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UV-C devices — Measurement of the output of a UV-C lamp

Dispositifs UV-C — Mesurage de la sortie d'une lampe UV-C

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The First World Health Organization (WHO) Global Conference on Air Pollution and Health took place at WHO headquarters in Geneva, Switzerland from 30 October to 1 November 2018. The conference participants considered the scientific evidence on air pollution and health and emphasized: Air pollution — both ambient and household — is estimated to cause 7 million deaths per year; 5,6 million deaths are from noncommunicable diseases and 1,5 million from pneumonia. There is an urgent need to scale up the global response to prevent diseases and deaths (available at http://www.who.int/phe/news/clean-air-for-health/en/).

Research shows that indoor air pollution can be 2 to 5 times greater than outdoor pollution and under particular circumstances; it can be up to 100 times. Since people generally spend more than 80 % to 90 % of our time indoors, the quality of indoor air pollution is a key element to good health of people. At the same time, indoor air pollution is one of 5 environmental risk factors to the public health. Under most indoor environments, microbial suspension in the air is the chief culprit to transmitted diseases and it is a factor that many people ignore because these organisms, whose body size is ranging from several micrometres to more than 10 micrometres, are invisible to the naked eye.

In recent years, these germs bring much more intense effect, including frequent occurrences of sick building syndrome, elevated nosocomial infection rate, rapid increase of air-conditioning energy consumption (a microbe film a few millimetres thick accumulates on the air conditioner coil, reducing the heat transfer efficiency of the air treatment unit), smelly air-conditioned rooms and resurgence of tuberculosis. Many people have a drop in their own productivity and spend more on medical care because headache, chest congestion, disturbance in respiration, neurasthenia, nausea and state of mind are fidgety are the most common symptoms for people staying in the air-conditioned rooms. In addition, people in air-conditioned rooms are more susceptible to the infection of ophthalmic and nasitis.

Meanwhile, clinical medical evidence suggests that various diseases, such as heart disease, neurasthenia, memory decline and influenza, correlate with polluted indoor air. The improvement of indoor air quality is desperately needed.

Ultraviolet air disinfection devices are invented in such circumstances. Most ultraviolet air disinfection devices circulate the air indoors. With media filtration and a high-efficiency UV-C lamp, disinfection devices have good effects of filtration of dust in air, meanwhile, it can kill germs and viruses directly and cut the spread of disease. Disinfection devices application can reduce indoor air pollution, improve indoor air quality and provide protection against pneumonia, influenza and other respiratory diseases.

UV-C devices — Measurement of the output of a UV-C lamp

1 Scope

This document specifies the measurement of the output of a UV-C lamp, types of UV-C lamp, lamp ballast, and safety issues.

It is applicable to the output measurement of linear UV-C disinfection lamps.

This document specifies a measurement method for evaluating output power of UV-C lamps installed in heating, ventilation and air conditioning (HVAC) systems. The method includes the simulation measurement of UV-C output power of UV-C lamps under various temperatures and various air velocities, and under conditions that the axial direction of the lamp is parallel or perpendicular to the air flow direction. It can reliably evaluate and compare the UV-C output power of UV-C lamps in the ultraviolet germicidal irradiation (UVGI) device based on the testing results. If the microbial inactivation rate of a particular UVGI device equipped with the same type of UV-C lamp is known, the microbial inactivation rate of the UVGI device at various temperatures and at various air velocities can be evaluated.

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.

ISO 15858, *UV-C Devices — Safety information — Permissible human exposure*

ISO 29464:2017, *Cleaning of air and other gases — Terminology*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

CIE S 017, *International Lighting Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 29464, CIE S 017 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
ultraviolet radiation
UV radiation
wavelength 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:

— UV-A: 315 nm to 400 nm;

— UV-B: 280 nm to 315 nm;

— *UV-C* (3.2): 200 nm to 280 nm;

— Vacuum UV: 100 nm to 200 nm.

[SOURCE: ISO 29464:2017, 3.6.18, modified — "UVA", "UVB" and "UVC" have been changed to "UV-A", "UV-B" and "UV-C".]

3.2
ultraviolet C
UV-C
ultraviolet radiation (3.1) from 200 nm to 280 nm

3.3
UV-C disinfection
disinfection method that uses *ultraviolet radiation* (3.1) with a wavelength between 200 nm and 280 nm to kill microorganisms

Note 1 to entry: *UV-C* (3.2) radiation attacks the vital DNA of the bacteria directly. The bacteria lose their reproductive capability and are destroyed.

