Designation: G224 – 23

Standard Practice for Operating UVC Lamp Apparatus for Exposure of Materials[1]

This standard is issued under the fixed designation G224; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice is limited to the basic principles for operating a low-pressure mercury lamp apparatus to assess degradation of materials due to exposure to UVC light; on its own, it does not deliver a specific result.

1.2 It is intended to be used in conjunction with a practice or method that defines specific exposure conditions for an application along with a means to evaluate changes in material properties. This practice is intended to reproduce the photodegradation effects that occur when materials are exposed to artificial light sources that emit radiation primarily in the UVC wavelength band, particularly in the range of 240 nm to 280 nm. This practice is limited to the procedures for obtaining, measuring, and controlling conditions of exposure.

NOTE 1—Practice G151 describes general procedures to be used when exposing materials in accelerated test devices that use laboratory light sources.

NOTE 2—A common use of UVC light sources is for the disinfection of surfaces and air, a process known as ultraviolet germicidal irradiation (UVGI). Water disinfection applications using UVC light sources have been in use for many decades.

1.3 This practice does not cover other light sources (e.g. LEDs, excimer lamps, etc.) or any lamps that emit wavelengths primarily outside the range in 1.2.

1.4 Specimens are exposed to UVC light controlled to a specified irradiance level under controlled temperature conditions.

1.5 Specimen preparation and evaluation of the results are covered in ASTM methods or specifications for specific materials. General guidance is given in Practice G151.

1.6 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials

G130 Test Method for Calibration of Narrow- and Broad-Band Ultraviolet Radiometers Using a Spectroradiometer

G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources

G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Materials

2.2 *IEC Standards:*[3]

IEC 60335-1 Household and similar electrical appliances - Safety - Part 1: General requirements

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions given in Terminology G113 are applicable to this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 As used in this practice, the term *sunlight* is identical to the terms *daylight* and *solar irradiance*, *global* as they are defined in Terminology G113.

3.2.2 *UVC, n*—portion of the electromagnetic spectrum comprising wavelengths between 100 nm and 280 nm, also spelled UV-C.

4. Summary of Practice

4.1 Specimens are exposed to a UVC light source under controlled conditions of irradiance and temperature.

[1] This practice is under the jurisdiction of ASTM Committee G03 on Weathering and Durability and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Exposure Tests.

Current edition approved Feb. 1, 2023. Published March 2023. DOI: 10.1520/G0224-23.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

NOTE 3—The effects of water in liquid or vapor form are not considered. It is expected that the relative humidity at the specimen surface will be less than 50 % and could be less than 10 % depending on test and laboratory conditions.

4.2 The exposure condition may be varied by selection of:

4.2.1 The lamp's irradiance level,

4.2.2 The use of alternating conditions of darkness and UVC exposure and the timing of each, and

4.2.3 The temperature during each exposure condition.

5. Significance and Use

5.1 Material resistance to photodegradation caused by exposure to artificial UVC light sources is a growing concern due to the use of ultraviolet germicidal irradiation (UVGI) to mitigate the spread of infectious diseases.

5.2 Materials and products intended for direct sunlight exposure are typically designed to resist the effects of the UVA and UVB light reaching the earth's surface, but generally they are not tested to determine the effects of exposure to UVC, which is filtered out by the atmosphere.

5.3 Compared to light in the UVA and UVB regions of the electromagnetic spectrum, UVC light, when absorbed by a material, can cause photodegradation to proceed at different rates and by different mechanisms as well as confining degradation to a thinner surface layer.

5.4 Indoor materials and products, which typically are not designed to withstand significant ultraviolet light exposure, are at even greater risk of premature degradation when subjected to UVC exposure.

5.5 This practice is intended to induce property changes consistent with those experienced by materials exposed to artificial UVC light sources with a similar spectral irradiance distribution to those specified in this practice.

6. Apparatus

6.1 Apparatus that comply with the requirements of Practice G154 meet the requirements of this standard provided they meet the additional requirements in this section.

6.2 *Laboratory Light Source*—The light source shall be one or more low-pressure mercury lamps, made with glass that blocks all emissions at wavelengths below 200 nm to prevent the generation of ozone.

