



Designation: G 151 – 00

Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources¹

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1. Scope

1.1 This practice provides general procedures to be used when exposing nonmetallic materials in accelerated test devices that use laboratory light sources. Detailed information regarding procedures to be used for specific devices are found in standards describing the particular device being used. For example, detailed information covering exposures in devices that use carbon-arc, xenon-arc, and fluorescent UV light sources are found in Practices G 152, G 153, and G 154, and G 154 respectively.

NOTE 1—Carbon-arc, xenon-arc, and fluorescent UV exposures are also described in Practices G 23, G 26, and G 53 which described very specific equipment designs. Practices G 152, G 153, and G 154, and G 154 are performance based standards that replace Practices G 23, G 26, and G 53.

1.2 This practice also describes general performance requirements for devices used for exposing nonmetallic materials to laboratory light sources. This information is intended primarily for producers of laboratory accelerated exposure devices.

1.3 This practice provides information on the use and interpretation of data from accelerated exposure tests. Specific information about methods for determining the property of a nonmetallic material before and after exposure are found in standards describing the method used to measure each property. Information regarding the reporting of results from exposure testing of plastic materials is described in Practice D 5870.

NOTE 2—Guide G 141 provides information for addressing variability in exposure testing of nonmetallic materials. ASTM Committee G 3 is developing a standard guide for application of statistics to exposure test results.

NOTE 3—This standard is technically equivalent to ISO 4892, Part 1.

1.4 *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 appro-*

priate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

- D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing²
- D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer and Related materials³
- D 3980 Practice for Interlaboratory Testing of Paint and Related Materials⁴
- D 5870 Practice for Calculating Property Retention Index of Plastics³
- E 41 Terminology Relating to Conditioning⁵
- E 171 Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials⁶
- E 585/E 585M Specification for Base-Metal Thermocouple Materials⁷
- E 644 Test Methods for Testing Industrial Resistance Thermometers⁷
- E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method⁵
- E 772 Terminology Relating to Solar Energy Conversion⁸
- E 839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Material⁷
- G 7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials⁵
- G 23 Practice for Operating Light Exposure Apparatus (Carbon-Arc) Type With and Without Water for Exposure of Nonmetallic Materials⁵
- G 24 Practice for Conducting Exposures to Daylight Filtered Through Glass⁵
- G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc) Type With and Without Water for Exposure

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 Annual Book of ASTM Standards, Vol 08.01.

³ Annual Book of ASTM Standards, Vol 06.01.

⁴ Discontinued 1998. See 1998 Annual Book of ASTM Standards, Vol. .

⁵ Annual Book of ASTM Standards, Vol 14.02.

⁶ Annual Book of ASTM Standards, Vol 15.09.

⁷ Annual Book of ASTM Standards, Vol 14.03.

⁸ Annual Book of ASTM Standards, Vol 12.02.

of Nonmetallic Materials⁵

G 53 Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV Condensation Type) for Exposure of Nonmetallic Materials⁵

G 113 Terminology Relating to Natural and Artificial Weathering Tests for Nonmetallic Materials⁵

G 130 Method for Calibration of Narrow- and Broad-Band Ultraviolet Radiometers Using a Spectroradiometer⁵

G 141 Guide for Addressing Variability in Exposure Testing on Nonmetallic Materials⁹

G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests⁵

G 152 Practice for Operating Open Flame Carbon-Arc Light Apparatus for Exposure of Nonmetallic Materials⁹

G 153 Practice for Operating Enclosed Carbon-Arc Light Apparatus for Exposure of Nonmetallic Materials⁹

G 154 Practice for Operating Fluorescent Light Apparatus for Exposure of Nonmetallic Materials⁹

G 155 Practice for Operating Xenon-Arc Light Apparatus for Exposure of Nonmetallic Materials⁹

G 156 Practice for Selecting and Characterizing Reference Materials Used to Monitor Consistency of Operating Conditions in an Exposure Test⁹

2.2 ISO Standards:

ISO 4892, Part 1 Plastics: Exposure to laboratory Light Sources—General Guidance¹⁰

ISO 9370 Plastics: Instrumental Determination of Radiant Exposure in Weathering Tests—General Guidance and Basic Test Method¹⁰

2.3 CIE Documents:

CIE Publication Number 85: 1989, Technical Report—Solar Spectral Irradiance¹¹

3. Terminology

3.1 *Definitions*—The definitions given in Terminologies E 41, E 772, and G 113 are applicable to this practice.