3.4
UV-C irradiance
power passing through a unit area perpendicular to the direction of propagation

Note 1 to entry: *UV-C* (3.2) irradiance is typically reported in watt per square metre (W/m^2). It is also usually reported in mW/cm^2 or uW/cm^2.

3.5
low pressure UV-C lamp
discharge lamp of the mercury vapour type, without a coating of phosphors, in which the partial pressure of the vapour does not exceed 100 Pa during operation and which mainly produces ultraviolet radiation of 253,7 nm

3.6
UV-C radiation conversion efficiency
ability of a *UV-C* (3.2) lamp to convert electrical power into UV-C radiation power

Note 1 to entry: The ratio is the UV-C radiation power accounting for the electrical power of the UV-C lamp. The UV-C conversion efficiency of a *low pressure UV-C lamp* (3.5) at 253,7 nm is between 25 % and 45 %. The UV-C conversion efficiency should be not less than 30 % in an air disinfection field under all circumstances due to energy consumption of the system.

3.7
UV-C radiometer
instrument used to measure *UV-C* (3.2) radiometric quantities, particularly *UV-C irradiance* (3.4) or fluence

[SOURCE: ISO 29464:2017, 3.6.15]

4 Types of UV-C lamps and ballasts

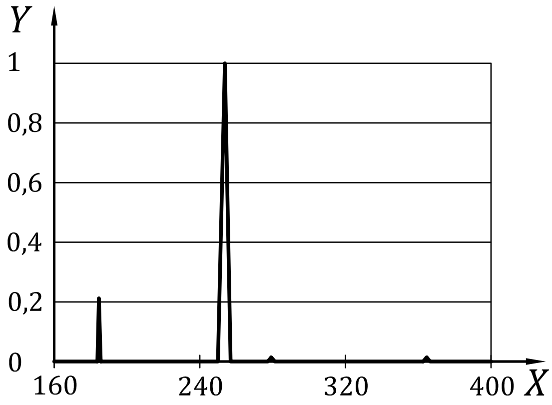
4.1 General

Ballasts shall comply with requirements for starting parameters and operating parameters of UV-C lamps. Lamps bases of UV-C lamps and cables between UV-C lamps and ballasts shall comply with performance and safety requirements.

4.2 Types of UV-C lamps

4.2.1 General

UV-C lamps are divided into medium pressure UV-C lamps and low pressure UV-C lamps; air disinfection devices usually use low pressure UV-C lamps. The low pressure UV-C lamps are made of liquid mercury or amalgam that controls mercury vapour pressure in the UV-C lamp to provide mercury atoms required for discharge. Mercury atoms produce 253,7 nm UV-C photons through electron bombardment. Figure 1 shows the spectrum of low pressure UV-C lamps.



Key

X wavelength (nm)

Y relative radiation ratio at various wavelengths (%)

Figure 1 — Low pressure mercury lamp spectrum

4.2.2 Linear UV-C lamps

The most common type of UV-C lamp, linear UV-C lamps can have any length or diameter and are typically characterized by having connectors at both ends or having a connector at a single end, requiring a compatible fixture, as shown in Figure 2 and Figure 3.

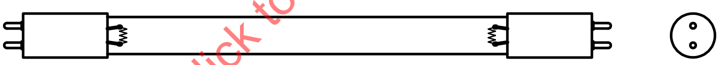


Figure 2 — Linear UV-C lamp with connectors at both ends

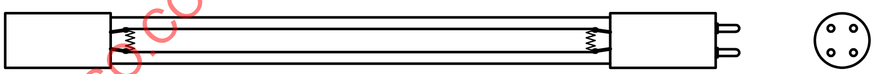


Figure 3 — Linear UV-C lamp with connector at a single end

4.3 Type of ballasts

4.3.1 General

The ballast provides the high initial voltage required to create the starting arc and then limits the current to prevent the UV-C lamp from self-destructing. UV-C lamp ballast can be either magnetic or electronic.

4.3.2 Magnetic ballasts

Magnetic ballasts are used to start the UV-C lamp and may be either standard electromagnetic or energy-efficient electromagnetic. The ballast provides a time-delayed inductive kick with enough voltage to ionize the gas mixture in the tube after which the current through the tube keeps the filaments energized. The starter will cycle until the tube lights up. While the UV-C lamp is on, a preheat ballast is just an inductor which at the main frequency (50 Hz or 60 Hz) has the appropriate impedance to limit the current to the UV-C lamp to the proper value. Ballasts shall be fairly closely matched to the UV-C lamp in terms of tube wattage, length, and diameter.

