Designation: G154 – 23

Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Materials[1]

This standard is issued under the fixed designation G154; 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 fluorescent UV lamp and water apparatus; 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 weathering effects that occur when materials are exposed to sunlight (either direct or through window glass) and moisture as rain or dew in actual usage. 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 nonmetallic materials in accelerated test devices that use laboratory light sources.

NOTE 2—A number of exposure procedures are listed in an appendix; however, this practice does not specify the exposure conditions best suited for the material to be tested.

1.3 Test specimens are exposed to fluorescent UV light under controlled environmental conditions. Different types of fluorescent UV lamp sources are described.

NOTE 3—In this standard, the terms *UV light* and *UV radiation* are used interchangeably.

1.4 Specimen preparation and evaluation of the results are covered in ASTM methods or specifications for specific materials. General guidance is given in Practice G151 and ISO 4892-1.

NOTE 4—General information about methods for determining the change in properties after exposure and reporting these results is described in ISO 4582 and Practice D5870.

1.5 This practice is not intended for corrosion testing of bare metals.

1.6 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 is technically similar to ISO 4892-3 and ISO 16474-3.

1.8 *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.*

1.9 *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]

D5870 Practice for Calculating Property Retention Index of Plastics

D6631 Guide for Committee D01 for Conducting an Interlaboratory Study for the Purpose of Determining the Precision of a Test Method

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

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

G177 Tables for Reference Solar Ultraviolet Spectral Distributions: Hemispherical on 37° Tilted Surface

2.2 *ISO Standards:*[3]

ISO 4582 Plastics—Determination of the Changes of Colour and Variations in Properties After Exposure to Daylight Under Glass, Natural Weathering or Artificial Light

ISO 4892-1 Plastics—Methods of Exposure to Laboratory Light Sources—Part 1, Guidance

[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.

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[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.

*A Summary of Changes section appears at the end of this standard

ISO 4892-3 Plastics—Methods of Exposure to Laboratory Light Sources—Part 3, Fluorescent UV lamps

ISO 16474-3 Paints and Varnishes—Methods of Exposure to Laboratory Light Sources—Part 3: Fluorescent UV Lamps

3. Terminology

3.1 *Definitions*—The definitions given in Terminology G113 are applicable to this practice.

3.2 *Definitions of Terms Specific to This Standard*—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.

3.2.1 *Fluorescent Ultraviolet (UV) lamp Apparatus*—an apparatus specifically designed for performing artificial accelerated weathering and irradiation tests using fluorescent UV lamps as the light source and including a means to expose the test specimens to moisture and controlled temperature.

4. Summary of Practice

4.1 Specimens are exposed to repetitive cycles of light and moisture under controlled environmental conditions.

4.1.1 Moisture is usually produced by condensation of water vapor onto the test specimen or by spraying the specimens with demineralized/deionized water.

4.2 The exposure condition may be varied by selection of:

4.2.1 The fluorescent lamp,

4.2.2 The lamp's irradiance level,

4.2.3 The type of moisture exposure,

4.2.4 The timing of the light, dark, and moisture periods, and

4.2.5 The temperature during each exposure condition.

5. Significance and Use

5.1 The use of this apparatus is intended to induce property changes consistent with the end use conditions, including the effects of the UV portion of sunlight, moisture, and heat. Typically, these exposures would include moisture in the form of condensing humidity. Exposures are not intended to simulate the deterioration caused by localized weather phenomena, such as atmospheric pollution, biological attack, and saltwater exposure. Alternatively, the exposure may simulate the effects of sunlight through window glass. (**Warning—**Refer to Practice G151 for full cautionary guidance applicable to all laboratory weathering devices.)

5.2 This practice provides general procedures for operating fluorescent UV lamp weathering devices that allow for a wide range of exposure conditions. Therefore, no reference shall be made to results from the use of this practice unless accompanied by a report detailing the specific operating conditions in conformance with Section 10.

5.2.1 It is recommended that a similar material of known performance (a control) be exposed simultaneously with the test specimen to provide a standard for comparative purposes. Generally, two controls are recommended: one known to have poor durability and one known to have good durability. It is recommended that at least three replicates of each material evaluated be exposed in each test to allow for statistical evaluation of results.

