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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Photobiological safety of lamps and lamp systems – Part 6: Ultraviolet lamp products

Sécurité photobiologique des lampes et des appareils utilisant des lampes – Partie 6: Appareils à lampes ultraviolettes

IEC 62471-6:2022-10(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PHOTOBIOLOGICAL SAFETY OF LAMPS AND LAMP SYSTEMS –

Part 6: Ultraviolet lamp products

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IEC 62471-6 has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment. It is an International Standard.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
76/714/FDIS	76/718/RVD

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 International Standard is English.

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/standardsdev/publications.

In this standard, the following print types are used:

conformity statements: in italic type.

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

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- withdrawn,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 products are safe and do not pose photobiological risks except under unusual exposure conditions; however, one group of products-ultraviolet lamp products-can under some conditions pose optical hazards during use and require risk assessment for direct and indirect exposure of the eyes and skin. Optical radiation hazards from all types of lamps or other broadband light sources are assessed by the application of IEC 62471:2006/CIE S009:2002. IEC 62471 covers light emitting diodes (LEDs), incandescent, low- and high- pressure gas-discharge, arc and other lamps. It also covers lamps which are designed primarily to emit ultraviolet radiant energy, such as ultraviolet sources intended to excite fluorescence of irradiated materials, for insect light traps, for scientific studies, mineral identification, for non-destructive testing, germicidal irradiation, and other purposes.

This document provides a risk group (RG) classification system for all ultraviolet lamp products, and the assessment distances and measurement conditions for different products (Annex A and Annex C). It includes manufacturing and user safety requirements that may be required as a result of an ultraviolet lamp product being assigned to a particular risk group. The scope is limited to products where the sole intent is to emit ultraviolet radiant energy. The advantage of applying this document, intended solely for ultraviolet lamp products, instead of the horizontal IEC 62471 standard, is that the risks from visible and infrared optical radiation need not be assessed using this document, as they are assumed to be insignificant for a lamp that emits mainly UV. The assigned risk group of an ultraviolet lamp product using this document may also be used to assist with any needed risk assessments, e.g. for occupational exposure in workplaces.

PHOTOBIOLOGICAL SAFETY OF LAMPS AND LAMP SYSTEMS –

Part 6: Ultraviolet lamp products

1 Scope

This part of IEC 62471 provides the optical radiation safety requirements for ultraviolet lamp products, including UV LED lamp products.

This document provides requirements for:

- optical radiation safety assessment and ultraviolet-product risk groups;
- user information for safety measures;
- appropriate labelling of ultraviolet lamp products.

This document addresses those lamps and lamp products where the ultraviolet emission serves the primary purpose of the product and where more than half of the radiant power emitted between 180 nm and 3 000 nm is in the spectral region 180 nm to 400 nm. If more than half of the optical radiation emitted between 180 nm and 3 000 nm is outside of the spectral region 180 nm to 400 nm, then the base standard IEC 62471 should be used. This document covers medical diagnostic and cosmetic devices/products that emit primarily UV radiation.

Because photobiological effects from UV radiation are based on the total accumulated exposure (dose) received, this document relies on the concept of ‘time-weighted average’ exposures where the assessment distance for determining the RG is chosen based on realistic exposure distances and exposure durations. In other words, it is not expected that people will be exposed at very close distances, e.g. 20 cm to 30 cm, for extended periods of time. This document provides assessment distances and specific guidance that are application-specific and realistic rather than the more general values in IEC 62471 where the specific application is unknown and time-weighted average exposures are not application-specific.

This document does not provide requirements for:

- lamps which primarily emit visible (such as GLS – general lighting source) and/or infrared radiant energy;
- lamp products used for general lighting or infrared illumination or heating, which are treated in separate standards;
- fluorescent ultraviolet lamps for tanning (covered by IEC 60335-2-27 and IEC 61228);
- medical treatment devices/products (see IEC 60601-2-57), but covers UV medical diagnostic products;
- non-optical hazards, e.g. ozone, mercury, etc.

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 60335-2-27, *Household and similar electrical appliances – Safety – Part 2-27: Particular requirements for appliances for skin exposure to optical radiation*

IEC 60417:2002, *Graphical symbols for use on equipment – 12-month subscription to regularly updated online database comprising all graphical symbols published in IEC 60417*

IEC 60601-2-57, *Medical electrical equipment – Part 2-57: Particular requirements for the basic safety and essential performance of non-laser light source equipment intended for therapeutic, diagnostic, monitoring and cosmetic/aesthetic use*

IEC 61549, *Miscellaneous lamps*

IEC 62471:2006/CIE S009:2002, *Photobiological safety of lamps and lamp systems*

ISO 7010: *Graphical symbols – Safety colours and safety signs – Registered safety signs*

ISO 15004-2: *Ophthalmic instruments – Fundamental requirements and test methods – Part 2: Light hazard protection*

CIE 247:2021*, Guide for the Gonioradiometric Measurement of Upper Air Ultraviolet Germicidal Irradiation Luminaires, ISBN 978-3-902842-19-0, Vienna*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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
actinic UV
UV radiation capable of producing a photochemical effect

Note 1 to entry: In the context of this document, the biological effects have a demonstrated action spectrum, S(λ), and refer most significantly to UV-B and UV-C effects, e.g, UV erythema (skin reddening), UV photokeratitis ('welder's flash' or 'snowblindness'), etc. See also Annex B.

3.2
assessment distance
distance used to determine the risk group classification of a lamp or lamp product

Note 1 to entry: The risk group assessment distance takes account of the TWA exposure (variable irradiance, exposure distances and durations).

Note 2 to entry: This is usually the distance from the closest point of human access to the emission, to the point of assessment or measurement.

3.3
blue light hazard
potential for a photochemically induced retinal injury resulting from radiation exposure at wavelengths primarily between 400 nm and 500 nm

Note 1 to entry: This damage mechanism normally dominates over thermal mechanisms for intense visible light for viewing times exceeding 10 s, but is rarely of concern from UV lamps (unless the basic lamp is an arc lamp).

[SOURCE: IEC 60050-845:2020,845-26-055]

3.4
competent person
person who can demonstrate a combination of knowledge and skills to effectively, efficiently, and safely carry out specific activities

3.5
consumer
person who purchases or employs goods and services for personal use

Note 1 to entry: Consumers include not only users of the ultraviolet lamp product, but also all persons who may have access to the lamp product or who may be in the vicinity of the product.

Note 2 to entry: Also termed “ordinary person” in IEC 62368-1.

3.6
controlled access location
location where an engineering and/or administrative control measure is established to restrict access except to authorised personnel with appropriate safety training

3.7
dose-limited product
product where the emitted radiant exposure (dose) is limited by time or actual exposure monitoring at the assessment distance to a set level during any day

Note 1 to entry: The emission limit is expressed in J/m^2.

3.8
emission limit
limit defined for each risk group, based upon reasonably foreseeable conditions of time-weighted average (TWA) exposure

Note 1 to entry: The emission limit incorporates both the concept of exposure duration and variable exposure distance and is derived from exposure limits, however, the risk group assessment distance incorporates the TWA exposure.

3.9
general lighting source
GLS
general term for lamps, nominally of “white” colour, intended for lighting spaces that are typically occupied or viewed by people

Note 1 to entry: See IEC 62471 for requirements.

Note 2 to entry: This document does not cover GLS lamps or lamp products.

3.10
germicidal lamp product
any UV lamp product designed to disinfect by ultraviolet germicidal (UVG) irradiation to inactivate microorganisms so they are no longer capable of replicating and causing adverse health effects

3.11
instructed person
person who has been instructed and trained by a competent person, or who is supervised by a competent person, to identify ultraviolet sources that may cause pain or injury and to take precautions to avoid unintentional exposure to those sources

[SOURCE: IEC 62368-1:2018, 0.2.3, modified to use competent instead of skilled person]

3.12
intended use
usage of a product, process or service in accordance with specifications, instructions and information provided by the manufacturer or supplier

3.13
UV lamp
electric lamp or light emitting diode (LED) lamp that radiates especially strongly in the ultraviolet, the visible radiation produced, if any, not being of direct interest

Note 1 to entry: There are several types of ultraviolet lamp used for photobiological, photochemical and biomedical purposes.

[SOURCE: IEC 60050-845:2020, 845-27-091, modified, with Note 2 to entry omitted and with LED lamp (845-27-054) addition]

3.14
UV lamp product
product incorporating a UV lamp or UV lamps, including fixtures, and possibly filters, where the ultraviolet emission is the primary purpose of the lamp product and where more than half of the optical radiation emitted between 180 nm and 3 000 nm is in the spectral region 180 nm to 400 nm

3.15
UV luminaire
apparatus which distributes, filters or transforms the ultraviolet radiant energy transmitted from at least one source of optical radiation and which includes, except the sources themselves, all the parts necessary for fixing and protecting the sources and, where necessary, circuit auxiliaries together with the means for connecting them to the power supply

[SOURCE: IEC 60050-845:2020,845-30-001, modified for UV]

3.16
photocuring lamp product
lamp product that usually employs UV-A to photopolymerize liquid polymers to a solid state

Note 1 to entry: Examples include photopolymerization of liquid inks in printing or rapid curing of plastic products.

3.17
time-weighted average exposure
TWA exposure
averaged cumulative exposure dose over a given period of time (normally any 30 000 s to approximately 8 h period) divided by the exposure duration to provide an effective irradiance for both variable distances and durations

Note 1 to entry: The TWA is essential in considering lengthy exposures to ultraviolet hazards, since variable exposure distances at different irradiances and durations determine the reasonably foreseeable worst-case exposures (for photochemical hazards) which correspond therefore to the measured/calculated irradiance at a specified distance for RG determination (analogous to the 500-lx assessment distance for GLS lamps). See Annex E.

3.18
ultraviolet radiation
optical radiation within the wavelength range from 100 nm to 400 nm

Note 1 to entry: The UV-C extends from 100 nm to 280 nm, UV-B from 280 nm to 315 nm, and UV-A from 315 nm to 400 nm.

Note 2 to entry: Ultraviolet radiation at wavelengths less than 180 nm is considered vacuum ultraviolet radiation for the purpose of this document and is not included in the scope.

[SOURCE: IEC 60050-845:2020, 845-21-008, modified: Notes 2 to 5 to entry omitted and new Note 2.]

3.19
ultraviolet-fluorescence illuminator
any UV-A lamp designed to illuminate and excite fluorescence to permit increased visualization of the material

Note 1 to entry: Examples include “black-light” fluorescent illuminators, security-code reading UV-A lamps used for counterfeit money detection, medical applications, etc.

4 Risk groups applied for ultraviolet lamp-product safety assessments

4.1 Basis for optical radiation safety risk group determination

IEC 62471/CIE S009 provides the fundamental method to determine the risk group of any individual lamp and also the default measurement condition to determine the risk group of any lamp or any product incorporating a lamp, unless a vertical (application-specific) standard exists that includes measurement conditions for its specific application. The risk groups in IEC 62471 indicate the degree of risk from potential optical radiation hazards and minimize the need for further measurements. The risk groups were developed based upon decades of lamp use experience and the analysis of accidental injuries related to optical radiation emission (where injuries were, generally, quite rare except from ultraviolet-emitting lamps or arc lamps). The risk groups are also used in determining appropriate measures for risk management. There are four basic risk groups:

- Exempt group (RG-0) where no optical hazard is considered reasonably foreseeable, even for continuous, unrestricted use. Typical examples are small UV-A LED lamps and UV-A fluorescent lamps used in ultraviolet fluorescence illuminators or in domestic insect light traps;
- Risk group 1 (RG-1) products are safe for most use applications, except where prolonged direct ocular exposures may be expected. An example of a risk group 1 lamp products are some battery-operated UV-A torches (flashlights) or large, industrial insect light traps;
- Risk group 2 (RG-2) products generally do not pose a realistic optical hazard because of either discomfort glare from lens fluorescence or where lengthy exposures are unrealistic; examples include some UV-C germicidal fixtures;
- Risk group 3 (RG-3) products pose a potential hazard even for very brief exposures at close distance, and product safety requirements are generally essential; examples include sunlamp products (IEC 60335-2-27), Vitamin-D lamp products and unenclosed UV-C germicidal lamp products.

IEC 62471 does not provide guidance on manufacturing requirements and control measures. These issues are addressed in application-specific vertical standards such as this document. Labelling requirements and user information for each UV-lamp-product risk group are provided in this document (see 7.2 and 7.3).