4.3.3 Electronic ballasts

Electronic ballasts are basically switching power supplies, which eliminate the large, heavy, 'iron' ballast in favour of an integrated high frequency inverter/switcher. Current limiting is then done by a very small inductor, which has sufficient impedance at the high frequency. Properly designed electronic ballasts are relatively reliable, which depend on the ambient operating temperature, location with respect to the heat produced by the UV-C lamp as well as other factors.

5 Measurement of the output of a UV-C lamp

5.1 Measurement method classification

There are two methods to measure the output of a UV-C lamp:

1. Measurement of the output of a UV-C lamp in a darkroom: Tests in laboratory (also known as static darkroom test) are conducted to ensure the accuracy and consistency of the measured results;
2. Measurement of the output of a UV-C lamp in a test chamber: For industrial application, the tests in a test chamber shall take account of the impact of environmental changes in field (such as temperature change and air velocity change). This method is described in Annex B.

5.2 Measurement of the output of a UV-C lamp in a darkroom

5.2.1 Instrument

The cosine correction for radiometers and spectroradiometers is critical to the proper measurement of the UV-C irradiance. The cosine correction shall be confirmed by the following method for each UV-C lamp and ballast combination so that the UV-C lamp measurements are consistent within and between laboratories.

The minimum measurement distance needs to be determined for the given UV-C lamp and UV-C radiometer in order to verify cosine response characteristics of the UV-C radiometer and reduce its cosine correction error. The method is as follows:

a) Take readings of the UV-C radiometer for different distances (radiometer position perpendicular to the UV-C lamp axis), see Figure 4;

b) Take several readings of the UV-C irradiance. For example, moving the radiometer from the closest point to the most remote point and then back again;

c) Average the irradiance readings for each distance;

d) Calculate the output UV-C radiation power of the UV-C lamp from the measured irradiance using Formula (1) for each distance;

e) Calculate the output UV-C radiation power of the UV-C lamp; plot the calculated UV-C power versus the distance;

f) When the measurement distance is greater than the minimum distance D_{min}, the measured UV-C irradiance is consistent with the UV-C output power through calculation as per Formula (1). The UV-C output power of the UV-C lamp should become independent of the distance;

g) The measurement distance shall be greater than D_{min}.

The distance derived by this method is valid for the combination of specific UV-C lamp length and specific individual radiometer.

5.2.2 Calibration

In order to ensure the accuracy and reliability of the data issued by the laboratory, the laboratory shall meet the requirements of ISO/IEC 17025.

The following instruments shall be calibrated as per the standard method:

a) UV-C radiometer shall have valid and traceable calibration documents;

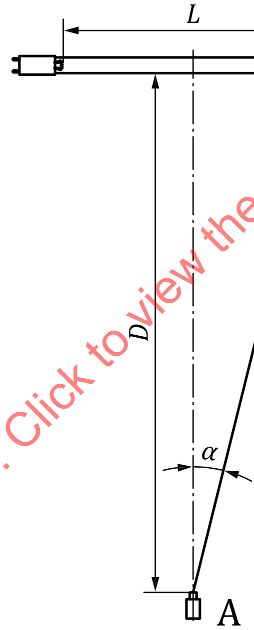
b) Calibration of the radiometer or the spectroradiometer shall comply with requirements of ISO/IEC 17025;

c) Power analyser shall have valid and traceable calibration documents.

5.2.3 UV-C radiation power calculation

5.2.3.1 UV-C radiation power calculation schematic diagram

For the UV-C radiation power calculation schematic diagram, see Figure 4.



Key

A UV-C radiometer

L UV-C lamp length (m) from electrode tip to electrode tip

D distance (m) from the UV-C lamp centre to the UV-C radiometer (here *D* is not less than D_{min}, many testing data indicate that D_{min} amounts to 2*L*, recommended *D* from 2*L* to 4*L*)

α half angle (rad) subtended by the UV-C lamp at the radiometer position; that is, tan α = *L*/(2*D*)

Figure 4 — Geometry of the measurement system

5.2.3.2 UV-C radiation power calculation

Based on the work of Keitz, the UV-C radiation power P of UV-C lamp shall be calculated from Formula (1).

$$P = \frac{E\,2\pi^2\,DL}{2\alpha + \sin 2\alpha} \tag{1}$$

where

- P is UV-C radiation power of the UV-C lamp (W);
- E is the measured irradiance (W/m^2);
- D is the distance from UV-C lamp centre to the UV-C radiometer (m);
- L is the UV-C lamp length from electrode tip to electrode tip (m);
- α is the half angle subtended by the UV-C lamp at the radiometer position (rad), $\tan\alpha = L/(2D)$.

