INTERNATIONAL

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Standard Practice for Operating Xenon Arc LightLamp Apparatus for Exposure of Non-Metallic Materials[1]

This standard is issued under the fixed designation G155; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*Scope

1.1 This practice is limited to the basic principles and procedures for operating a xenon arc lamp and water apparatus; on its own, it does not deliver a specific result.

1.2 This practice covers the basic principles and operating procedures for using xenon arc light and water apparatus 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 humidity, rain, or dew in actual use. This practice is limited to the procedures for obtaining, measuring, and controlling conditions of exposure. 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.

NOTE 1—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.

NOTE 2—Practice G151 describes performance criteria for all exposure devices that usegeneral procedures and performance requirements to be used when exposing materials in an apparatus that uses laboratory light sources. This practice replaces Practice G26, which describes very specific designs for devices used for xenon-arc exposures. The apparatus described in Practice G26 is covered by this practice.

1.3 Test specimens are exposed to filtered light from an optically-filtered xenon arc lightlamp under controlled environmental conditions. Different types of optical filters in combination with xenon arc light sources and different filter combinations are described.

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. More specific information about methods for determining the change in properties after exposure and reporting these results is described in Practice D5870.

NOTE 3—General information about methods for determining the change in properties after exposure and reporting these results is described in Practice D5870.

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

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

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 practice is technically similar to the following ISO documents: ISO 4892-2, ISO 16474-2, ISO 105-B02, ISO 105-B04, ISO 105-B05, ISO 105-B06, and ISO 105-B10.

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 safety, health, and healthenvironmental practices and determine the applicability of regulatory limitations prior to use.*

1.8.1 *Should any ozone be generated from the operation of the lamp(s), it shall be carried away from the test specimens and operating personnel by an exhaust system.*

1.6 This practice is technically similar to the following ISO documents: ISO 4892-2, ISO 11341, ISO 105 B02, ISO 105 B04, ISO 105 B05, and ISO 105 B06.

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]

D3980D2565 Practice for Interlaboratory Testing of Paint and Related MaterialsXenon-Arc Exposure of Plastics Intended for Outdoor Applications (Withdrawn 1998)

D5870 Practice for Calculating Property Retention Index of Plastics

E691D6695 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test MethodXenon-Arc Exposures of Paint and Related Coatings

D7869 Practice for Xenon Arc Exposure Test with Enhanced Light and Water Exposure for Transportation Coatings

G26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials (Discontinued 2001) (Withdrawn 2000)[3]

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

G153 Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials

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

2.2 *ASTM Adjuncts:*

SMARTS2: Simple Model of the Atmospheric Radiative Transfer of Sunshine[4]

2.3 *CIE Standards:Standard:*[5]

CIE-Publ. No. 85: Recommendations for the Integrated Irradiance and the Spectral Distribution of Simulated Solar Radiation for Testing Purposes

2.4 *International Standards Organization ISO Standards:*[6]

ISO 113416474-2 PaintPaints and Varnishes—Artificial Weathering Exposure to Artificial Radiation to Filtered Xenon Arc RadiationVarnishes—Methods of Exposure to Laboratory Light Sources—Part 2: Xenon-arc Lamps

ISO 105 B02105-B02 Textiles—Tests for Colorfastness—Part B02 Colorfastness to Artificial Light: Xenon Arc Fading Lamp Test

ISO 105 B04105-B04 Textiles—Tests for Colorfastness—Part B04 Colorfastness to Artificial Weathering: Xenon Arc Fading Lamp Test

ISO 105 B05105-B05 Textiles—Tests for Colorfastness—Part B05 Detection and Assessment of Photochromism

[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] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute, 11 W.ASTM International Headquarters. Order Adjunct No. ADJG017342d St., 13th Floor, New York, NY 10036)..

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.IHS Markit, https://global.ihs.com.