4.2 Assessment criteria (background) for UV lamp products

The standard measurement conditions consider the emission spectrum and, for ultraviolet radiation, the irradiance to determine risk to the eye and/or the skin. The measurement conditions are intended to optimize the signal of trace amounts of UV-B and UV-C radiation that are emitted from lamp products intended to emit largely in the UV-A spectral region. The risk-group assessment distance is related to potentially hazardous exposure conditions and time-weighted-average (TWA) effective assessment distances based upon reasonably foreseeable worst-case exposure durations. This is built into the emission limits. The concept of a hazard distance normally does not apply to photochemical hazards, since UV hazardous doses accumulate, and the daily exposure determines the potential hazard. For time-varying sources, the accumulated exposure (dose) determining the TWA exposure will be the same as a continuous (CW) exposure for the same total duration. Optical sources are rarely at a fixed distance from the eyes, nor does an individual stare at a UV source for 30 000 s (approximately 8 h) a day, or more. The UV (actinic) S(λ) corneal/skin limit (see Annex D) applies to chronic exposure, where daily skin exposure will be higher than ocular exposure in almost all

applications. The risk-group assessment distances, therefore, vary for each application and are listed in Table 2, Table 3 and Table 4 for various types of lamp products.

Assessment and measurement conditions necessarily differ for different special application lamp systems, such as insect light-traps, germicidal lamps, UV photocuring lamp products or UV-A fluorescence illuminators. Different application groups define a range of operational, maintenance and servicing conditions. Thus, the assessment applied to UV lamp products in this document justifies somewhat different measurement conditions than default measurement/assessment conditions in IEC 62471 for some products.

In general, the assessment of a single lamp/LED cannot be automatically transferred to the final lamp product. Under specific conditions, the assessment of a single lamp/LED is directly transferable to the lamp system. The risk group will remain the same, or may be reduced (e.g., by filters, etc.). However, as a general rule the UV luminaire will alter the spectrum or geometry of the irradiance field. The use of reflectors or appropriate focussing optics may increase the irradiance and increase the risk group, in which case the lamp assessment is not transferrable to the lamp system. Results may not be transferrable if multiple lamps are used in a lamp system.

The requirements in this application-specific (vertical) standard are for the risk group that can be used in some specific applications. Examples include unrestricted-use products which can be used in the home or uncontrolled environments. Performance features are based upon the risk group specifications and application-specific control measures. Basic guidance, based on the likelihood of direct source viewing, is provided in Clause 7. The hierarchy of applicable safety measures follow the internationally accepted priority ranking of manufacturer safety measures. That is, engineering controls (e.g., filters, shielding, interlocks, relevant proximity sensing, etc.) are the highest priority, followed by administrative measures (such as warnings and labels, see 7.3) and then personal protective equipment as the last resort.

An underlying assumption of this document is that it is not necessary to reduce optical radiation exposure to as low as reasonably achievable; however, as a general guideline, needless emissions that would produce unnecessary human exposure should be minimized.

5 Measurements to determine applicable risk group

5.1 General

This document addresses those lamps and lamp products for which more than half of the optical radiation (radiant power) emitted between 180 nm and 3 000 nm is in the spectral region 180 nm to 400 nm. Examples generally include low and medium pressure mercury lamps, UV LED lamps, excimer lamps and deuterium lamps.

For other lamp types, it is not intended that a spectral measurement be performed to verify this condition for emission. Prior knowledge of the spectral emission regions of the lamp or the spectral transmittance/ reflectance properties of optics used in the lamp product is sufficient to determine whether or not a product falls within the scope.

In case of doubt, a simple test to determine whether a particular lamp meets this criterion could be performed using a thermal detector and a long wavelength pass filter having a cut-on around 400 nm (UV blocking).

Measurements of irradiance in the UV are limited to a full cone angle of 80° (i.e. ± 40) field of view (FOV).

NOTE Due to the large reduction factor for skin, it is appropriate to apply the 80° FOV that applies for ocular risks (ICNIRP, 2004). Normally the 80° FOV will capture all of the significant radiation. However, if a detector with a wider FOV (e.g., a cosine-response detector) is used, the assessment will over-estimate the exposure.

- The specified output shall be determined for foreseeable variations in the environment (temperature, air pressure, humidity, outdoor-use, etc.).

- The emitted radiant power of an installed system shall not increase nor change its direction as a result of any reasonably foreseeable events or single fault condition.

5.2 Time-weighted averaged irradiance

The applicable emission limits for risk groups for time-weighted averaged irradiance are specified in Table 1.

Although the full spectral range in consideration is 180 nm to 400 nm, measurement need not be performed over the full range as described below.

In the region between 180 nm and 200 nm, atmospheric oxygen strongly absorbs photons. As a result, few spectroradiometers are specified and it is difficult to obtain traceable spectral irradiance standards operating over this range. Measurement below 200 nm should therefore be reserved only for the special case of a low-pressure mercury lamp with vacuum UV transmitting quartz envelope.

In the region between 200 nm and 250 nm, low spectroradiometer sensitivity may cause measurement results with poor signal-to-noise ratio. While this may be remedied (see Clause C.6), prior knowledge of the spectral emission regions of the lamp or the spectral transmittance/ reflectance properties of optics used in the lamp product may be used to limit the spectral range of measurement to 250 nm to 400 nm.

Table 1 – Emission limits for risk groups for time-weighted averaged irradiance

Hazard	Wavelength range nm	Symbol for emission level	Emission[a] limits			Units
			Exempt group	Risk group 1	Risk group 2	
UV (actinic)[b]	180 to 400	E_s	0,001	0,003	0,03	$W \cdot m^{-2}$
UV-A[c]	315 to 400	E_{UVA}	10	33	100	$W \cdot m^{-2}$

[a] Emission limits are expressed as irradiance specified at a given application dependent assessment distance and not at the surface of the source. Actinic irradiance is spectrally weighted: the UV-A irradiance is not.

[b] For dose-limited products, the spectrally-weighted dose emission limit is 30 $J \cdot m^{-2}$. See 5.3.3.

[c] In the unusual case of a lamp source to be directly and intentionally viewed for more than 1 000 s in any 30 000 s (approximately 8 h) period (view-related risk), the dose emission limit for the exempt limit is reduced to 10 kJ/m^2 as determined by the intended stare time.

5.3 Risk group assessment conditions

5.3.1 Maximum output conditioning

The optical source shall be operated at maximum optical power to achieve the highest accessible radiant power emission.

5.3.2 Measurement and assessment distances for UV lamp products

When measuring irradiance or spectral irradiance from UV lamp products, measurements of effective UV-B and UV-C irradiance and/or spectral irradiance shall be made at a distance that is sufficiently close in order to minimize the measurement errors from stray light where filtered, but biologically significant, emissions are very weak. However, in the case that the radiant output is so intense that the instrument detector might be saturated, then the measurement distance shall be greater. If the measurement distance differs from the risk group assessment distance in Table 2, Table 3 and Table 4, then it is necessary to transfer the measurements to the assessment distance. Normally the transfer of measurements made at a closer distance is obtained by determining the ratio of $S(\lambda)$-weighted UV to total irradiance or radiant power (i.e., µW-eff/mW-total) in the same manner as determining the µW/lm ratio when assessing GLS lamps. The actual measurement values and the extrapolated measurement values at the assessment distance shall be reported.

5.3.3 Risk-group assessment distances

Table 2, Table 3 and Table 4 provide the risk-group assessment distances for specific ultraviolet lamp products. Table 2 applies to products intended for use by consumers in uncontrolled environments that require no restrictions other than the provision of user information. Under normal or abnormal operating conditions, ordinary persons should not be exposed to ultraviolet sources capable of causing pain or injury. Under a single fault condition, ordinary persons should not be exposed to ultraviolet sources capable of causing injury. Those products used in applications that require special use training and generally only administrative controls are listed in Table 2; these are normally intended for professional use or use by instructed persons.

Under normal operating conditions, abnormal operating conditions or single fault conditions, instructed persons should not be exposed to parts comprising ultraviolet sources capable of causing injury. Lamps and lamp products intended for use by consumers/ordinary persons or instructed persons shall not emit accessible RG-3 emission levels. Those products requiring engineering controls and/or personal protective equipment as well as administrative controls and special training, and typically limited to professional use by competent persons are in Table 2. For UV lamp products listed in Table 2, if the $S(\lambda)$-weighted irradiance and the UV-A irradiance meets the exempt group limits at the assessment distance, no further testing is required. However, a calculation should be performed to ensure that the S(λ)-weighted irradiance and the UV-A irradiance cannot exceed the emission limit for RG-2 at 20 cm (unless a closer distance is indicated in Table 2). If the UV lamp product's $S(\lambda)$-weighted irradiance exceeds the emission limit for RG-2 at 20 cm, then the product should be labelled RG-3 and its use should be restricted, meaning that the UV lamp product should not be used by consumers/ordinary persons. For UV lamp products not listed in Table 2, Table 3 and Table 4, the assessment distance shall be 1 m, or the manufacturer's recommended use distance in the case that lengthy exposure times (i.e. greater than 100 s) at this distance are feasible.

Systems that emit radiation exceeding the emission limit for RG-2, but with access restricted due to installation by a competent person to restrict the likelihood of persons being exposed above the RG-2 limits remain RG-3 products unless engineering controls prevent access.

Table 2 – Risk group assessment distances for unrestricted-use[a] products

Lamp product	Assessment distance m
Fluorescence illuminators, hand-held	1,0
Fluorescence room and staging illuminators, e.g. UV-A “black light”	2,0
Fluorimeters/Transilluminators	0,5
Home-use skin clearing illuminators	0,5, but, see 5.3.5
Insect light traps (< 50 W) and domestic use	1,0
Nail-curing products, home-use	0,5 m, also, limited to the dose limit at manufacturer’s use distance[b]
UV surface cleaning, handheld (see 6.3.3)	0,2
UV water disinfection products	1,0

[a] For use by consumers (sometimes called “ordinary persons”), i.e., persons without special training or skills.

[b] The irradiance at this distance can be obtained via a calculation, using either the inverse square, or the 1/distance relationship, depending on whether the source approximates a point source, or a linear source.

Table 3 – Risk group assessment distances for restricted-use products intended to be used by instructed persons

Lamp product	Assessment distance m
Dental diagnostic illuminator	1,0; but see 5.3.5
Dental photocuring illuminator	0,5 for user; apply emission dose limit at Manufacturer's use distance for patient (see 5.3.5)
Medical diagnostic	0,5 for user; apply emission dose limit at Manufacturer's use distance for patient (see 5.3.5)
Medical treatment	Out of scope – see IEC 60601-2-57
Ophthalmic diagnostic devices	Out of scope – see ISO 15004-2
Nail-curing products- professional	See 5.3.5[a], 0,2 assessment for ocular hazards
Insect light traps (50-150 W) (> 150 W)	 2,0 3,0
Photocuring products (inks, etc.)	1.0
UV germicidal – in-duct irradiation and air purifier units	0,5 from any access point
UV fluorescence illuminator	0,6
UV lacquer hardening/curing	1,0
UV powder curing	1,0
UV optical fibre curing	1,0
UV surface activation	1,0
Sunlamp products/indoor tanning appliances	Out of scope – see IEC 60335-2-27
UV surface cleaning, handheld (see 6.3.3)	0,6
UV germicidal – Upper room irradiation units	1,0 (on axis) Additional post-installation requirement below 1,8 m above intended floor level to assess TWA exposure of occupants – see Annex E and Annex F.
UV germicidal air purifiers (leakage radiation from the enclosure)	0,4

[a] The irradiance at this distance can be obtained via a calculation, using either the inverse square, or the 1/distance relationship, depending on whether the source approximates a point source, or a linear source.

Table 4 – Risk group assessment distances for lamps or lamp products intended for use by professional, competent persons

Lamp product	Assessment distance m
Dental photocuring illuminator	0,5, but see 5.3.4 and 5.3.5 at contact
Medical treatment	Out of scope – see IEC 60601-2-57
Open-room germicidal products for occupied spaces[a]	1,0 on maximum beam axis
Open-room germicidal products for restricted access[a]	0,5
Upper-room germicidal products[a]	0,5 (small source) and 1,0 (linear source) Additional post-installation requirement below 1,8 m above intended floor level to assess TWA exposure of occupants – see 6.3.4
UV germicidal – In-duct system	0,5 from service access point
UV water-purification systems	0,5 from service access point

5.3.4 Dose-limited products

Some lamp products are designed to be dose-limited, in which case the risk group classification can be performed by comparing the emission limit with the value calculated by multiplying the maximum possible dose emitted by the maximum possible exposure duration within any 30 000 s (approximately 8 h) period (i.e., 0,001 $W \cdot m^{-2}$ × 30 000 s is 30 $J \cdot m^{-2}$).

5.3.5 Products intended to expose the skin or eyes

For products intended to expose the skin or eyes, if the UV-A emission exceeds the RG-2 emission limit at the manufacturer's specified use distance, dual limits shall be applied. In addition to the $S(\lambda)$ weighted dose-emission limit (see Annex D for the $S(\lambda)$ weighting values), the total irradiance (200 nm to 3 000 nm) shall also be limited to 1 kW/m^2 at the tissue surface to preclude overheating.

6 Engineering requirements for RG-2 and RG-3 ultraviolet systems

6.1 General

RG-2 and RG-3 lamps, lamp systems, and products containing lamps which provide UV-C and/or UV-B emissions shall comply with requirements of 6.2 to 6.6. These requirements limit the access to UV-C and/or UV-B emission levels that could exceed the applicable actinic UV hazard exposure limit for the skin and eye (hazardous UV-C and/or UV-B). These are most likely to be GUV products.

