm is commonly subdivided into: IR-A (780 nm to 1400 nm), IR-B (1400 nm to 3000 nm), and IR-C (3000 nm to 10^6 nm).

Infrared radiation is often evaluated in terms of the spectral total radiation per unit area (irradiance) incident upon a surface. Examples of applications of infrared radiation are industrial heating, drying, baking, and photo-reproduction. Some applications, such as infrared viewing systems, involve detectors sensitive to a restricted range of wavelengths. In these cases, the spectral characteristics of the source and detector are of importance.

3.15 intended use

Use of a product, process or service in accordance with specifications, instructions and information provided by the supplier.

3.16 irradiance (at a point of the surface) (see ILV 845-01-37)

Quotient of the radiant flux $d\Phi$ incident on an element of a surface containing the point, by the area dA of that element, i.e.,

$$E = \frac{d\Phi}{dA} \quad (3.2)$$

Unit: $W \cdot m^{-2}$

3.17 lamp (see ILV 845-07-03)

Source made to produce optical radiation, usually visible.

Note: The term "lamp" is sometimes used for certain types of luminaires.

These types of luminaires consist of a lamp with shade, reflector, enclosing globe, housing, or other accessories.

As used in this standard, the term means an electrically powered source, other than a laser, that produces radiation in the visible region of the electromagnetic spectrum. Devices that generate light and have integral components for optical control, such as lenses or reflectors, also are considered lamps. Examples include a lensed LED, lens-end lamp, and reflector types, that consist of a source within a parabolic or elliptical reflector assembly, normally including a lens cover.

3.18 lamp system

Any manufactured product or assemblage of components that incorporates or is intended to incorporate a lamp.

3.19 large source

Size of the source image on the retina which is so large that radial heat flow in the radial direction from the center of the image to the surrounding biological tissue is negligibly small compared to heat flow in the axial direction.

3.20 laser

Source emitting coherent optical radiation produced by stimulated emission.

3.21 light

See visible radiation.

3.22 light emitting diode (LED) (see ILV 845-04-40)

Solid state device embodying a p-n junction emitting optical radiation without gain when excited by an electric current.

3.23 lumen (see ILV 845-01-51)

SI unit of luminous flux: Luminous flux emitted in a unit solid angle (steradian) by a uniform point source having a luminous intensity of 1 candela, or equivalently, the luminous flux of a beam of monochromatic radiation whose frequency is $540 \cdot 10^{12}$ hertz and whose radiant flux is 1/683 watt.

3.24 luminaire (see ILV 845-10-01)

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

The words "luminaire" and "lamp system" are often assumed to be synonymous. For the purposes of this standard, the word "luminaire" is restricted to apparatus used for distributing light in general lighting, while "lamp system" implies use of lamps in other than general lighting applications.

3.25 luminance (in a given direction, at a given point of a real or imaginary surface) (L_v) (see ILV 845-01-35)

Quantity defined by the formula

$$L_v = \frac{d\Phi_v}{dA \cdot \cos \theta \cdot d\Omega} \quad (3.3)$$

where $d\Phi_v$ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction; dA is the area of a section of that beam containing the given point; θ is the angle between the normal to that section and the direction of the beam.

Unit: $\text{cd} \cdot \text{m}^{-2}$

3.26 lux (see ILV 845-01-52)

SI unit of illuminance: Illuminance produced on a surface of area 1 square metre by a luminous flux of 1 lumen uniformly distributed over that surface.

3.27 ocular hazard distance

Distance from a source within which the radiance or irradiance for a given exposure duration exceeds the applicable exposure limit.

Unit: m

3.28 optical radiation (see ILV 845-01-02)

Electromagnetic radiation at wavelengths between the region of transition to X-rays (wavelength approximately 1 nm) and the region of transition to radio waves (wavelength approximately 10^6 nm).

Ultraviolet radiation in the wavelength range below 180 nm (vacuum UV) is strongly absorbed by the oxygen in air. For the purpose of this standard the wavelength band of optical radiation is limited to wavelengths greater than 200 nm. Further, the eye transmits optical radiation to the retina between 380 and 1400 nm. Thus this wavelength range requires special consideration in determining the photobiological safety of the retina.