[6] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

ISO 105–B06105-B06 Textiles—Tests for Colorfastness—Part B06 Colorfastness to Artificial Light at High Temperatures: Xenon Arc Fading Lamp Test
ISO 4892-1105-B10 Plastics—Methods of Exposure to Laboratory Light Sources, Part 1, General GuidanceTextiles—Tests for Colorfastness—Part B10: Artificial Weathering—Exposure to Filtered Xenon Arc Radiation
ISO 4892-2 Plastics—Methods of Exposure to Laboratory Light Sources, Part 2, Xenon-Arc Sources
ISO TS 19022 Plastics—Method of Controlled Acceleration of Laboratory Weathering by Increased Irradiance

2.5 *Society of Automotive Engineers' SAE Standards:*[7]
SAE J2412 Accelerated Exposure of Automotive Interior Trim Components Using a Controlled Irradiance Xenon-Arc Apparatus
SAE J2527 Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Xenon-Arc Apparatus

3. Terminology

3.1 *Definitions—TheDefinitions—*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.

4. Summary of Practice

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

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

4.2 The exposure condition may be varied by selection of:

4.2.1 Lamp filter(s),The type of optical system used to adjust the spectrum, including xenon arc lamp(s), optical filter(s), and reflector(s),

4.2.2 The lamp's irradiance level,setpoint,

4.2.3 The type of moisture exposure,Optional moisture exposure in the form of (controlled) relative humidity within the apparatus, spraying the test specimen(s) with demineralized/deionized water, immersing the specimens in water, or by condensation of water vapor onto specimens,

4.2.4 The timing of the light and moisture exposure,sequence and duration of the various cycle step(s) (including light, dark, moisture), and

4.2.5 The temperature of light exposure,and types of thermometers and other temperature sensor(s) used.

4.2.6 The temperature of moisture exposure, and

4.2.7 The timing of a light/dark cycle.

4.3 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.

4.4 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.

5. Significance and Use

5.1 The use of this apparatus is intended to induce property changes associated with the end use conditions, including the effects

[7] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

of sunlight, moisture, and heat. These exposures may include a means to introduce moisture to the test specimen. apparatus exposes specimens to light, heat, and optionally moisture, often to attempt to replicate specimen property changes observed in outdoor and indoor end-use environments. 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. Typically, these exposures would include moisture in the form of humidity.

NOTE 2—**Caution:** Refer to Practice G151 for full cautionary guidance applicable to all laboratory weathering devices.

5.2 Variation in results may be expected when operating conditions are varied within the accepted limits of this practice. This practice allows a wide range of exposure conditions that may produce significantly different results. Therefore, no reference shall be made to results from the use of this practice its use unless accompanied by a report in conformance with Section 10 detailing the specific operating conditions in conformance with the Report Section.conditions.

5.2.1 It is recommended that a A control (a similar material of known performance (a control) performance) should be exposed simultaneously with the test specimen to provide a standardreference for comparative purposes. It is best practice to use control materials two different control materials: one known to have relatively poor and good durability. It is recommended that at durability and one known to have relatively good durability. At least three replicates of each material evaluated be exposed in each test to allow for test specimen and control material should be exposed concurrently to permit statistical evaluation of results.

5.3 Comparison of results obtained from specimens exposed in different apparatus (even if the apparatus is the same model) using the identical setpoints and operational controls should not be made unless reproducibility has been established between apparatus for the material to be tested.

5.4 Refer to Practice G151 for cautionary guidance applicable to all laboratory weathering apparatus.

5.5 It is recommended that users follow good laboratory practices in order to reduce variability in exposures (**1**).[8]

6. Apparatus

6.1 *Laboratory Light Source*—The light source shall be one or more quartz jacketed quartz-jacketed xenon arc lamps which emit radiation from below 270 nm in the ultraviolet throughultraviolet, throughout the visible spectrum, and into the infrared. In order for xenon arcs to simulate terrestrial daylight, optical filters must be used to remove reduce transmission of short wavelength UV radiation. radiation below 295 nm, the terrestrial solar cut-on wavelength. Filters to reduce irradiance at wavelengths shorter than 310 nm must be used to simulate daylight filtered through window glass. In addition, filters to remove infrared radiation may be used to prevent unrealistic excessive radiant heating of test specimens that can cause thermal degradation not experienced commonly observed during outdoor exposures.

