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UV-C Devices — Safety information — Permissible human exposure

Dispositifs UV-C — Information sur la sécurité — Limites admissibles pour l'exposition humaine

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Foreword

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 142, *Cleaning equipment for air and other gases*.

Introduction

This International Standard was developed in response to a worldwide demand for minimum specifications on UVC safety for products and equipment utilizing UVC lamp fixtures. In this International Standard, when it comes to personal damage of UV disinfection, the whole UVC band range is more likely to be included. As for lamps of product equipment, UVC prefers to the 254 nm wavelength.

UVC radiation is a low-penetrating form of UV as compared to UVA or UVB radiation. Measurements of human tissue show that 4 % to 7 % of UVC radiation, along with a wide range of wavelengths from 250 nm to 400 nm, is reflected[6] and absorbed in the first 2 µm of the stratum corneum. Hence, the amount of UVC transmitted through the epidermis is minimized.[7]

UVC radiation is invisible to humans and exposure to UVC radiation may have an effect on health. Ocular damage generally begins with photokeratitis but can also result in photokeratoconjunctivitis. Symptoms, which may not be evident until several hours after exposure, can include an abrupt sensation comparable to sand in eyes, tearing, and eye pain of various degrees. Such symptoms may appear within 1 h to 12 h after UVC exposure and resolve fully within 24 h to 48 h. Acute overexposure to UVC band radiation may cause incapacity due to eye discomfort, but this generally regresses after several days, leaving no permanent damage.

Cutaneous damage consists of erythema, a reddening of the skin akin to sunburn but without tanning. The maximum effect of erythema occurs at a wavelength of 297 nm in the UVB band. UVC radiation at a wavelength of 254 nm is less effective in causing erythema. Therefore, the areas subject to exposure should be marked. Warning signs should be placed in certain locations to protect personnel or passers-by from UV hazards. Appropriate locations include access doors, air handling unit outside walls, equipment room doors, etc.

The International Commission on Illumination (CIE) 2010 completed a review of UVC photocarcinogenesis risks from germicidal lamps using basic biophysical principles due to the attenuation provided by the stratum corneum and epithelial tissues of the skin. Upper air disinfection could be safely used without significant risk for long-term delayed effects such as skin cancer.[5]

UV-C Devices — Safety information — Permissible human exposure

1 Scope

This International Standard specifies minimum human safety requirements for the use of UVC lamp devices.

It is applicable to in-duct UVC systems, upper-air in room UVC systems, portable in-room disinfection UVC devices, and any other UVC devices which may cause UVC exposure to humans.

It is not applicable to UVC products used for water disinfection.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 170, *Personal eye-protection — Ultraviolet filters — Transmittance requirements and recommended use*

EN 14255-1, *Measurement and assessment of personal exposures to incoherent optical radiation — Part 1: Ultraviolet radiation emitted by artificial sources in the workplace*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
wavelength
distance between repeating units of a wave pattern

Note 1 to entry: Commonly designated by the Greek letter lambda (λ).

3.2
waveband
spectrum section
spectrum band
electromagnetic spectrum that is usually divided into a large spectral region, small spectral band and narrow spectral lines

Note 1 to entry: Waveband is commonly expressed as a specific *wavelength* (3.1) range of values, sometimes uses numbers or letters as code.

3.3
ultraviolet radiation
wavelength (3.1) of the electromagnetic spectrum of radiation from 10 nm to 400 nm

Note 1 to entry: The range between 100 nm and 400 nm is commonly subdivided into:[1]

— UVA: 315 nm to 400 nm;

— UVB: 280 nm to 315 nm;

— UVC: 200 nm to 280 nm;

— Vacuum UV: 100 nm to 200 nm.

3.4
UV dose
product of UV irradiance and specific exposure time on a given microorganism or surface

Note 1 to entry: UV dose is expressed in millijoules per square centimetre (mJ/cm^2).

3.5
fluence rate
fluence across a surface

Note 1 to entry: Fluence rate is expressed in J/m^2, J/cm^2, or $W{\cdot}s/cm^2$.