3.29 photokeratoconjunctivitis

Inflammatory response of the cornea and conjunctiva following exposure to ultraviolet (UV) radiation. Wavelengths shorter than 320 nm are most effective in causing this condition. The peak of the action spectrum is approximately at 270 nm.

Note: Different action spectra have been published for photokeratitis and photoconjunctivitis (CIE 106/2 and CIE 106/3–1993); however, the latest studies support the use of a single action spectrum for both ocular effects (CIE 106/1–1993).

3.30 pulsed lamp

Lamp that delivers its energy in the form of a single pulse or a train of pulses where each pulse is assumed to have a duration of less than 0,25 s. A lamp with a continuous train of pulses or modulated radiant energy where the peak radiated power is at least ten times the average radiated power.

Note 1: The **duration** of a lamp pulse is the time interval between the half-power points on the leading and the trailing edges of the pulse.

Note 2: In this standard, General lighting service lamps are defined to be Continuous wave lamps (see clause 3.5). Examples of pulsed lamps include photoflash lamps, flash lamps in photocopy machines, pulse-modulated LEDs, and strobe lights.

3.31 radiance (in a given direction at a given point of a real or imaginary surface) (L) (see ILV 845-01-34)

Quantity defined by the formula,

$$L = \frac{d\Phi}{dA \cdot \cos \theta \cdot d\Omega} \quad (3.4)$$

where $d\Phi$ is the radiant power (flux) transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction; dA is the area of a section of that beam containing the given point; θ is the angle between the normal to that section and the direction of the beam.

Unit: $\text{W} \cdot \text{m}^{-2} \cdot \text{sr}^{-1}$

The same definition holds for the time-integrated radiance L_t if, in the equation for L , the radiant power $d\Phi$ is replaced by the radiant energy dQ .

3.32 radiant energy (see ILV 845-01-27)

Time integral of the radiant power, Φ over a given duration, Δt .

$$Q = \int_0^t \Phi \cdot dt \quad (3.5)$$

Unit: J

3.33 radiant exposure (at a point of a surface, for a given duration) (see ILV 845-01-42)

Quotient of the radiant energy, dQ , incident on an element of the surface containing the point over the given duration, by the area dA of that element.

$$H = \frac{dQ}{dA} \quad (3.6a)$$

Unit: $\text{J} \cdot \text{m}^{-2}$

Equivalently the radiant exposure is defined as the integral of the irradiance, E , at a given point over a given duration, Δt .

$$H = \int_{\Delta t} E \cdot dt \quad (3.6b)$$

3.34 radiant power (Φ) (see ILV 845-01-24)

Power emitted, transmitted or received in the form of radiation. Radiant power is often called *radiant flux*.

Unit: watt (W)

3.35 retina (see ILV 845-02-01)

Tissue situated inside the back of the eye that is sensitive to light stimuli; it contains photoreceptors, the cones and the rods, and nerve cells that transmit to the optic nerve the signals resulting from stimulation of the photoreceptors.

3.36 retinal burn

Photochemical or thermal retinal lesion.

3.37 retinal hazard region

Spectral region from 380 nm to 1400 nm (visible plus IR-A) within which the normal ocular media transmit optical radiation to the retina.

3.38 skin hazard distance

Distance at which the irradiance exceeds the applicable exposure limit for 8 hours exposure.

Unit: m

3.39 spectral distribution (see ILV 845-01-17)

Quotient of the radiant, luminous or photon quantity $dX(\lambda)$ contained in an elementary range $d\lambda$ of wavelength at the wavelength λ , by that range.

$$X_\lambda = \frac{dX(\lambda)}{d\lambda} \quad (3.7)$$

Unit: $[X] \cdot \text{nm}^{-1}$

Note: The term spectral distribution is to be preferred when dealing with the function $X_\lambda(\lambda)$ over a wide range of wavelengths, not at a particular wavelength.