NOTE 4—While it is recognized that the visible and infrared wavelength outputs of the xenon arc lamp/optical system are essential for a complete simulation of terrestrial sunlight, this practice sets requirements for only the ultraviolet and very short wavelength components (<400 nm). Users may establish their own spectral power distribution requirements for longer wavelengths where needed.

6.1.1 The following factors can affect the spectral power distribution of optically filtered xenon arc light sources as used in these apparatus:

6.1.1.1 Differences in the composition and thickness of filters canwill have large effects on the amount of short wavelength UV radiation transmitted.UV radiation transmitted. Exposures conducted using different types or different combinations of optical filters can produce different results.

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[7] Ketola, W., Skogland, T., Fischer, R., "Effects of Filter and Burner Aging on the Spectral Power Distribution of Xenon Arc Lamps," *Durability Testing of Non-Metallic Materials, ASTM STP 1294*, Robert Herling, Editor, ASTM, Philadelphia, 1995.

[8] Searle, N. D., Giesecke, P., Kinmonth, R., and Hirt, R. C., " Ultraviolet Spectral Distributions and Aging Characteristics of Xenon Arcs and Filters," *Applied Optics*, Vol. No. 8, 1964, pp. 923–927.

[9] Ketola, W., Robbins, J. S., "UV Transmission of Single Strength Window Glass," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*, Warren D. Ketola and Douglas Grossman, Editors, ASTM, Philadelphia, 1993.

[10] Gueymard, C., "Parameterized Transmittance Model for Direct Beam and Circumsolar Spectral Irradiance," *Solar Energy*, Vol 71, No. 5, 2001, pp. 325-346.

[11] Gueymard, C. A., Myers, D., and Emery, K., "Proposed Reference Irradiance Spectra for Solar Energy Systems Testing," *Solar Energy*, Vol 73, No 6, 2002, pp. 443-467.

[8] Myers, D. R., Emery, K., and Gueymard, C., "Revising and Validating Spectral Irradiance Reference Standards for Photovoltaic Performance Evaluation," Transactions of the American Society of Mechanical Engineers, *Journal of Solar Energy Engineering*, Vol 126, pp 567–574, Feb. 2004. The boldface numbers in parentheses refer to the list of references at the end of this standard.

TABLE X3.1 Common Exposure Conditions

Cycle	Filter	Irradiance	Wavelength	Exposure Cycle
1	Daylight	0.35 $W/(m^2 \cdot nm)$	340 nm	102 min light at 63°C black panel temperature 18 min light and water spray (air temp. not controlled)
2	Daylight	0.35 $W/(m^2 \cdot nm)$	340 nm	102 min light at 63°C black panel temperature 18 min light and water spray (air temp. not controlled) repeated nine times for a total of 18h; followed by 6 h dark at 95 (±4.0) % RH, at 24°C black panel temperature
3	Daylight	0.35 $W/(m^2 \cdot nm)$	340 nm	1.5 h light, 70 % RH, at 77°C black panel temperature 0.5 h light and water spray (air temp. not controlled)
4	Window Glass	0.30 $W/(m^2 \cdot nm)$	340 nm	100 % light, 55 % RH, at 55°C black panel temperature
5	Window Glass	1.10 $W/(m^2 \cdot nm)$	420 nm	102 min light, 35 % RH, at 63°C black panel temperature 18 min light and water spray (air temp. not controlled)
6	Window Glass	1.10 $W/(m^2 \cdot nm)$	420 nm	3.8 h light, 35 % RH, at 63 °C black panel temperature 1 h dark, 90 % RH, at 43 ° C black panel temperature

6.1.1.2 Aging of optical filters from exposure can result in changes in filter transmission. The aging properties of filters can be