Where relevant product safety standards provide specific requirements, these may be applied in lieu of 6.2 to 6.6.

NOTE Product safety standards can have additional or more restrictive requirements, or not permit specific construction or function details.

Example: IEC 62368-1 requires for any ordinary (consumer) or instructed person, that emission exceeding levels of RG-2 is contained by the enclosure of the lamps and lamp system or the enclosure of the equipment.

- Products shall be designed so as not to emit needless, potentially hazardous optical radiation.

- The products shall be designed for foreseeable variations of installation conditions (i.e. the possibility of installation on the ceiling, in an aircraft, etc.).

Conformity is checked by inspection.

6.2 Protective housing

6.2.1 General

The product shall have a protective housing that, when in place, prevents access to potentially hazardous UV-C or UV-B, i.e. the accessible emissions shall not exceed the emission limit for RG-1.

Conformity is checked by inspection and as specified in 6.2.2 and 6.2.3.

NOTE A protective housing can act alone; it is then only effective when it is in place. A protective housing can also act in conjunction with an interlock or proximity sensor; in this case, protection is ensured whatever the position of the protective housing.

6.2.2 Enclosures

Enclosures used as protective housing shall have:

a) the necessary rigidity to withstand reasonably foreseeable mechanical impacts;

b) made from a material not degraded by UV irradiation in a way that could increase the actinic UV accessible emissions; and

c) be constructed such that access to hazardous actinic UV is only possible with the use of a tool.

Conformity is checked by inspection.

6.2.3 Openings, panels and doors

Enclosure openings, panels and doors, that allow access to hazardous UV-C, shall either:

a) be constructed such that the use of a tool is required to open any lids, panels or doors;

b) for any service or maintenance openings intended for instructed persons, be provided with a non-defeatable interlock system complying with 6.5;

c) for any service or maintenance openings intended for competent persons, may be provided with

   i) a non-defeatable interlock system complying with 6.5; or

   ii) a defeatable interlock system complying with 6.5 and an emission warning system or warning device complying with 6.4 and 6.5; or

d) comply with requirements of 6.3;

NOTE The interlock can be a password, physical key or other specific tool.

Conformity is checked by inspection.

6.3 RG-2 and RG-3 products

6.3.1 General

Where the intended use requires access to potentially hazardous UV-C or UV-B, the product shall be provided with alternative means for ensuring protection against hazardous UV-C or UV-B as listed below.

Conformity is checked by inspection and as specified in 6.2.2 and 6.2.3.

6.3.2 Proximity sensor

Where it would be possible to be exposed to potentially hazardous UV-C or UV-B, a proximity sensor shall be used in lieu of protective housing or interlock system. The proximity sensor shall automatically terminate the emission within 1 s in the event of encroachment into the area of primary emission. The proximity sensor shall prevent lamp turn-on if presence of an individual is detected prior to delayed turn-on. Manual reset is required if sensed encroachment has terminated emission. If the technology or application would preclude this termination of emission, the Manufacturer shall provide a risk assessment that the emission is reduced below the limit of RG-2 at 20 cm from the source.

Conformity is checked by inspection.

6.3.3 Orientation control

Handheld UV surface cleaning products shall have an orientation control, that disables the emission for hazardous UV-C or UV-B, when the product is moved out of normal use orientation as specified by the manufacturer.

NOTE Orientation control can be a tilt sensor or photoelectric switch.

If the products may be left unattended, orientation control may not be an acceptable or sufficient means of risk reduction for products which are intended to be used in a domestic setting, or for use in a commercial setting. In this case, additional means of risk reduction are necessary.

Conformity is checked by inspection.

6.3.4 Upper-room germicidal UV luminaire alignment

UV luminaires used for upper-room GUV shall be provided with a means of adjusting the alignment at the site of installation to allow the competent person undertaking the installation to properly direct the UV beam such that exposures in the lower room are below the appropriately time-weighted human exposure limits at 1,8 m above the floor and to the floor below. The manufacturer shall provide the upper room irradiance pattern (see for example CIE 247: 2021) to assist the installer.

6.3.5 Delayed-ON timer

For products intended to be used in open or upper rooms, a delayed-ON switch may be used, but sufficient to allow users to move to a safe distance prior to emission in lieu of an interlock (6.2.3) or proximity sensor (6.3.2). The delay shall be no shorter than 5 s.

Conformity is checked by inspection.

6.3.6 Exposure time control / auto-shutoff

For products intended to be used in open or upper rooms, an automatic shut-off timer may be used that will disable emissions after a specific amount of time, to allow users to access the product after intended exposure in lieu of an interlock (6.2.3) or proximity sensor (6.3.2).

Conformity is checked by inspection.

6.4 Emission warning

Where emission exceeding levels of RG-1 can be accessible (or interlocks can be defeated), the product shall have an UV-C emission warning device. The warning shall give a visible or audible signal when the system is switched on. Lamps (such as low-pressure mercury) that emit visible radiation or a fluorescent tab that glows during emission shall be considered to meet the visible emission warning.

Conformity is checked by inspection.

6.5 Reliability

Any electronic system or sensor, used for the protection of persons shall ensure that a single fault in the system or component is either unlikely to occur during the expected life of the equipment, or cannot cause a hazard.

NOTE The reliability and design requirements can be determined by applying, for example IEC 61508 (SIL) or ISO 13849 (PL) or other solutions providing equivalent functional safety.

Conformity is checked by inspection.

6.6 Emission controls

6.6.1 General

The product shall be provided with controls allowing the operator safe handling of the equipment.

Conformity is checked by inspection and as specified in 6.6.2 and 6.6.3.

6.6.2 Emissions stop

A means permanently attached to the product to disable hazardous UV-C or UV-B emissions shall be provided.

Conformity is checked by inspection.

6.6.3 Key control

Products intended for use by competent persons only, where it is reasonably foreseeable that these may be left unattended in a domestic or commercial setting, shall be provided with a key-operated master control.

If this is a physical key it shall be removable and any UV-C emission shall not be accessible when the key is removed.

NOTE 1 This can be a password, physical key or other specific tool.

NOTE 2 Products left unattended in a domestic or commercial setting, can be activated by a consumer or an ordinary person, inadvertently causing a potentially hazardous situation.

Conformity is checked by inspection.

7 Information and labelling – Manufacturer's requirements

7.1 General

The primary purpose of risk-group classification by the manufacturer is to determine the need for any engineering controls and to inform the user of potential hazards that may require precautions or limitations on installation. Therefore, when a UV lamp product is placed in either risk groups 2 or 3, it is important for the user to be informed of the potential hazards to the eye and skin and what hazard controls are appropriate. Risk group 1 and exempt products do not pose a risk requiring controls, since it is unrealistic that UV lamps will be directed at the eye for hours for any application (including medical).

The lamp product risk group classification indicates necessary safety measures to reduce the risk for the application as specified in the applicable vertical standard.

7.2 User information

The manufacturer shall provide the user sufficient information to operate safely depending on the risk group of the UV lamp product. The user information includes the risk group classification of the product and any required precautions. If the UV lamp product is RG-3, the user information shall indicate that this product is ‘For professional use only’, or ‘For installation by competent professionals only’, as applicable. If fixtures or modifying optics can be used with the system, possible worst-case exposure hazard values and hazard distances shall be listed in the user manual.

NOTE In the wavelength range 180 nm to 400 nm, where the risk-group classification is based on irradiance or radiant exposure, the assessment of a single lamp cannot be automatically transferred to the final lamp product.

Conformity is checked by inspection.

7.3 Labelling on UV lamps

7.3.1 RG-0 UV lamps – no labelling required.

7.3.2 RG-1 UV lamps – user instructions/lamp packaging shall state that UV is emitted from the lamp.

7.3.3 RG-2 UV lamps – user instructions/lamp packaging shall state that UV is emitted from the lamp. A label is required stating that “UV emitted from this product.” If any special-use/safety instructions are required for safe use, the ISO “read instructions” symbol (ISO 7010-m002), shall be added.

7.3.4 RG-3 UV lamps – a warning label as specified in IEC 61549 or as shown in Figure 1 shall be on the product. The following (or equivalent) wording shall state: “WARNING, UV emitted from this lamp. Avoid exposure of eye and skin to unshielded lamp; RG3 lamp. Skin or eye injury could result.” If any special-use/safety instructions are required for safe use, the ISO “read instructions” symbol (ISO 7010-m002), shall be added.

7.4 Labelling on UV lamp products

7.4.1 RG-0 UV lamp products

Ultraviolet lamp products that are classified as RG0 require no additional labelling. However, a label indicating that UV is emitted is optional.

7.4.2 RG-1 UV lamp products

A label indicating that UV is emitted is not required but is optional. However, there should be information provided in the user instructions indicating that UV (and which part of the UV waveband, e.g. UV-C, UV-B or UV-A, or the emitted peak wavelength in the case of LED lamps, as applicable) is emitted from this product.

7.4.3 RG-2 UV lamp products

The classified risk group and the hazard shall be labelled (Figure 1 or Figure 2, as appropriate).

There should be information provided in the user instructions indicating that UV (and which part of the UV waveband, e.g. UV-C, UV-B or UV-A, or the emitted peak wavelength in the case of LED lamps, as applicable) is emitted from this product.

NOTE The wavebands (UV-A, UV-B or UV-C) to be reported are those that exceed relevant emission limits.

Instruction manuals and product information shall state “Avoid direct exposure to eyes or skin”. A label (see Figure 1 or Figure 2) shall be applied on the product.

7.4.4 RG-3 UV lamp products

The product shall be labelled with the classified risk group (see Figure 1 or Figure 2, as appropriate).There shall be information provided in a label on the product and in the user instructions indicating that UV (and which part of the UV waveband, e.g. UV-C, UV-B or UV-A, or the emitted peak wavelength in the case of LED lamps, as applicable) is emitted from this product.

Instruction manuals and product information shall contain the following warnings “WARNING: Turn off the UV lamp before opening” and “WARNING: Use UV radiation eye and skin protection during servicing.If the insertion or removal of a removable modifying optic increases the risk group, a warning label shall be attached to the optic. A label shall be applied on the product similar to:

“Warning!

No direct exposure of the eyes or skin”

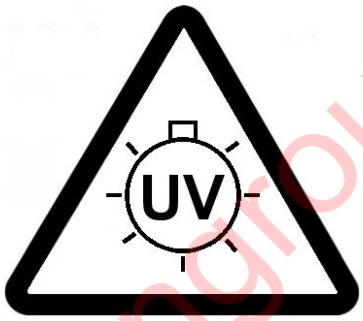

Figure 1 – Based on graphic 6040 of UV lamp inside triangle from IEC 60417

For UV lamp products, the following informative labels (Figure 2) shall be applied as appropriate.

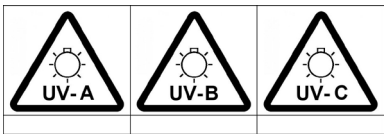

Figure 2 – Alternative labels to provide added information for narrow-band UV lamps

In accordance with IEC 61549, the UV-C label should be applied for UV-C germicidal lamps.

7.5 User manual

7.5.1 General

Normal intended use and installation requirements shall be described in detail. If required, training and restricted area requirements shall be specified in the user manual.

7.5.2 Risk reduction measures

After a thorough risk analysis by the manufacturer on the final product, it may be appropriate to implement additional risk reduction guidance such as:

- Requirements for outdoor product use
- Specific warnings
- Guidance on replacing lamps, such as “Replace lamps only with electrical power turned off,” and provide guidance on appropriate replacement lamps
- Other protective measures to be taken, e.g., wearing of fingerless gloves by the nail curing client, if appropriate.

7.5.3 Limited use

RG-3 products require professional use or special installation (e.g., upper-room UVG), and user instructions shall clearly state the irradiation zone and the requirement for special installation or supervised use.

7.6 Maintenance and service

Potential hazards may exist during lamp or product servicing. Re-lamping instructions shall clearly state risks and proper procedures. Only persons with the correct training and information shall perform maintenance or service of a lamp or lamp product containing an RG-3 lamp. In the case of maintenance or service of the lamp system with a lamp of RG-3, only persons who have the correct training and information about the risk should perform these tasks. The establishment of a temporary controlled access location and the need for any special protective face-shield, gloves or other personal protective equipment shall be clearly stated in the maintenance instructions.

Annex A
(informative)

Typical applications of UV lamp products

A.1 Background

Ultraviolet lamps and lamp systems are employed in a variety of applications, from novelty “black light” illuminators, theatrical spotlights, and fluorescence applications to medical lamps, insect light traps and germicidal irradiation. Typical lamp types are:

- Low-pressure mercury-fluorescent lamps [tubular and compact fluorescent (CFL)]
- Low-pressure mercury, UV-C lamps (‘germicidal lamps’)
- Rare-gas halide, such as krypton-chloride UV-C excimer lamps
- UV LED lamps (generally 50 nm full-width at half maximum (FWHM) or less)
- UV-Filtered metal-vapour discharge lamps
- UV-Filtered incandescent lamps

Most typically, lamps are deployed in applications as listed in Clause A.2.