This formula has been tested by comparing with goniometric measurements of the UV-C lamp output and by comparing results from laboratories in different countries. The results are considered accurate within 5 % and have shown good agreement among laboratories.

Formula (1) is applicable to the UV-C output power calculation of linear UV-C lamps; it is not applicable to other types of UV-C lamps. For other types of ultraviolet lamps, it is necessary to correct the angle radiation measurement or adopt the method of integrating spheres to measure and calculate UV-C output power.

5.2.4 Necessary conditions

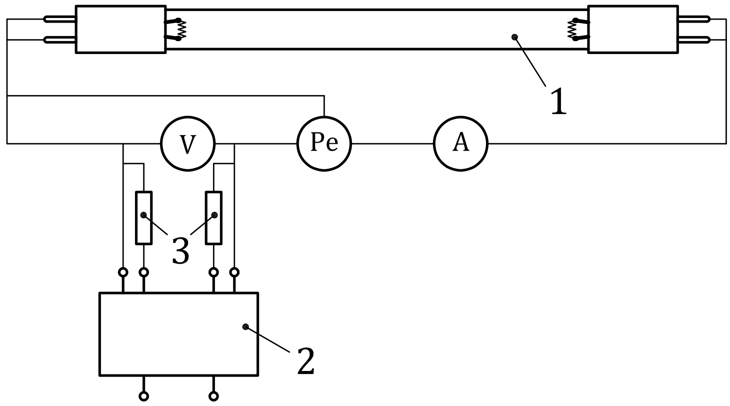
The following general conditions shall be fulfilled:

1. The measurements shall be conducted in still room air, not in a moving air stream;
2. The UV-C lamp orientation shall be horizontal;
3. Reflected light shall be avoided (e.g. through use of baffles, differential measurement with beam stops);
4. The UV-C radiometer shall have an adequate cosine response for the UV-C lamp length and distance used; this can require a distance D that is not less than $2L$, measured from the UV-C lamp's axis.

5.2.5 Measurements

5.2.5.1 Basic wiring diagram for electrical parameters measurements

Figure 5 is the basic wiring diagram for electrical parameters measurement of the UV-C lamp system; the UV-C lamp as showed operates with the preheated electronic ballast, while other types of ballast shall refer to the wiring diagram supplied by the manufacturer.



Key

1 UV-C lamp

2 electronic ballast

3 equivalent resistance of the filament

V voltmeter, used to measure input electric voltage of the UV-C lamp

Pe power meter, used to measure input electric power of the UV-C lamp

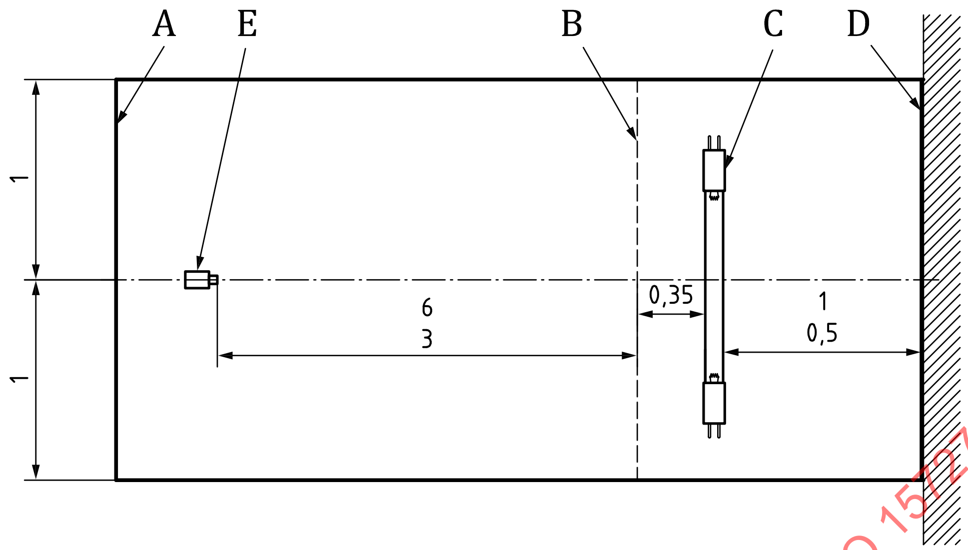
A ampere meter, used to measure input electric current of the UV-C lamp

