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SUMMARY OF "RECOMMENDED PRATICE FOR PHOTOBIOLOGICAL SAFETY FOR LAMPS AND LAMP SYSTEMS – GENERAL REQUIREMENTS

- The ultra-violet exposure limits represent conditions under which it is believed that nearly all individuals may be repeatedly exposed to UV radiation without adverse health effects.
- However, they do not apply to individuals who may have been unknowingly exposed to a photosensitizing agent.
- There are over 100 substances either swallowed or applied that can make someone photosensitive without their knowledge.
- **Any UV exposure during this time is essentially "turbo" charging any damage that can occur.**

ANSI/IESNA RP-27.1-05

Approved American National Standard

ANSI

Recommended Practice *for* Photobiological Safety *for* Lamps and Lamp Systems – General Requirements

IES

The LIGHTING AUTHORITY®

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Photobiological Safety for Lamps and Lamps Systems - General Requirements

1.0 INTRODUCTION

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

To evaluate a broad-band optical source, such as an arc lamp, an incandescent lamp, a fluorescent lamp, an array of lamps or a lamp system, it first is necessary to determine the spectral distribution of optical radiation emitted from the source at the point or points of nearest human access. This accessible emission spectral distribution of interest for a lighting system may differ from that actually being emitted by the lamp alone due to the filtration by any optical elements (e.g., projection optics) in the light path. Secondly, the size, or projected size, of the source must be characterized in the retinal hazard spectral region. Thirdly, it may be necessary to determine the variation of irradiance and projected radiance (see the **Glossary**) with distance. The performance of the necessary measurements is not an easy task without sophisticated instruments. Users must normally rely upon the expertise of manufacturers for information on lamps and lamp systems. Safety requirements and reference measurement techniques for lamps and specific lamp systems are provided in later standards of this series, viz., RP-27.2, RP-27.3...

Finally, there are well known optical radiation hazards associated with some lamps and lamp systems. The purpose of these standards is to inform the public and original equipment manufacturers (OEMs) about potential radiation hazards that may be associated with various lamps and lamp systems. It is also the purpose of these standards to provide guidance, advice, and standard methods for evaluating and informing the user, both the public and the OEM, about the potential optical radiation hazards that may be associated with these products.

2.0 SCOPE

This Recommended Practice covers the evaluation and control of optical radiation hazards from all electrically powered sources of optical radiation that emit in the wavelength range from 200 nm through 3,000 nm (3.0 μm) except for light emitting diodes (LEDs) used in optical fiber communication systems and for lasers which are covered in a separate series of ANSI standards (Series Z136). Federal mandatory requirements for lamps subject to specific Federal Regulations take precedence over requirements in subsequent standards included in this series.

Note 1: Units of wavelength in this document are exclusively in nanometers (nm).

Note 2: Subtended angles are denoted by the full included angle, not the half angle.

3.0 DEFINITIONS

For standard nomenclature and definitions, radiometric and photometric quantities, and illuminating engineering terminology, refer to ANSI/IESNA RP-16-2005, Nomenclature and Definitions for Illuminating Engineering. Certain frequently used terms are defined in the Glossary.

3.1 Blue Light Hazard

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 for times exceeding 10 s.

3.2 Continuous Wave (CW) Lamp

A lamp that is operated with a continuous output for a 0.25 s period of time or greater, i.e., a non pulsed lamp (see **Section 3.15**). In this standard, General Lighting Source (GLS) lamps are defined to be Continuous Wave lamps.

3.3 Erythema

The temporary reddening of the skin such as the delayed thermal reddening produced by exposure to actinic ultraviolet radiation or the immediate thermal reddening produced by exposure to infrared radiation. (See **Section 3.12**).

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

3.4 Exposure Limit

A value of exposure to the eye or skin that is not expected to result in adverse biological effects is called the exposure limit.

3.5 Exposure Distance

Nearest points of human exposure consistent with the application of the lamp.

3.6 General Lighting Source, GLS

A general term for lamps intended for lighting spaces that are typically occupied or viewed by people. Examples would be lamps for lighting offices, schools, homes, factories, roadways, or automobiles. It does not include lamps for such uses as film projection, reprographic processes, "suntanning," industrial processes, medical treatment, and searchlight applications. It also does not include lamps with outer envelopes constructed from quartz material that is not doped to block UV-B and UV-C (see **Section 3.19**). Although lamps with undoped quartz outer envelopes may be used in locations typically occupied by people, their potential to emit ultraviolet power requires that they be more carefully evaluated. The process for classifying lamps is described in sections of the third document in this series, *Recommended Practice for Photobiological Safety for Lamps - Risk Group Classification and Labeling, RP 27.3.*

3.7 Hazard Distance

See Skin Hazard Distance (**Section 3.18**) or Ocular Hazard Distance (**Section 3.13**).