Cycle	Filter	Irradiance	Wavelength	Exposure Cycle
7	Extended UV	0.55 W/(m^2·nm)	340 nm	40 min light, 50 % RH, at 70 (±2) °C black panel temperature and 47 (±2) °C chamber air temperature 20 min light and water spray on specimen face 60 min light, 50 % RH, at 70 (±2) °C black panel temperature; and 47 (±2) °C chamber air temperature 60 min dark and water spray on specimen front and back, 95 %RH, 38 (±2) °C black panel temperature and 38 (±2) °C chamber air temperature
7A	Daylight	0.55 W/(m^2·nm)	340 nm	40 min light, 50 (±5.0) % RH, at 70 (±2) °C black panel temperature and 47 (±2) °C chamber air temperature 20 min light and water spray on specimen face; 60 min light, 50 % RH, at 70 (±2) °C black panel temperature; and 47 (±2) °C chamber air temperature 60 min dark and water spray on specimen front and back, 95 % RH, 38 (±2) °C black panel temperature and 38 (±2) °C chamber air temperature

Cycle	Filter	Irradiance	Wavelength	Exposure Cycle
~~8~~	~~Extended UV~~	~~0.55 W/m²·nm~~	~~340 nm~~	~~3.8 h light, 50 % RH, at 89 (±3) °C black panel temperature and 62 (±2) °C chamber air temperature~~ ~~1.0 h dark, 95 % RH, at 38 (±2) °C black panel temperature and 38 (±2) °C chamber air temperature~~
~~9~~	~~Daylight~~	~~180 W/m²~~	~~300–400 nm~~	~~102 min light at 63°C black panel temperature~~ ~~18 min light and water spray (temperature not controlled)~~
~~10~~	~~Window Glass~~	~~162 W/m²~~	~~300–400 nm~~	~~100 % light, 50 % RH, at 89°C black panel temperature~~
~~11~~	~~Window Glass~~	~~1.5 W/(m²·nm)~~	~~420 nm~~	~~Continuous light at 63°C black panel temperature, 30 % RH~~
~~12~~	~~Daylight~~	~~0.35 W/(m²·nm)~~	~~340 nm~~	~~18 h consisting of continuous light at 63°C black panel temperature 30 % RH~~ ~~6 h dark at 90 % RH, at 35°C chamber air temperature~~

TABLE 1 Relative Ultraviolet Spectral Power Distribution Specification for Xenon Arc Lamp(s) with Daylight Filters[A]

Spectral Bandpass Wavelength λ in nm	General[B]		Type I[C]		Type II[D]		Benchmark Solar Radiation Percent[F,G,H]
	Min. %[E]	Max %[E]	Min. %[E]	Max %[E]	Min. %[E]	Max %[E]	
λ < 300[I]	2.6	8.1	0	0.2	0.2	1.1	5.8
300 ≤ λ ≤ 320			2.6	6	3.5	7.0	
320 < λ ≤ 340	28.3	40.0	10.0	17.0	10.0	17.0	40.0
340 < λ ≤ 360			18.3	23.2	18.3	23.2	
360 < λ ≤ 380	54.2	67.5	25.0	30.5	25.0	30.5	54.2
380 < λ ≤ 400			29.2	37.0	29.2	37.0	

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

[B] The data in this column is based on the approximate rectangular integration of 112 spectral power distributions for water and air cooled xenon-arcs with daylight filters of various lots and ages measured in the 1990s. The spectral power distribution data is for filters and xenon arc lamps within the recommended operating lifetime of the apparatus manufacturer. The minimum and maximum data are at least three sigma limits from the mean for all measurements.

[C] Type I filters more closely match the spectrum of noon summer sunlight. This designation was obtained by reviewing the spectral performance of commercially available optical filter systems with a cut-on wavelength of ~295 nm from various manufacturers.

[D] Type II filters transmit more shortwave UV than noon summer sunlight. These filters more closely match the daylight filters that have historically been used in xenon arc lamp apparatus and are more likely to give a similar performance for correlation to historic test conditions. This designation was obtained by reviewing the spectral performance of commercially available optical filter systems with a cut-on wavelength shorter than 295 nm from various manufacturers.

[E] 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 xenon arc lamp with daylight filters, 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 xenon arc apparatus in which the spectral power distributions differ by as much as that allowed by the tolerances. Contact the manufacturer of the xenon arc lamp apparatus for spectral power distribution data for the xenon arc lamp/optical filter system used.