Figure 5 — Basic wiring diagram for electrical parameters measurements

5.2.5.2 Typical test chamber

The UV-C lamp output shall be measured after a UV-C lamp 100 h burn-in period. The UV-C lamp output shall be based on a UV-C lamp operating under air conditions, in which the UV-C lamp has reached a maximum output and then decreases to a steady state, indicating that the UV-C lamp has passed through an optimum into an overheated condition. This will generate a UV-C irradiance curve as a function of time, which will illustrate the maximum and steady state output values. Figure 6 shows a typical test chamber (typically called a darkroom), in which the UV-C lamp is mounted about 1 m off the floor and the UV-C radiometer is mounted at the same height as the UV-C lamp.

Dimensions in metres



Key

A black curtains
B slotted divider
C UV-C lamp
D wall
E UV-C radiometer

Figure 6 — Top view of a typical test chamber

5.2.5.3 Measurement procedure

The measurement procedure is as follows:

1. Record or monitor the ambient temperature (±1 °C tolerance); preferably, the ambient temperature can adjust within the range of the actual UV-C lamp operating temperature, so that the data of irradiance vs. time can be tested;
2. Determine that the distances for radiometer readings are valid;
3. Start recording the readings (UV-C irradiance, electrical measurements, etc.) after the UV-C lamp is turned on;
4. The sampling rate shall match the rate of changing of the UV-C irradiance readings;
5. One reading every 10 s is often sufficient to mark the maximum;
6. Record the irradiance until a steady state is achieved; record the steady state value of the irradiance;
7. Record the ambient temperature again;
8. Calculate the output UV-C radiation power of the UV-C lamp using Formula (1);
9. Calculate the output UV-C radiation conversion efficiency of the UV-C lamp using Formula (2).

$$\eta = \frac{P}{P_e} \tag{2}$$

where

η is the UV-C radiation conversion efficiency of the UV-C lamp (%);

P is the UV-C radiation power of the UV-C lamp (W);

P_e is the input power of the UV-C lamp (W), see Figure 5.

5.2.5.4 Cautions

Reflected light during the measurement of the UV-C radiation shall be avoided. Specific measures to avoid the reflected light are as follows:

1. Use non-reflecting materials for walls, floor, and baffles;
2. Be aware that the UV-C reflectance can be different from reflectance in the visible range. Wood and black cloth have very low UV-C reflectance;
3. Test: to check the amount of reflected light, compare the UV-C radiometer signal to that measured when direct irradiation is blocked out. Report the corrected result.

More information about methods and requirements for reducing reflected light are provided in Annex A.

5.2.5.5 UV-C lamp and ballast efficiency

UV-C lamp radiation power is generally compared with the electrical (line) power consumed in order to calculate the efficiency of the UV-C lamp/ballast system. It is recommended that the input power to the ballast be accurately measured as true root mean square (RMS), so that the efficiency can be calculated. This electrical power measurement shall be done accurately.

5.2.5.6 Measurement report

The measurement report shall include:

1. full and detailed information about the UV-C lamp (e.g., manufacturer, identification etc.);
2. full and detailed information about the ballast (e.g., manufacturer, identification etc.);
3. UV-C lamp orientation during testing (horizontal required);
4. active arc length L (between the ends of the filaments for a linear UV-C lamp);
5. measurement of the distance D from the UV-C lamp centre (with tolerance) to the calibration plane of the radiometer;
6. laboratory room temperature (°C);
7. sensor and radiometer brand, model number and serial numbers for the radiometer, radiometer and any filters or other optical elements (e.g., diffuser) on the radiometer;
8. valid, traceable radiometer or spectroradiometer calibration documentation;
9. calculated peak and steady state UV-C power, with uncertainty;
10. valid and traceable calibration documents of the power meter;
11. measured voltage and current into the ballast;

12. measured electrical power across the UV-C lamp and "from the wall" with uncertainty;

    NOTE The "from-the-wall" power includes power consumption in the ballast or power supply.

13. calculated UV-C lamp efficiency (%) both with respect to the electrical power consumed by the UV-C lamp and the "from-the-wall" electrical power;

14. photos of the lamp and testing chamber (to prove lamp and air flow directions and location).