3.8 Infrared Radiation

For practical purposes any radiant energy within the wavelength range 770 nm to 10^6 nm. The infrared spectrum is divided into three spectral bands for safety purposes: IR-A (770 nm to 1400 nm), IR-B (1400 nm to 3000 nm), and IR-C (3000 nm to 10^6 nm).

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

3.9 Lamp

The generic name for a man-made source of light is "lamp." As used in this standard, the term means an electrically powered source, other than a light emitting diode (LED) used in a fiber-optic communication system or a laser. By extension, the term is also used to denote sources that radiate in regions of the spectrum adjacent to the visible region, i.e., in the ultraviolet and infrared spectral ranges. Devices that generate light and have integral components for optical control, such as lenses or reflectors, also are considered lamps. Examples include a lens-end lamp, and a PAR lamp with a reflector or lens cover.

Note: A device consisting of a lamp with shade, reflector, enclosing globe, housing, or other accessories has often been called a "lamp." However, in this standard, a lamp with such other components is termed a "lamp system" to distinguish between the assembled unit and the light source within it.

3.10 Lamp System

Any manufactured product or assemblage of components which incorporates, or is intended to incorporate a lamp is considered to be a "lamp system."

3.11 Lamp Packaging

Any carton, outer wrapping, or other means of containment that is intended for the storage, shipment, or display of a lamp(s) or that is intended to identify the contents or to recommend its use is considered to be "lamp packaging."

3.12 Minimal Perceptible Erythema, MPE

The minimum erythemal dose (MED) is the radiant exposure density, e.g., $J \cdot m^2$, that is just sufficient to elicit a perceptible delayed erythema, i.e., a Minimum Perceptible Erythema (MPE). The MED varies with skin type, time between exposure and evaluation, and ultraviolet spectral distribution. (See **Section 3.3**).

3.13 Ocular Hazard Distance

The distance from a source within which the "projected radiance" (see **Glossary**) or irradiance exceeds the applicable exposure limit for momentary (0.25 s to 0.5 s) viewing.

3.14 Photokeratoconjunctivitis

An inflammatory response of the cornea and conjunctiva following exposure to ultraviolet (UV) radiation.

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

3.15 Pulsed Lamp

A lamp that delivers its energy in the form of a single pulse or a train of pulses where each pulse shall have a time duration of less than 0.25 s.

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

Note 2: In this standard, General Lighting Source lamps are defined to be Continuous Wave lamps (see **Section 3.2**). Examples of pulsed lamps include photoflash lamps, flashlamps in photocopy machines, and strobe lights.

3.16 Retinal Burn

A photochemical or thermal retinal lesion.

3.17 Retinal Hazard Region

The spectral region from 375 nm to 1400 nm (visible plus IR-A) within which the normal ocular media transmit optical radiation to the retina.

3.18 Skin Hazard Distance

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

3.19 Ultraviolet Radiation

For practical purposes, ultraviolet (UV) radiation is any radiation within the wavelength range from 100 nm to 400 nm. 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 as defined by the Commission Internationale de l'Eclairage (CIE). Frequently in photobiology, the wavelength bands are taken as UV-C from 200 nm to 290 nm, UV-B from 290 nm to 320 nm, and UV-A from 320 nm to 400 nm. Ultraviolet radiation at wavelengths less than 200 nm is considered vacuum ultraviolet radiation. Note that the radiation between 380 nm and 400 nm is visible radiation (see **Section 3.20**) although it also is within the formal definition of the ultraviolet band.

3.20 Visible Radiation

Radiation within the wavelength range from 380 nm to 770 nm is considered to be visible radiation. See "light" in the **Glossary**.

3.21 Visual Angle

The angle subtended by an object or detail at the point of observation is considered to be the visual angle. It usually is measured in radians, milliradians, degrees, or minutes of arc.

4.0 EXPOSURE LIMITS

4.1 General

Personnel working with or in the vicinity of lamps and lamp systems should not be exposed to levels exceeding the following limits.

