Designation: G 155 – 00a

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

This standard is issued under the fixed designation G 155; 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 covers the basic principles and operating procedures for using xenon arc light and water apparatus 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 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—Practice G 151 describes performance criteria for all exposure devices that use laboratory light sources. This practice replaces Practice G 26, which describes very specific designs for devices used for xenon-arc exposures. The apparatus described in Practice G 26 iscovered by this practice.

1.2 Test specimens are exposed to filtered xenon arc light under controlled environmental conditions. Different types of xenon arc light sources and different filter combinations are described.

1.3 Specimen preparation and evaluation of the results are covered in ASTM methods or specifications for specific materials. General guidance is given in Practice G 151 and ISO 4892-1. More specific information about methods for determining the change in properties after exposure and reporting these results is described in ISO 4582.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

1.5.1 *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 1134, ISO 105 B02, ISO 105 B04, ISO 105 B05, and ISO 105 B06.

2. Referenced Documents

2.1 *ASTM Standards:*

D 3980 Practice for Interlaboratory Testing of Paint and Related Materials[2]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[4]

G 113 Terminology Relating to Natural and Artificial Weathering Tests for Nonmetallic Materials[4]

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources[4]

2.2 *CIE Standards:*

CIE-Publ. No. 85: Recommendations for the Integrated Irradiance and the Spectral Distribution of Simulated Solar Radiation for Testing Purposes[5]

2.3 *International Standards Organization Standards:*

ISO 1134, Paint and Varnishes—Artificial Weathering Exposure to Artificial Radiation to Filtered Xenon Arc Radiation[6]

ISO 105 B02, Textiles—Tests for Colorfastness—Part B02 Colorfastness to Artificial Light: Xenon Arc Fading Lamp Test[6]

ISO 105 B04, Textiles—Tests for Colorfastness—Part B04 Colorfastness to Artificial Weathering: Xenon Arc Fading Lamp Test[6]

ISO 105 B05, Textiles—Tests for Colorfastness—Part B05 Detection and Assessment of Photochromism[6]

ISO 105 B06, Textiles—Tests for Colorfastness—Part B06

[1] This practice is under the jurisdiction of ASTM Committee G3 on Weathering and Durability and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Exposure Tests.

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[2] Discontinued 1998. See *1998 Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 14.04.

[5] Available from Secretary, U.S. National Committee, CIE, National Institute of Standards and Technology, Gaithersburg, MD 20899.

[6] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

Colorfastness to Artificial Light at High Temperatures: Xenon Arc Fading Lamp Test[6]

ISO 4582, Plastics—Determination of the Changes of Colour and Variations in Properties After Exposure to Daylight Under Glass, Natural Weathering or Artificial Light[6]

ISO 4892-1, Plastics—Methods of Exposure to Laboratory Light Sources, Part 1, General Guidance[6]

ISO 4892-2, Plastics—Methods of Exposure to Laboratory Light Sources, Part 2, Xenon-Arc Sources[6]

2.4 *Society of Automotive Engineers' Standards:*

SAE J1885, Accelerated Exposure of Automotive Interior Trim Components Using a Controlled Irradiance Water Cooled Xenon Arc Apparatus[7]

SAE J1960, Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Water Cooled Xenon Arc Apparatus[7]

3. Terminology

3.1 Definitions—The definitions given in Terminology G 113 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 G 113.

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 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),

4.2.2 The lamp's irradiance level,

4.2.3 The type of moisture exposure,

4.2.4 The timing of the light and moisture exposure,

4.2.5 The temperature of light exposure,

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 of sunlight, moisture, and heat. These exposures may include a means to introduce moisture to the test specimen. 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 G 151 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. 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 the Report Section.

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. It is recommended that at least three replicates of each material evaluated be exposed in each test to allow for statistical evaluation of results.

