

RECOMMENDED PRACTICE:
RISK GROUP CLASSIFICATION AND
MINIMIZATION OF PHOTOBIOLOGICAL
HAZARDS FROM ULTRAVIOLET
LAMPS AND LAMP SYSTEMS
AN AMERICAN NATIONAL STANDARD



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Publication of this document
has been approved by IES.
Suggestions for revisions
should be directed to IES.

**Prepared by the
IES Photobiology Committee**



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1.0 Introduction and Scope

1.1 Introduction

The purpose of this Recommended Practice is to summarize the photobiological hazards of exposure to ultraviolet (UV) radiation and to provide recommendations to minimize the risks of such effects from ultraviolet lamps and lamp systems.

Although most lamps and lamp systems (see **Sections 3.18** and **3.19**) are safe and pose no photobiological risks except under unusual exposure conditions, one group of products—ultraviolet lamp systems—may pose optical radiation hazards during use that 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 application of *ANSI/IES RP-27-20, Lighting Science: Photobiological Safety of Lamps and Lamp Systems*¹ (combined from the previously separate ANSI/IES RP-27.1-15, ANSI/IES RP-27.2-00(R2017), and ANSI/IES RP-27.3-17). It addresses LEDs, incandescent, low- and high-pressure gas-discharge, arc, and other lamps. ANSI/IES RP-27.1-22 expands this information by covering lamp systems that are designed primarily to emit ultraviolet radiant energy, such as ultraviolet sources intended to excite fluorescence of irradiated materials, as used in insect light traps, scientific studies, mineral identification, non-destructive testing, germicidal irradiation, and other purposes.

This document provides risk group classification for all ultraviolet lamp systems, and the measurement conditions for different applications, thus superseding the more general risk group classifications used in ANSI/IES RP-27-20 for UV lamp systems. It includes manufacturing and user safety requirements that may be required as a result of an ultraviolet lamp system being assigned to a particular risk group. The assigned risk group of an ultraviolet lamp system also may be used to assist with any needed risk assessments, e.g., for occupational exposure in workplaces.

1.2 Scope

Recommendations in this document apply only to lamps and lamp systems designed primarily to emit

ultraviolet (UV) radiant energy for consumer, industrial, scientific, and medical applications. The scope is limited to lamps and lamp systems 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. If more than half of the optical radiation emitted between 180 nm to 3,000 nm is outside of the spectral region 180 nm to 400 nm, then the base standard, ANSI/IES RP-27-20, applies.

ANSI/IES RP-27.1-22 does not apply to general lighting sources (GLS) or laser systems.

2.0 Normative References

2.1 ANSI/IES LS-1-22

Illuminating Engineering Society. *Lighting Science: Nomenclature and Definitions for Illuminating Engineering*. New York: IES; 2022.

2.2 ANSI/IES RP-27-20

Illuminating Engineering Society. *Recommended Practice: Photobiological Safety for Lighting Systems*. New York: IES; 2020.

2.3 ANSI/IES RP-44-21

Illuminating Engineering Society. *Recommended Practice: Ultraviolet Germicidal Irradiation (UVGI)*. New York: IES; 2021.

3.0 Definitions

Standard nomenclature and definitions, radiometric and photometric quantities, and illuminating engineering terminology are found in *ANSI/IES LS-1-22, Lighting Science: Nomenclature and Definitions for Illuminating Engineering* (see **Section 2.1**). Other definitions found in ANSI/IES RP-27-20 (see **Section 2.2**) may also apply.

3.1 actinic radiation hazard

Optical radiation, most notably UV-B and UV-C, capable of producing a photobiological effect. The relative

spectral hazard is defined by the weighting function $S(\lambda)$, published by ACGIH.

3.2 assessment distance

The distance used to determine the risk group classification of a lamp or lamp system.

Note: Because photobiological effects from UV radiation are based on the total accumulated exposure (dose) received, this standard relies on the concept of time-weighted average exposures, where the assessment distance for determining the risk group 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 to 30 cm—for extended periods. This standard provides assessment distances and specific guidance that are application-specific and realistic rather than more-general values where the specific application is unknown and time-weighted average exposures are not application-specific.

3.3 blue light hazard (BLH)

The potential for a photochemically induced retinal injury resulting from radiation exposure at wavelengths primarily between 400 nm and 500 nm. This damage mechanism dominates over thermal mechanisms for intense visible light and for times exceeding 10 seconds but is rarely of concern from UV lamp systems (unless the basic lamp is an arc lamp).