These criteria are based on recommendations in Threshold Limit Values (TLVs®) of the American Conference of Governmental Industrial Hygienists and recommendations in publications of the International Commission on Non-ionizing Radiation Protection (ICNIRP). [See **Bioeffect Datasheet #7**]. The specific techniques of applying these criteria to lamps and lamp systems are given in later standards of this series, viz., RP-27.2, and RP-27.3.

The limiting aperture dimensions for irradiance measurements given in this document are for general application. However, they may not be appropriate for certain specific conditions and devices. Future documents in this series may modify these dimensions for those situations.

4.2 Ultraviolet Exposure Limits

4.2.1 General

The ultraviolet exposure limits represent conditions under which it is believed that nearly all individuals in the general population may be repeatedly exposed without adverse health effects. However, they do not apply to photosensitive individuals or to individuals concomitantly exposed to photosensitizing agents. (Fitzpatrick et al., eds., *Sunlight and Man,* Univ. of Tokyo Press, Tokyo, Japan, 1974.) Such individuals, in general, are more susceptible to adverse health effects from optical radiation than individuals who are not photosensitive or concomitantly exposed to photosensitizing agents. The susceptibility of photosensitive individuals varies greatly, and it is not possible to set exposure limits for this portion of the population. These exposure limits shall be used as guides in the control of exposure to continuous sources where the exposure duration is not less than 0.1 ms. These values shall be used as guides in the control of exposure and shall not be regarded as a fine line between safe and dangerous levels.

4.2.2 200 nm to 400 nm Skin and Eye Exposure Limit. The exposure limits for human exposure to ultraviolet radiation incident upon the unprotected skin or eye where irradiance values are known and exposure time is controlled are as follows:

The effective irradiance exposure for the unprotected skin or eye should not exceed the values given in **Table 1** within an 8-hour period.

To determine the effective ultraviolet irradiance, E_S, of a broad-band source, the following weighting formula shall be used:

$$E_S = \sum_{200}^{400} E_\lambda \bullet S(\lambda) \bullet \Delta\lambda \quad (1)$$

where:
E_S is the effective ultraviolet irradiance in $W \bullet cm^{-2}$
E_λ is the spectral irradiance in $W \bullet cm^{-2} \bullet nm^{-1}$
$S(\lambda)$ is the ultraviolet hazard weighting function (see **Table 2**)
$\Delta\lambda$ is the calculation interval in nm
the summation extends from 200 nm to 400 nm.
The permissible exposure time for exposure to ultraviolet radiation incident upon the unprotected eye or skin shall be computed by:

$$t(\max) = \frac{0.003}{E_S} \quad (2)$$

where:
t(max) is the permissable exposure time in seconds
denominator E_S is the effective ultraviolet irradiance in $W \bullet cm^{-2}$
the value "0.003" is in $J \bullet cm^{-2}$

The exposure time may also be determined using **Table 1** which provides exposure times corresponding to an effective irradiance in $\mu W \bullet cm^{-2}$.

4.2.3 *320 nm to 400 nm Eye Exposure Limit.* For the spectral region 320 nm to 400 nm the total ultraviolet irradiance for the unprotected eye, E_{UV}, should not exceed 1 $mW \bullet cm^{-2}$ for periods greater than 10^3 s (approximately 16 minutes). For exposure times less than 10^3 s, the total radiant exposure to the eye should not exceed 1.0 $J \bullet cm^{-2}$.

TABLE 1
Permissible Ultraviolet Exposures

Duration of Exposure Per Day		Effective Ultraviolet Irradiance E_s ($\mu W \cdot cm^{-2}$)
8	hours	0.1
4	hours	0.2
2	hours	0.4
1	hour	0.8
30	minutes	1.7
15	minutes	3.3
10	minutes	5
5	minutes	10
1	minute	50
30	seconds	100
10	seconds	300
1	second	3,000
0.5	second	6,000
0.1	second	30,000

All the preceding exposure levels for ultraviolet radiation apply to sources that subtend an angle less than 80°, sources within 40°of the normal to the irradiance area. Sources which subtend a greater angle need to be measured only over an angle of 80°.

This can be expressed as:

$$E_{UV} \leq 0.001 \qquad \text{(for } t \geq 10^3\text{)} \qquad (3a)$$

$$t(\max) \leq \frac{1.0}{E_{UV}} \qquad \text{(for } t < 10^3\text{)} \qquad (3b)$$

where:
t is time in seconds
t(max) is time in seconds
E_{UV} is the total ultraviolet irradiance between 320 nm and 400 nm on the unprotected eye in W • cm^{-2}
the value "1.0" is in J • cm^{-2}.