5.2.2 Comparison of results obtained from specimens exposed in the same model of apparatus should not be made unless reproducibility has been established among devices for the material to be tested.

5.2.3 Comparison of results obtained from specimens exposed in different models of apparatus should not be made unless correlation has been established among devices for the material to be tested (see Guide D6631 for guidance).

6. Apparatus

6.1 *Laboratory Light Source*—The light source shall be one or more fluorescent UV lamps. A variety of fluorescent UV lamps can be used for this procedure. Differences in lamp intensity or spectrum may cause significant differences in test results.

6.1.1 Do not mix different types of lamps. Mixing different types of lamps (as described in 6.1.4) in a fluorescent UV apparatus causes major inconsistencies to the radiation received by the samples.

6.1.1.1 A detailed description of the type(s) of lamp(s) used shall be stated in the test report. The particular testing application determines which lamp is used. See Appendix X1 for lamp application guidelines.

6.1.2 The apparatus should include an irradiance control system to monitor and control the irradiance. In apparatuses without irradiance control, the actual irradiance levels at the test specimen surface may vary due to the type of lamps, manufacturer of the lamps, age of the lamps, accumulation of dirt or other residue on the lamps, distance to the lamp array, air temperature within the chamber and ambient laboratory temperature.

NOTE 5—In general, in apparatuses without irradiance control, lamp output will decrease with increasing chamber or laboratory temperature, or both.

6.1.3 Fluorescent lamps age with extended use. Follow the apparatus manufacturer's instructions on the procedure necessary to maintain desired irradiance (**1, 2**).[4]

6.1.4 *Standard Fluorescent UV Lamps*—Fluorescent UV lamps are available with a choice of spectral power distributions that vary significantly. The more common are identified as UVA-340, UVA-351, and UVB-313. These numbers represent the characteristic nominal wavelength (in nm) of peak emission for each of these lamp types. The actual peak emissions are at 343 nm, 350 nm, and 313 nm, respectively.

6.1.4.1 *Spectral Power Distribution (also known as Spectral Irradiance) of UVA-340 Lamps for Daylight UV*—The spectral power distribution of UVA-340 fluorescent lamps shall comply with the requirements specified in Table 1.

NOTE 6—The main application for UVA-340 lamps is for simulation of the short and middle UV wavelength region of daylight.

6.1.4.2 *Spectral Power Distribution of UVA-351 Lamps for Daylight UV Behind Window Glass*—The spectral power distribution of UVA-351 lamp for Daylight UV behind Window Glass shall comply with the requirements specified in Table 2.

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

TABLE 1 Relative Ultraviolet Spectral Power Distribution Specification for Fluorescent UVA-340 Lamps for Daylight UV[A,B]

Spectral Bandpass Wavelength λ in nm	Minimum Percent[C]	Benchmark Solar Radiation Percent[D,E]	Maximum Percent[C]
$\lambda < 290$			0.01
$290 \leq \lambda \leq 320$	5.9	5.8	9.3
$320 < \lambda \leq 360$	60.9	40.0	65.5
$360 < \lambda \leq 400$	26.5	54.2	32.8

[A] Data in Table 1 are the irradiance in the given bandpass expressed as a percentage of the total irradiance from 290 nm to 400 nm. The manufacturer is responsible for determining conformance to Table 1. Annex A1 states how to determine relative spectral irradiance.

[B] The data in Table 1 are based on the rectangular integration of 65 spectral power distributions for fluorescent UV devices operating with UVA 340 lamps of various lots and ages. The spectral power distribution data is for lamps within the aging recommendations of the device manufacturer. The minimum and maximum data are at least the three sigma limits from the mean for all measurements.

[C] The minimum and maximum columns will not necessarily sum to 100 % because they represent the minimum and maximum for the data used. For any individual spectral power distribution, the calculated percentage for the bandpasses in Table 1 will sum to 100 %. For any individual fluorescent UVA-340 lamp, the calculated percentage in each bandpass must fall within the minimum and maximum limits of Table 1. Test results can be expected to differ between exposures using devices with fluorescent UVA-340 lamps in which the spectral power distributions differ by as much as that allowed by the tolerances. Contact the manufacturer of the fluorescent UV devices for specific spectral power distribution data for the fluorescent UVA-340 lamp used.

