Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials[1]

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1. Scope

1.1 This practice covers the basic principles and operating procedures for using enclosed carbon-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 23, which describes very specific designs for devices used for carbon-arc exposures. The apparatus described in Practice G 23 is covered by this practice.

1.2 Test specimens are exposed to enclosed carbon arc light under controlled environmental conditions.

1.3 Specimen preparation and evaluation of the results are covered in various 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 light source, it shall be carried away from the test specimens and operating personnel by an exhaust system.

2. Referenced Documents

2.1 *ASTM Standards:*

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

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

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[4]

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

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

2.2 *ISO Standards:*

ISO 4582, Plastics—Determination of the Changes of Colour and Variations in Properties After Exposure to Daylight Under Glass, Natural Weathering or Artificial Light[5]

ISO 4892-1, Plastics—Methods of Exposure to Laboratory Light Sources, Part 1, General Guidance[5]

ISO 4892-4, Plastics—Methods of Exposure to Laboratory Light Sources, Part 4, Open-Flame Carbon Arc Lamp[5]

2.3 *CIE Standards:*

CIE-Publ. No. 85: Recommendations for the Integrated Irradiance and the Spectral Distribution of Simulated Solar Radiation for Testing Purposes[6]

3. Terminology

3.1 *Definitions*—The definitions that are applicable to this practice are provided in Terminology G 113.

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

[1] This practice is under the jurisdiction of ASTM Committee G-3 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 American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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

4.2 The exposure condition may be varied by selection of the following:

4.2.1 Filter,

4.2.2 The type of moisture exposure,

4.2.3 The timing of the light and moisture exposure,

4.2.4 The temperature of light exposure, and

4.2.5 The timing of a light/dark cycle.

4.3 Comparison of results obtained from specimens exposed in 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.

5.2 *Cautions*—Refer to Test Method G 151 for full cautionary guidance applicable to all laboratory weathering devices.

5.2.1 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 Section 10.

5.2.2 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*—Enclosed carbon arc light sources typically use carbon rods which contain a mixture of metal salts. An electric current is passed between the carbon rods which burn and give off ultraviolet, visible, and infrared radiation. Use carbon rods recommended by the device manufacturer.

6.1.1 *Filter*—The most commonly used filters are borosilicate glass globes which fit around the carbon burners. Other filters may be used by mutual agreement by the interested parties as long as the filter type is reported in conformance with the report section in Test Method G 151.

6.1.2 The emission spectra of the enclosed carbon arc shows strong emission in the long wavelength ultraviolet region. Emissions in the visible, infrared, and short wavelength ultraviolet below 350 nm generally are weaker than in sunlight (see Table 1).

6.1.3 The following factors can affect the spectral power distribution of enclosed carbon arc light sources:

TABLE 1 Typical Relative Spectral Power Distribution for Enclosed Carbon Arc with Daylight Filters (Representative Data)

Ultraviolet Wavelength Region
Irradiance as a Percentage of Total Irradiance from 300 to 400 nm

Bandpass (nm)	Enclosed Carbon Arc Daylight Filters[A]	Sunlight[B]
250–280	0 %	0 %
281–290	0 %	0 %
291–300	0 %	0 %
301–320	0 %	5.6 %
321–340	0.3 %	18.5 %
341–360	20.2 %	21.7 %
361–380	28.0 %	26.6 %
381–400	51.5 %	27.6 %

Ultraviolet and Visible Wavelength Region
Irradiance as a Percentage of Total Irradiance from 300 to 800 nm[C]

Bandpass (nm)	Enclosed Carbon Arc Daylight Filters[A]	Sunlight[D]
300–400	53.5 %	11 %
401–700	30.5 %	72 %

[A] *Carbon Arc Data*—This data are for a typical spectral power distribution for an enclosed carbons arc with borosilicate glass globe. Not enough spectral data is available for meaningful analysis to develop a specification. ASTM Subcommittee G03.03 is working to collect sufficient data in order to develop a specification.

[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 cn, 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.

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

[D] *Sunlight Data*—The sunlight data is from Table 4 of CIE Publication No. 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 water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm.

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

6.1.3.2 Aging (solarization) 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 burner.

6.1.3.3 Accumulation of dirt or other residue on filters can affect filter transmission.

6.1.3.4 Differences in chemical composition of carbons.

6.1.4 *Spectral Irradiance for Enclosed Carbon with Daylight Filters*—The data in Table 1 are representative of the spectral irradiance received by a test specimen mounted in the specimen plane.

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 or for the formation of condensate on the exposed face of the specimen.

6.2.1 The radiant source(s) shall be located with respect to the specimens such that the irradiance at the specimen face complies with the requirements in Test Method G 151.

6.3 *Instrument Calibration*—To ensure standardization and accuracy, the instruments associated with the exposure apparatus, for example, timers, thermometers, wet bulb sensors, dry bulb sensors, humidity sensors, UV sensors and 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 *Thermometer*—Either insulated or uninsulated black or white panel thermometers may be used. Thermometers shall conform to the descriptions found in Test Method 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.

NOTE 2—Typically, these devices control by black panel temperature only.

6.4.1 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 Test Method G 151.

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

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

6.5.1 *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 applied so that the specimens are uniformly wetted. The spray system shall be made from corrosion resistant materials that do not contaminate the water used.

6.5.1.1 *Quality of Water for Sprays*—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 Test Method G 151 for detailed water quality instructions.

6.5.1.2 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.

6.5.2 *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 light source.

6.6 *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.

6.6.1 The specimen holders typically, but not necessarily, are mounted on a revolving cylindrical rack, which is rotated around the light source at a speed dependent on the type of equipment, and which is centered both horizontally and vertically with respect to the exposure area in the specimen holders.

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

7. Test Specimen

7.1 Refer to Test Method 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 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 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 Test Method 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.