NOTE 4—Low-pressure mercury lamps emit ultraviolet light primarily in two spectral lines: 254 nm and 185 nm (**1**)[4]. The 185 nm line is capable of generating ozone when exposed to air, but certain glass types are able to absorb it and prevent ozone production. These lamps emit additional spectral lines in the visible range, giving them a blue-violet appearance. The visible spectral lines are not considered in this document.

NOTE 5—Low-pressure mercury lamps are similar in construction to typical UV fluorescent lamps, except they lack the white phosphor coating that creates the fluorescence effect.

6.2.1 Low-pressure mercury lamps are differentiated from other mercury lamps by their significantly lower gas fill pressure. Other types of mercury lamps, such as medium or high pressure lamps, shall not be used.

NOTE 6—For example, medium-pressure mercury lamps have fill pressures of approximately 1 bar or higher, which significantly changes their spectral irradiance. In contrast, low-pressure mercury lamps typically have fill pressures less than 10 mbar.

6.2.2 Lamps meeting these requirements are referred to as UVC-254 lamps. A spectral irradiance distribution, bandpass corrected, is shown in Fig. 1. See Appendix X1 for information on measuring the spectral irradiance of low-pressure mercury lamps.

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.

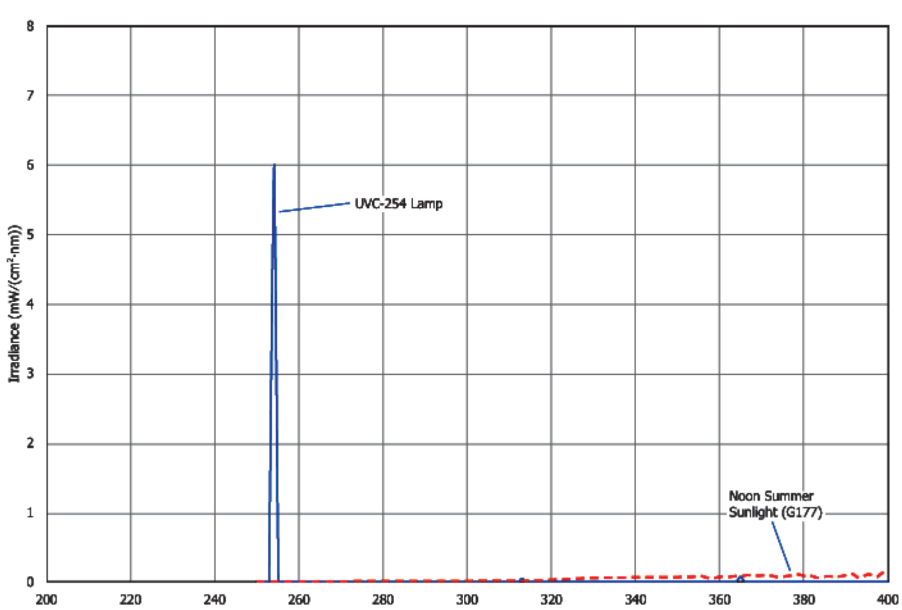

FIG. 1 Spectral Irradiance of UVA-254 Lamps, shown with irradiance of 6.0 mW/(cm^2·nm) at 254 nm, and reference sunlight spectrum, G177

6.3 *Test chamber*—The design of the test chamber may vary, but it shall be equipped to prevent UVC irradiance exposure of the test operator. Additionally, it shall provide means to control the test temperature.

NOTE 7—See CIE Technical Report 187 for information on health and safety concerns related to exposure to UVC lamps (**2**).

6.4 *Irradiance Control*—Irradiance shall be measured and adjusted to maintain the specified level. Unless agreed upon between interested parties, the apparatus shall be equipped with an on-board irradiance sensor coupled with an electronic feedback loop to monitor and control the amount of radiant energy at a wavelength of 254 nm received at the specimen plane. The irradiance sensor shall comply with the requirements in Practice G151.