[D] The benchmark solar radiation data is defined in ASTM G177 and is for atmospheric conditions and altitude chosen to maximize the fraction of short wavelength solar UV. While this data is provided for comparison purposes only, it is desirable for the laboratory accelerated light source to provide a spectrum that is a close match to the benchmark solar spectrum.

[E] For the benchmark daylight spectrum, the UV irradiance (290 nm to 400 nm) is 9.8 % and the visible irradiance (400 nm to 800 nm) is 90.2 % expressed as a percentage of the total irradiance from 290 nm to 800 nm. Because the primary emission of fluorescent UV lamps is concentrated in the 290 nm to 400 nm bandpass, there are limited visible light emissions from fluorescent UV lamps.

TABLE 2 Relative Spectral Power Distribution Specification for Fluorescent UVA-351 Lamps for Daylight UV Behind Window Glass[A,B]

Spectral Bandpass Wavelength λ in nm	Minimum Percent[C]	Window Glass Filtered Daylight Percent[D,E]	Maximum Percent[C]
$\lambda < 300$		0.0	0.2
$300 \leq \lambda \leq 320$	1.1	≤ 0.5	3.3
$320 < \lambda \leq 360$	60.5	34.2	66.8
$360 < \lambda \leq 400$	30.0	65.3	38.0

[A] Data in Table 2 are the irradiance in the given bandpass expressed as a percentage of the total irradiance from 300 nm to 400 nm. The manufacturer is responsible for determining conformance to Table 1. Annex A1 states how to determine relative spectral irradiance.

[B] The data in Table 2 are based on the rectangular integration of 21 spectral power distributions for fluorescent UV devices operating with UVA 351 lamps of various lots and ages. The spectral power distribution data is for lamps within the aging recommendations of the device manufacturer. The minimum and maximum data are at least the three sigma limits from the mean for all measurements.

[C] The minimum and maximum columns will not necessarily sum to 100 % because they represent the minimum and maximum for the data used. For any individual spectral power distribution, the calculated percentage for the bandpasses in Table 2 will sum to 100 %. For any individual fluorescent UV device operating with UVA 351 lamps, the calculated percentage in each bandpass must fall within the minimum and maximum limits of Table 2. Test results can be expected to differ between exposures using fluorescent UV devices in which the spectral power distributions differ by as much as that allowed by the tolerances. Contact the manufacturer of the fluorescent UV devices for specific spectral power distribution data for the lamps used.

[D] The window glass filtered solar radiation data is for a solar spectrum with atmospheric conditions and altitude chosen to maximize the fraction of short wavelength solar UV (defined in ASTM G177) that has been filtered by window glass. The glass transmission is the average for a series of single strength window glasses tested as part of a research study for ASTM Subcommittee G3.02 **(3)**. While this data is provided for comparison purposes only, it is desirable for the laboratory accelerated light source to provide a spectrum that is a close match to this benchmark window glass filtered solar spectrum.

[E] For the benchmark window glass filtered solar spectrum, the UV irradiance (300 nm to 400 nm) is 8.2 % and the visible irradiance (400 nm to 800 nm) is 91.8 % expressed as a percentage of the total irradiance from 300 nm to 800 nm. Because the primary emission of fluorescent UV lamps is concentrated in the 290 nm to 400 nm bandpass, there are limited visible light emissions from fluorescent UV lamps.

NOTE 7—The main application for UVA-351 lamps is for simulation of the short and middle UV wavelength region of daylight that has been filtered through window glass **(3)**.

6.1.4.3 *Spectral Power Distribution of UVB-313 Lamps*—The spectral power distribution of UVB-313 fluorescent lamps shall comply with the requirements specified in Table 3. Fluorescent UVB lamps have the spectral distribution of radiation peaking near the 313-nm mercury line, and as such, are not recommended for sunlight simulation.

NOTE 8—UVB 313 lamps emit significant amounts of radiation below 295 nm, the nominal cut on wavelength of global solar radiation, that may result in aging processes not occurring outdoors. See Table 3.

6.2 *Test Chamber*—The design of the test chamber can vary, but it shall be constructed from corrosion and UV resistant material and, in addition to the light source, if required provide for means of controlling temperature and relative humidity. When required, provision shall be made for the spraying of water on the test specimen for the formation of condensate on the exposed face of the specimen or for the immersion of the test specimen in water.