Notes for ***Section 4.2.2*** *and* ***Section 4.2.3:***

Note 1: All the preceding exposure limits for ultraviolet radiation apply to sources that subtend an angle of less than 80° (1.4 radian) i.e., sources within 40° of the normal to the irradiance area. Sources that subtend a greater angle need to be measured only over an angle of 80°.

Note 2: A limiting aperture no greater than 2.5 cm diameter shall be used with sources producing a uniform optical radiation pattern. However, with sources of optical radiation that do not produce a uniform optical radiation pattern (i.e., contain hot spots less than 2.5 cm), a 7 mm aperture shall be used. The measurement shall be made in that position of the beam giving the maximum reading.

TABLE 2
Spectral Weighting Function for Assessing Ultraviolet Hazards

Wavelength[1] λ,nm	**UV Hazard Function S(λ)**	**Wavelength λ,nm**	**UV Hazard Function S(λ)**
		310	0.015
		313*	0.006
200	0.030	315	0.003
205	0.051	316	0.0024
210	0.075	317	0.0020
215	0.095	318	0.0016
220	0.120	319	0.0012
225	0.150	320	0.0010
230	0.190	322	0.00067
235	0.240	323	0.00054
240	0.300	325	0.00050
245	0.360	328	0.00044
250	0.430	330	0.00041
254*	0.500	333	0.00037
255	0.520	335	0.00034
260	0.650	340	0.00028
265	0.810	345	0.00024
270	1.000	350	0.00020
275	0.960	355	0.00016
280*	0.880	360	0.00013
285	0.770	365*	0.00011
290	0.640	370	0.000093
295	0.540	375	0.000077
297*	0.460	380	0.000064
300	0.300	385	0.000053
303*	0.120	390	0.000044
305	0.060	395	0.000036
308	0.026	400	0.000030

[1] Wavelengths chosen are representative; other values should be interpolated at intermediate wavelengths.
* Emission lines of a mercury discharge spectrum.

4.3 Light and Near Infrared Radiation Exposure Limits

The limits for exposure to broad-band light and IR-A radiation for the eye apply to exposure within an 8-hour period and require knowledge of the spectral radiance, L_λ, and total irradiance, E, of the source as measured at the position(s) of the eyes of the exposed person. Such detailed spectral data of a white light source is generally required only if the luminance of the source exceeds 10^4 cd • m^{-2}. At a luminance less than this value, the exposure limit should not be exceeded. The exposure limits are given in **Sections 4.3.1 - 4.3.6**.

The light and near infrared limits represent conditions under which it is believed that nearly all individuals in the general population may be repeatedly exposed without adverse health effects. However, they do not apply to photosensitive individuals or to photosensitive individuals or to individuals concomitantly exposed to photosensitizing agents. These exposure limits shall be used as guides in the control of exposure and shall not be regarded as a fine line between safe and dangerous levels.

4.3.1 Retinal Thermal Hazard Exposure Limit

To protect against retinal thermal injury, the integrated spectral radiance of the light source, L_R, weighted by the burn hazard weighting function, $R(\lambda)$, (from **Table 3**), should not exceed the levels defined by:

$$L_R = \sum_{400}^{1400} L_\lambda \cdot R(\lambda) \cdot \Delta\lambda \leq \frac{5}{\alpha t^{0.25}} \qquad (4)$$

where:
L_R is the burn hazard weighted radiance of the light source in W • cm^{-2} • sr^{-1}
L_λ is the spectral radiance in W • cm^{-2} • sr^{-1} • nm^{-1}
$R(\lambda)$ is the burn hazard weighting function
t is the viewing duration (or pulse duration if the lamp is pulsed) expressed in seconds but restricted to durations of 1 μs to 10 s
$\Delta\lambda$ is the calculation interval in nm
α is the visual angle of the source or projected source in radians defined by the 50 percent peak radiance points
the summation extends from 400 nm to 1400 nm.

Note: **Equation 4** is empirical and is not dimensionally correct unless a dimensional correction factor $K_1 = 1$ W • cm^{-2} • sr^{-1} • rad • $s^{0.25}$ is inserted in the right hand numerator.