4. Significance and Use

4.1 Significance:

4.1.1 When conducting exposures in devices that use laboratory light sources, it is important to consider how well the accelerated test conditions will reproduce property changes and failure modes associated with end-use environments for the materials being tested. In addition, it is essential to consider the effects of variability in both the accelerated test and outdoor exposures when setting up exposure experiments and when interpreting the results from accelerated exposure tests.

4.1.2 No laboratory exposure test can be specified as a total simulation of actual use conditions in outdoor environments. Results obtained from these laboratory accelerated exposures can be considered as representative of actual use exposures only when the degree of rank correlation has been established

for the specific materials being tested and when the type of degradation is the same. The relative durability of materials in actual use conditions can be very different in different locations because of differences in UV radiation, time of wetness, relative humidity, temperature, pollutants, and other factors. Therefore, even if results from a specific exposure test conducted according to this practice are found to be useful for comparing the relative durability of materials exposed in a particular exterior environment, it cannot be assumed that they will be useful for determining relative durability of the same materials for a different environment.

4.1.3 Even though it is very tempting, calculation of an *acceleration factor* relating x h or megajoules of radiant exposure in a laboratory accelerated test to y months or years of exterior exposure is not recommended. These acceleration factors are not valid for several reasons.

4.1.3.1 Acceleration factors are material dependent and can be significantly different for each material and for different formulations of the same material.

4.1.3.2 Variability in the rate of degradation in both actual use and laboratory accelerated exposure test can have a significant effect on the calculated acceleration factor.

4.1.3.3 Acceleration factors calculated based on the ratio of irradiance between a laboratory light source and solar radiation, even when identical bandpasses are used, do not take into consideration the effects on a material of irradiance, temperature, moisture, and differences in spectral power distribution between the laboratory light source and solar radiation.

NOTE 4—If use of an acceleration factor is desired in spite of the warnings given in this practice, such acceleration factors for a particular material are only valid if they are based on data from a sufficient number of separate exterior and laboratory accelerated exposures so that results used to relate times to failure in each exposure can be analyzed using statistical methods. An example of a statistical analysis using multiple laboratory and exterior exposures to calculate an acceleration factor is described by J.A. Simms (1).¹²

4.1.4 There are a number of factors that may decrease the degree of correlation between accelerated tests using laboratory light sources and exterior exposures. More specific information on how each factor may alter stability ranking of materials is given in Appendix X1.

4.1.4.1 Differences in the spectral distribution between the laboratory light source and solar radiation.

4.1.4.2 Light intensities higher than those experienced in actual use conditions.

4.1.4.3 Test conditions where specimens are exposed continuously to light when actual use conditions provide alternate periods of light and dark.

4.1.4.4 Specimen temperatures higher than those in actual conditions.

4.1.4.5 Exposure conditions that produce unrealistic temperature differences between light and dark colored specimens.

4.1.4.6 Exposure conditions that do not have any temperature cycling or that produce temperature cycling, or thermal shock, or both, that is not representative of use conditions.

⁹ *Annual Book of ASTM Standards*, Vol 14.04.

¹⁰ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

¹¹ Available from the Commission Internationale de L'Eclairage, CIE, Central Bureau, Kegelgasse 27, A-1030 Vienna, Austria or the U.S. National Committee for CIE, National Institute for Science and Technology, Gaithersburg, MD.

¹² The boldface numbers in parentheses refer to the list of references at the end of this standard.

4.1.4.7 Unrealistically high or low levels of moisture.

4.1.4.8 Absence of biological agents or pollutants.

4.2 Use of Accelerated Tests with Laboratory Light Sources:

4.2.1 Results from accelerated exposure tests conducted according to this standard are best used to compare the relative performance of materials. A common application is conducting a test to establish that the level of quality of different batches does not vary from a control material with known performance. Comparisons between materials are best made when they are tested at the same time in the same exposure device. Results can be expressed by comparing the exposure time or radiant exposure necessary to change a characteristic property to some specified level.

4.2.1.1 Reproducibility of test results between laboratories has been shown to be good when the stability of materials is evaluated in terms of performance ranking compared to other materials or to a control^{13,14}; therefore, exposure of a similar material of known performance (a control) at the same time as the test materials is strongly recommended.

4.2.2 In some applications, weathering reference materials are used to establish consistency of the operating conditions in an exposure test.

4.2.3 Reference materials, for example, blue wool test fabric, also may be used for the purpose of timing exposures. In some cases, a reference material is exposed at the same time as a test material and the exposure is conducted until there is a defined change in property of the reference material. The test material then is evaluated. In some cases, the results for the test material are compared to those for the reference material. These are inappropriate uses of reference materials when they are not sensitive to exposure stresses that produce failure in the test material or when the reference material is very sensitive to an exposure stress that has very little effect on the test material.