NOTE 9—Most commercially available apparatus used for testing in accordance with this practice do not control relative humidity.

6.2.1 The light source(s) shall be located with respect to the specimens such that the uniformity of irradiance at the specimen face complies with the requirements in Practice G151.

6.2.2 Lamp replacement, lamp rotation, and specimen repositioning can be required to obtain uniform exposure of all specimens to UV radiation and temperature. Follow manufacturer's recommendation for lamp replacement and rotation.

6.2.3 Specimens in the extreme left and right side of the exposure area (at the ends of the lamps) experience a lower irradiance than other specimens **(4)**. While these positions do meet the irradiance requirements in G151 when repositioning is used (see 9.5), it is recommended that these positions are excluded when test and control specimens do not completely fill the specimen racks (see Fig. 1).

6.3 *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. Calibration schedule and procedure shall be in accordance with manufacturer's instructions. Calibration should be traceable to a national metrological institute (NMI).

6.4 *Radiometer*—The use of a radiometer to monitor and control the amount of radiant energy received at the sample is recommended. If a radiometer is used, it shall comply with the requirements in Practice G151.

TABLE 3 Relative Spectral Power Distribution Specification for Fluorescent UVB 313 lamps[A,B]

Spectral Bandpass Wavelength λ in nm	Minimum Percent[C]	Benchmark Solar Radiation Percent[D,E]	Maximum Percent[C]
$\lambda < 290$	1.3		5.4
$290 \le \lambda \le 320$	47.8	5.8	65.9
$320 < \lambda \le 360$	26.9	40.0	43.9
$360 < \lambda \le 400$	1.7	54.2	7.2

[A] Data in Table 3 are the irradiance in the given bandpass expressed as a percentage of the total irradiance from 250 nm to 400 nm. The manufacturer is responsible for determining conformance to Table 3. Annex A1 states how to determine relative spectral irradiance.
[B] The data in Table 3 are based on the rectangular integration of 44 spectral power distributions for fluorescent UV devices operating with UVB 313 lamps of various lots and ages. The spectral power distribution data is for lamps within the aging recommendations of the device manufacturer. The minimum and maximum data are at least the three sigma limits from the mean for all measurements.
[C] The minimum and maximum columns will not necessarily sum to 100 % because they represent the minimum and maximum for the data used. For any individual spectral power distribution, the calculated percentage for the bandpasses in Table 3 will sum to 100 %. For any individual UVB 313 lamp, the calculated percentage in each bandpass must fall within the minimum and maximum limits of Table 3. Test results can be expected to differ between exposures conducted in fluorescent UV devices using UVB 313 lamps in which the spectral power distributions differ by as much as that allowed by the tolerances. Contact the manufacturer of the fluorescent UV device for specific spectral power distribution data for the device operated with the UVB 313 lamp used.
[D] The benchmark solar radiation data is defined in ASTM G177 and is for atmospheric conditions and altitude chosen to maximize the fraction of short wavelength solar UV. This data is provided for comparison purposes only.
[E] For the benchmark solar spectrum, the UV irradiance (290 nm to 400 nm) is 9.8 % and the visible irradiance (400 nm to 800 nm) is 90.2 % expressed as a percentage of the total irradiance from 290 nm to 800 nm. Because the primary emission of fluorescent UV lamps is concentrated in the 290 nm to 400 nm bandpass, there are limited visible light emissions from fluorescent UV lamps.

6.5 *Thermometer*—Either insulated or un-insulated black or white panel thermometers may be used. The un-insulated thermometers may be made of either steel or aluminum. Thermometers shall conform to the descriptions found in Practice G151.

NOTE 10—Typically, these devices are controlled by black-panel thermometer, and not by chamber air temperature.

6.5.1 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 can result in significantly different temperature profiles in the test chamber.

6.5.2 The thermometer shall be mounted on the specimen rack so that its surface is in the same relative position and subjected to the same influences as the test specimens.

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

6.6 *Moisture*—A means for exposing the specimen to moisture shall be provided. The moisture may be in the form of water spray, condensation, or humidity.