3.6
irradiance
power of electromagnetic radiation incident on a surface per unit surface area

Note 1 to entry: Irradiance is expressed in microwatts per square centimetre ($\mu W/cm^2$).[2]

3.7
effective irradiance
power of UVC radiation from electromagnetic radiation received on a surface per unit surface area

3.8
disinfection
less lethal process of inactivating microorganisms compared to sterilization

3.9
ultraviolet germicidal irradiation
UVGI
killing or inactivating microorganisms by emitting radiation predominantly at a *wavelength* (3.1) of 253,7 nm

3.10
radiometer
instrument used to measure radiometric quantities, particularly UV *irradiance* (3.6) or fluence

3.11
in-duct systems
UVC lamp devices placed up-stream or down-stream of the cooling coil or in other enclosed sections of the HVAC duct system

Note 1 to entry: See Reference [4].

3.12
upper-air in room systems
UVC lamp devices mounted underneath room ceilings with UVC energy directed upward with adjustable louvers to keep UVC rays above eye and head level

Note 1 to entry: See Reference [4].

3.13
portable in-room disinfection UVC device
easy-to-carry equipment to use in spaces requiring ultraviolet ray disinfection

EXAMPLE UVC device installed on mobile car.[4]

3.14
exposure
subjection to infectious agents, irradiation, particulates, or chemicals that could have harmful effects

3.15
permissible exposure time
PET
calculated time period that humans, with unprotected eyes and skin, can be exposed to a given level of UV *irradiance* (3.6) without exceeding the NIOSH recommended exposure limit (REL) or ACGIH *Threshold Limit Value® (TLV®)* (3.16) for UV radiation

Note 1 to entry: See References [8], [9], and [10].

3.16
Threshold Limit Value®
TLV®
guidelines on *exposure* (3.14) level under which most people can work consistently for eight hours a day, day after day, without adverse effects

Note 1 to entry: Used by the ACGIH to designate degree of exposure to contaminants.

Note 2 to entry: TLVs can be expressed as approximate milligrams of particulate per cubic meter of air (mg/m^3). TLVs are listed either for 8 h as a time-weighted average (TWA) or for 15 min as a short-term exposure limit (STEL).

Note 3 to entry: See Reference [10].

3.17
ocular damage
any damage to the eye, particularly that caused by *exposure* (3.14) to UV energy

3.18
photokeratitis
corneal inflammation after overexposure to *ultraviolet radiation* (3.3)

Note 1 to entry: See Reference [3].

3.19
photokeratoconjunctivitis
inflammation of cornea and conjunctiva after *exposure* (3.14) to UV radiation

Note 1 to entry: Exposure to *wavelengths* (3.1) shorter than 320 nm is most effective in causing this condition. The peak of the action spectrum is approximately 270 nm.[3]

3.20
stratum corneum
outer dead layer of human skin

3.21
cutaneous damage
any damage to the skin, particularly that caused by *exposure* (3.14) to UVC energy

3.22
erythema
<actinic> reddening of the skin, with or without inflammation, caused by the actinic effect of solar radiation or artificial optical radiation

3.23
personal protective equipment
PPE
protective clothing, helmets, goggles, respirators, or other gear designed to protect the wearer from injury from a given hazard, typically used for occupational safety and health purposes

4 Sources of UVC exposure

4.1 General

UVC sources can be the following:

a) in-duct UVC systems;

b) upper-air in room UVC systems;

c) portable in-room disinfection UVC devices.

4.2 UVC energy penetration

UVC energy does not normally penetrate through solid substance, and is attenuated by most materials. Quartz glass, soda barium glass, and PTFE plastic have high transmissions for UVC radiation.

UVC energy can be reflected from polished metals and several types of painted and non-painted surfaces; however, a surface's ability to reflect visible light cannot be used to indicate its UV reflectance. The fact that a blue glow can be observed on the metal surface from an operating low-pressure UV lamp could indicate the presence of UVC, and a measurement should be performed to ensure there is no exposure risk.

NOTE Ultraviolet energy is invisible to the normal human eye; however, it follows the same optical path as the visible blue light spectrum generated by the UVC lamp.