5.3 Measurement of the output of a UV-C lamp in a test chamber

Analogue measurement method of the output of a UV-C lamp under various ambient temperatures and various air velocities is conducted in a test chamber that does not reflect UV rays and that shall be in accordance with Annex B.

6 Safety issues

6.1 General

This clause addresses basic safety issues that relate to UVGI systems. The basic safety shall be in accordance with ISO 15858. Some aspects have regulations while others are recommended or represent current industry practice.

6.2 Protective clothing and eyewear

It is not recommended that any personnel be subject to direct UV-C exposure, but in the event such exposure is likely, personnel shall wear protective clothing, including full coverage of exposed skin if possible and protection of eyes with eyewear. Gloves shall be used to protect the hands. Most eyewear, including prescription glasses, are sufficient to protect the eyes from UV-C, but not all will offer complete coverage and standard issue protective goggles can be the most suitable alternative.

6.3 UV-C photodegradation of organics

Prolonged UV-C exposure can discolour or damage various types of organic materials and plants. In general, UV-C radiation will not only impact aesthetic effects, but also damage substances such as clothes, discolouring and embrittlement of plastic-coated wires with the result of potential fire hazard.

6.4 Ozone production

Ozone is a hazardous indoor pollutant that can be produced by the UV-C lamp. Some UV-C lamps are designed with a narrow spectral range of UV-C output and produce little or no ozone. Other UV-C lamps, especially the more common UV-C lamps that produce a broad-range UV-C spectrum, can produce enough ozone that it can be smelled in the indoor air. Ozone can cause damage to the lungs from prolonged or chronic inhalation and can also cause certain types of damage or degradation to materials. Although there are no known cases in which ozone produced by a UV-C lamp has caused any major health problem, the possibility exists and any undue levels of indoor ozone noted after a UV-C installation shall be investigated. Before testing, ozone sensors shall be set up to monitor the ozone leakage.

6.5 UV-C internal and external leakage

UV-C installations in an air handling unit (AHU) shall be designed so as to minimize the escape of UV-C through ductwork, gaps, and supply registers. Stray UV-C emerging from an AHU installation can cause harm to individuals in the local area, including maintenance personnel and passers-by. Various options are available to reduce the leakage of UV-C through ducting to supply registers, including the installation of light baffles (air vanes with multiple bends and painted black to absorb UV-C), the use of filters as light blocks, and the adjusting of register vanes to redirect light upwards.

Small cracks through which UV-C can leak out of an installation can result in exposure of plastic wiring (for example) outside the AHU, leading to a potential long-term fire hazard. In general, a visual inspection is sufficient to determine whether any UV-C leakage is occurring, and this is often best performed by turning out all lights and looking for the telltale blue glow showing up outside the installation (other than through windows, which are UV-C proof).

6.6 Mercury content of the UV-C lamp

Most UV-C lamps contain varying quantities of mercury, which is considered a hazardous substance. Disposal of the UV-C lamp shall take into account the fact that the mercury must be disposed of in an environmentally safe manner and according to regulations. When a UV-C lamp gets damaged or burnt, operators shall follow proper handling procedures.

6.7 Personal protective equipment

To prevent operators from suffering a UV-C damage, they shall wear personal protective equipment, such as protective goggles, face shield, safety glasses. Eye protection shall be applied to people or can be adjusted to provide the appropriate cover. The glasses shall ensure the comfort and provide adequate peripheral vision. When hands and bodies of operators suffer a UV-C damage, they shall wear proper gloves and protective clothing during experiments.

Annex A
(informative)

Suggested methods to minimize the effects of reflected UV-C

A.1 Radiometer mask method

In this method, a black cardboard or wooden mask is placed at a distance of about 0,35 m from the UV-C lamp, where the size and the positioning of the mask cast a complete shadow over the radiometer.

The mask should be of a size that completely blocks the direct rays from the UV-C lamp, but not much larger. In this case the irradiance reading from the radiometer represents only UV-C reflected from the floor, ceiling and walls. The irradiance reading should be subtracted from the overall irradiance reading and should represent less than 1 % of the total irradiance at the radiometer.

A.2 Two-chamber method

UV-C can reach the UV-C radiometer by reflection from walls, the floor and the ceiling. This reflected UV-C shall be avoided or subtracted from the radiometer signal in order to get proper irradiance values. A two-sector approach can be used for this purpose.