6.6.1 *Water Spray*—The test chamber may be equipped with a means to introduce intermittent water spray onto the test specimens under specified conditions. The spray shall be uniformly distributed over the specimens. The spray system shall be made from corrosion resistant materials that do not contaminate the water used.

NOTE 11—Temperature is typically not controlled in spray segments.

6.6.1.1 *Spray Water Quality*—Spray water shall have a conductivity below 5 μS/cm, contain less than 1-ppm solids, and leave no observable stains or deposits on the specimens. Very low levels of silica in spray water can cause significant deposits on the surface of test specimens. Care should be taken to keep silica levels below 0.2 ppm. In addition to distillation, a combination of deionization and reverse osmosis can effectively produce water of the required quality. The pH of the water used should be reported. See Practice G151 for detailed water quality instructions.

6.6.2 *Condensation*—The test chamber may be equipped with a means to cause condensation to form on the face of the test specimen exposed to test chamber conditions (front side). Typically, water vapor is generated by heating water and filling the chamber with hot vapor, which then is made to condense on the test specimens by convective cooling on the back side of the specimens.

NOTE 12—The temperature and amount of condensate forming on the specimens is influenced by the specimen thickness, thermal conductance, and the temperature differential between the test chamber and the room. Condensation may be difficult to achieve for highly thermally-insulative or very thick specimens.

6.6.3 *Relative Humidity*—The test chamber may be equipped with a means to measure and control the relative humidity. Such instruments shall be shielded from the lamp radiation.

6.7 *Specimen Holders*—Holders for test specimens shall be made from corrosion resistant materials that will not affect the test results. Corrosion resistant alloys of aluminum or stainless steel have been found acceptable. Brass, steel, or copper shall not be used in the vicinity of the test specimens.

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. Exposure Conditions

8.1 The user shall define the exposure conditions appropriate for their application. Any exposure conditions may be used as long as the exact conditions are detailed in the report. Appendix X2 lists exposure conditions taken from several material test methods. These conditions are provided for reference only; none are specifically preferred and no recommendations are implied. This practice is not intended as a primary means for defining exposure cycles for a given application. Refer to the appropriate international standard for defining an appropriate exposure cycle.

9. Procedure

9.1 Identify each test specimen by suitable indelible marking, but not on areas used in testing.

9.2 Determine which property of the test specimens will be evaluated. Prior to exposing the specimens, quantify the

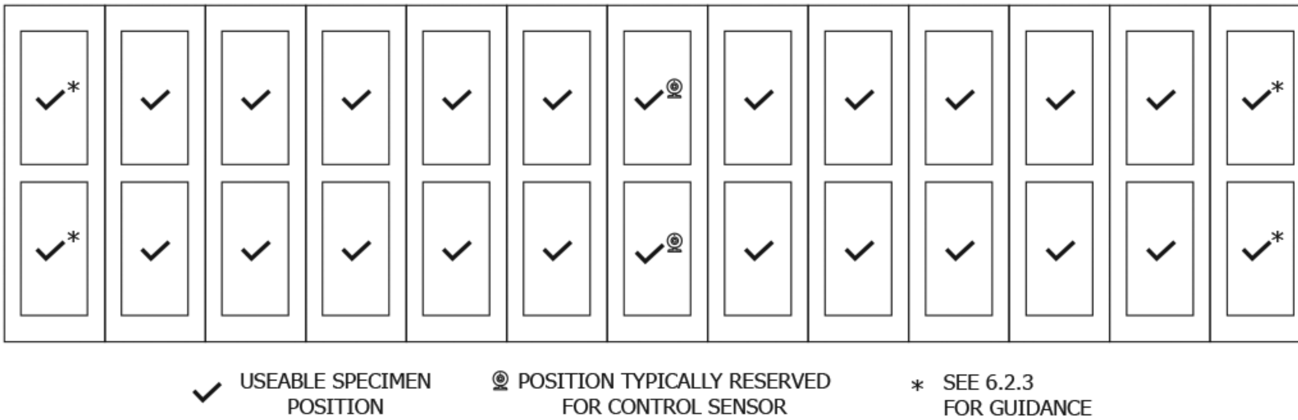

FIG. 1 Typical Exposure Area of a UV-lamp Apparatus with Useable and Recommended Specimen Positions Marked.

appropriate properties in accordance with recognized ASTM or international standards. If required (for example, destructive testing), use unexposed file specimens to quantify the property. See ISO 4582 for detailed guidance.