NOTE 5—Definitions for control and reference material that are appropriate to weathering tests are found in Terminology G 113.

NOTE 6—Practice G 156 describes procedures for selecting and characterizing weathering reference materials used to establish consistency of operating conditions in a laboratory accelerated test.

NOTE 7—Results from accelerated exposure tests only should be used to establish a pass/fail approval of materials after a specific time of exposure to a prescribed set of conditions when the variability in the exposure and property measurement procedure has been quantified so that statistically significant pass/fail judgments can be made.

5. Requirements for Laboratory Exposure Devices

5.1 Light Source:

5.1.1 The exposure device shall provide for placement of specimens and any designated sensing devices in positions which provide uniform irradiance by the light source.

NOTE 8—In some devices, several individual light sources are used simultaneously. In these devices, the term *light source* refers to the combination of individual light sources being used.

¹³ Fischer, R., "Results of Round Robin Studies of Light- and Water-Exposure Standard Practice," *Symposium on Accelerated and Outdoor Durability Testing of Organic Materials*, ASTM STP 1202, ASTM, 1993.

¹⁴ Ketola, W., and Fischer, R. "Characterization and Use of Reference Materials in Accelerated Durability Tests," VAMAS Technical Report No. 30, available from NIST, Gaithersburg, MD.

5.1.2 Manufacturers of exposure devices shall assure that the irradiance at any location in the area used for specimen exposures is at least 70 % of the maximum irradiance measured in this area. Procedures for measuring irradiance uniformity are found in Annex A1.

NOTE 9—During use, the irradiance uniformity in exposure devices can be affected by several factors, such as deposits, which can develop on the optical system and chamber walls. Irradiance uniformity also can be affected by the type and number of specimens being exposed. The irradiance uniformity as assured by the manufacturer is valid for new equipment and well defined measuring conditions.

5.1.3 Periodic repositioning of the specimens during exposure is not necessary if the irradiance at positions farthest from the center of the specimen area is at least 90 % of that measured at the center of the exposure area.

5.1.4 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 to used for specimen placement.

5.1.4.1 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.

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

5.1.4.3 Randomly position replicate specimens within the exposure area that meets the irradiance uniformity requirements defined in 5.1.4

5.1.5 Replace lamps and filters according to the schedule recommended by the device manufacturer. Follow the apparatus manufacturer's instructions for lamp and filter replacement and for pre-aging of lamps or filters, or both.

5.1.6 CIE Publication No. 85–1989 provides data on solar spectral irradiance for typical atmospheric conditions, which can be used as a basis for comparing laboratory light sources with daylight. For example, global solar irradiance in the 300 to 2450 nm band is given as 1090 W/m² for relative air mass 1, with 1.42 cm precipitable water, and 0.34 cm of ozone (measured at a pressure of 1 atmosphere and temperature of 0°C). Table 1 shows a broad band condensed spectral irradiance for global solar radiation at this atmospheric condition in the UV, visible and infrared portions of the spectrum. This represents the maximum global solar irradiance that would be experienced by materials exposed on a horizontal surface at the equator near noon on a clear day at the spring or autumn equinox.

TABLE 1 Spectral Global Solar Irradiance (condensed from Table 4 of CIE Publication No. 85–1989)

Wavelength (nm)	Irradiance (Wm ⁻²)	Percent Total (300-2450 nm)	Percent of UV and Visible (300-800 nm)
300-320	4.1	0.4	0.6
320-360	28.5	2.6	4.2
360-400	42.0	3.9	6.2
300-400	74.6	6.8	11.0
400-800	604.2	55.4	89.0
300-800	678.8	62.2	100.0
800-2450	411.6	37.8	...
300-2450	1090.4	100.0	...

5.1.6.1 Direct radiation from xenon burners, open flame carbon arcs, and some fluorescent lamps contains considerable amounts of short wavelength ultraviolet radiation not present in daylight. With proper selection of filters for these light sources, much of the short wavelength light can be eliminated. Even when filters are used, however, a small, but significant, amount of this short wavelength (less than 300 nm) radiation often is present in the spectral distribution of the filtered light source. Fluorescent UV lamps can be selected to have a spectral output corresponding to a particular ultraviolet region of solar radiation. The xenon arc, when appropriately filtered, produces radiation with a spectral power distribution that is a good simulation of average solar radiation throughout the UV and visible region.