A.2 Applications of UV lamp products

A.2.1 Near-UV (UV-A) “black-light” sources to view fluorescent pigments

Hand-held and fixed UV-A lamps with typical peak emissions at 350 nm to 400 nm are used in a variety of applications for exciting fluorescent coatings, paints, pigments, etc., and to visualize the visible fluorescent emission for non-destructive testing. The viewer may or may not wear UV-blocking eyewear—primarily to improve contrast of the visible fluorescence emission spectrum. Hand-held UV-A spotlights or “flashlights” are used in non-destructive testing of coatings and dyes. Similar sources are used to detect authentication codes on money, bank notes, identification cards and identification stamps. In all of these applications, the risk group determination is based upon the highest time-weighted exposure assessed at the reasonably foreseeable worst-case exposure condition (surface reflections from a viewing distance of 30 cm to 50 cm from the fluorescent material), which corresponds to a standardized assessment distance from the source of 100 cm for 30 000 s (approximately 8 h). In actual use, the UV-A beam is directed away from the viewer and the user would not receive such a high exposure.

Permanently installed “black-light” systems are used in the entertainment industry, museums, bars and banks and are not installed to encourage direct viewing other than unintentional viewing for momentary periods. Hence the time-weighted assessment conditions lead to an assessment distance of 1 m.

A.2.2 Near-UV (UV-A) insect attractant lamp products

Both fixed and portable UV-A lamp systems with typical peak emissions generally within the spectral range of 350 nm to 370 nm are used in a variety of applications for insect light traps (ILTs). Effective installation requires that the ILTs are placed away from individuals so that insects are attracted to the UV-A source and not attracted to individuals or permanently occupied locations. Therefore, the highest time-weighted exposure is assessed at distances of 1 m or greater—even for indoor units, depending upon application.

A.2.3 UV germicidal (UV-C) lamp products

Ultraviolet germicidal (UVG) lamp products are generally designed to block all emission of UV into occupied spaces. UVG irradiation is employed in water-purification and air-handling systems and domestic air-purifiers that have interlocked enclosures that prevent potentially hazardous UV exposure during normal operation. Interlocks also normally preclude access to UV even during maintenance or servicing. However, in the control of airborne infectious agents (bioaerosols) such as tuberculosis bacillus, upper-room (see NOTE), open UVG fixtures are used in some hospitals, prisons and institutions where infection control is critical to irradiate only the upper-room volume above at least 1,8 m (see Annex E) and potentially hazardous exposures are possible in the occupied lower part of the room when fixtures are improperly installed or poorly maintained. The time-weighted exposure shall be assessed with proper assessment and measurement geometry. Installation instructions are essential in this application and a safety assessment after room installation is also essential. Measurements are therefore made not only in the air-treatment zone, but in the non-treatment, occupied zone. Risk group assignment is based on measurements in the air-treatment zone and installation should assure safety in the occupied zone. This is because there are no engineering controls to limit access to the upper room volume.

NOTE The 99-percentile eye-height is ~180 cm for a standing human, ~130 cm for seated humans, and 112 cm eye height in a high hospital bed.

UV germicidal lamps are traditionally low-pressure, mercury-discharge lamps with most (over 90 %) emission at 254 nm (UV-C). Newer types of UV germicidal lamps include LEDs and excimer plasma (e.g. KrCl) lamps. The lamp envelope was traditionally of quartz, but today most typically of a UV-C transmitting glass (e.g., Vicor) that limits ozone production (Claus, 2021).

Hand-held, UV surface cleaning products (e.g., UV wands) are sold in some consumer markets as well as for professional use. Informed applications can be safe for professional use. Most sold for consumer use either have insufficient irradiance to allow a simple movement over the surface to be disinfected or emit unsafe level of UV radiation to achieve germicidal effect and could cause skin and/or eye injuries. Some products have an orientation switch that terminates emission unless the wand is directed downward; however, this safety feature does not fully eliminate the risk of injury from direct and indirect UV radiation. Handheld UV surface cleaning products shall not be used by an ordinary person or a consumer. UV tanning equipment (not in scope – provided for information only).

Consumer demand for a cosmetic tan led to the development and distribution of commercial UV tanning equipment. Although such equipment necessarily exposes the human skin to radiant exposures in excess of the recommended limits for exempt lamp products, there are means to minimize the potential risks for delayed effects. The term “sunlamp product” or “sunbed” is frequently used to describe all tanning appliances consisting of either a single UV radiation-emitting lamp (emitting UV-A and/or UV-B radiation) as in some facial tanners, or a number of such lamps incorporated in a bed, canopy, panel, or any combination thereof. Potential adverse health effects of suntanning exposure to UV radiation are well documented and reasonably well quantified (WHO, 1994, 2017).

In many countries national regulations for sunlamp products exist. For example, in the US., sunlamp products are required to meet the Code of Federal Regulations (CFR) of the US Food and Drug Administration (21 CFR 1040.20). That regulation provides optical radiation performance requirements designed to minimize risks to the user.

A.2.4 UV nail curing and treatment

UV lamp products for photocuring of nail polish and nail laminates employ UV-A lamps installed in a fixture to minimize ocular exposure. Irradiances of ~10 $mW \cdot cm^{-2}$ (100 $W \cdot m^{-2}$) are typical at the nail (see Dowdy and Sayre, 2013). The manufacturer may choose to recommend protective measures, such as the wearing of fingerless gloves during use.

A.2.5 UV medical and dental sources

UV lamp products using a UV-A (“black-light”) fluorescent or filtered incandescent lamp are widely used in diagnostic instruments. Frequently referred to as “Wood’s Lamps,” these hand-held products are found in emergency rooms, ophthalmology departments and dermatology departments for fluorescence detection. These will generally be RG-0 or RG-1. UV-A induced fluorescence of proteins and DNA is useful in a range of applications. Dental examinations may employ UV-A for identification of tooth plaque and periods of exposure rarely exceed 2 min to 3 min. Medical laboratory UV trans-illuminators (both UV-A and UV-B) are used to view DNA or RNA that has been separated by electrophoresis through an agarose gel, which are visible by their fluorescence.

UV phototherapy medical devices are used to treat diagnosed skin disorders such as, but not limited to, psoriasis, vitiligo, etc.

UV-A also has been used in the past for photocuring in restorative dentistry, although photocuring materials now generally require short visible wavelengths rather than UV-A.

Annex B
(informative)

Potentially hazardous biological effects

B.1 Background

Potentially hazardous ultraviolet radiation exposures from lamp products may produce either acute (short-term, transient) effects or delayed effects from chronic (long-term, day-after-day) exposures, and these biological effects are briefly described in this annex. Beneficial biological effects, such as the production of vitamin-D in the skin or improved immunity, are not therefore included in this annex (See CIE 174:2006, CIE 201:2011, and CIE 219:2016); however, it may be noted that even very low-risk lamp products such as RG-1 can produce these beneficial effects from lengthy exposures.

Most UV photobiological effects show a strong degree of “reciprocity,” i.e., the dose response shows a reciprocity relation of exposure rate (irradiance) and exposure duration; i.e., a given response requires the same radiant exposure whether delivered in milliseconds or a couple hours. Another important characteristic of UV photobiological effects is strong wavelength dependence, and photobiologists always attempt to define an “action spectrum” that describes the relative effectiveness of differing wavelengths in producing a given response. While the determination of action spectra is straightforward for acute effects such as sunburn or “welders’ flash,” it is nearly impossible to define accurately for delayed effects such as UV cataract that require years of chronic exposure. Action spectra for such delayed effects are only suggested by some animal studies or only approximate wavebands can be determined.

B.2 Adverse acute biological effects from ultraviolet irradiation

B.2.1 Photokeratitis and photoconjunctivitis

Photokeratitis and Photoconjunctivitis are acute, transient inflammatory response of the cornea and conjunctiva of the eye, generally from UV-B (280 nm to 315 nm) and UV-C (100 nm to 280 nm) if present in the lamp spectrum. Non-technical descriptions of photokeratitis and associated photoconjunctivitis are: “welder’s flash” and “snowblindness” because of the association with exposures from those sources of shorter-wavelengths (e.g., UV-B from sunlight and UV-B and UV-C from open arcs). The cornea of the eye provides the front-most optical surface of the eye and the conjunctiva is the outermost tissue covering the sclera (white) of the eye. UV photokeratitis is almost always associated with a photoconjunctivitis; therefore, the combined effect is also correctly termed “photokeratorconjunctivitis.” Symptoms include: “sand in the eye,” blepharospasm (sudden, violent, involuntary contraction of the muscles of the eyelid), some clouding of vision; reaction in the palpebral fissure (opening between the upper and lower eyelids). Photokeratitis is not uncommon from accidental over-exposures to UV from germicidal lamps and mercury and xenon-arc lamps, but only in special applications. There are a limited number of reports of accidental over-exposures such as germicidal UV-C lamps inappropriately fitted to insect light-trap products.

Ultraviolet radiation between ~200 nm and ~400 nm can produce photokeratitis, the wavelength principally between 230 nm and 320 nm are most effective. The action spectrum peaks at approximately 270 nm (Pitts, 1971, 1974) although an earlier study suggested 288 nm (Cogan and Kinsey, 1946). Thresholds are well documented in both humans and in animal models, and the data available are generally in good agreement (Chaney, 2005). The inflammatory reaction is generally delayed by 4 h to12 h following the exposure and the time elapsed depends upon how much difference in exposure and threshold, heavy exposures producing reaction in shortest time; clearing in 24 h to 48 h, except for extremely severe exposures. The photochemical reaction initiates a chain of biological reactions. Since the normal turnover of surface corneal (epithelial) cells is ~ 48 h, the injured cells are soon removed in normal metabolic turnover. Thus, there are no known permanent effects from single exposures; although chronically repeated exposures to solar UV-B may be a major factor in the aetiology of Labrador keratopathy. More recent studies of photokeratitis from short UV-C wavelengths between 200 nm and 254 nm were prompted by use of germicidal UV in this spectral region (Kaidzu, 2021), and show remarkably higher thresholds at wavelengths less than 230 nm (sometimes referred to as “far-UV-C”). An immediate sensation of mild irritation has been experienced during irradiation by 222 nm that may be the result of an increase in tear-film evaporation (Sliney, 2021); but this sensation during irradiation does not occur with longer wavelengths such as 254 nm.

B.2.2 UV-Cornea reference documents

Chaney EK, Sliney DH, Re-evaluation of the ultraviolet hazard action spectrum–the impact of spectral bandwidth, *Health Phys.* 2005;89(4):322-32

Cogan, D.G. and Kinsey, V.E., Action Spectrum of Keratitis Produced by Ultraviolet Radiation, *Arch. Ophthalmol*., 35:670-617,1946

Hedblom, E.E., Snowscape Eye Protection, *Arch. Environ. Health*, 2:685-704, 1961

Kaidzu S, Sugihara K, Sasaki M, Nishiaki A, Ohashi H, Igarashi T, Tanito M., Re-Evaluation of Rat Corneal Damage by Short Wavelength UV Revealed Extremely Less Hazardous Property of Far-UV-C, *Photochem Photobiol*., 2021, doi: 10.1111/php.13419

Pitts DG, Tredici TJ, The Effects of Ultraviolet on the Eye, *Ameri. Ind. Hyg. Ass. J.,* 32(4):235-246,1971

Pitts, D.G., The Human Ultraviolet Action Spectrum, *American Journal Optom. Physiol. Opt*., 51, 946-960,1974

Sliney D.H., Stuck, B.E, A need to revise human exposure limits for ultraviolet UV-C radiation, *Photochem Photobiol*, 2021. doi: 10.1111/php.13402

World Health Organization (WHO):1994, *Ultraviolet Radiation, Environmental Health Criteria Document*, EHC-160, 2nd edn., WHO, Geneva

B.2.3 Erythema (sunburn)

Erythema (popularly referred to as “sunburn”) is a reddening of the skin resulting from over-exposure of the skin to UV (principally from UV-B) radiant energy. This reddening of the skin is transient – reaching a peak response in 8 h to 24 h (sooner if UV-C). Action spectra are published, and the peak normally is at ~300 nm (ICNIRP, 2004).

