Designation: D1499 – 13

Standard Practice for Filtered Open-Flame Carbon-Arc Exposures of Plastics[1]

This standard is issued under the fixed designation D1499; 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*

1.1 This practice covers specific procedures and test conditions that are applicable for exposure of plastics in filtered open-flame carbon-arc devices conducted in accordance with Practices G151 and G152. This practice also covers the preparation of test specimens, the test condition suited for plastics, and the evaluation of test results.

1.2 This practice does not cover enclosed carbon-arc exposures of plastics, which had been allowed in Practice D1499. Enclosed carbon-arc exposures of plastics are described in Practice D6360, and in G153, which gives requirements for exposing nonmetallic materials in enclosed carbon-arc devices.

1.3 The values stated in SI units are to be regarded as standard. The values in parentheses are given for information only.

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

NOTE 1—This practice is technically equivalent to ISO 4892-4.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D3980 Practice for Interlaboratory Testing of Paint and Related Materials (Withdrawn 1998)[3]

D5870 Practice for Calculating Property Retention Index of Plastics

D6360 Practice for Enclosed Carbon-Arc Exposures of Plastics

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

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

G141 Guide for Addressing Variability in Exposure Testing of Nonmetallic Materials

G147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests

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

G152 Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials

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

G169 Guide for Application of Basic Statistical Methods to Weathering Tests

2.2 *ISO Standard:*[4]

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

3. Terminology

3.1 The definitions in Terminology G113 are applicable to this practice.

4. Significance and Use

4.1 The ability of a plastic material to resist deterioration of its electrical, mechanical, and optical properties caused by exposure to light, heat, and water can be very significant for many applications. This practice is intended to induce property changes associated with end-use conditions, including the effects of sunlight, moisture, and heat. The exposure used in this practice is not intended to simulate the deterioration caused by localized weather phenomena, such as, atmospheric pollution, biological attack, and saltwater exposure.

4.2 *Cautions*—Variation in results may be expected when operating conditions are varied within the accepted limits of this practice. Therefore, no reference to the use of this practice shall be made unless accompanied by a report prepared in accordance with Section 9 that describes the specific operating

[1] This practice is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.50 on Durability of Plastics.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

conditions used. Refer to Practice G151 for detailed information on the caveats applicable to use of results obtained in accordance with this practice.

NOTE 2—Additional information on sources of variability and on strategies for addressing variability in the design, execution, and data analysis of laboratory-accelerated exposure tests is found in Guide G141.

4.2.1 The spectral power distribution of light from an open-flame carbon-arc is significantly different from that produced in light and water exposure devices using other carbon-arc configurations or other light sources. The type and rate of degradation and the performance rankings produced by exposures to filtered open-flame carbon-arcs can be much different from those produced by exposures to other types of laboratory light sources.

4.2.2 Interlaboratory comparisons are valid only when all laboratories use the same type of carbon-arc, filters, and exposure conditions.

4.3 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.[5,6] Therefore, exposure of a similar material of known performance (a control) at the same time as the test materials is strongly recommended. It is recommended that at least three replicates of each material be exposed to allow for statistical evaluation of results.

4.4 Test results will depend upon the care that is taken to operate the equipment in accordance with Practice G152. Significant factors include regulation of line voltage, freedom from salt or other deposits from water, temperature and humidity control, and conditions of the electrodes.

5. Apparatus

5.1 Use filtered open-flame carbon-arc apparatus that conforms to the requirements defined in Practices G151 and G152.

5.2 Unless otherwise specified, the spectral power distribution of the filtered open-flame carbon-arc shall conform to the requirements in Practice G152 for carbon-arc with daylight filters.