[F] 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.

[G] Versions of this standard dated 2000 and earlier used solar radiation data from Table 4 of CIE Publication Number 85. See Appendix X4 for more information comparing the solar radiation data used in this standard with that for CIE 85 Table 4.

[H] For the benchmark solar spectrum, the UV irradiance (290 to 400 nm) is 9.8 % and the visible irradiance (400 to 800 nm) is 90.2 % expressed as a percentage of the total irradiance from 290 to 800 nm. The percentages of UV and visible irradiances on samples exposed in xenon arc apparatus may vary due to the number and reflectance properties of specimens being exposed.
[I] In addition to the maximum specification for wavelengths shorter than 300 nm in Table 1, transmission of wavelengths shorter than 290 nm should not exceed 0.15 % of the total irradiance from 290 to 400 nm, for all Daylight filters.

TABLE 2 Relative Ultraviolet Spectral Power Distribution Specification for ~~Xenon-Arc~~ Xenon Arc Lamp(s) with Window Glass Filters[A,B]

Spectral Bandpass Wavelength λ in nm	Minimum Percent[C]	Window Glass Filtered Solar Radiation Percent[D,E,F]	Maximum Percent[C]
$\lambda < 300$		0.0	0.29
$300 \le \lambda \le 320$	0.1	≤ 0.5	2.8
$320 < \lambda \le 360$	23.8	34.2	35.5
$360 < \lambda \le 400$	62.5	65.3	76.1

[A] Data in Table 2 are the irradiance in the given bandpass expressed as a percentage of the total irradiance from 300 to 400 nm. The manufacturer ~~is responsible for determining~~ shall ensure conformance to Table 2. Annex A1 states how to determine relative spectral irradiance.
[B] The data in Table 2 are based on the rectangular integration of 36 spectral power distributions for water cooled and air cooled xenon-arcs with window glass filters of various lots and ~~ages.~~ ages measured in the 1990s. The spectral power distribution data is for filters and ~~xenon-burners~~ xenon arc lamps within the aging recommendations of the ~~device~~apparatus manufacturer. The minimum and maximum data are at least ~~the~~ three sigma limits from the mean for all measurements.
[C] ~~The~~ 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 xenon-lamp with window glass filters, 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 xenon arc ~~devices~~ lamp apparatus in which the spectral power distributions differ by as much as that allowed by the tolerances. Contact the manufacturer of the ~~xenon-arc devices~~ xenon arc lamp apparatus for specific spectral power distribution data for the ~~xenon-arc and filters~~ xenon arc lamp/optical filter system used.
[D] ~~The~~ The window glass filtered solar 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.~~ G03.02 (**8**). While this data is provided for comparison purposes only, it is desirable for a xenon-arc with window glass filters to provide a spectrum that is a close match to this window glass filtered solar spectrum.
[E] ~~Previous versions~~ Versions of this standard dated 2000 and earlier used window glass filtered solar radiation data based on Table 4 of CIE Publication Number 85. See Appendix X4 for more information comparing the solar radiation data used in the standard with that for CIE 85 Table 4.
[F] For the benchmark window glass filtered solar spectrum, the UV irradiance (300 to 400 nm) is 8.2 % and the visible irradiance (400 to 800 nm) is 91.8 % expressed as a percentage of the total irradiance from 300 to 800 nm. The percentages of UV and visible irradiances on samples exposed in xenon arc ~~devices~~ lamp apparatus with window glass filters may vary due to the number and reflectance properties of specimens being exposed, and the UV transmission of the window glass filters used.

~~influenced by the composition. Aging of filters can result~~ spectral transmission, resulting in a significant reduction in the ~~short wavelength UV emission of a xenon burner.~~UV radiation emitted by the xenon arc lamp/optical filter system.

6.1.1.3 Accumulation of ~~deposits~~ deposits, dirt, or other residue on ~~filters can effect filter transmission.~~the optical filters or xenon arc lamp can affect the UV radiation emitted by the xenon arc lamp/optical filter system.