B.2.4 Erythema reference documents

International Commission on Non-Ionizing Radiation Protection (ICNIRP):2004 Guidelines on Limits of Exposure to Ultraviolet Radiation of Wavelengths Between 180 nm and 400 nm (Incoherent Optical Radiation), *Health Physics,* 87 (2): 171-186

ISO/CIE 17166:2019, *Erythema reference action spectrum and standard erythema dose*

B.3 Adverse biological effects from chronic exposure to ultraviolet irradiation

B.3.1 Skin cancer

Skin cancers are most frequently related to chronic (or possibly very severe acute) over-exposure to ultraviolet radiation (most significantly UV-B). Squamous cell skin cancers are most associated with many years of chronic exposure to sunlight and incidence is high among outdoor workers. These cancers are very much related to latitudes where UV insolation is highest. By contrast, melanocytic skin cancers frequently appear in unexposed areas of the trunk, back or upper legs that are generally not chronically exposed and the epidemiological evidence relating to UV exposures appear to point to severe sunburns – particularly in youth (Armstrong and Kricker, 2001). The carcinogenic risk from UV-C and UV-A is very low compared to UV-B (CIE, 2016). The photocarcinogenic action spectrum peaks at ~ 300 nm and rapidly drops to values less than 5 % in the UV-C. The non-melanoma skin cancer (NMSC) action spectrum is compared to action spectra to acute effects, skin erythema and photokeratitis. These are shown as linear and semi-log plots of CIE NMSC action spectrum in Figure B.1 and Figure B.2.

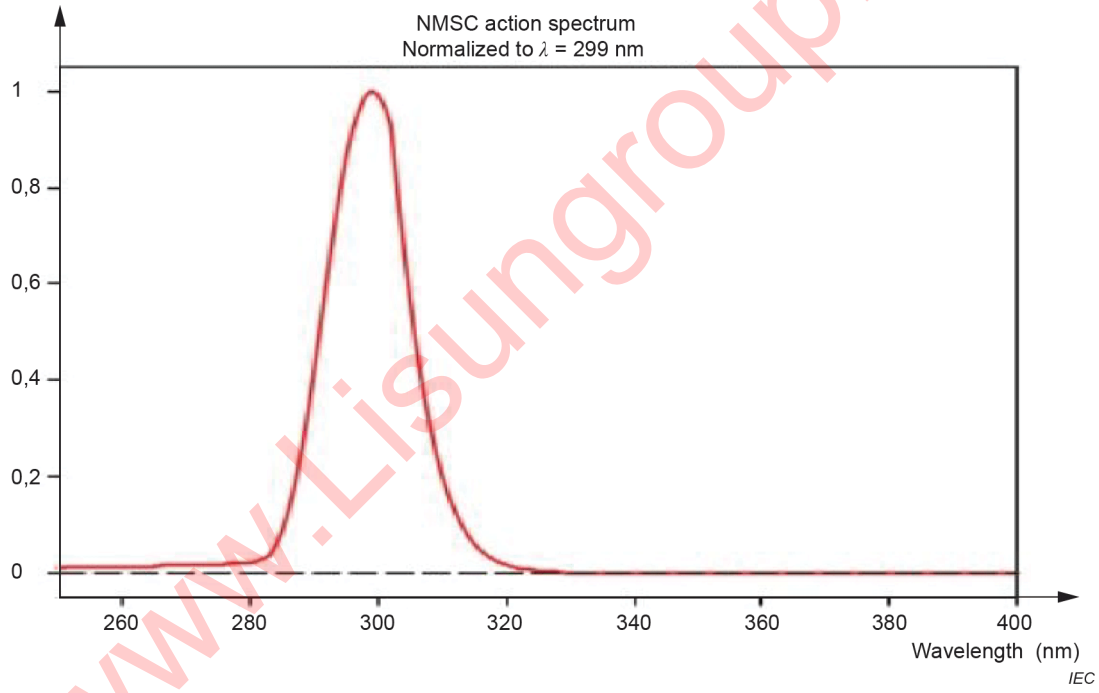

Figure B.1 – CIE standard action spectrum for NMSC

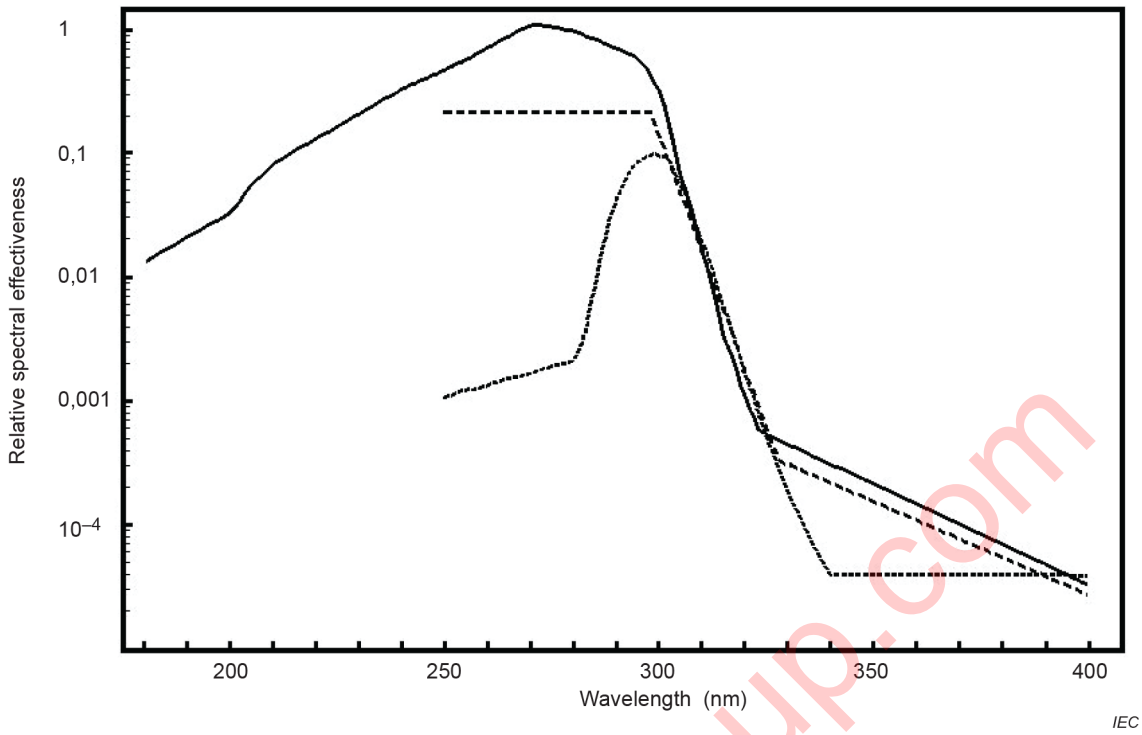

Figure B.2 – Semi-logarithmic comparison of three action spectra (ICNIRP $S(\lambda)$: solid line; McKinlay, Diffey erythema : dashed; NMSC: dots)

B.3.2 Skin cancer reference documents

Armstrong, B.K., Kricker, A.:2001, The epidemiology of UV induced skin cancer, *J Photochem Photobiol* B;63(1-3):8-18, doi: 10.1016/s1011-1344(01)00198-1

Forbes, P.D., Cole, C.A., Frank deGruijl, F., 2021, Origins and evolution of photocarcinogenesis action spectra, Including germicidal UVC, *Photochem. Photobiol*., doi: 10.1111/php.13371

ISO/CIE 28077:2016, *Photocarcinogenesis action spectrum (non-melanoma skin cancers)*

CIE Report 187:2010, *Photocarcinogenesis risks from germicidal lamps*

International Commission on Non-Ionizing Radiation Protection (ICNIRP):2004, Guidelines on Limits of Exposure to Ultraviolet Radiation of Wavelengths Between 180 nm and 400 nm (Incoherent Optical Radiation), *Health Physics* 87 (2): 171-186

B.3.3 Pterygium and pinguecula

Pterygium is tissue in the conjunctiva that becomes vascularized and grows into the cornea, and may decrease vision as it enters the central cornea. Pinguecula is a buildup of excess conjunctival tissue near the nasal or temporal junction of the sclera and cornea. Outdoor workers who are chronically exposed to high levels of UV-B in tropical latitudes frequently develop these types of neoplasia. Although pterygium, if left unmanaged can interfere with vision, it can be surgically managed. There are no reports of these effects from artificial sources.

B.3.4 Pterygium and pinguecula reference documents

Bradley JC, Yang W, Bradley RH, Reid TW, Schwab IR, The science of pterygia, *Br J Ophthalmol,* 94(7):815-20,2010

Dolin PJ, Johnson GJ., Solar ultraviolet radiation and ocular disease: a review of the epidemiological and experimental evidence, *Ophthalmic Epidemiol.,* 1(3):155-64,1994

Kwok LS, Coroneo MT., A model for pterygium formation,*Cornea,* 13(3):219-24,1994

Nemet A.Y., Vinker S., Segal, O., Mimouni, M., Kaiserman, I., Epidemiology and associated morbidity of pterygium: a large, community-based case-control study, *Semin. Ophthalmol*; 31(5):446-51,doi: 10.3109/08820538.2014.962169

Rezvan, F., Khabazkhoob, M., Hooshm E., Yekta, A., Saatchi M., Hashemi, H.,2018, Prevalence and risk factors of pterygium: a systematic review and meta-analysis, *Surv Ophthalmol.*, 63(5):719-735

Saw, S.M., Tan, D.,1999, Pterygium: prevalence, demography and risk factors, *Ophthalmic Epidemiol*,6(3):219-28, doi: 10.1076/opep.6.3.219.1504

Sherwin JC, Hewitt AW, Kearns LS, Griffiths LR, Mackey DA, Coroneo MT,2013, The association between pterygium and conjunctival ultraviolet autofluorescence: The Norfolk Island Eye Study, *Acta Ophthalmol.*, 91(4):363-70

Taylor, H, (Ed.), *Pterygium*, The Hague, Netherlands, Kugler Publications, 2000, 181 pp

B.3.5 Cataract

Environmental ultraviolet radiation has long been considered one etiologic (risk) factor in the pathogenesis of age-related cataract. In recent decades the weight of evidence has indicated that UV (particularly solar UV-B) plays a role in the formation of one type of cataract – cortical cataract. The hypothesis of Coroneo and the epidemiological studies of Sasaki et al (2003, 2011) notably support this evidence. Nuclear cataract appears to be associated with a lifetime of high ambient temperature exposure (Sliney, 2002).

B.3.6 Cataract reference documents

Coroneo MT, Müller-Stolzenburg NW, Ho A, 1991, Peripheral light focusing by the anterior eye and the ophthalmohelioses, *Ophthalmic Surg*

Sasaki H, Sakamoto Y, Fujita N, Hatsusaka N, Sliney DH, Sasaki K, 2011, UV-B exposure to the eye depending on solar altitude, *Eye Contact Lens*, 37(4):191-5

Sasaki H, Kawakami, Y., Ono, M., Jonasson, F., Shui, Y.B., Cheng, H-M., Robman, L., McCarty, C., Chew, S.J., Sasaki K.,2003, Localization of Cortical Cataract in Subjects of Diverse Races and Latitude, *Invest. Ophthalmol. Vis. Sci.*, 44(10):4210-4214

Sliney DH.,2002, Geometrical gradients in the distribution of temperature and absorbed ultraviolet radiation in ocular tissues, *Dev Ophthalmol*., 35:40-59

B.3.7 Labrador keratopathy

Labrador keratopathy is known by a number of ophthalmological names, such as spheroidal degeneration of the cornea and droplet keratopathy, which is characteristic of rare diseases. This is seen, for example in ice fishermen who receive substantial, chronic UV-B irradiation of the cornea during early spring fishing when snow and ice still exist in circumpolar environments.

B.3.8 Corneal reference documents

Dolin PJ, Johnson GJ., Solar ultraviolet radiation and ocular disease: a review of the epidemiological and experimental evidence, *Ophthalmic Epidemiol.,* 1(3):155-64, 1994

Taylor HR, West SK, Rosenthal FS, Munoz B, Newland HS, Emmett EA,Corneal changes associated with chronic UV irradiation, *Arch Ophthalmol*., 1989

B.3.9 Visual effects from UV-A exposure – Lens fluorescence

Although UV-A is not generally considered to have a direct stimulation of vision at the retina, except in small children and very young adults (Brainard, 1999; Sliney, 2016), light produced by lens fluorescence is noticeable. UV-A that reaches and is heavily absorbed in the crystalline lens at wavelengths above 365 nm from UV lamp sources – even below human exposure limits – can induce a veiling glare bright enough to impact visual performance. A study by Zuclich et al (2005) showed that the fluorescence luminance produces a visual glare disruption that varied little with the age of their subjects. This can provide some avoidance reaction when experienced near a UV-A lamp.

Brainard GC, Beacham S, Sanford BE, Hanifin JP, Streletz L, Sliney D,1999, Near ultraviolet radiation elicits visual evoked potentials in children, *Clin Neurophysiol*., 110(3):379-83

Sliney DH., 2016, What is light? The visible spectrum and beyond, *Eye,* Nature, Lond, 30(2):222-9

Zuclich JA, Previc FH, Novar BJ, Edsall PR,2005, Near-UV/blue light-induced fluorescence in the human lens: potential interference with visual function, *J. Biomed. Opt.,* 10(4):10044021-1-10044021-7

B.3.10 Photoretinitis – or photic maculopathy (blue light hazard)

Photoretinitis (also termed photic maculopathy or “eclipse burn” by ophthalmologists), results from an acute retinal exposure (generally for minutes to hours) from wavelengths between 305 nm to 700 nm – principally from wavelengths between 400 nm and 500 nm. However, assessments of a variety of UV-A lamps has shown that the very small blue light hazard function values (generally a weighting function of only 0,01) in the UV-A has shown that assessment of this theoretical risk will not alter the risk-group outcome; and for this reason, this assessment is not required for UV lamp products covered in this document. This is a photochemically initiated injury to the retina. In very rare (aphakic) individuals who do not have their normal crystalline lens (or have had the crystalline lens removed), substantial retinal exposures to the wavelengths from 380 nm down to nearly 305 nm can be of concern.