For a non circular projected source area, α is determined from the arithmetic mean of the shortest and the longest dimensions. For example, α for a 20 cm long by 3 cm diameter tubular source at a viewing distance of r = 200 cm in a direction normal to the lamp axis would be determined from the mean dimension of $l = (20+3)/2 = 11.5$ cm.

$$\alpha = l/r = 11.5/200 = 0.058 \text{ radian}$$

If the calculated α exceeds 0.1 radian, use $\alpha = 0.1$ in **Equation 4**. If the calculated α is less than 0.011 radian, use $\alpha = 0.011$ in **Equation 4**. No criteria for thermal hazards are relevant for exposure durations longer than 10 s, because while thermal injury is the dominant injury mechanism to 10 s, photochemical mechanisms predominate for exposure duration longer than 10 s.

Note 1: For these exposure limits, a 7 mm diameter ocular pupil is assumed for viewing durations less than approximately one second.

Note 2: L_λ shall be averaged over a right circular cone field-of-view of 0.011 radian included angle.

Note 3: In the case of multiple source elements that are not contiguous, this criterion applies to a single source element. Also, it applies to the source as a whole when the average radiance over the full source is used.

4.3.2 Retinal Blue Light Hazard Exposure Limit

To protect against retinal photochemical injury from chronic blue-light exposure, the integrated spectral radiance of the light source weighted against the blue-light hazard function $B(\lambda)$ (from **Table 3**) should not exceed the levels defined by:

$$(L_B \cdot t) = \sum_{300}^{700} L_\lambda \cdot B(\lambda) \cdot t \cdot \Delta\lambda \leq 100 \text{ (for } t \leq 10^4) \qquad (5a)$$

$$L_B = \sum_{300}^{700} L_\lambda \cdot B(\lambda) \cdot \Delta\lambda \leq 0.01 \text{ (for } t > 10^4) \qquad (5b)$$

where:
$(L_B \cdot t)$ is in J • cm^{-2} • sr^{-1}
L_B is the blue light hazard weighted radiance in W • cm^{-2} • sr^{-1}
L_λ is the spectral radiance in W • cm^{-2} • sr^{-1} • nm^{-1}
$B(\lambda)$ is the blue-light hazard weighting function
$\Delta\lambda$ is the calculation interval in nm
t is the exposure duration in seconds
the summations extend from 400 nm to 700 nm.

For a weighted source radiance, L_B, exceeding 10 mW cm^{-2} sr^{-1}, the maximum permissible exposure duration, t(max), is:

TABLE 3
Spectral Weighting Functions for Assessing Retinal Hazards from Broad-Band Optical Sources

Wavelength, nm	Aphakic Hazard Function A(λ)	Blue-Light Hazard Function B(λ)	Burn Hazard Function R(λ)
305	6.00	0.01	—
310	6.00	0.01	—
315	6.00	0.01	—
320	6.00	0.01	—
325	6.00	0.01	—
330	6.00	0.01	—
335	6.00	0.01	—
340	5.88	0.01	—
345	5.71	0.01	—
350	5.46	0.01	—
355	5.22	0.01	—
360	4.62	0.01	—
365	4.29	0.01	—
370	3.75	0.01	—
375	3.56	0.01	—
380	3.19	0.01	0.0063
385	2.31	0.0125	0.0125
390	1.88	0.025	0.025
395	1.58	0.05	0.05
400	1.43	0.10	0.10
405	1.30	0.20	0.20
410	1.25	0.40	0.40
415	1.20	0.80	0.80
420	1.15	0.90	0.9
425	1.11	0.95	0.95
430	1.07	0.98	0.98
435	1.03	1.0	1.0
440	1.0	1.0	1.0
445	0.97	0.97	1.0
450	0.94	0.94	1.0
455	0.90	0.90	1.0
460	0.80	0.80	1.0
465	0.70	0.70	1.0
470	0.62	0.62	1.0
475	0.55	0.55	1.0
480	0.45	0.45	1.0
485	0.40	0.40	1.0
490	0.22	0.22	1.0
495	0.16	0.16	1.0
500-600	$10^{[(450-\lambda)/50]}$	$10^{[(450-\lambda)/50]}$	1.0
600-700	0.001	0.001	1.0
700-1050	N/A	N/A	$10^{[(700-\lambda)/500]}$
1050-1150	N/A	N/A	0.2
1150-1200	N/A	N/A	$0.2 \times 10^{[0.02(1150-\lambda)}$
1200-1400	N/A	N/A	0.2

N/A = Not Applicable

$$t(\max)=\frac{100}{L_B} \text{ (for } t \leq 10^4) \qquad (6)$$

where:
$t(\max)$ is the maximum permissible exposure duration in seconds
t is exposure time in seconds
L_B is the blue light hazard weighted radiance in $W \cdot cm^{-2} \cdot sr^{-1}$
the value "100" is in $J \cdot cm^{-2} \cdot sr^{-1}$.