6.1.1.4 Aging of the xenon ~~burner itself~~ arc lamp from use can result in changes in ~~lamp output. Changes in lamp output may also be caused by accumulation of dirt or other residue in or on the burner envelope.~~spectral output of the lamp.

NOTE 5—More information on the effects of composition, aging, and deposits on a xenon arc lamp/optical filter system can be found in Refs (**2-7**).

6.1.2 ~~Follow the device~~ As a result of the potential for significant changes in spectral irradiance due to effects described in 6.1.1.2, 6.1.1.3, and 6.1.1.4, users should follow the apparatus manufacturer's instructions for ~~recommended maintenance.~~maintenance and replacement of xenon arc lamps and optical filters.

6.1.3 *Spectral Irradiance of Xenon Arc Lamp(s) with Daylight Filters*—~~Filters~~ Optical filters are used to ~~filter~~modify xenon arc lamp emissions ~~in a simulation of terrestrial sunlight. The~~ to simulate terrestrial sunlight. Any xenon arc lamp/optical filter system with a spectral power distribution ~~of xenon arcs with new or pre-aged filters~~that complies with the ultraviolet spectral ~~shall comply with the~~ requirements specified in Table 1~~.~~ is considered a "Daylight" filter. The manufacturer shall ensure compliance for the xenon arc lamp/optical filter systems, prior to initial use.

6.1.3.1 *General Daylight Filters*—These filters meet the requirements in the General column of Table 1. The General column represents the broad definition for Daylight filters found in previous versions of this standard. Both Type I and Type II filters are subsets of General Daylight filters.

6.1.3.2 *Type 1 Daylight Filters*—These filters meet both the requirements in the General column and the Type I column of Table 1. They are designed to best represent a match to the terrestrial solar cut-on at approximately 295 nm of outdoor noon summer sunlight.

NOTE 6—Type I Daylight filters include optical filters defined in Practice D7869.

6.1.3.3 *Type II Daylight Filters*—These filters meet both the requirements in General column and Type II column of Table 1. They transmit appreciable ultraviolet radiation at wavelengths below the terrestrial solar cut-on at ~295 nm.

NOTE 7—Type II Daylight filters include the borosilicate glass filters that were among the first optical filters that were designed to represent an outdoor solar spectrum, representing the best technology available at the time. Type I Daylight filters were subsequently developed to provide a better match to outdoor sunlight. Results may differ between tests conducted with Type I and Type II Daylight filters.

6.1.4 *Spectral Irradiance of Xenon Arc Lamp(s) With Window Glass Filters*—Filters are used to ~~filter~~modify xenon arc lamp emissions in a simulation of sunlight filtered through window ~~glass.~~glass~~Table 2 shows~~(**8** ~~the relative spectral power distribution limits for xenon arcs filtered with window glass filters. The~~). Any xenon arc lamp/optical filter system with a spectral power distribution ~~of xenon arcs with new or pre-aged filters shall comply with the~~ that complies with the ultraviolet spectral requirements specified in Table 2~~.~~ is considered a "Window" or "Window Glass" filter. The manufacturer shall ensure compliance for the xenon arc lamp/optical filter systems, prior to initial use.

6.1.5 *Spectral Irradiance of Xenon Arc Lamp(s) With Extended UV Filters*—~~Filter that transmit more short wavelength UV are sometimes used to accelerate test result.~~ Optical filters are used to modify xenon arc lamp emissions to transmit more UV radiation below 295 nm. Although this type of ~~filter has been~~optical system is specified in some ~~tests, they transmit significant radiant energy below 300 nm (the typical cut-on wavelength for terrestrial sunlight) and~~ tests to accelerate degradation, it may result in aging processes that do not ~~occurring outdoors. The spectral irradiance for a xenon arc with extended UV filters shall comply with the requirements of~~ occur outdoors. Any xenon arc lamp/optical filter system with a spectral power distribution that complies with the ultraviolet spectral requirements specified in Table 3~~.~~ is considered an "Extended UV" filter. The manufacturer shall ensure compliance for the xenon arc lamp/optical filter systems, prior to initial use.