Although not a significant concern until the production of GaN LEDs emitting between ~390 nm and ~410 nm, a subset of cataract (pseudophakic) patients can have substantial energy transmitted to the retina through their intraocular lens implants, since some “UV-absorbing” intraocular lenses can transmit significant energy down to ~ 360 nm, in which case these sources are very uncomfortably bright to these individuals and discomfort glare greatly limits the potentially hazardous exposures. In the normal (phakic) eye, the peak of the action spectrum occurs at approximately 445 nm (Ham, 1976) and at approximately 310 nm in aphakic (Ham, 1989) non-human primates; the $B(\lambda)$ and $A(\lambda)$ spectral weighting functions are based on that work. The aphakic $A(\lambda)$ function is used in safety standards for ophthalmic instruments used during ophthalmic surgery (e.g., ISO 15004-2). For greater detail see IEC 62471:2006, Annex A on biological effects.

B.3.11 Retinal-photochemical biological effects reference documents

Ham, W.T. Jr, Mueller, H.A., and Sliney, D.H., Retinal Sensitivity to Damage by Short-Wavelength Light, *Nature*, 260(5547), 153-155,1976

Ham, W.T. Jr, Ruffolo, J.J. Jr, Mueller, H.A., and Guerry, D. III, The Nature of Retinal Radiation Damage: Dependence on Wavelength, Power Level and Exposure Time, *Vision Res.*, 20(12), 1105-1111, 1980

Lund, D.L., Stuck, B.E., and Edsell, P., Retinal Injury Thresholds for Blue Wavelength Lasers, *Health Phys.*, 90 (5): 477-484,2006

Annex C
(informative)

Measurement of ultraviolet lamp products

C.1 General

The assessment of the photobiological safety of ultraviolet lamp within scope of this document is restricted to a consideration of the UV and UV-A hazards through measurements of irradiance or spectral irradiance at the appropriate distance from the product.

A range of instruments are available to perform such measurements, including radiometers, thermal detectors and spectroradiometers. Further general guidance on measurements may be found in IEC TR 62471-4.

C.2 Radiometers

UV radiometers are generally specified to cover one or more of the UV regions (UV-A, UV-B, UV-C) or to match the actinic UV hazard weighting function or CIE erythemal action spectrum. It is generally difficult to design radiometers having a flat spectral response over an extended spectral region, replicate accurately the cut-on and cut-off of even simple functions such as the UV-A response or accurately match complicated biological action spectra. As a result, spectral mismatch errors may result (CIE 220). These errors are minimized where the UV radiometer is supplied with a calibration against a source having the same spectral distribution as that under test, such as is readily available for the measurement of the low pressure mercury 253,65 nm line (germicidal UV).

Where a radiometer is used that responds over the full range of a spectral weighting function, but does not follow the spectral weighting factors of that function, un-weighted values should be used in this assessment.

Thermal detectors are available, but their wide spectral response can complicate the assessment of broadband sources, without the use of filters to eliminate irrelevant spectral bands. This may result in significant uncertainties.

C.3 Spectroradiometers

Spectroradiometers include CCD array spectrometers and single- or double- monochromator-based instruments for which IEC TR 62471-4 specifies recommended measurement bandwidth and wavelength accuracy.

Whilst spectroradiometers, in allowing the determination of the spectral irradiance of the source under test, may yield the most accurate results, in measuring the emission of the source under test in narrow spectral regions, the signal level at the instrument photodetector may be low giving rise to a poor signal to noise ratio (SNR), particularly at the shorter wavelengths. Indeed, where low sensitivity detectors are used, the noise floor of the instrument may dominate the measurement result.

Furthermore, in the case of CCD array spectrometers and single monochromators, stray radiant power from wavelengths other than those in consideration may be incorrectly recorded. For example, in measuring the UV-C spectral irradiance of a UV-A source:

- within the CCD array spectrometer, UV-A radiation might reach the pixels covering the UV-C wavelengths;
- within the single monochromator tuned to transmit a UV-C wavelength to the system detector, UV-A light may also reach the system detector.

Stray radiant power is generally limiting only for the actinic UV hazard for which detection of trace levels of optical radiation are to be measured and can potentially give rise to significant errors. To obtain 1 % accuracy, rejection of out-of-band radiation needs to be on the order of 10^6. This can be easily achieved using double monochromators but can be obtained with single monochromators and CCD array spectrometers providing that filters are used to improve the suppression of stray radiant power.

The above concerns are particularly relevant when considering the effective UV irradiance which extends down to 200 nm and for which the emission limit irradiance is relatively low.

C.4 Entrance optic

Whilst radiometers and spectroradiometers are generally provided with cosine-corrected entrance optics having a full hemispherical field of view, exposure guidelines specify that the measurement of spectral irradiance/ irradiance be measured over an 80° cone angle.

Where the UV lamp product subtends an angle greater than this, an aperture should be employed to limit the field of view as indicated in Figure C.1 where D is the diameter of the instrument entrance aperture, H distance between the aperture and the plane of the entrance aperture, and A is the half-angle of the 80° full measurement cone angle.

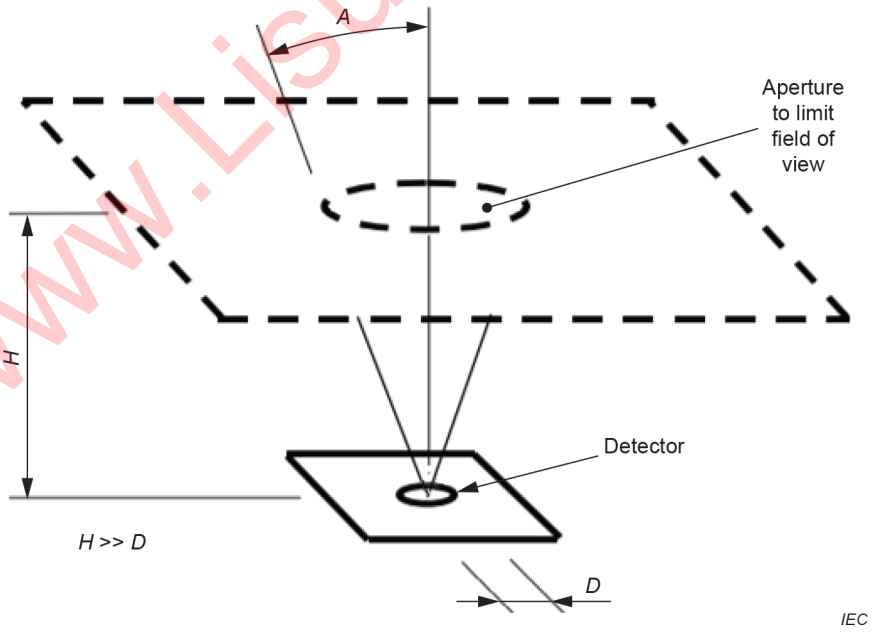

Figure C.1 – Geometry of irradiance / spectral irradiance measurements

C.5 Spectroradiometer- radiometer approach

An approach including both a spectroradiometer and a UV radiometer may provide a flexible means of assessment. An initial parallel measurement at 1 m to 2 m from the UV product with the entrance aperture of both instruments co-located enables the generation of a correction factor to account for any potential spectral mismatch error as noted in Clause C.2 and enables the use of more portable radiometer in assessing the emission around the product under test.

This approach is of particular use when assessing upper-room germicidal fixtures and for assessments in the field.

C.6 Measurement distance versus assessment distance

C.6.1 General

Measurements of spectral irradiance need not necessarily be performed at the assessment distance in Table 2, Table 3 and Table 4. Where the spectral irradiance produced by a product at the assessment distance is low, noise may dominate the measurement result over part or all of the spectral range. Where the spectral irradiance of the source is extremely high, system detectors may be saturated and the instrument may be damaged. In both cases, measurement should be performed at another distance in order to minimize the measurement errors.

Where the measurement distance differs from the risk group assessment distance, it is necessary to transfer the measurements to the assessment distance.

C.6.2 Spectroradiometer approach

Where the spectral irradiance measurement at the assessment distance does not produce results with satisfactory signal to noise ratios (SNRs) over part of the UV spectral range, an approach based on two spectral irradiance measurements is recommended.

The spectral irradiance is measured at the assessment distance, $E_0(\lambda)$, and at a closer distance to the product, $E_1(\lambda)$, making sure to avoid detector saturation and heat damage to the instrument. In recording a higher spectral irradiance, $E_1(\lambda)$ will report values with a better SNR and a higher dynamic range above the instrument noise floor.

Normalizing the $E_1(\lambda)$ spectrum to match the spectral irradiance reported in the $E_0(\lambda)$ spectrum will provide a clean measurement result. The corrected $E_{0,\mathrm{corr}}(\lambda)$ is determined from the following formula. A normalising wavelength, λ_n, is taken from the wavelength where the SNR is high.

$$E_{0,corr}(\lambda) = \frac{E_1\ (\lambda) \times E_0\ (\lambda_n)}{E_1\ (\lambda_n)}$$

However, more reliable results will be found based on the integral over a range of wavelengths, λ_1 to λ_2, with satisfactory SNR.

$$E_{0,corr}(\lambda) = \frac{E_1\ (\lambda) \times \int_{\lambda_1}^{\lambda_2} E_0\ (\lambda)\, d\lambda}{\int_{\lambda_1}^{\lambda_2} E_1\ (\lambda)\, d\lambda}$$

C.6.3 Radiometer approach

This approach applies in two scenarios:

- Where the spectral irradiance measurement at the assessment distance produces results with satisfactory SNR over part- but not all- of the UV spectral range.
- Where the spectral irradiance at the assessment distance is too high or too low to measure.

A UV radiometer may only be used directly (with factory calibration) if it is calibrated against a similar spectral distribution as that of the source under test and it responds over a range not exceeding that for which satisfactory SNR is obtained at the measurement distance.

A measurement of the spectral distribution of the source, $E_1(\lambda)$ may be determined using a spectroradiometer at a greater or shorter distance than the assessment distance (as required) with a view to use a calibrated radiometer to obtain values at the assessment distance, $E_{0,\mathrm{rad}}$.

Where the UV radiometer is calibrated for the same type of source, the $E_1(\lambda)$ may be integrated over the spectral range of the radiometer (λ_1 to λ_2, applying the relevant weighting function as required) and the UV and UV-A effective irradiances computed from:

$$E_{\mathrm{UV}} = E_{0,\mathrm{rad}} \frac{\int_{200}^{400} E_1\ (\lambda) \times S(\lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} E_1\ (\lambda)\, d\lambda}$$

$$E_{\mathrm{UV-A}} = E_{0,\mathrm{rad}} \frac{\int_{315}^{400} E_1\ (\lambda)\, d\lambda}{\int_{\lambda_1}^{\lambda_2} E_1\ (\lambda)\, d\lambda}$$

Where the radiometer is not calibrated against the spectral distribution of the product under test, a parallel measurement of the spectral irradiance, $E_1(\lambda)$, and irradiance recorded by the radiometer, $E_{1,\mathrm{rad}}$ should be performed at the measurement distance:

$$E_{\mathrm{UV}} = E_{0,\mathrm{rad}} \frac{\int_{200}^{400} E_1\ (\lambda) \times S(\lambda) d\lambda}{E_{1,\mathrm{rad}}}$$

$$E_{\mathrm{UV-A}} = E_{0,\mathrm{rad}} \frac{\int_{315}^{400} E_1\ (\lambda)\, d\lambda}{E_{1,\mathrm{rad}}}$$

C.7 Reference documents

CIE 220:2016, *Characterization and calibration methods of UV radiometers*

IEC TR 62471-4: *Photobiological safety of lamps and lamp systems – Part 4: Measuring methods*

Annex D
(informative)

Spectral weighting function $S(\lambda)$ from 180 nm to 400 nm for assessing actinic radiation hazard

Table D.1 – Spectral weighting function $S(\lambda)$ values at 1 nm intervals

Wavelength nm	$S(\lambda)$
(180)[a]	0.012
(185) [a]	0,0155
(190) [a]	0,019
(195) [a]	0,0245
200	0,030000
201	0,033359
202	0,037094
203	0,041247
204	0,045865
205	0,051000
206	0,055089
207	0,059507
208	0,064278
209	0,069433
210	0,075000
211	0,078631
212	0,082438
213	0,086429
214	0,090613
215	0,095000
216	0,099544
217	0,104305
218	0,109294
219	0,114522
220	0,120000
221	0,125477
222	0,131203
223	0,137192
224	0,143453
225	0,150000
226	0,157262
227	0,164876
228	0,172858
229	0,181226
230	0,190000
231	0,199088

