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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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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

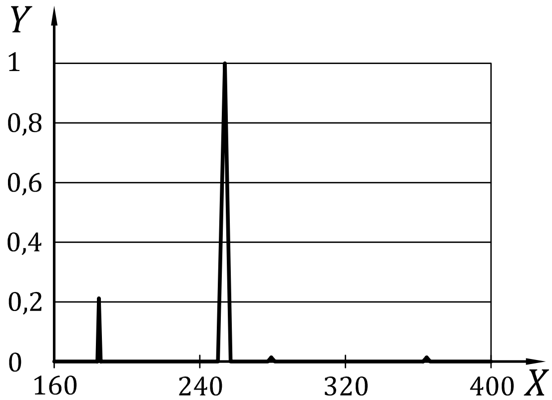
4.1 General

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.

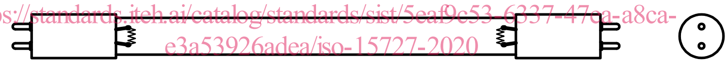


Figure 2 — Linear UV-C lamp with connectors at both ends

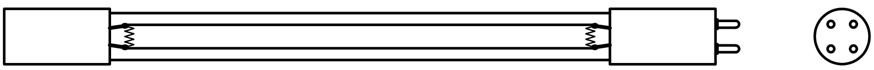


Figure 3 — Linear UV-C lamp with connector at a single end

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, $\tan \alpha = L/(2D)$

Figure 4 — Geometry of the measurement system