3.4 blue light hazard radiance, L_b

Effective photobiological radiance with the spectral radiance, L_{λ} , spectrally weighted with the blue light hazard spectral weighting function, $B(\lambda)$. [Source for definition: CIE ILV,² item 17-26-057.]

Note 1 to entry: The wavelength range for the blue light hazard radiance is specified in ICNIRP recommendations as $\lambda = 300$ nm to $\lambda = 700$ nm.

Note 2 to entry: This definition is based on the assumption that an action spectrum is adopted for the actinic effect considered, and that its maximum value is 1.

Note 3 to entry: It is essential to specify which actinic action spectrum is used, as the unit is the same for any action spectrum.

Note 4 to entry: The blue light hazard radiance is expressed in watt per square meter per steradian ($\text{W}\cdot\text{m}^{-2}\cdot\text{sr}^{-1}$).

Note 5 to entry: This entry was numbered 17-99 in CIE S 017:2011.

3.5 competent person

One who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to people, and who has authorization to take prompt corrective measures to eliminate them. [Source: OSHA 1926.32(f).³]

3.6 consumer

A person who purchases goods and services for personal use. Consumers include not only users of an ultraviolet lamp or lamp system but also all persons who may have access to the lamp or lamp system, or who may be near the product. Sometimes referred to as an “ordinary person.”

3.7 controlled access location

The location where an engineering and/or administrative control measure is established to restrict access except to authorized personnel with appropriate safety training.

3.8 dose-limited product

A lamp or lamp system 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. The dose limit is expressed in millijoules per square centimeter (mJ/cm^2).

3.9 effective exposure distance

The nearest distance of time-weighted human exposure consistent with the intended use of the lamp or lamp system for which the time-weighted emission has been considered.

3.10 emission limit

A limit defined for each risk group, based upon reasonably foreseeable conditions of exposure. It incorporates exposure duration, exposure distance, and time-weighted averaging, and is derived from exposure limits.

Note: In the rare situation where the BLH is evaluated, the emission limit may be expressed as radiance.

3.11 Exempt Group

The risk group classification for which there is no photobiological hazard.

3.12 exposure limit

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

Note: For the most current limits, refer to the ACGIH's guide to TLVs,⁴ which is updated annually.

3.13 general lighting source lamp (GLS)

As a light source description for risk group classification (of lamps): A general term for a continuous wave (CW) lamp intended for lighting spaces that are typically occupied or viewed by people. Used to differentiate from non-general lighting sources in the process of determining risk group classification.

3.14 germicidal UV (GUV) lamp system

Any UV lamp system designed to disinfect using a UV-C anti-microbial effect to inactivate pathogens so that they are no longer capable of replicating and causing adverse health effects.

3.15 instructed person

A person who has been instructed and trained by a skilled, competent person, or who is supervised by a competent person, to identify ultraviolet sources that may cause adverse effects and to take precautions to avoid unintentional exposure to those sources. [Adapted from IEC 62368-1:2018.⁵]

3.16 intended use

Usage of a lamp, lamp system, process, or service in accordance with specifications, instructions, and information provided by the manufacturer or supplier.

3.17 lamp

A generic term for a manufactured source created to produce optical radiation.

Note: For the purposes of this document, the term includes any kind of electrical source emitting in the optical range, including LEDs and excimer lamp sources.

3.18 lamp system

Any manufactured product or assemblage of components that incorporates, or is intended to incorporate, one or more lamps.

Note: A UV lamp system is one that is intended to emit UV radiation for its primary application, or for which the emission of UV radiation is a major function.

3.19 lamp packaging

Any lamp carton, outer wrapping, or other means of containment that is intended for the storage, shipment, or display of one or more lamps, or that is intended to identify the contents or to recommend its use.

3.20 luminaire, UV

For the purpose of this document: A lamp system that distributes, filters, or transforms the UV radiant energy transmitted from at least one source of optical radiation and which includes all the parts necessary for attaching (sometimes referred to as "fixing") and protecting the sources and, where necessary, circuit auxiliaries together with the means for connecting them to the power supply. UV luminaires commonly are employed in upper-room germicidal applications.

3.21 photocuring lamp system

A lamp system that usually employs UV-A to photopolymerize liquid polymers to a solid state. Examples include UV photopolymerization of liquid inks in printing, and rapid curing of plastic products.

3.22 photokeratoconjunctivitis

A delayed inflammatory response of the cornea and conjunctiva following exposure to UV radiation.

Wavelengths shorter than 320 nm are most effective in causing photokeratoconjunctivitis. The peak of the action spectrum is at approximately 270 nm.