3.40 spectral irradiance

Quotient of the radiant power $d\Phi(\lambda)$ in a wavelength interval $d\lambda$, incident on an element of a surface, by the area dA of that element and by the wavelength interval $d\lambda$.

$$E_\lambda = \frac{d\Phi(\lambda)}{dA \cdot d\lambda} \quad (3.8)$$

Unit: $\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$

3.41 spectral radiance (for a wavelength interval $d\lambda$, in a given direction at a given point) (L_λ)

Ratio of the radiant power $d\Phi(\lambda)$ passing through that point and propagating within the solid angle $d\Omega$ in the given direction, to the product of the wavelength interval $d\lambda$ and the area of a section of that beam on a plane perpendicular to this direction ($\cos \theta dA$) containing the given point and to the solid angle $d\Omega$.

$$L_\lambda = \frac{d\Phi(\lambda)}{dA \cdot \cos \theta \cdot d\Omega \cdot d\lambda} \quad (3.9)$$

Unit: $\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1} \cdot \text{sr}^{-1}$

3.42 steradian (see ILV 845-01-20)

SI unit of solid angle. A solid angle that, having its vertex at the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

3.43 ultraviolet radiation (UV) (see ILV 845-01-05)

Optical radiation for which the wavelengths are shorter than those for visible radiation.

Note: For ultraviolet (UV) radiation, the range between 100 nm and 400 nm is commonly subdivided into: UV-A, from 315 nm to 400 nm; UV-B, from 280 nm to 315 nm; and UV-C, from 100 nm to 280 nm.

These designations for the UV should not be taken as precise limits, particularly for photobiological effects.

In some fields of photobiology the wavelength bands are taken from 200 nm to 290 nm, from 290 nm to 320 nm, and from 320 nm to 400 nm. Sometimes these are (incorrectly) called by the names UV-A, UV-B and UV-C, respectively. Ultraviolet radiation at wavelengths less than 180 nm is considered vacuum ultraviolet radiation. Note that radiation between 380 nm and 400 nm is considered visible radiation although it is also within the formal definition of the ultraviolet band.

3.44 visible radiation (see ILV 845-01-03)

Any optical radiation capable of directly causing a visual sensation.

Note: There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant power reaching the retina and the responsivity of the observer. The lower limit is generally taken between 360 nm and 400 nm and the upper limit between 760 nm and 830 nm.

3.45 visual angle

Angle subtended by an object or detail at the point of observation is considered to be the visual angle. The SI unit for the angle is the radian although it may also be measured in milliradians, degrees, or minutes of arc.

4. EXPOSURE LIMITS (EL'S)

4.1 General

Individuals in the vicinity of lamps and lamp systems shall not be exposed to levels exceeding the limits developed in the following sections. The exposure limit (EL) values are taken from various ICNIRP guidelines which, in turn, are based on the best available information from experimental studies (see Annex A for summary of publications).

The exposure limits represent conditions under which it is believed that nearly all individuals in the general population may be repeatedly exposed without adverse health effects. However, they do not apply to abnormally photosensitive individuals or to individuals concomitantly exposed to photosensitizing agents, which makes individuals much more susceptible to adverse health effects from optical radiation. Such individuals, in general, are more susceptible to adverse health effects from optical radiation than individuals who are not abnormally photosensitive or concomitantly exposed to photosensitizing agents. The susceptibility of photosensitive individuals varies greatly, and it is not possible to set exposure limits for this portion of the population.

The exposure limits in this standard apply to continuous sources where the exposure duration is not less than 0,01 ms and not more than any 8-hour period, and should be used as guides in the control of exposure. The values should not be regarded as precisely defined lines between safe and unsafe levels.

The limits for exposure to broad-band visible and IR-A radiation for the eye require knowledge of the spectral radiance of the source, L_{λ} , and total irradiance, E , as measured at the position(s) of the eye of the exposed person. Such detailed spectral data of a light source are generally required only if the luminance of the source exceeds $10^4 \text{ cd}\cdot\text{m}^{-2}$. At a luminance less than this value, the exposure limits are expected to be not exceeded. The exposure limits are given in clause 4.3.