6. Apparatus

6.1 *Laboratory Light Source*—The light source shall be one or more quartz jacketed xenon arc lamps which emit radiation from below 270 nm in the ultraviolet through the visible spectrum and into the infrared. In order for xenon arcs to simulate terrestrial daylight, filters must be used to remove short wavelength UV radiation. 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 heating of test specimens that can cause thermal degradation not experienced during outdoor exposures.

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

6.1.1.1 Differences in the composition and thickness of filters can have large effects on the amount of short wavelength UV radiation transmitted.

6.1.1.2 Aging of filters can result in changes in filter transmission. The aging properties of filters can be influenced by the composition. Aging of filters can result in a significant reduction in the short wavelength UV emission of a xenon burner.

6.1.1.3 Accumulation of deposits or other residue on filters can effect filter transmission.

6.1.1.4 Aging of the xenon burner itself 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.

6.1.2 Follow the device manufacturer's instructions for recommended maintenance.

6.1.3 *Spectral Irradiance of Xenon Arc with Daylight*

[7] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

Filters—Filters are used to filter xenon arc lamp emissions in a simulation of terrestrial sunlight. The spectral power distribution of xenon arcs with new or pre-aged filters[8,9] shall comply with the requirements specified in Table 1.

6.1.4 Other filters which allow more short wavelength UV are sometimes used to accelerate the test results. The spectra produced will fall outside of these limits in the short wavelength region. Use of these filters is not recommended.

6.1.5 *Spectral Irradiance of Xenon Arc With Window Glass Filters*—Filters are used to filter xenon arc lamp emissions in a simulation of sunlight filtered through window glass.[10] Table 2 shows the relative spectral power distribution limits for xenon arcs filtered with window glass filters. The spectral power distribution of xenon arcs with new or pre-aged filters shall comply with the requirements specified in Table 2.

6.1.6 The actual irradiance at the tester's specimen plane is a function of the number of xenon burners used, the power applied to each, and the distance between the test specimens and the xenon burner. If appropriate, report the irradiance and the bandpass in which it was measured.

[8] 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.

[9] 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.

[10] 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.

TABLE 1 Relative Spectal Power Distribution Specification for Xenon Arc with Daylight Filters

Bandpass, nm	Xenon Arc with Daylight Filters[A,B]	Sunlight[C]
Ultraviolet Wavelength Region Irradiance as a percentage of total irradiance from 300 to 400 nm		
290–300	<1 %	0 %
301–320	2.1–6.4 %	5.6 %
321–340	11.1–15.0 %	18.5 %
341–360	19.4–23.3 %	21.7 %
361–380	26.3–29.3 %	26.6 %
381–400	30.6–36.4 %	27.6 %
Ultraviolet and Visible Wavelength Region Irradiance as a percentage of total irradiance from 300 to 800 nm[D]		
300–400	9.2–12.3 %	11 %[E]
401–700	64.0–77.3 %	72 %[E]

[A]There can be small, but significant irradiance below 290 nm for xenon arc lamps with daylight filters. The amount of this short wavelength UV radiation depends on the transmission and age of the filters used.

[B]Xenon arc data—The ranges given are based on spectral power distribution measurements made for water- and air-cooled devices with various lots and ages of daylight filters. The ranges given are based on three sigma limits from the averages of this data. Xenon arc filters that provide a spectral power distribution closer to sunlight than those that are shown in these tables are considered to meet the requirements of this standard.

[C]Sunlight data—The sunlight data is for global irradiance on a horizontal surface with an air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.081 at 300 nm and 0.62 at 400 nm.

[D]Data from 701 to 800 nm is not shown.

[E]Sunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm.