9.3 *Mounting of Test Specimens*—Attach the specimens to the specimen holders in the equipment in such a manner that the specimens are not subject to any unnecessary applied stress. To assure uniform exposure conditions, fill all of the spaces, using blank panels of corrosion resistant material if necessary.

9.3.1 Masking or shielding the face of test specimens with an opaque cover for the purpose of showing the effects of exposure on one panel is not recommended. Misleading results may be obtained by this procedure, since the masked portion of the specimen is still exposed to temperature and humidity that in many cases will affect results. Preferably, evaluation of color, appearance, and other property changes of exposed materials are to be made based on comparisons to unexposed specimens of the same material that have been stored in the dark.

9.4 *Exposure to Test Conditions*—Program the selected test conditions to operate continuously throughout the required number of repetitive cycles. Maintain these conditions throughout the exposure. Interruptions to service the apparatus and to inspect specimens shall be minimized.

NOTE 13—Exposure conditions that include condensation or specimen spray (including the cycles in Table X2.1) often end with a wet phase. It is recommended to end the exposure (also for intermediate evaluations, repositioning) during or at the end of a dry phase. This can be achieved, for example, by programming the test duration by radiant exposure rather than exposure time or number of cycles.

9.5 *Specimen Repositioning*—Periodic repositioning of the test specimens during exposure is good laboratory practice to minimize the effect of variability in irradiance, temperature, and moisture exposure in the test chamber. Irradiance uniformity shall be determined in accordance with Practice G151 Annex A1 (Procedures for Measuring Irradiance Uniformity in Specimen Exposure Area). Recommendations for repositioning procedures, if used, are provided in Practice G151 Appendix X2 (Suggested Procedures for Reducing Variability by Periodic Random Positioning or Systematic Repositioning of Specimens).

9.5.1 If the irradiance at the positions farthest from the center of specimen area is measured to be at least 90 % as per Practice G151, repositioning is not required but can still be beneficial.

9.5.2 If irradiance at positions farther from the center of the exposure area is between 70 % and 90 % of that measured at the center, one of the following three techniques shall be used for specimen placement (see 6.2.3).

9.5.2.1 Periodically reposition specimens during the exposure period to ensure that each receives an equal amount of radiant exposure. The repositioning procedure and schedule shall be agreed upon by all interested parties.

9.5.2.2 Place test specimens only in the exposure area where the irradiance is at least 90 % of the maximum irradiance.

9.5.2.3 To compensate for exposure variability within the apparatus, randomly position replicate specimens within the exposure area that meets the irradiance uniformity requirements as defined in 9.5.2.

9.6 *Inspection*—If it is necessary to remove a test specimen for periodic inspection, take care not to handle or disturb the test surface. After inspection, the test specimen shall be returned to the test chamber with its test surface in the same orientation as previously exposed. Specimens should be handled when dry.

9.7 *Maintenance*—The apparatus requires periodic maintenance to maintain control of the exposure parameters. Perform required maintenance and calibration in accordance with manufacturer's instructions.

9.8 Expose the test specimens for the specified period of exposure. See Practice G151 for further guidance.

9.9 At the end of the exposure, quantify the appropriate change in properties in accordance with recognized ASTM or other international standards and report the results in conformance with Practice G151.

NOTE 14—Periods of exposure and evaluation of test results are addressed in Practice G151.

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; accelerated weathering; durability; exposure; fluorescent UV lamps; laboratory weathering; light; lightfastness; non-metallic materials; temperature; ultraviolet; weathering

ANNEX

(Mandatory Information for Equipment Manufacturers)

A1. DETERMINING CONFORMANCE TO RELATIVE SPECTRAL POWER DISTRIBUTION TABLES

A1.1 Conformance to the relative spectral power distribution tables is a design parameter for fluorescent UV device with the different lamps that can be used. Manufacturers of equipment claiming conformance to this practice shall determine conformance to the spectral power distribution tables for all fluorescent lamps provided, and provide information on maintenance procedures to minimize any spectral changes that may occur during normal use.