NOTE 8—In small devices, it may not be practical to have a sensor continuously monitoring the irradiance because the area of the sensor can represent a significant proportion of the exposure area. In such cases, a common technique for ensuring specified irradiance levels are maintained is to measure and adjust the irradiance in the specimen area before the exposure, repeat as necessary at specified intervals during the exposure, and measure again at the end of the exposure.

6.5 *Thermometer*—Either an insulated or uninsulated black-panel thermometer shall be used to control test conditions. These may be constructed from either aluminum or steel, and they shall comply with the requirements in Practice G151.

6.5.1 The thermometer shall be mounted in the specimen plane such that it is in the same relative position and orientation to the lamps and receives the same conditions as the test specimens.

6.5.2 The apparatus may provide chamber air temperature control. Positioning and calibration of chamber air sensors shall be in accordance with Practice G151.

6.5.3 Test apparatus may be equipped with means to control relative humidity and/or spray water onto specimens, but these functions are not commonly used in typical UVC exposures.

6.6 *Specimen Holders*—Specimen holders shall be made of materials that are not susceptible to degradation caused by UVC irradiation. The holders shall be equipped with panels or other means to fill unused specimen areas during a test.

6.7 *Calibration*—To ensure standardization and accuracy, the instruments associated with the exposure apparatus (for example, thermometers, UV sensors, and radiometers) require periodic calibration to ensure repeatability of test results.

6.7.1 *Irradiance*—See Practice G151 for information on calibrating the on-board irradiance sensor with a reference radiometer. Periodic calibration checks of the on-board irradiance sensor shall be performed according to the chamber manufacturer's instructions and recommended frequency. At a minimum, these checks shall be performed when lamps are replaced or when test conditions are changed. The reference radiometer shall be calibrated at least once per year.

NOTE 9—The calibration methods referenced in Practice G151 have not been validated for calibrating UVC light sources. ASTM Committee G03 and other industry committees are assessing if referenced methods are appropriate for calibration of UVC light sources.

6.7.2 *Thermometer*—The thermometer used to control the test temperature shall be calibrated once per year or more frequently in accordance with manufacturer's instructions. Calibration should be traceable to a national metrological institute (NMI).

NOTE 10—Typically, these devices are controlled by black-panel thermometer, and not by chamber air temperature. Uninsulated black-panel thermometers are recommended for use with highly thermally-conductive or very thin specimens. Insulated black-panel thermometers are recommended for use with insulating or thick specimens. Different types of black-panel thermometers may result in significantly different temperature profiles in the test chamber.

7. Test Specimen

7.1 Refer to Practice G151 for guidance on test specimen form and preparation, number of test specimens, and specimen storage and conditioning.

8. Procedure

8.1 Prior to exposure, determine which specimen property or properties will be evaluated. Measure these properties in accordance with recognized ASTM or other international standards. If required for destructive tests or other reasons, use unexposed file specimens to quantify the property.

8.2 Ensure that the chamber, especially its irradiance measurement system, has been calibrated according to manufacturer guidelines.

8.3 *Specimen Mounting*—Mount the specimens in holders so that the surface of interest faces the lamps. Mount specimens in such a way that applied stresses are minimized, unless such stresses are part of the test design.

8.4 Program the chamber to run the selected test conditions continuously throughout the required number of hours or cycles. See Section 9 for guidance on choosing test conditions and duration. Interruptions to the test for maintenance or to inspect specimens shall be minimized.

8.5 *Specimen Repositioning*—Periodic specimen repositioning is recommended to compensate for variations of irradiance and temperature within the specimen area. Repositioning is required if specimens are placed in positions where the irradiance is less than 90 % of the value measured at the center of the specimen area. Refer to Practice G151 for guidance on determining irradiance uniformity.

8.6 *Specimen Inspections*—If a specimen is removed for a periodic evaluation, take care to avoid disturbing the test surface. After inspection, the specimen shall be returned to the test chamber in the same orientation as previously exposed.

8.7 At the end of the exposure, measure the changes to properties determined in 8.1 and report the results according to Practice G151.

9. Exposure Conditions and Test Duration

9.1 A variety of exposure conditions may be used. See Table X2.1 for examples of possible test cycles. The exact conditions shall be detailed in the test report.