In this method, the test chamber is divided into two light-tight sectors, with the divider between the two sectors at least 0,35 m from the centre of the UV-C lamp. The UV-C lamp and radiometer should be at least 0,25 m (preferably about 1 m) from the floor and preferably about 1 m from the wall behind the UV-C lamp.

A rectangular hole 0,03 m longer than the arc length and 0,02 m wider than the width of the UV-C lamp should be cut in the divider, so that the UV-C radiometer can "see" the entire arc length of the UV-C lamp through the hole. See Figure 6 for a possible setup.

When the two-sector chamber approach is used, the procedure is the same as that described in the main body of this document. In addition, a measurement should be made with the hole between the two chambers covered with black cardboard. The radiometer signal in that case should be virtually zero.

Annex B
(normative)

Measurement of the output of a UV-C lamp in a test chamber

B.1 Measurement introduction and conditions

B.1.1 The method includes the simulation measurement of UV-C output power of UV-C lamps under various temperatures and various air velocities, and under conditions that the axial direction of the lamp is parallel to and perpendicular to the air flow direction.

B.1.2 Range of input power supply: the supply voltage shall be equal to the rated voltage of the ballast. The supply voltage shall be stabilized at ±0,5 % during the UV-C lamp stabilization period and this tolerance shall be controlled within 0,2 % in the measurement process.

B.1.3 Range of input AC power supply frequency: 50 Hz or 60 Hz.

B.1.4 Environmental temperature range: (25 ± 1) °C.

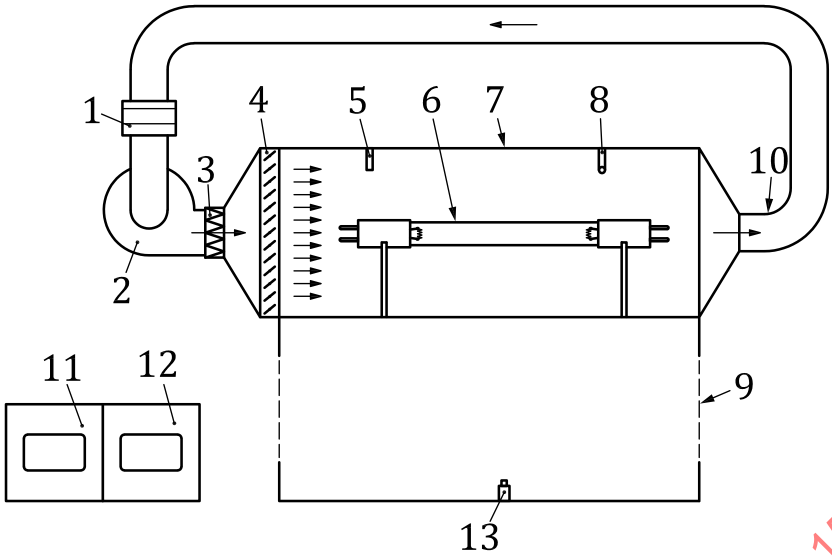
B.1.5 Environmental humidity range: maximum relative humidity 65 %.

B.2 Testing system

B.2.1 Classification and composition of the testing system

The testing system mainly includes a test chamber, temperature control module, air velocity control module, UV-C radiometer, as shown in Figure B.1 and Figure B.2.

The testing system is divided into two categories according to the placement direction of the UV-C lamp and different air inlet directions. Figure B.1 shows a temperature and air velocity adjustable testing system when the axis of the UV-C lamp is parallel to the air inlet direction.