4.2 Specific factors involved in the determination and application of retinal exposure limits

4.2.1 Pupil diameter

The radiant flux that enters the eye and is absorbed by the retina (380 nm to 1400 nm range) is proportional to the pupil area. It is known that the pupil diameter decreases from around 7 mm diameter at very low luminance ($< 0,01 \text{ cd}\cdot\text{m}^{-2}$) to about 2 mm at luminance values on the order of $10000 \text{ cd}\cdot\text{m}^{-2}$. A weak visual stimulus is defined herein as one whose maximum luminance (averaged over a circular field-of-view subtending $0,011$ radian) is less than $10 \text{ cd}\cdot\text{m}^{-2}$. For a given luminance the individual pupil diameter varies considerably. Therefore, in the establishment of these exposure limits only two different pupil diameters were assumed, as follows:

- When the luminance of the source is adequately high ($> 10 \text{ cd}\cdot\text{m}^{-2}$), and the exposure duration is greater than $0,25 \text{ s}$, e.g., as applicable for the blue light hazard or retinal thermal hazard, a 3 mm pupil diameter (7 mm^2 area) was used to derive the exposure limit.
- When the luminance of the source is low, i.e., infrared radiation is present with little or no visible stimulus, the EL is based on a 7 mm ($38,5 \text{ mm}^2$ area) pupil diameter. The 7 mm diameter is also assumed when evaluating the photobiological hazard from pulsed sources and/or for exposure durations of less than $0,25 \text{ s}$.
- For situations where a near infrared source is used with high ambient light levels a pupil diameter of 3 mm may be assumed and the EL limits may be adjusted to higher values by the square of the ratio of the pupil diameter. Under such conditions the EL can be increased by a factor of $(7/3)^2 = 5,5$.

4.2.2 Angular subtense of source and measurement field-of-view

For radiation in the wavelength range 380 nm to 1400 nm the area of the retina irradiated is an important element in determining the EL's for both the blue light and retinal thermal hazards. Since the cornea and lens of the eye focuses the apparent source on the retina the best method to describe the irradiated area is to relate this area to the angular subtense of the apparent source, α . Due to physical limitations of the eye the smallest image that can be formed on the retina of a still eye is limited to a minimum value, $\alpha_{\min}$, even for a point source. In this standard the value for $\alpha_{\min}$ is $0,0017$ radian. Measurements of emitted radiation from apparent point sources, either pulsed or very high radiance continuous wave sources, that relate to the retinal thermal ELs at $0,25$ second (blink reflex time), shall use the $0,0017$ radian angular subtense as the measurement field of view.

For times greater than about $0,25$ second, rapid eye movements begin to smear the image of the source over a larger angle, called α_{eff} in this standard. For exposure times of ten seconds the smeared image of a point source covers an area of the retina equivalent to an angle of about $0,011$ radian. Thus the effective angular subtense α_{eff} to be used in measuring radiance to compare to the EL for the retinal thermal or blue light hazard at ten seconds exposure duration shall be $0,011$ radian. For continuity the dependence of α_{eff} between $0,25 \text{ s}$ and 10 s is assumed to increase from $\alpha_{\min}$ to $0,011$ radian as the square root of time, i.e., α_{eff} is proportional to $\alpha_{\min} t^{0,5}$, i.e., $\alpha_{\text{eff}} = \alpha_{\min} \sqrt{t/0,25}$. Little data is available to support this time dependence, so it should be used with caution. The time dependent relationship is normally not needed as the source radiance is usually evaluated at $0,25 \text{ s}$ or at 10 s , as can be determined by reviewing the risk criteria described in clause 6.

In addition, for the blue light hazard, for exposure times greater than 100 seconds, the irradiated area of the retina from a small source will be further spread over a larger area due to task determined eye movements, except for situations where the eye is fixed medically, e.g., during ophthalmological operations. For measurements of radiance from sources to be compared to the blue light hazard exposure limit, the effective angular subtense α_{eff} is set equal to $0,011$ radian for times less than 100 s . For times greater than 10000 s , α_{eff} is set to $0,1$ radian. Again, for convenience, it is assumed that α_{eff}