Note 1: For these exposure limits, a 3 mm diameter ocular pupil is assumed.

Note 2: The spectral radiance, L_λ, shall be averaged over a right circular cone field-of-view of 0.011 radian included angle.

Note 3: In the case of multiple source elements that are not contiguous, this criterion applies to a single source element. Also, it applies to the source as a whole when the average radiance over the full source is used.

4.3.3 Retinal Blue Light Hazard Exposure Limit - Small Source

For a light source subtending an angle less than 0.011 radian (11 milliradian), the limits of **Section 4.3.2** are relaxed such that the spectral irradiance at the eye E_λ weighted against the blue-light hazard function $B(\lambda)$ should not exceed the levels defined by:

$$(E_B \cdot t)=\sum_{300}^{700} E_\lambda \cdot t\, B(\lambda) \cdot \Delta\lambda \leq 0.01 \text{ (for } t \leq 10^4)^* \qquad (7a)$$

$$E_B=\sum_{300}^{700} E_\lambda \cdot B(\lambda) \cdot \Delta\lambda \leq 10^{-6} \text{ (for } t > 10^4)^* \qquad (7b)$$

where:
$(E_B \cdot t)$ is in $J \cdot cm^{-2}$
E_B is the blue light hazard weighted irradiance in $W \cdot cm^{-2}$
E_λ is the spectral irradiance at the eye in $W \cdot cm^{-2} \cdot nm^{-1}$
$B(\lambda)$ is the blue-light hazard weighting function
$\Delta\lambda$ is the calculation interval in nm
t is the exposure duration in seconds
the summations extend from 400 nm to 700 nm.

For a source where the blue light weighted irradiance, E_B, exceeds $1 \mu W \cdot cm^{-2}$, the maximum permissible exposure duration is:

$$t(\max) \leq \frac{0.01}{E_B} \text{ (for } t \leq 10^4) \qquad (8)$$

* To be changed from 10^4 s to 10^2 s. See ANSI/IESNA RP-27.3-06

where:
$t(\max)$ is the maximum permissible exposure duration in seconds
t is exposure time in seconds
E_B is the blue light weighted irradiance in $W \cdot cm^{-2}$
the value "0.01" is in $J \cdot cm^{-2}$

Note 1: A limiting aperture no greater than 2.5 cm diameter shall be used with sources producing a uniform optical radiation pattern. However, with sources of optical radiation that do not produce a uniform optical radiation pattern (i.e., contain hot spots less than 2.5 cm), a 7 mm aperture shall be used. The measurement shall be made in that position of the beam giving the maximum reading.

Note 2: These small source equations are equivalent to using **Section 4.3.2** with the spatial averaging for small sources specified in Note 2 of that section.

4.3.4 The Aphakic Eye Hazard Exposure Limit

To find the exposure values for individuals who have had cataract surgery (or otherwise lack a normal ocular lens) when an ultraviolet blocking intraocular lens has not been implanted, the aphakic retinal hazard weighting function $A(\lambda)$ (from **Table 3**) shall be used in **Equation 5** through **Equation 8** in place of $B(\lambda)$. The summation shall be from 305 nm to 700 nm.

4.3.5 Infrared Radiation Hazard Exposure Limit

To avoid thermal injury of the cornea and possible delayed effects upon the lens of the eye (cataractogenesis), ocular exposure to infrared radiation, E_{IR}, over the wavelength range 770 nm to 3000 nm should be limited to $0.01 \ W \cdot cm^{-2}$ for periods exceeding 1000 s. This limit can be expressed as:

$$E_{IR}=\sum_{770}^{3000} E_\lambda \cdot \Delta\lambda \leq 0.01 \text{ (for } t > 1000) \qquad (9a)$$

For exposures of less than 1000 s the irradiance limit should be:

$$E_{IR}=\sum_{770}^{3000} E_\lambda \cdot \Delta\lambda \leq 1.8 \cdot t^{-0.75} \text{ (for } t < 1000) \qquad (9b)$$

where:
E_{IR} is the ocular exposure to infrared radiation in $W \cdot cm^{-2}$
E_λ is the spectral irradiance in $W \cdot cm^{-2} \cdot nm^{-1}$
$\Delta\lambda$ is the calculation interval in nm
t is the exposure time in seconds
the summations extend from 770 nm to 3000 nm.

Note 1: For certain optical instruments, an averaging aperture less than 7 mm but greater that 3 mm may be required in further documents in this series.