TABLE 2 Relative Spectral Power Distribution Specification for Xenon Arc with Window Glass Filters

Bandpass, nm	Xenon Arc with Window Glass Filters[A]	Estimated Window Glass Filtered Sunlight[B]
Ultraviolet Wavelength Region Irradiance as a percentage of total irradiance from 300 to 400 nm		
290–300	<0.1 %	0 %
301–320	0.0–3.3 %	0.1–1.5 %
321–340	1.9–14.3 %	9.4–14.8 %
341–360	18.8–23.0 %	23.2–23.5 %
361–380	27.5–34.1 %	29.6–32.5 %
381–400	31.8–46.7 %	30.9–34.5 %
Ultraviolet and Visible Wavelength Region Irradiance as a percentage of total irradiance from 300 to 800 nm[C]		
300–400	8.6–10.4 %	9.0–11.1 %[D]
401–700	64.2–80.8 %	71.3–73.1 %[D]

[A]Xenon arc data—The ranges given are based on spectral power distribution measurements made for water- and air-cooled devices with various lots and ages of window glass filters. The ranges given are based on three sigma limits from the averages of this data. Xenon arc filters that provide a spectral power distribution closer to window glass filtered sunlight than those that are shown in these tables are considered to meet the requirements of this standard.

[B]Sunlight data—The sunlight data is for global irradiance on a horizontal surface with an air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.081 at 300 nm and 0.62 at 400 nm. The range is determined by multiplying solar irradiance by the upper and lower limits for transmission of single strength window glass samples used for studies conducted by ASTM Subcommittee G03.02.

[C]Data from 701 to 800 nm is not shown.

[D]Sunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm. The range is determined by multiplying solar irradiance by the upper and lower limits for transmission of single strength window glass samples used for studies conducted by ASTM Subcommittee G03.02.

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.

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 G 151.

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

6.4 *Radiometer*—The use of a radiometer to monitor and control the amount of radiant energy received at the specimen is recommended. If a radiometer is used, it shall comply with the requirements in Practice ASTM G 151.

6.5 *Thermometer*—Either insulated or un-insulated black or white panel thermometers may be used. Thermometers shall conform to the descriptions found in Practice G 151. The type of thermometer used, the method of mounting on specimen holder, and the exposure temperature shall be stated in the test report.

6.5.1 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.

6.5.2 Some specifications may require chamber air temperature control. Positioning and calibration of chamber air temperature sensors shall be in accordance with the descriptions found in Practice G 151.

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

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 materials that do not contaminate the water employed.

6.6.1.1 *Quality of Water for Sprays and Immersion*—Spray water must 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 0.1 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 G 151 for detailed water quality instructions.

6.6.1.2 *Condensation*—A spray system designed to cool the specimen by spraying the back surface of the specimen or specimen substrate may be required when the exposure program specifies periods of condensation.

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.

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

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.

6.7.1 The specimen holders are typically, but not necessarily, 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.

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.

6.7.3 Specimen holders may rotate on their own axis. When these holders are used, they may be filled with specimens placed back to back. Rotation of the holder on its axis alternately exposes each specimen to direct radiation from the xenon burner.

6.8 *Apparatus to Assess Changes in Properties*—The necessary apparatus required by ASTM or ISO relating to the determination of the properties chosen for monitoring shall be used (see also ISO 4582).

7. Test Specimen

7.1 Refer to Practice G 151.

8. Test Conditions

8.1 Any exposure conditions may be used as long as the exact conditions are detailed in the report. Appendix X1 lists some representative exposure conditions. These are not necessarily preferred and no recommendation is implied. These conditions are provided for reference only.

9. Procedure

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

9.2 Determine which property of the test specimens will be evaluated. Prior to exposing the specimens, quantify the appropriate properties in accordance with recognized 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 applied stress. To assure uniform exposure conditions, fill all of the spaces, using blank panels of corrosion resistant material if necessary.

NOTE 3—Evaluation of color and appearance changes of exposed materials must be made based on comparisons to unexposed specimens of the same material which have been stored in the dark. 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 method, since the masked portion of the specimen is still exposed to temperature and humidity that in many cases will affect results.

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.

9.5 *Specimen Repositioning*—Periodic repositioning of the specimens during exposure is not necessary if the irradiance at the positions farthest from the center of the specimen area is at least 90 % of that measured at the center of the exposure area. Irradiance uniformity shall be determined in accordance with Practice G 151.

9.5.1 If irradiance at positions farthest 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.

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