A1.2 The relative spectral power distribution data for this practice were developed using the rectangular integration technique. Eq A1.1 is used to determine the relative spectral irradiance using rectangular integration. Other integration techniques can be used to evaluate spectral power distribution data, but may give different results. When comparing relative spectral power distribution data to the spectral power distribution requirements of this practice, use the rectangular integration technique.

A1.3 To determine whether a specific fluorescent UV lamp for a fluorescent UV device meets the requirements of Table 1, Table 2, or Table 3, measure the spectral power distribution from the lower wavelength indicated in Eq A1.1 to an upper wavelength of 400 nm. Typically, this is done at 2 nm increments. The total irradiance in each wavelength bandpass is then summed and divided by the specified total UV irradiance according to Eq A1.1. Use of this equation requires that each spectral interval must be the same (for example, 2 nm) throughout the spectral region used.

$$I_R = \frac{\sum_{\lambda_i = A}^{\lambda_i = B} E_{\lambda_i}}{\sum_{\lambda_i = C}^{\lambda_i = 400} E_{\lambda_i}} \times 100 \qquad \text{(A1.1)}$$

where:

I_R = relative irradiance in percent,
E = irradiance at wavelength λ_i (irradiance steps must be equal for all bandpasses),
A = lower wavelength of wavelength bandpass,
B = upper wavelength of wavelength bandpass,
C = lower wavelength of total UV bandpass used for calculating relative spectral irradiance (290 nm for UVA 340 lamps, 300 nm for UVA 351 lamps, or 250 nm for UVB 313 lamps), and
λ_i = wavelength at which irradiance was measured.

APPENDIXES

(Nonmandatory Information)

X1. APPLICATION GUIDELINES FOR TYPICAL FLUORESCENT UV LAMPS

X1.1 General

X1.1.1 A variety of fluorescent UV lamps may be used in this practice. The lamps shown in this section are representative of their type. Other lamps may be used. The particular application determines which lamp should be used. The lamps discussed in this Appendix differ in the total amount of UV energy emitted and their wavelength spectrum. Differences in lamp energy or spectrum may cause significant differences in test results. A detailed description of the type(s) of lamp(s) used shall be stated in detail in the test report.

X1.1.2 All spectral power distributions (SPDs) shown in this section are representative only and are not meant to be used to calculate or estimate total radiant exposure for tests in fluorescent UV devices. Actual irradiance levels at the test specimen surface will vary due to the type and/or manufacturer of the lamp used, the age of the lamps, the distance to the lamp array, and the air temperature within the chamber.

NOTE X1.1—All SPDs in this appendix were measured using a spectroradiometer with a double grating monochromator (1-nm band pass) with a quartz cosine receptor. The fluorescent UV SPDs were measured at the sample plane in the center of the allowed sample area. SPDs for sunlight were measured in Phoenix, AZ at solar noon at the summer solstice with a clear sky, with the spectroradiometer on an equatorial follow-the-sun mount.

X1.2 Simulations of Direct Solar UV Radiation Exposures

X1.2.1 *UVA-340 Lamps*—For simulations of direct solar UV radiation the UVA-340 lamp is recommended. Because UVA-340 lamps typically have little or no UV output below 295 nm (that is considered the "cut-on" wavelength for terrestrial sunlight), they usually do not degrade materials as rapidly as UVB lamps, but they may allow enhanced correlation with actual outdoor weathering. Tests using UVA-340 lamps have been found useful for comparing different nonmetallic materials such as polymers, geotextiles, and UV stabilizers. Fig. X1.1 illustrates the SPD of the UVA-340 lamp compared to noon, summer sunlight.

X1.2.2 *UVB-313 Lamps*—The UVB region (280 nm to 315 nm) includes the shortest wavelengths found in sunlight at the earth's surface and is responsible for causing considerable damage to some polymers. There are two commonly available types of UVB-313 lamps that meet the requirements of this document. These are known commercially as the UVB-313 and the FS-40. These lamps emit different amounts of total energy, but both peak at 313 nm and produce the same UV wavelengths in the same relative proportions. The FS-40 lamp was originally designed for non-irradiance-controlled apparatuses and has been typically superseded by UVB-313 lamps in irradiance-controlled apparatuses. In non-irradiance-controlled apparatuses, UVB-313 lamps will provide more UV than FS-40 lamps. In tests using the same cycles and temperatures, UVB-313 lamps typically thus result in shorter times to failure. In irradiance-controlled apparatuses, the same irradiance set-point will result in the same UV from both lamp types. In tests using the same cycles and temperatures, both lamps will produce similar times to failure.