6.1.6 The laboratory light source(s) shall be located with respect to the specimens such that the irradiance at the specimen plane complies with Practice G151.

6.1.7 The ~~actual~~ irradiance at the ~~tester's~~ specimen plane is a function of the number of xenon ~~burners~~ arc lamps used, the power applied to each, ~~and the~~ the optical filter(s) used, the distance between the test specimens and the xenon ~~burner. If appropriate, report the~~ arc lamp(s), and the reflective properties of any test specimens. The irradiance and the bandpass in which it was ~~measured.~~measured should be recorded.

6.2 *Test Chamber*—The design of the test chamber may vary, but it should be constructed from corrosion resistant ~~material and, in addition to the radiant source, may 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.~~material.

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

TABLE 3 Relative Ultraviolet Spectral Power Distribution Specification for Xenon Arc Lamp(s) with Extended UV Filters[A,B]

Spectral Bandpass Wavelength λ in nm	Minimum Percent[C]	Benchmark Solar Radiation Percent[D,E,F]	Maximum Percent[C]
250 ≤ λ < 290	0.1		0.7
290 ≤ λ ≤ 320	5.0	5.8	11.0
320 < λ ≤ 360	32.3	40.0	37.0
360 < λ ≤ 400	52.0	54.2	62.0

[A] Data in Table 3 are the irradiance in the given bandpass expressed as a percentage of the total irradiance from 250 to 400 nm. The manufacturer ~~is responsible for determining~~ shall ensure 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 81 spectral power distributions for water cooled and air cooled xenon-arcs with extended UV filters of various lots and ~~ages.~~ ages measured in the 1990s. The spectral power distribution data is for filters and ~~xenon burners~~ xenon arc lamps within the aging recommendations of the ~~device~~apparatus manufacturer. The minimum and maximum data are at least the three sigma limits from the mean for all measurements.

[C] ~~The~~ 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 xenon-arc lamp with extended UV filters, 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 using xenon arc ~~devices~~ lamp apparatus in which the spectral power distributions differ by as much as that allowed by the tolerances. Contact the manufacturer of the ~~xenon-arc devices~~ xenon arc lamp apparatus for specific spectral power distribution data for the ~~xenon-arc and filters~~ xenon arc lamp/optical filter system used.

[D] ~~The~~ The benchmark solar radiation data is defined in ASTM G177 and is for atmospheric conditions and altitude chosen to maximize the fraction of short ~~wavelenght~~wavelength solar UV. This data is provided for comparison purposes only.

[E] ~~Previous versions~~ Versions of this standard dated 2000 and earlier used solar radiation data from Table 4 of CIE Publication Number 85. See Appendix X4 for more information comparing the solar radiation data used in the standard with that for CIE 85 Table 4.

[F] For the benchmark solar spectrum, the UV irradiance (290 to 400 nm) is 9.8 % and the visible irradiance (400 to 800 nm) is 90.2 % expressed as a percentage of the total irradiance from 290 to 800 nm. The percentages of UV and visible irradiances on samples exposed in xenon arc ~~devices~~ lamp apparatus may vary due to the number and reflectance properties of specimens being exposed.

6.3 *Instrument Calibration*—To ensure standardization and accuracy, the instruments associated with the exposure apparatus ~~(that is,~~(such as timers, thermometers, wet bulb sensors, dry bulb sensors, humidity sensors, UV sensors, radiometers) require periodic calibration to ensure repeatability of test results. ~~Whenever possible,~~ Instrument calibration should be traceable to national or international standards. Calibration ~~schedule~~frequency and procedure should be in accordance with manufacturer's ~~instructions.~~instructions and good laboratory practices.

NOTE 8—For guidance on good laboratory practices for instrument calibration, see NIST GMP-11 (**9**).

6.4 *Radiometer*—~~The use of a~~ An integrated radiometer to monitor and control the amount of radiant energy received at the specimen ~~is recommended.~~ plane should be used. If a radiometer is used, it shall comply with the requirements in Practice ~~ASTM~~ G151.