3.23 risk group (RG)

A classification scheme for lamps and lamp systems that indicates the photobiological hazard. Four risk groups, from Exempt to High Risk, are defined. (See **Section 5.4.**)

3.24 time-weighted average (TWA) exposure

The averaged cumulative exposure (dose) delivered over a given period (occurring on a daily 8-hour basis) divided by the exposure duration, to provide an effective irradiance for both variable distances and durations.

Note: The TWA is essential in considering lengthy exposures to UV hazards, since variable exposure distances at different irradiances and durations determine the reasonably foreseeable worst-case exposures (for photochemical hazards), which therefore correspond to the measured or calculated effective irradiance at a specified distance for RG determination (analogous to the 500-lx assessment distance for GLS lamps, as explained in ANSI/IES RP-27-20; see **Section 2.2**).

3.25 ultraviolet radiation

Radiant energy within the wavelength range 10 nm to 400 nm.⁶

Note: For *photobiological* purposes, the subdivisions in the UV range between 100 nm and 400 nm are⁶:

- UV-A: 315 to 400 nm
- UV-B: 280 to 315 nm
- UV-C: 100 to 280 nm

3.26 UV fluorescence illuminator

Any UV lamp system designed to illuminate and excite fluorescent materials to permit increased visualization. Examples include “black light” fluorescent illuminators, security-code readers, and Wood’s lamp systems for medical applications.

3.27 view-related risk

The risk for intended viewers of a source under application-specific realistic conditions exceeding 1,000 seconds in one day.

4.0 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 attractants and germicidal irradiation. Typical lamp types are:

- Low-pressure mercury lamps (tubular and compact lamps with UV-emitting phosphors)
- Low-pressure mercury UV-C lamps
- UV LEDs (bandwidth generally 50 nm or less)
- Excimer lamps, e.g., krypton chloride
- UV-filtered metal-vapor discharge lamps
- Filtered UV xenon lamps (pulsed or continuous)
- UV-filtered tungsten-halogen lamps

Lamps are employed most typically in the applications described in **Sections 4.1** through **4.6**.

4.1 Near-UV (UV-A) “Black Light” Sources to View Fluorescent Pigments

Handheld and fixed (i.e., attached) UV-A fluorescence illuminators with typical peak emissions at 350 to 400 nm are used in a variety of applications, including for exciting fluorescent coatings, paints, and pigments, and to visualize the visible fluorescent emission for non-destructive testing. The viewer may or may not wear UV-blocking eyewear, to improve the contrast of the visible fluorescence emission spectrum or to protect against accidental direct exposure.

Handheld UV-A spotlights or “flashlights” are used in conjunction with fluorescent dyes in non-destructive testing, e.g., of coatings and cracks. 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. In actual use, the UV-A beam is directed away from the viewer and the user would not receive a potentially hazardous exposure.

Permanently installed “black light” systems are used in, for example, the entertainment industry, museums, bars, banks (for currency checking), and bowling alleys, and are installed to encourage viewing of the lit scene rather than the source, other than unintentional or momentary views.

4.2 Near-UV (UV-A) Insect Attractant Lamps and Lamp Systems

Both fixed (i.e., attached) and portable UV-A lamp systems with typical peak emissions generally within the spectral range of 350 to 370 nm are used in a variety of applications for insect light traps (ILTs). Effective installation requires that the ILTs be 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 meter or more, even for indoor units, depending upon application.

4.3 Germicidal Ultraviolet (GUV) Lamps and Lamp Systems

GUV lamp systems for ultraviolet germicidal irradiation (UVGI) traditionally use low-pressure mercury-discharge lamps with primary emission at 254 nm (in the UV-C range).⁷ Lamp envelopes were originally made from quartz, but today most lamps use UV-C transmitting glass that will block the 185-nm mercury line that produces significant ozone (see **Section 6.4 Ozone**). Radiation from short-wavelength (less than approximately 240 nm) GUV lamp systems can result in increased ozone in the indoor environment. When these systems are used in occupied areas, the lamp's safety commissioning process should include an assessment of potential room occupant exposure to ozone. For germicidal efficacy, the UV lamps themselves are almost by necessity in Risk Group 3.