4.3 UVC radiation measurement

UVC radiation measurement shall comply with the measuring method in EN 14255–1. Handheld radiometers with sensors tuned to read 240 nm to 270 nm wavelength shall be used for on-site measurement of UVC energy. Measures shall be performed during commissioning and before operation of the UVGI installation for in-duct, upper-air in room UVC disinfection devices.

4.4 Measuring Threshold Limit Values

4.4.1 Inspect device placement and eye level irradiance measurements using a 254 nm selective radiometer.

4.4.2 UVC levels shall be measured with a UV radiometer directly facing the UVC device [between 1,83 m and 2,13 m (6,0 ft and 7,0 ft)] at various locations in a room, and shall be taken in the same location each time. If the readings indicate a dosage exceeding 6 mJ/cm^2, the UV systems shall be deactivated until adjustments can be made or the manufacturer can be contacted.

4.4.3 Devices are to be adjusted if eye level exposure exceeds the 8 h TLV for UVC 254 nm wavelength.

4.4.4 UVC measurements should be taken at eye level [between 1,83 m and 2,13 m (6,0 ft and 7,0 ft)] at compass points from each configurations. Check reflective surfaces, e.g. TV's or monitors.

4.4.5 Measurements are performed at initial installation; whenever new UV lamps are installed (newer lamp designs may provide increased irradiance), and whenever modifications are made to the UVGI system or room (e.g. adjustment of device height, location or position of louvers, addition of UV-absorbing or UV-reflecting materials, room dimension changes, modular partition height changes).

4.4.6 Probability of exposure should be evaluated in relation to placement of the lamps. The areas subject to exposure should be marked.

4.4.7 If radiation measurements have been carried out, the personnel should be informed about measuring results and their relation to exposure limits and consequential health risks.

5 Exposure limits to UVC

5.1 General information

The Centers for Disease Control and Prevention (CDC) and National Institute for Occupational Safety and Health (NIOSH)[8] published in 1972 a recommended exposure limit (REL[9]) for occupational exposure to UV radiation. The REL[9] is intended to protect workers from the acute effects of UV exposure. Photosensitive persons and those exposed concomitantly to photoactive chemicals might not be protected by the recommended standard.

5.2 Maximum permissible UVC exposure

This International Standard adopts the REL[9] maximum permissible UVC exposure values, and the maximum permissible UVC exposure shall not exceed the ACGIH TLV and NIOSH REL[9] of 6,0 mJ/cm^2 for an 8 h day, 40 h work week exposure to UV radiation at 254 nm.[8][10]

Table 1 — Maximum permissible UVC exposure for radiation at 254 nm

Permissible exposure time	Effective irradiance μW/cm^2
24 h	0,07
18 h	0,09
12 h	0,14
10 h	0,17
8 h	0,2
4 h	0,4
2 h	0,8
1 h	1,7
30 min	3,3
15 min	6,7
10 min	10
5 min	20
1 min	100
30 s	200
15 s	400
5 s	1 200
1 s	6 000
NOTE This table is based on NIOSH/ACGIH maximum UV exposure times.	

Threshold Limit Value® (TLV®) consideration should be based on real-time occupancy of spaces treated by UVGI.[10] This recommendation is supported by recent UV monitoring data from First and colleagues,[11] who found that peak meter readings poorly predict actual exposure of room occupants.

5.3 Personal protective equipment

Exposures exceeding the levels listed in Table 1 require that workers use personal protective equipment (PPE). PPE shall consist of the following:

a) UV-resistant eyewear, such as goggles, face shields, and safety glasses; selecting a suitable eye protector shall comply with EN 170;

b) clothing known to be non-transparent to UVC penetration, which covers exposed skin.

5.4 Personnel safety training

Personnel safety is paramount as they are not only the people most likely to get exposed to UV, but they shall also handle the materials and inspect the installations. Workers should be provided with as much training as necessary, included health and safety training, and some degree of training in the handling of lamps and materials (especially in regard to lamp mercury content).[12]

Personnel working with UVC devices or near UVC installations shall be trained on the following:

a) required PPE;

b) health and safety topics;

c) handling of UVC lamps;

d) hazards generated by accidental UVC exposure in work areas;

e) first aid response post exposure.

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