Note 2: A limiting aperture no greater than 2.5 cm diameter shall be used with sources producing a uniform optical radiation pattern. However, with sources of optical radiation that do not produce a uniform optical radiation pattern (i.e., contain hot spots less than 2.5 cm), a 7 mm aperture shall be used. The measurement shall be made in that position of the beam giving the maximum reading.

4.3.6 Infrared Radiation Hazard Exposure Limit - Weak Visual Stimulus.

For an infrared heat lamp or any near-infrared source where a weak visual stimulus is inadequate to activate the aversion response, the near infrared (770 nm to 1400 nm) radiance, L_{IR}, as viewed by the eye for exposure times greater than 10 s should be limited to:

$$L_{IR} = \sum_{770}^{1400} L_\lambda \bullet \Delta\lambda \leq \frac{0.6}{\alpha} \quad \text{(for t > 10)} \qquad (10)$$

where:
L_{IR} is the near infrared radiance in $W \bullet cm^{-2} \bullet sr^{-1}$
L_λ is the spectral radiance in $W \bullet cm^2$ @ $sr^{-1} \bullet nm^{-1}$
$\Delta\lambda$ is the calculated interval in nm
t is exposure time in seconds
α is the angle (in radians) described in **Section 4.3.1** (including the provisions for non-circular sources and maximum/minimum limits)
the summations extend from 770 nm to 1400 nm.

The limit expressed in **Equation 10** is based upon a 7 mm diameter ocular pupil.

A weak visual stimulus is defined herein as one whose maximum luminance (averaged over a circular field-of-view subtending 0.011 radian) is less than 10 cd $\bullet$ m^{-2}.

Note 1: **Equation 10** is empirical and is not dimensionally correct unless a dimensional correction factor $K_2 = 1\ W \bullet cm^{-2} \bullet sr^{-1} \bullet rad$ is inserted in the right hand numerator.

Note 2: L_λ shall be averaged over a right circular cone field-of-view of 0.011 radian included angle.

4.3.7 Skin - Thermal Hazard Exposure Limit.

Visible and infrared radiant exposure (400 nm to 3000 nm) of the skin should be limited to:

$$H = \sum_{400}^{3000} E_\lambda \bullet t \bullet \Delta\lambda \leq 2 \quad (\textit{for } t \leq 1) \quad (11a)$$

$$H = \sum_{400}^{3000} E_\lambda \bullet t \bullet \Delta\lambda \leq 2t^{0.35} \quad (\textit{for } 1 < t \leq 10) \quad (11b)$$

where:
H is the radiant exposure in $J \bullet cm^{-2}$
E_λ is the spectral irradiance in $W \bullet cm^{-2} \bullet nm^{-1}$
$\Delta\lambda$ is the calculated interval in nm
t is exposure time in seconds
the summations extend from 400 nm to 3000 nm.

Note 1: A limiting aperture no greater than 2.5 cm diameter shall be used with sources producing a uniform optical radiation pattern. However, with sources of optical radiation that do not produce a uniform optical radiation pattern (i.e., contain hot spots less than 2.5 cm), a 7 mm aperture shall be used. The measurement shall be made in that position of the beam giving the maximum reading.

Note 2: This exposure limit is based on skin injury due to a rise in tissue temperature and applies only to small area irradiation. Exposure limits for periods greater than 10 s are not provided. Severe pain occurs below the skin temperature for skin injury, and an individual's exposure normally will be limited for comfort. Large body area irradiation and heat stress are not evaluated since this involves consideration of heat exchange between the individual and the environment, physical activity, and various other factors.

Note 3: **Equation 11b** is empirical[1] and is not dimensionally correct unless a dimensional correction factor $K_3 = 1s^{-0.35}$ is inserted in the right hand numerator.

5.0 MEASUREMENTS OF LAMPS AND LAMP SYSTEMS

The second document in this series, *Recommended Practice for Photobiological Safety for Lamps and Lamp Systems - Measurement Techniques*, ANSI/IESNA RP-27.2, describes the measurement and evaluation techniques required for this document.

The cumulative error effects due to all known sources of inaccuracy, including human factors, operating conditions, and instrumental error, shall be taken into account in the determination of the hazard.

Measurements shall be attempted only by persons trained or experienced in radiometry. Routine survey measurements are neither required nor advisable when the classifications are known and the appropriate control measurements implemented.