Wavelength nm	$S(\lambda)$
232	0,208611
233	0,218589
234	0,229044
235	0,240000
236	0,250953
237	0,262407
238	0,274383
239	0,286906
240	0,300000
241	0,311141
242	0,322696
243	0,334680
244	0,347109
245	0,360000
246	0,373023
247	0,386517
248	0,400500
249	0,414988
250	0,430000
251	0,446523
252	0,463681
253	0,481498
254	0,500000
255	0,520000
256	0,543733
257	0,568548
258	0,594497
259	0,621629
260	0,650000
261	0,679247
262	0,709810
263	0,741748
264	0,775123
265	0,810000
266	0,844866
267	0,881234

Wavelength nm	$S(\lambda)$
268	0,919166
269	0,958732
270	1,000000
271	0,991869
272	0,983804
273	0,975804
274	0,967870
275	0,960000
276	0,943438
277	0,927162
278	0,911167
279	0,895448
280	0,880000
281	0,856810
282	0,834230
283	0,812246
284	0,790841
285	0,770000
286	0,742042
287	0,715099
288	0,689135
289	0,664113
290	0,640000
291	0,618618
292	0,597951
293	0,577974
294	0,558664
295	0,540000
296	0,498397
297	0,460000
298	0,398914
299	0,345939
300	0,300000
301	0,221042
302	0,162865
303	0,120000
304	0,084853
305	0,060000
306	0,045404
307	0,034358
308	0,026000
309	0,019748
310	0,015000
311	0,011052
312	0,008143

Wavelength nm	$S(\lambda)$
313	0,006000
314	0,004243
315	0,003000
316	0,002400
317	0,002000
318	0,001600
319	0,001200
320	0,001000
321	0,000819
322	0,000670
323	0,000540
324	0,000520
325	0,000500
326	0,000479
327	0,000459
328	0,000440
329	0,000425
330	0,000410
331	0,000395
332	0,000380
333	0,000366
334	0,000353
335	0,000340
336	0,000327
337	0,000315
338	0,000303
339	0,000291
340	0,000280
341	0,000271
342	0,000263
343	0,000255
344	0,000248
345	0,000240
346	0,000231
347	0,000223
348	0,000215
349	0,000207
350	0,000200
351	0,000191
352	0,000183
353	0,000175
354	0,000167
355	0,000160
356	0,000153
357	0,000147

Wavelength nm	$S(\lambda)$
358	0,000141
359	0,000136
360	0,000130
361	0,000126
362	0,000122
363	0,000118
364	0,000114
365	0,000110
366	0,000106
367	0,000103
368	0,000099
369	0,000096
370	0,000093
371	0,000090
372	0,000086
373	0,000083
374	0,000080
375	0,000077
376	0,000074
377	0,000072
378	0,000069
379	0,000066

Wavelength nm	$S(\lambda)$
380	0,000064
381	0,000062
382	0,000059
383	0,000057
384	0,000055
385	0,000053
386	0,000051
387	0,000049
388	0,000047
389	0,000046
390	0,000044
391	0,000042
392	0,000041
393	0,000039
394	0,000037
395	0,000036
396	0,000035
397	0,000033
398	0,000032
399	0,000031
400	0,000030

[a] These values apply to sources emitting radiation below 200 nm (e.g. low-pressure mercury lamps with quartz envelopes emitting 185 nm radiation).

NOTE Logarithmic interpolation was used in Table D.1 to calculate values between the 5 nm interval values published by ICNIRP from 200 nm to 400 nm. ACGIH have amended the limits for UV-C (2022) and therefore differ in that wavelength region from ICNIRP.

Annex E
(informative)

Examples of risk group classification applying the concept of TWA of a spectrally-weighted emission

E.1 Spectral weighting to determine effective irradiance using $S(\lambda)$

Determination of the spectrally weighted exposure limit is the first step before assessing the TWA exposure. Spectral weighting is employed to determine an UV effective irradiance E_{eff} for a non-monochromatic source.

$$E_{\text{eff}} = \sum_{200}^{400} E_{\lambda} \times S(\lambda) \times \Delta\lambda$$

where

E_{λ} is the spectral irradiance,

$S(\lambda)$ is the UV hazard spectral weighting function, and

$\Delta\lambda$ is the wavelength interval (e.g., 1 nm if using Table D.1).

E.2 Time weighting of an exposure

A good example of how time-weighted averaging (TWA) is employed to assess risk from scattered UV-C in the occupied space is exemplified by an upper-room GUV installation with a UV luminaire employing a traditional low-pressure mercury lamp. Figure E.1 is an example of the assessment by one competent installer performed as an array of measurements to assure the appropriate TWA was not exceeded in each region of occupied spaces.

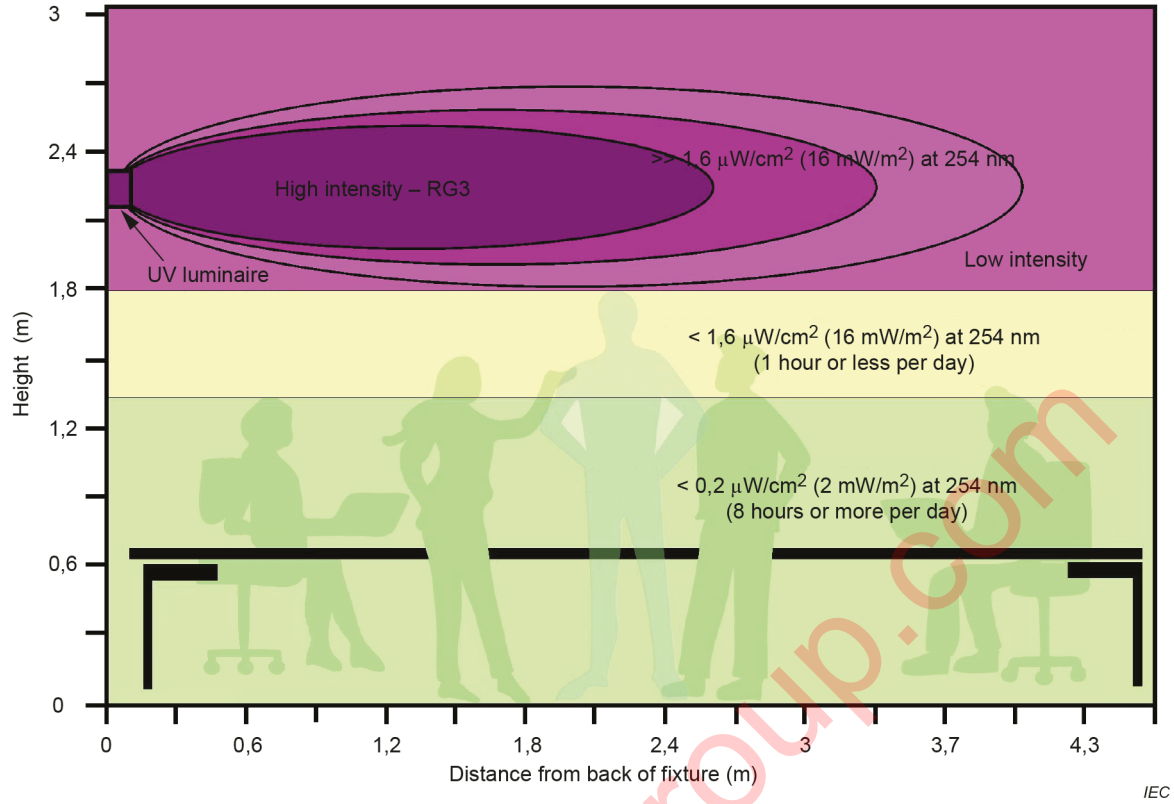

Figure E.1 – Example of how an occupational hygienist might determine different zones of exposure by time-weighting

Figure E.1 shows zones with assessed levels of unweighted exposure. For a wavelength of 254 nm, $S(\lambda)$ = 0,5, so the weighted values are half those given in Figure E.1. In this case a time-motion study provided a maximal standing duration of 1 h in one day, so a 1-h TWA at eye level of 1,8 m was assessed; whereas there were seated positions (eye level 1,3 m above the floor) that required an 8-h (not to exceed the emission limit for RG-0) limit for the effective irradiance of 1 mW·m^{-2}. However, the lamp product remains RG-3.

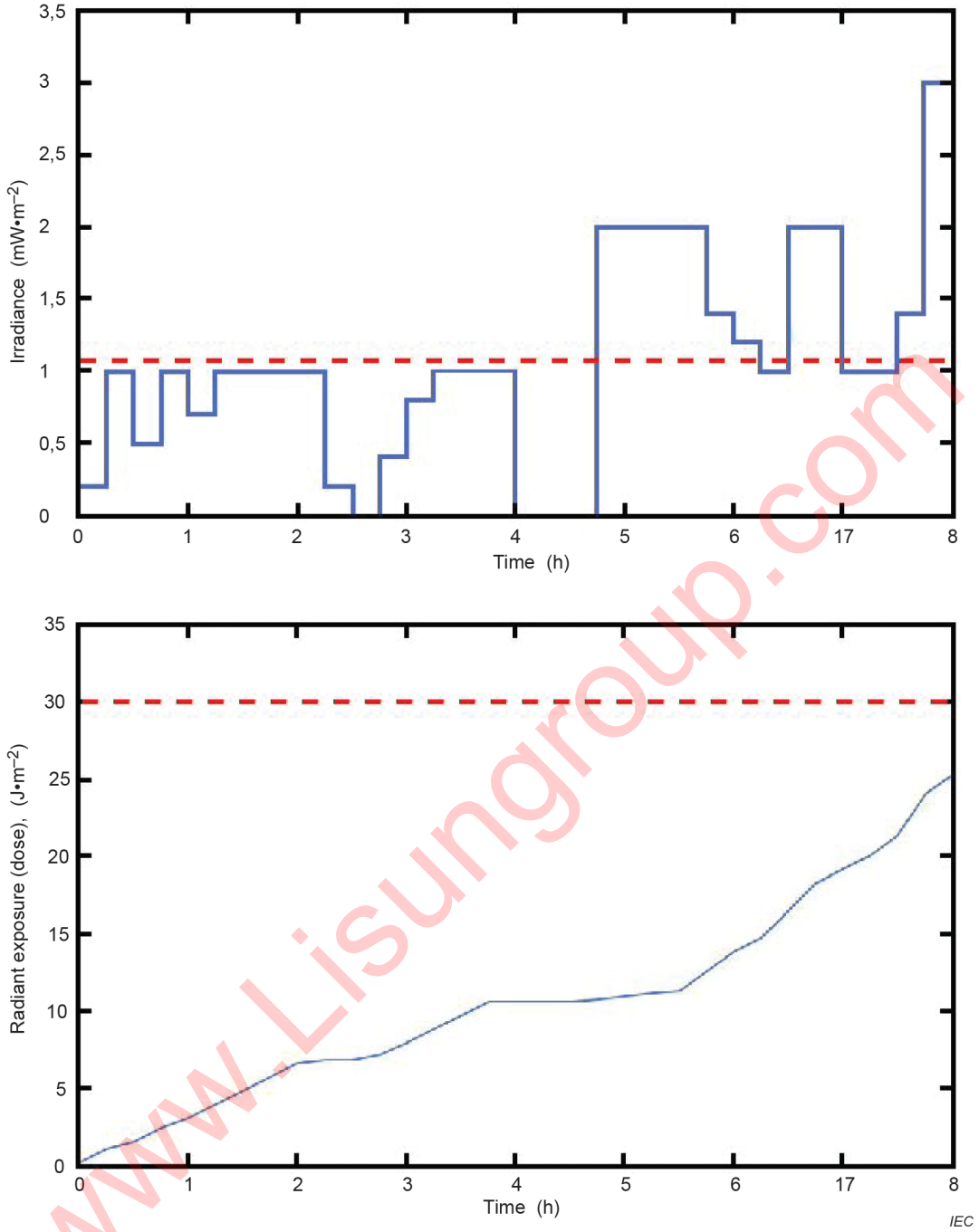

Figure E.2 – Time-weighted averaging (TWA) over an 8 h period

The top panel of Figure E.2 shows the actual irradiance pattern during a day for an individual in a GUV setting. The bottom panel shows the accumulated radiant exposure (photobiological "dose") over the same time period. The horizontal dashed line in the upper panel has been moved up slightly above 1 $mW \cdot m^{-2}$ for clarity of the figure.

E.3 Field radiometric measurements for final acceptance testing of a GUV installation

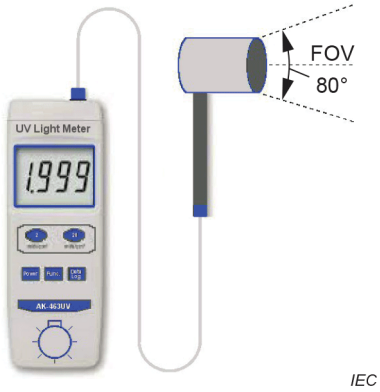

Figure E.3 – Field GUV safety meter with 80° full field of view

For final acceptance testing, field-portable radiometers with 80° field of view (FOV) are best used to assure that lower-room irradiance values are below acceptable levels. The measurement uncertainties (such as wavelength calibration, field of view, instrument noise, out-of-band stray light and ambient illumination) should be added to the measured reading. See Figure E.3. Instruments used to assess the irradiance should have sufficient sensitivity to measure the lowest applicable TWA irradiance value.