6.5 *Thermometer*—Either insulated or un-insulated black or white panel thermometers may be used. Thermometers shall conform to the descriptions and requirements found in Practice G151. The type of thermometer used, the method of mounting (for example, on a specimen ~~holder,~~holder), and the exposure temperature shall be stated in the test report.

6.5.1 The thermometer shall be mounted ~~on~~within the specimen ~~rack~~ exposure area so that ~~its surface is in~~ it receives the same ~~relative position and subjected to the same influences as the~~radiation and cooling conditions as a flat test panel surface per the recommended configuration in Practice G151~~test specimens.~~.

6.5.2 Some test specifications may require chamber air temperature control. Positioning and calibration of any chamber air temperature sensors shall be in accordance with the descriptions found in Practice G151. Controlling chamber air temperature allows better and more reproducible specimen temperatures and may reduce test variability (**10**).

6.5.3 Aspects of the apparatus' design, along with its heating, cooling, and control systems and ambient laboratory conditions, can have a significant impact on the amount of time it takes for the apparatus' thermometer to reach steady-state temperature during an exposure step. As a result, this affects how long specimens remain at the desired temperature, since exposure steps are typically fixed in total duration. The rate and magnitude of specimen degradation during exposure can be significantly impacted by these factors. Users are cautioned when comparing results from apparatus with different thermometer time-to-steady-state temperature characteristics.

6.6 *Moisture*—The test specimens may be exposed to moisture in the form of water spray, condensation, immersion, or ~~high humidity.~~humidity, or a combination thereof.

6.6.1 *Water Spray*—The test chamber may be equipped with a means to introduce intermittent water spray onto the front or the back of the test specimens, under specified conditions. The spray shall be uniformly distributed over the specimens. The spray system shall be made from ~~corrosion resistant~~ corrosion-resistant materials that do not contaminate the spray water ~~employed.~~(**11**).

6.6.1.1 *Quality of Water for Sprays and Immersion*—~~Spray~~ To minimize stains or deposits on specimens, spray water must have a conductivity below 5 ~~µS/cm,~~ µS/cm and contain less than ~~1-ppm solids, and leave no observable stains or deposits on the specimens. Very~~ 1 ppm solids. Care should be taken to keep silica levels below 0.1 ppm because even 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 0.1 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.~~requirements.

6.6.1.2 *Condensation*—A spray system designed to cool the specimen by spraying the back surface of the specimen or specimen substrate during a dark condition (that is, with the lamps off) may be required when the exposure program specifies periods of condensation.

NOTE 9—The mechanism used to form condensation on the face of specimens is to cool the back side of thermally conductive specimens with a cool water back spray during warm, humid, dark conditions. Condensation is created by cooling the specimen surface temperature below the test chamber air's dewpoint. Refer to Note X3.3 in Appendix X3 for more information on the implementation of backspray in historical xenon arc test methods.

6.6.2 *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.~~direct radiation and water spray. Controlling relative humidity allows better reproducibility of exposure conditions and may reduce test variability.

6.6.3 *Water Immersion*—The test chamber may be equipped with a means to immerse specimens in water under specified ~~conditions.~~ conditions (for example, controlled water temperature). The immersion system shall be made from ~~corrosion resistant~~ corrosion-resistant materials that do not contaminate the ~~water employed.~~immersion water.

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~~to be acceptable. Specimen holders shall not be ~~used in the vicinity of the test specimens.~~made from brass, steel (non-stainless), or copper.

6.7.1 The specimen holders ~~are typically, but not necessarily,~~ may be mounted on a revolving cylindrical rack ~~that is rotated around the lamp system at a speed dependent on the type of equipment and that is centered both horizontally and vertically with respect to the exposure area.~~or a flat tray.

6.7.1.1 If mounted on a revolving cylindrical rack, the rack shall be centered both horizontally and vertically with respect to the exposure area. The rotation speed may be varied.

6.7.2 Specimen holders may be in the form of an open frame, leaving the back of the specimen exposed, or they may provide the specimen with a solid backing. Any backing used may affect test results and shall be agreed upon in advance between the interested parties.