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[1] Based on Bioastronautics Data Book (1964), NTIS No. N65-15594, p.7-15

5.1 Radiance

This measurement shall be used to determine the maximum radiance of the source. In the case of non uniform source profiles, the measurements of spectral radiance, L_λ, shall be averaged over a right circular cone field-of-view of 0.011 radian included angle at a minimum accessible viewing distance, but not less than 20 cm. In the case of nonuniform source profiles, such as those resulting from inhomogeneous "hot spots," the measurements shall be taken from the regions of greatest radiance at the minimum accessible viewing distance, but not less than 20 cm.

5.2 Irradiance or Radiant Exposure Field of View

In measuring the irradiance or radiant exposure, care shall be taken to ensure that the field of view of the instrument is sufficiently large to assure accurate measurements.

5.3 Instruments

Many optical power, energy, pulse shape, and pulse-repetition frequency measuring devices which are commercially available can be used to determine compliance with the standard.

5.4 Test Conditions

Measurements for compliance with this standard shall be made under the following circumstances:

- Under those conditions and procedures which maximize the accessible levels, including start-up, stabilized emission, and shut-down of the product.
- All user controls and adjustments adjusted in combination to result in the maximum accessible level of radiation.
- At points in space to which human access is possible, (e.g., if performance of the lamp or lamp system requires removal of portions of a protective housing and defeat of interlocks, measurements shall be made at points accessible in that configuration).
- The measuring instrument detector so positioned and so oriented with respect to the product as to result in the maximum detection of radiation by the instrument.

The power source for the lamp or lamp system being measured for compliance shall be at the manufacturer's principal specified operating condition of voltage, current, or power for the device. If the specified condition is a range, then the value within that range producing the maximum level of radiation shall be used.

6.0 SPECIFIC REQUIREMENTS

6.1 Labeling

Lamps and Lamp Systems that emit optical radiation in excess of the exposure limits specified in **Section 4.0**, should contain an appropriate label(s) in product information, catalogs, and user information including:

- A statement of "caution" or "warning," sometimes called the signal word.
- A statement describing the potential hazard. This should simply advise as to what might be expected to occur (i.e., skin irritation or eye injury).
- Identification of precautions that could (or should) be taken to avoid the risk. For example, information on shielding or a warning against staring at a particular source.
- An abbreviated statement that specifies the Risk Group (assuming an applicable Risk Group classification exists).

Note: Examples of some appropriate labels are tained in **Annex C**.

6.2 Technical Information

• A manufacturer *should* provide or cause to be provided upon request representative spectral distribution data for the optical radiation from the products it manufactures in the form of: (1) spectral radiant power, or (2) spectral radiance, or (3) spectral intensity, or (4) spectral irradiance, and the lumen-to-radiant power conversion factor. The data shall be provided over the wavelength range 300 nm to 800 nm. If there is potentially hazardous emission in the range from 200 nm to 1400 nm, the data range shall be extended to include it.

• The manufacturer should provide, upon request, available radiometric information relating to the potential hazards associated with the products, e.g., effective ultraviolet irradiance at 10 cm, 20 cm, and 100 cm. This may also include suggestions for engineering designs for protective enclosures, globes, fixtures, and luminaries.

• A manufacturer should provide or cause to be provided upon request representative spectral irradia[illegible] in SI units as specified in **Section 5.4** and at reference positions to clearly specify the spectral emissions for lamps and lamp systems over the wavelength range from 200 nm to 1400 nm.

Note: More specific labeling and safety information for specific lamps or lamp systems may be required as stated in companion documents to this Recommended Practice. (*Recommended Practice for Photobiological Safety for Lamps - Risk Group Classification and Labeling*, ANSI/IESNA RP-27.3 and subsequent documents in the series.)

6.3 Lamp System Requirements

Lamp systems should be so designed as to minimize the emission of unnecessary radiations which may be associated with the incorporated lamps and any hazards which may be associated with the temperature of the external surfaces. Safety engineering features such as protective housing, interlocks, diffusers, key control switches, and emission indicators should be incorporated into the product based upon the embedded lamp (and as appropriate).

6.4 User Precautions - General

Users shall take appropriate hazard control measures including:

- Prevention of eye or skin injuries when using lamps or products which emit hazardous radiations as described in the user information provided with the lamp or product.
- Prevention of: (1) thermal injury to the skin, or (2) combustion of flammable materials when using lamps or products which have surface temperatures in excess of 44° C (111° F).
- Provision of adequate ventilation to minimize exposure to ozone that may be produced by lamps that emit UV-C radiation.
- Prevention of electrical injury by turning off the lamp power when replacing the bulb.