5.1.7 A radiometer, which complies with the requirements outlined in ISO 9370 may be used to measure irradiance, E , or the spectral irradiance, E_λ , and the radiant exposure, H , or the spectral radiant exposure, H_λ , on the specimen surface.

5.1.7.1 If used, the radiometer shall be mounted so that it receives the same irradiance as the specimen surface. If it is not positioned within the specimen plane, it shall be calibrated for irradiance at the specimen distance.

5.1.7.2 The radiometer shall be calibrated in the emission region of the light source used. Calibration of narrow or broad-band ultraviolet radiometers with a spectroradiometer shall be conducted according to Method G 130. Calibration shall be checked according to the radiation measuring instrument manufacturer's instructions. A full calibration of the radiometer shall be conducted at least once/year. More frequent calibrations are recommended.

5.1.7.3 When measured, the irradiance in the wavelength range agreed upon by all interested parties shall be reported. Some apparatus provide for measuring irradiance in a specific wavelength range for example, 300–400 or 300–800 nm, or in a narrow bandpass centered around a single wavelength, for example, 340 nm.

5.2 Temperature:

5.2.1 The surface temperature of exposed materials depends on the ambient temperature, the amount of radiation absorbed, the emissivity of the specimen, the thermal conduction within the specimen, and the heat transmission between specimen and air or specimen holder. Since it is not practical to monitor the surface temperature of individual test specimens, a specified black-panel sensor is used to measure and control temperature within the test chamber. It is strongly recommended that the black panel temperature sensor be mounted on a support within the specimen exposure area so that it receives the same radiation and cooling conditions as a flat test panel surface using the same support. The black panel also may be located at a fixed distance position different from the test specimens and calibrated for temperature in the specimen exposure area. This is not recommended, however, because black panels mounted at a fixed position away from the specimens may not indicate temperatures representative of the test specimens, even if they are calibrated to record temperature at positions within the specimen exposure area, due to differences in light intensity and movement of air.

5.2.2 Exposure devices shall use either an uninsulated black panel or an insulated black panel as black panel sensor. Requirements for each type are found in Annex A2.

5.2.3 The temperature indicated by the uninsulated black-panel or insulated thermometer depends on the irradiance of the laboratory light source and the temperature and speed of air moving in the test chamber. Uninsulated black-panel temperatures generally correspond to those for dark coatings on metal panels. Insulated black panel thermometer temperatures generally correspond to those for the exposed surface of dark samples with poor thermal conductivity. At conditions used in typical exposure tests, the temperature indicated by an insulated black panel thermometer will be 3–12°C higher than an uninsulated black panel thermometer. The response time for temperature changes is slightly slower for insulated black panel thermometers compared to uninsulated black panel thermometers.

5.2.3.1 At low irradiance, the difference between the temperature indicated by an uninsulated black panel or insulated black panel and the real specimen may be small. When light sources that emit very little infrared radiation are used, there generally will be very small difference in temperatures indicated by the two types of black panels or between light and dark colored specimens.

5.2.4 In order to evaluate the range of surface temperatures of the exposed specimens, the use of an uninsulated white panel or insulated white panel thermometer is recommended, in addition to the uninsulated black panel or insulated black panel thermometer. In some cases, temperature of either the uninsulated or insulated white panel thermometer may be used to specify exposure conditions. The uninsulated or insulated white panel shall be constructed in the same way as the corresponding uninsulated or insulated black panel thermometer, except for use of a white coating with a good resistance to aging. The reflectance of the white coating between 300 and 1000 nm shall be at least 90 % and at least 60 % between 1000 and 2500 nm.

5.2.5 Exposure devices which control temperature of a black or white temperature sensor shall be able to maintain temperature within $\pm 3^\circ\text{C}$ of the desired temperature. Manufacturers of exposure devices shall assure that the temperature of a black or white panel temperature sensor placed anywhere within the specimen exposure area shall be within $\pm 5\%$ of the desired centigrade temperature.

5.2.6 The test report shall indicate whether an insulated or uninsulated black or white panel was used. If either type of black or white panel thermometer is not positioned in the specimen exposure area, the exact position used shall be described in the test report.

NOTE 10—There can be differences in temperature indicated by a single type of black panel thermometer, depending on the specific design of the device supplied by different manufacturers. Work is being conducted within Subcommittee 6 ISO TC/61 to characterize the differences between the different types of temperature sensing devices and between temperature sensing devices of the same type.

5.2.7 If chamber air temperature is measured, the temperature sensing element shall be shielded from the light source and water spray. Exposure devices, which control temperature of