NOTE X1.2—The Fig. X1.2 illustrates the difference between the lamps.

X1.2.2.1 All UVB-313 lamps emit UV below the normal sunlight cut-on. This short wavelength UV can produce rapid polymer degradation and often causes degradation by mechanisms that do not occur when materials are exposed to sunlight. This may lead to anomalous results. Fig. X1.2 shows the spectral power distribution (SPD) of typical UVB-313 lamps compared to the SPD of noon, summer sunlight.

X1.3 Simulations of Exposures to Solar UV Radiation Through Window Glass

X1.3.1 *Filtering Effect of Glass*—Glass of any type acts as a filter on the sunlight spectrum (see Fig. X1.3). Ordinary glass is essentially transparent to light above about 370 nm. However, the filtering effect becomes more pronounced with decreasing wavelength. The shorter, more damaging UVB wavelengths are the most greatly affected. Window glass filters out most of the wavelengths below about 310 nm. For purposes of illustration, only one type of window glass is used in the accompanying graphs. Note that glass transmission characteristics will vary due to manufacturer, production lot, thickness, or other factors.

X1.3.2 *UVA-351 Lamps*—For simulations of sunlight through window glass, UVA-351 lamps are recommended. The UVA-351 is used for these applications because the low end cut-on of this lamp is similar to that of direct sunlight which has been filtered through window glass (Fig. X1.4).

NOTE X1.3—UVB-313 lamps are not recommended for simulations of sunlight through window glass. Most of the emission of UVB-313 lamps is in the short wavelength UV that is filtered very efficiently by glass. Because of this, very little energy from this short wavelength region will reach materials in "behind glass" applications. This is because window glass filters out about 80 % of the energy from UVB-313 lamps, as shown in Fig. X1.5. As a result of filtering out these short wavelengths, its total effective energy is very limited. Further, because there is little longer

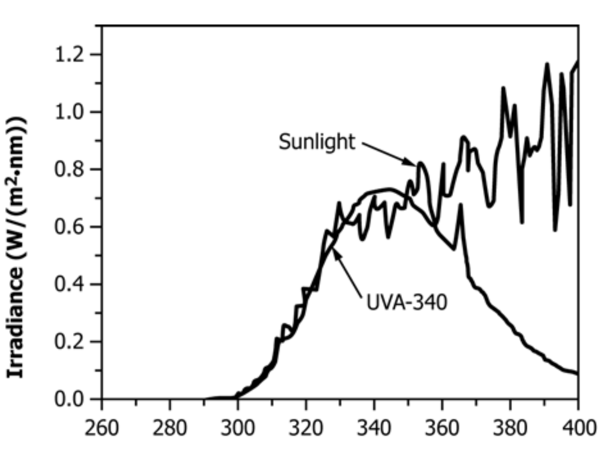

FIG. X1.1 Spectral Power Distributions of UVA-340 Lamp and Sunlight

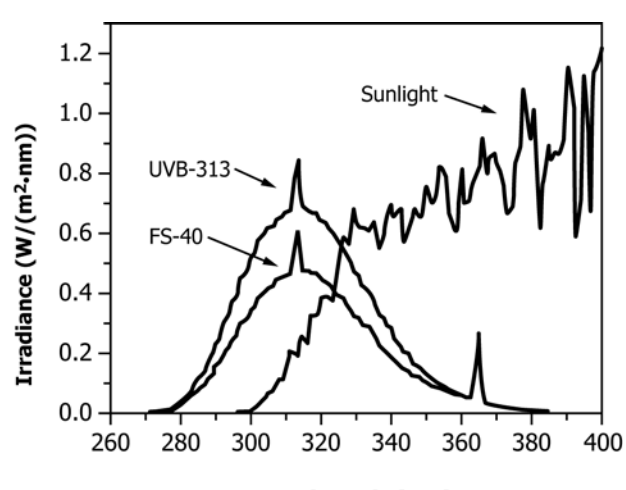

FIG. X1.2 Spectral Power Distributions of UVB Lamps and Sunlight