Traditional GUV lamp systems have generally been designed to block emission of UV into occupied spaces. GUV is employed in water-purification and air-handling systems, and in domestic air-purifiers that generally have interlocked enclosures to 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 the tuberculosis bacillus, and measles and influenza viruses, upper-room GUV luminaires are used in some hospitals, prisons, and institutions, where infection control is critical. The aim is to irradiate only the upper-room volume, placing the GUV luminaires at least 2.1 meters (7 ft) above the floor level. Since the system

will be Risk Group 3 when measured correctly on axis, proper installation of GUV luminaires ensures that TWA exposure does not exceed the Threshold Limit Value® (TLV®) in the occupied lower part of the room, less than 180 cm (about 5 ft 11 in.) above floor level (refer to *ANSI/IES RP-44-21, Recommended Practice: Ultraviolet Germicidal Irradiation (UVGI)* for additional information; see **Section 2.3**). Acceptable exposure levels above 180 cm will vary depending on ceiling height.

UV LED lamps and lamp systems have been emerging in recent years. Those using UV LEDs for germicidal applications typically emit radiation with peak emission between 265 and 280 nm. The efficiency of germicidal UV LEDs is improving rapidly, including the more recent development of shorter wavelength devices with peak emissions between 220 and 240 nm.

UV-C emission at 222 nm from krypton chloride excimer (KrCl*)[†] lamps has been recently introduced in germicidal lamp systems that have the potential of being used in occupied spaces with lower skin and eye risk to the occupants.⁸ The potential risk due to ozone generation may need to be considered, particularly for high-power excimer and unfiltered UV luminaires (see **Section 6.4**).

Note: The Harvard School of Public Health performed assessments at an eye height of 172 cm (5 ft 8 in.)—e.g., for a 180-cm (6-ft) standing human—and at an eye height of 112 cm (3 ft 8 in.), representing a reclining person in the highest hospital bed, as measured from the floor. Today, 180 cm, corresponding to the 99th-percentile height of the eyes of a standing person, is used.

Additional information on GUV lamps and lamp systems may be found in *IES CR-2-20-V1, IES Committee Report: Germicidal Ultraviolet (GUV) – Frequently Asked Questions*⁹ and in *ANSI/IES RP-44-21, Recommended Practice: Ultraviolet Germicidal Irradiation (UVGI)* (see **Section 2.3**).

4.4 UV Tanning Equipment

Tanning devices are not covered in this standard. However, such devices shall comply with *FDA 21CFR*

[†] The symbol for the krypton chloride excimer is KrCl*; in this symbol, the "*" indicates the excited state of the excimer molecule.

1040.20, *Performance Standard for Sunlamp Products*¹⁰ or equivalent regulation outside the United States. This FDA regulation provides all optical radiation performance requirements designed to minimize risks to the user. Hence, this Recommended Practice does not provide additional requirements or emission limits.

4.5 UV Nail Curing and Treatment

UV lamps and lamp systems for photocuring of nail polish and nail laminates employ UV-A lamps installed in a fixture that is designed to minimize ocular exposure. Irradiances of approximately 10 to 20 mW·cm⁻² are typical at the nail.¹¹ Two assessment-distance criteria are required: 1) for the skin at 1 cm; and 2) for the eyes at 20 to 50 cm, since this provides a conservative TWA viewing distance, considering the usage time of a professional operator. Normally, these lamps and lamp systems should be in RG-0 or RG-1. Cautionary wording would be applicable for RG-2 (see **Section 7.4**).

4.6 UV Medical and Dental Sources

Medical lamps and lamp systems 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 lamps are found in emergency rooms, ophthalmology departments, and dermatology departments for fluorescence detection and fluorimetry. UV-A-induced fluorescence of proteins and DNA is useful in a range of applications. Dental examinations employ UV-A radiation for identification of tooth plaque, and it has been used for photocuring in restorative dentistry. 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. Assessment distance varies by application.

UV-A and UV-B radiation is used in a variety of medical treatments (e.g., dermatology phototherapy).

5.0 Emission Limits and Measurement for Risk Group Determination

5.1 Emission Limits

Table 5-1 provides emission limits (expressed as irradiance) for UV lamps and lamp systems. Normally, UV lamps and lamp systems will not emit visible or IR-A radiation (780 to 3,000 nm) that would approach retinal thermal, blue light, or low-luminance retinal thermal limits, as provided in ANSI/IES RP-27-20 (see **Section 2.2**). A complete list of emission limits for UV lamps and lamp systems is provided in ANSI/IES RP-27-20.