Annex F
(informative)

Upper room GUV – Background and rationale to achieve safety

F.1 General

This Annex applies to GUV products used in upper-room and whole-room air disinfection. Whole-room and upper-room GUV provide the primary example of widespread use of RG-3 UV lamp products. Upper-room GUV is intended to disinfect the air in the upper room above an occupied space; whereas, whole-room GUV irradiates all space in the room, but means exist to preclude direct human exposure above applicable limits by means of limiting emission into occupied areas by design or by proximity sensors and similar means. This annex reviews the products that have the potential for human exposure if not properly installed and provides the rationale for manufacturer requirements. It is intended to guide manufacturers, particularly when developing safe upper-room GUV products where the source is RG-3.

F.2 Product goals

The goal for the GUV product manufacturer requirements of this document has been to minimize the production of faulty “UV luminaires” (the term currently used by several standards committees for upper-air GUV products) that will make it difficult for installers to improperly install, and thereby place occupants needlessly at risk. The great challenge faced here, has been that past experience over more than half a century (First *et al.*, 2005) demonstrates that accidental overexposures of room occupants occur in almost all cases as a result of incorrect installation without effective final acceptance safety evaluation on-site. Hence the goal of this document has been to provide minimal requirements for UV-luminaire manufacturers to produce UV luminaires that are readily and properly installed to prevent these hazardous situations. Currently, the installer is responsible for the final commissioning process (final acceptance testing) once the UV luminaires are positioned in the desired mounting based upon the room layout and air circulation patterns. Thus, requirements and testing of a manufacturer’s GUV product are really limited to only the UV emission to assure that potentially hazardous direct UV irradiances do not fall into the occupied space after installation. The manufacturer cannot control the proper installation by the user or installer. Therefore, any manufacturer requirements and associated measurements are basically only testing the ability of the luminaire, if properly installed. Upper-room GUV luminaires should adequately collimate the emitted radiant energy within the irradiation zone. The test protocol in this document is to ensure that manufacturers understand what they need to do to ensure safety as well as to ensure uniformity between testing laboratories.

F.3 Product test measurement conditions

F.3.1 General

Test room dimensions need to be specified, since ceiling reflections and wall reflections and size/extent of the room should not limit the effective range of the “ray lengths.” It is recommended that the test room should have a very high ceiling to permit testing of a range of designs. For well-collimated designs intended for low ceiling applications, the beam will not produce significant ceiling reflections and in any case this is a major factor for the installer to test. The ceiling height should be at least 6 m to accommodate semi-open fixtures (as employed in some warehouses or large, high-ceiling retail stores). The length of the testing room should be at least 12 m, based upon experience in final acceptance testing of UV luminaires in situ. The fixture should be sufficiently above the floor to perform the needed lower-room measurements and sufficiently high to avoid floor reflections (if not tested with the fixture base at the intended minimal height of the UV luminaire base at 6,1 m). There should be a minimal room width of 6 m, but preferably at least 9 m wide. These minimal testing room dimensions are based on measurements of side emissions in actual installations.

F.3.2 Elevation plane for radiometric measurements

Where to take measurements is clearly specified. The height above the floor for measurements to perform the below-axis UV-C radiometric measurements for safety shall be 1,8 m, since the 99th -percentile for standing eye height is ~1,75 m to 1,8 m (thus, 1,8 m to be more conservative) height above the floor.

F.3.3 Test grid for measurements

A test grid is specified as an initial sample. For example the horizontal plane at 1,8 m above the floor is most typically divided into a grid with 0,5 m spacing, although the testing laboratory based on experience with a given UV luminaire can adjust the actual number of measurements.

F.3.4 Detector acceptance angle (field-of-view)

The detector FOV/orientation(s) should be specified for acceptance testing. The ICNIRP UV exposure guidelines and 5.1 (Note 3) of IEC 62471:2006 specify that the irradiance should be measured with an 80° cone (± 40°) field of view (FOV). Although in a final test after installation ceiling reflections are tested with a vertical orientation, this is not the objective for the testing laboratory, which should orient the cone of acceptance toward the UV luminaire, which will be the worst-case assessment in the laboratory.

NOTE ACGIH increased some UV-C limits below 250 nm in 2022, but these changes are not considered in this document.

F.3.5 Instrument performance specifications

The performance specifications of the radiometric detector and meter should be provided in any testing report. If a broad-band meter is used, it should be fully characterized to provide the $S(\lambda)$-weighted irradiance for the lamp spectrum tested. For example, a low-pressure mercury vapour lamp emission is dominated by 254 nm where $S(\lambda)$ is 0,5; hence the daily irradiance limit of 0,1 μW·cm^{-2} (1 mW·m^{-2}) effective is actually 0,2 μW·cm^{-2} (2 mW·m^{-2}) when unweighted.

Means of calibrating the portable meter used in testing could be provided based upon spectroradiometric measurements for the type of lamp that are then spectrally weighted to provide a transfer calibration for the field-test meter.

F.4 GUV luminaires

F.4.1 Adjustable UV luminaires

Adjustable UV luminaires are most desirable to permit flexible installation by competent persons to assure maximal emission into the upper room and safe levels below 1,8 m. From the installer's point-of view, some current testing proposals to test upper-room UV luminaires in a fixed position with a 1° downward direction creates a difficult luminaire to safely install. Such a testing proposal can have an unintended consequence for safety. In actual use experience, adjustable baffles (i.e., louvers) and/or reflectors or output power, have been designed by manufacturers to aid the installer in making final adjustment to ensure safety. If these directional adjustment features are tested in a worst-case downward fashion, they defeat the intent and destroy the safety value for the installer. This document recommends an adjustment of at least 5° to 10° to ensure adequate safety in the lower room. The flexibility can also be useful to avoid reflections from objects in the irradiation space. The manufacturer test should be performed in the "neutral position" with a 1° downward direction unless the UV luminaire has a self-leveling feature.

F.4.2 Interlock safeguards on removable baffles

Interlocks are required to inactivate the UV-C lamp when baffles or safeguards are removed for lamp exchange.

F.4.3 Labelling requirements

Additional marking and instructions require only the appropriate label for the product and contradictory labeling should be avoided.

Experience shows that multiple, conflicting warnings – even though intended for different readers – can produce a negative reaction by the user that does not serve the interest of safety.

F.4.4 Efficacy and information for the user

The wavelength(s) and irradiance at 1 m from the UV luminaire is to be specified to aid the user to estimate efficacy for a given bioaerosol. The efficacy of some GUV products have been highly criticized by public health experts. The public health concern has been that buyers and installers might read that a product is certified to meet IEC safety requirements, but could also be quite ineffective. It should be clearly specified that a safety certification does not imply effectiveness. For example, if a buyer of a “germicidal UV product” were to purchase a UV-A luminaire with an efficacy of one log disinfection/day, they might think it equivalent to a UV-C product that provides one-log disinfection every 10 min. A GUV product that primarily emits in the UV-B or UV-A has been shown to be ineffective for air disinfection: the primary emission should be limited to 200 nm to 280 nm.

F.5 Acceptance testing

F.5.1 Scope of the installation acceptance testing

The actual risk may depend on the wavelength and intended use and consideration should be given to the differences between intense UV-C sources and other products. There is a need to consider more than one category of GUV upper-room UV luminaire depending on the design and size of the room. The required radiometric tests may differ by category (e.g. Table 3 or Table 4).

F.5.2 Time-weighted averaging

Realistic, reasonably foreseeable exposure conditions are to be reflected in any manufacturer’s testing. The important photobiological risk assessment depends upon the time-weighted average (TWA) exposure, and an assumption of a lengthy, 8 h continuous exposures in a standing position, facing the UV luminaire may be unreasonable for some products (see ACGIH:2022 and ISO 15858). The manufacturer’s instructions should provide examples of how an installer would assess the TWA exposure and properly interpret the ACGIH TLV or ICNIRP EL (essentially equivalent in the UV-C for low pressure mercury lamps). The use of these guidelines or standards by the installer may be recommended in the users’ manual.

NOTE ACGIH increased some UV-C limits below 250 nm in 2022, but these changes are not considered in this document.

F.6 Reference documents

American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2019, *ASHRAE Handbook: Heating, Ventilating, and Air-Conditioning Applications*, SI Edition. Chapter 62, Ultraviolet Air and Surface Treatment, Table 3, Suggested UVC Fixture Mounting Heights. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers

First, MW, Weker, RA, Yasui, S and Nardell, EA, Monitoring human exposures to upper-room germicidal ultraviolet irradiation, *J Occup Environ Hyg*., 2005, May;2(5):285-92. doi: 10.1080/15459620590952224

National Fire Protection Association,2020, *NFPA 70, National Electric Code 2020*, Clauses 320.23(A), 394.23(A), 398.15(C) and 411.6(C), Quincy, MA: National Fire Protection Association

Centers for Disease Control and Prevention, National Center for Health Statistics, *National Health and Nutrition Survey (NHANES). (2007-8),* Table 205, Cumulative Percent Distribution of Population by Height and Sex: 2007 to 2008. Atlanta, GA: Centers for Disease Control and Prevention, https://www2.census.gov/library/publications/2010/compendia/statab/130ed/tables/11s0205.pdf

The Eastman Kodak Company,2003, *Ergonomic design for people at work*, 2nd Edition, New York, NY: John Wiley and Sons, Inc., DOI:10.1002/9780470172469

American Conference of Governmental Industrial Hygienists, 2022, TLVs and BEIs: Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Ultraviolet Radiation. Cincinnati, OH: American Conference of Governmental Industrial Hygienists

ISO 15858:2016, *UV-C devices – Safety information – Permissible human exposure*

Iluminating Engineering Society,2021, Recommended Practice UVGI, *IES standard RP 44*, New York, the Illuminating Engineering Society

Bibliography

IEC 60050-845:2020, *International Electrotechnical Vocabulary (IEV) – Part 845: Lighting*

IEC 61010-2-040, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 2-040: Particular requirements for sterilizers and washer-disinfectors used to treat medical materials*

IEC 61228, *Fluorescent ultraviolet lamps used for tanning – Measurement and specification method*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 62035:2014, *Discharge lamps (excluding flourescent lamps) – Safety specifications*
IEC 62035:2014/AMD1:2016

IEC 62061, *Safety of machinery – Functional safety of safety-related control systems*

IEC 62368-1:2018, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

ISO 13849 (all parts): *Safety of machinery – Safety-related parts of control systems*

ISO/CIE 17166:2019, *Erythema reference action spectrum and standard erythema dose*

ISO/CIE 28077:2016, *Photocarcinogenesis action spectrum (non-melanoma skin cancers)*

International Commission on Non-Ionizing Radiation Protection (ICNIRP):2004, Guidelines on Limits of Exposure to Ultraviolet Radiation of Wavelengths Between 180 nm and 400 nm (Incoherent Optical Radiation), *Health Physics*, 87(2):171-186

CIE 174, *Action Spectrum for the Production of Previtamin D3 in Human Skin*, ISBN: 978-3-901906 50 3, 2006, Vienna

CIE 201, *Recommendations on minimum levels of solar UV exposure,* ISBN: 978-3-902842-39-8, 2011, Vienna

CIE 219, *Maintaining summer levels of 25(OH)D during winter by minimal exposure to sunbeds: requirements and weighing the advantages and disadvantages*, ISBN: 978-3-902842-31-2, 2016, Vienna

CIE S 017/E:2020, ILV, *International Lighting Vocabulary*, 2nd Edition

CIE 220:2016, *Characterization and calibration methods of UV radiometers*

Claus, H., Ozone Generation by Ultraviolet Lamps, *Photochem. Photobiol* , 2021, doi: 10.1111/php.13391

CDC/NIOSH Publication No. 2009-105, *Basic Upper-Room Ultraviolet Germicidal Irradiation Guidelines for Healthcare Settings*

WHO, 1994 *Ultraviolet radiation,* Environmental health criteria: 160, ISBN 92 4 157160 8, Geneva (https://inchem.org/documents/ehc/ehc/ehc160.htm)

WHO, 2017 *Artificial tanning devices: Public health interventions to manage sunbeds*, ISBN 978-92-4-151259-6, Geneva

United States Code of Federal Regulations, Title 21, Chapter I, Subchapter J, 21 CFR 1040.20, *Sunlamp products and ultraviolet lamps intended for use in sunlamp products,* Washington, DC

Dowdy JC, Sayre RM, Photobiological safety evaluation of UV nail lamps, *Photochem Photobiol.*, 2013 Jul-Aug,89(4):961-7, doi: 10.1111/php.12075

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