9.2 The irradiance set point is limited by minimum and maximum levels achievable by the apparatus' control system. The range of achievable settings depends on the lamp power, distance between specimens and lamps, and general chamber design characteristics.

9.3 Temperature conditions should not exceed the maximum temperature of the service environment to avoid unrealistic results.

NOTE 11—Service environments range between typical indoor conditions and approximately 60 °C.

9.4 When possible, estimate the expected radiant exposure of UVC energy the material of interest would receive over its service life and expose specimens to at least an equivalent dose.

9.4.1 If the test is intended to simulate the dose received due to regular UVGI cycles, the following formula may be useful:

$$D_L = d_G \times C_L, \tag{1}$$

where:

D_L = the UVC dose received over a material's service lifetime,
d_G = the UVC dose of a typical germicidal cycle, and
C_L = the number of UVGI cycles a material experiences over its service life, where hourly, daily, weekly, or monthly cycles are often assumed.

9.4.2 If the UVC dose of the typical UVGI cycle is unknown, a value of 1 J/cm^2 may be assumed (**3, 4**).

NOTE 12—Widely differing UVC dose values from UVGI cycles have been reported. Even considering this variability, tests according to this practice are expected to be much shorter in duration compared to weathering tests to achieve comparable degradation seen in most service environments (**5, 6**).

9.5 Conditions may alternate between periods of light and dark or be run with continuous irradiance. When the service environment consists of brief periods of UVC exposure followed by normal indoor or natural conditions, tests that omit periods of darkness can cause different degradation mechanisms than those in the service environment.

10. Report

10.1 The test report shall conform to Practice G151. It shall include a description of test specimens, exposure conditions, type of lamps, duration of exposure, etc.

11. Precision and Bias

11.1 As stated in the scope, this practice does not produce a specific result. As such, a precision and bias statement is not appropriate. A precision and bias statement is appropriate for the result of a specific exposure in combination with a property measurement.

12. Keywords

12.1 accelerated; durability; exposure; germicidal lamp; low pressure mercury lamp; non-metallic materials; UVC; UVGI

APPENDIXES

(Nonmandatory Information)

X1. MEASURING THE SPECTRAL IRRADIANCE OF UVC-254 LAMPS

X1.1 Fig. 1 shows the spectral irradiance of UVC-254 lamps. Unlike other light sources used in weathering tests, lowpressure mercury lamps produce spectral lines rather than a continuous spectrum. This presents special challenges when performing spectral irradiance measurements of UVC-254 lamps. In order to attain sufficient signal to noise ratios when measuring the UV spectral irradiance of typical weathering light sources, spectroradiometers must be setup with a bandpass which is too wide to accurately characterize the spectral line of the UVC-254 lamp (**7**). In this case, the spectral line at 254 nm (253.7 nm to be more precise) is detected as a band around 254 nm, and this bandpass depends on width of the entrance and exit slits of the monochromator, the fineness of the diffraction grating, and other characteristics of the spectroradiometer.

X1.2 Fig. 1 shows the spectral irradiance with bandpass correction (**8, 9**) applied. However, with a typical spectroradiometer setup for measuring the UV spectral irradiance of weathering light sources, bandpasses of 2 nm or 5 nm are often used. At a 2 nm bandpass, for example, the spectral line is measured as if the energy were dispersed approximately ±2 nm around the line. When measuring with such a setup, the actual irradiance can be accurately determined by summating the tabular output values over the entire bandpass and assigning the sum to represent the 254 nm spectral line. Failure to follow this procedure will result in erroneous low irradiance readings at 254 nm, with errors as much as 50 % or greater.

X1.3 Because of the significant irradiance contribution from light rays arriving at the specimen plane from oblique angles, special care should be taken to ensure the cosine response of the radiometer's UV detector has been properly characterized and appropriate corrections applied to the measurement. Refer to Test Method G130 for further information.

NOTE X1.1—In one study of commercially available UVC radiometers, some devices significantly under-measured the total UVC irradiance due to poor cosine response of the detector (**10**). At least one measured only about one-third of the actual irradiance.