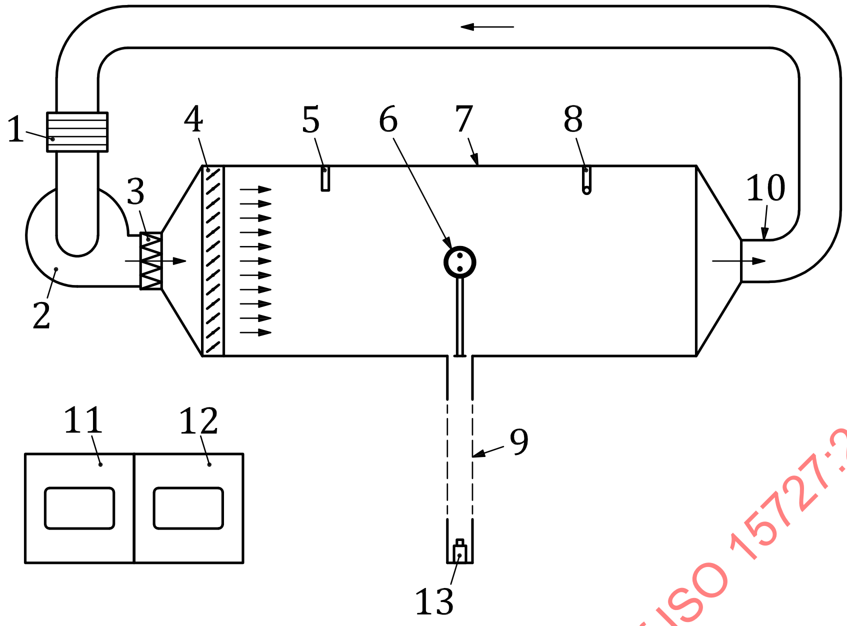


Key

1 temperature control module
2 air velocity control module
3 air filter
4 uniform flow deflector
5 anemometer
6 UV-C lamp to be tested
7 test chamber
8 temperature sensor
9 test channel
10 circular duct
11 electric measuring instruments
12 air velocity and temperature display
13 UV-C radiometer

Figure B.1 — Testing system when the axis of the UV-C lamp is parallel to the air inlet direction

Figure B.2 shows a temperature and air velocity adjustable testing system when the UV-C lamp is perpendicular to the air inlet direction.



Key

1 temperature control module
2 air velocity control module
3 air filter
4 uniform flow deflector
5 anemometer
6 UV-C lamp to be tested
7 test chamber
8 temperature sensor
9 test channel
10 circular duct
11 electric measuring instruments
12 air velocity and temperature display
13 UV-C radiometer

Figure B.2 — Testing system when the axis of the UV-C lamp is perpendicular to the air inlet direction

B.2.2 Temperature control module

Provide stable temperatures for the test and adjust the temperature of the test chamber to comply with testing requirements. Temperature fluctuation is not more than 1 °C.

B.2.3 Air velocity control module

Provide stable airflow power source to guarantee that air velocities in the circular duct comply with testing requirements. Air velocity deviation is within ±10 %.

B.2.4 Air filter

Purify gases entering the test chamber to prevent dust or other sundries from affecting the test. The air filter generally refers to the static or high-efficient filtration module.

B.2.5 Uniform flow deflector

Guarantee inlet air uniformity. The uniform flow deflector generally refers to a black metal sheet with holes. The hole shall comply with design requirements. It shall guarantee gases in the circular duct under a constant flow state.

B.2.6 Anemometer

The anemometer is placed at the air inlet end for real-time detection of inlet air velocities in the circular duct.

Range: (0 to +20) m/s;

Precision: ±0,03 m/s +5 % measurement value;

Resolution ratio: 0,01 m/s.

B.2.7 UV-C lamp to be tested

The UV-C lamp to be tested is fixed to the base with a holder that is made of thermal insulating materials.

B.2.8 Test chamber

The size of the test chamber shall comply with design requirements. A square chamber is recommended. The size of the space for the UV-C lamp is 2,5 m (length) × 2,5 m (width) × 0,65 m (height). The distance from the centre of the UV-C lamp to the inner wall of the test chamber is not less than 0,25 m. The chamber of the testing system shall be blackened and shall not reflect UV lights.

B.2.9 Temperature sensor

The temperature sensor is placed at the air inlet end for real time measurement of air inlet temperature in the test chamber.

It may use platinum resistance, thermocouple or other similar thermometers, and complies with the following requirements:

— Effective temperature range: 0 °C to 150 °C;

— Precision: 0,1 °C;

— Permissible error: (0,1 + 0,001 7 $|t|$) °C ($|t|$ is the absolute temperature value, in °C).

B.2.10 Test channel

The test channel is used to place the UV-C radiometer that receives UV rays emitted by the UV-C lamp through the test channel. The inner wall of the channel needs to be blackened and does not reflect UV rays. The channel shall be extendible and its extension scope can comply with adjustment of the distance from the UV-C radiometer and the UV-C lamp. Its recommended size is 4,0 m (length) × 2,5 m (width) × 0,1 m (height). The test channel is connected to the test chamber and shall be sealed, which will not affect the stability of temperatures and air velocities in the test chamber.

B.2.11 Circular duct

It is recommended to use a square circular duct with a width of 1,5 m and a height of 0,65 m.

B.2.12 Electric measuring instruments

Instruments are true root mean square, which basically do not have waveform distortion and are applicable for operating frequency.