5.2 Time-Weighted Averaging (TWA) of Exposures

TWA is a critical aspect of assessing the risks from UV lamp systems. It is recognized that cumulative daily exposure over variable exposure distances with different irradiances and exposure durations exist for almost all UV applications. The assessment distance (see **Section 5.3**) is determined for the reasonably foreseeable worst-case TWA exposure and is equivalent to that distance where the photochemical hazard would exist after considering the normal movements of the individual in relation to the source during the day (see **Tables 5-2a** through **5-2c**, in **Section 5.4**). Time-weighted averaging is therefore a method to obtain an exposure dose integrated over longer periods during which the irradiance may change. **Annex B** provides additional information on TWA.

Table 5-1. Emission Limits for Risk Groups of Ultraviolet Lamps and Lamp Systems

Risk ^a	Metric	Formula in RP-27-20	Exempt, RG-0 (max 8 h)	RG-1 (max 2.8 h)	RG-2 (max 1,000 s)	Units
Actinic UV, $S(\lambda)$	E_s	§ 5.4.1	0.1	0.3	3.0	μW·cm ⁻² (effective) ^b
Near UV, 315 – 400 nm	E_{UV}	§ 5.4.2	1.0	3.3	10	mW·cm ⁻²

Table notes:

a. Although highly unlikely, a UV lamp or lamp system with significant short-wavelength visible radiant emission could require assessment for blue-light-hazard spectrally weighted radiance (L_B). If concern exists, refer to ANSI/IES RP-27-20 for limits (see **Section 2.2**).

b. Spectrally weighted by $S(\lambda)$.

5.3 Measurement and Assessment Distances for UV Lamp Systems

Where possible, measurements of effective UV-B and UV-C irradiance and/or spectral irradiance from UV lamp systems normally should be made at the relevant risk group assessment distance given in **Tables 5-2a** through **5-2c** (see **Section 5.4**). It is often the case, however, that the source UV irradiance is low, so it is desirable to measure the irradiance sufficiently close to the source, i.e., less than the risk group assessment distance, to minimize measurement errors from detector dark current (noise). This is particularly true if high resolution spectral measurements are to be obtained. The measured irradiance shall then be transferred to the relevant risk group assessment distance given in **Tables 5-2a** through **5-2c** (see **Section 5.4**). The measurements should be transferred to the assessment distance through a known relationship (ratio) between the measured and assessed distances. This ratio may be experimentally determined or known from historical mathematical methods.

When the assessment distance for a UV luminaire is significantly less than 3 times the largest dimension of the source, the inverse-square law is not applicable because the distance is too close. In such a case, the ratio shall be experimentally determined. For example, if a 1-m linear fluorescent-tube luminaire is measured at 20 cm normal to and at the center of luminaire output, and the assessment distance is 50 cm in **Table 5-2c**, then the transfer ratio for the irradiance at 50 cm needs to be determined experimentally. A good way to obtain the transfer ratio in this case is to use a broadband detector and obtain the irradiance ratio at both the measured and assessed distances. This experimentally determined ratio is then applied to the spectral measurements. Using the inverse-square law in this case would have led to large errors in the assumed emission at the assessment distance.

However, in the unlikely case that the radiant output is too high and may damage or saturate the instrument detector, the measurement distance will be greater than the assessment distance. In this case, the distances from the source may be sufficiently large to obtain the transfer ratio using the inverse-square law.

For a broadband UV-A source, it may be necessary to determine the stray UV-B irradiance. In this case, spectral measurements obtained at a short measurement distance, e.g., 20 cm to improve signal-to-noise ratio, will be used to determine the UV-B irradiance. The UV-B irradiance at the assessment distance, e.g., 50 cm, can then be obtained by using a broadband irradiance detector to determine the ratio needed to find the UV-B irradiance at 50 cm.

In all cases, the actual measurement values or the extrapolated measurement values at the assessment distance should be reported.

5.4 Risk Group Assessment Distance Criteria

From **Section 5.3**, the irradiance due to the source is now known at the assessment distance. This information, along with the TWA exposure values, permits the evaluation of the risk group using the values shown in **Table 5-1**.

Tables 5-2a through **5-2c** provide the risk group assessment distance criteria for specific UV lamp systems. **Table 5-2a** applies to lamps and lamp systems intended for use by *consumers in uncontrolled environments* and which require no restrictions other than the provision of user information. Under normal or abnormal operating conditions, ordinary persons should not be exposed to UV sources at dose levels capable of causing injury.

Lamps and lamp systems requiring special use training and generally only administrative controls are listed in **Table 5-2b**; 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 UV sources at dose levels capable of causing injury. Lamps and lamp systems intended for use by consumers (i.e., ordinary persons) or instructed persons shall not emit RG-3 emission levels.

Those lamps and lamp systems 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 listed in **Table 5-2c**.