6. Test Specimen

6.1 The size and shape of specimens to be exposed will be determined by the specifications of the particular test method used to evaluate the effects of the exposure on the specimens; the test method shall be determined by the parties concerned. Where practical, it is recommended that specimens be sized to fit specimen holders and racks supplied with the exposure apparatus. Unless supplied with a specific backing as an integral part of the test, specimens shall be mounted so that only the minimum specimen area required for support by the holder shall be covered. This unexposed surface must not be used as part of the test area. When necessary, to provide rigidity, flexible specimens should be attached to, or backed by, a panel made of aluminum, 0.025-in. (0.64-mm) thick.

6.2 Unless otherwise specified, expose at least three replicate specimens of each test and control material.

6.3 Retain a supply of unexposed file specimens of all material evaluated.

6.3.1 When destructive tests are run, ensure that sufficient file specimens are retained so that the property of interest can be determined on unexposed file specimens each time exposed materials are evaluated.

6.4 Specimens should not be removed from the exposure apparatus for more than 24 h and then returned for additional tests, since this does not produce the same results on all materials as tests run without this type of interruption. When specimens are removed from the exposure apparatus for 24 h or more and then returned for additional exposure, report the elapsed time in accordance with Section 9.

NOTE 3—Since the stability of the file specimen may also be time-dependent, users are cautioned that over prolonged exposure periods, or where small differences in the order of acceptable limits are anticipated, comparison of exposed specimens with the file specimen may not be valid. Instrumental measurements are recommended whenever possible.

6.5 Follow the procedures described in Practice G147 for identification and conditioning and handling of test specimens, and reference materials prior to, during, and after exposure.

6.6 Do not mask the face of a specimen for the purpose of showing on one panel the effects of various exposure times. Misleading results may be obtained by this method, since the masked portion of the specimen is still exposed to temperature and humidity cycles that in many cases will affect results.

6.7 Since the thickness of a specimen may markedly affect the results, thickness of test and control specimens shall be within ±10 % of the nominal dimensions.

NOTE 4—This is especially important when mechanical properties are being investigated.

6.8 Incident energy at the extremes of the specimen exposure area in older equipment may be only 60 to 70 % of that at the center. If the irradiance at any position within the exposure area is less than 90 % of the peak irradiance, follow one of the procedures outlined in Practice G152 to ensure either equal radiant exposure or compensation for differences in radiant exposure.

7. Procedure

7.1 It is recommended that a control material be exposed simultaneously with experimental materials for determination of relative performance, if performance comparisons are not being made between the test materials themselves. All concerned parties must agree on the control material used.

7.1.1 Identification of any control specimen used shall accompany the report.

7.2 Mount the test specimens in the specimen exposure area with the test surfaces facing the lamp. When the test specimens

[5] Fischer, R., "Results of Round Robin Studies of Light- and Water-Exposure Standard Practices," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*, Warren D. Ketola and Douglas Grossman, eds., American Society for Testing and Materials, Philadelphia, 1993.

[6] 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.

do not completely fill the exposure area, fill the empty spaces with blank metal panels to maintain the test conditions within the chamber.

7.3 Confine specimens to an exposure area where the irradiance is at least 90 % of that measured at the center of the exposure area. In areas where the irradiance is between 70 and 90 % of maximum irradiance, follow one of the procedures outlined in Practice G152 to ensure either equal radiant exposure or compensation for differences in radiant exposure. Determine irradiance uniformity in accordance with Practice G151.

7.4 Practice G152 lists several exposure cycles that are used for filtered open-flame carbon-arc exposures of nonmetallic materials. Obtain mutual agreement between all concerned parties for the specific exposure cycle used. Additional intervals and methods of wetting, by spray, condensation, or immersion, or a combination of these, may be substituted upon mutual agreement between the concerned parties.

NOTE 5—Spray, condensation, and immersion are different types of moisture exposures and frequently produce different results.

7.4.1 By historical convention, the following exposure cycle has been commonly used for plastics.

NOTE 6—Unless otherwise specified, operate the apparatus to maintain the specified operational fluctuations for the parameters below. If the actual operating conditions do not agree with the machine settings after the equipment has stabilized, discontinue the test and correct the cause of the disagreement before continuing.

NOTE 7—Set points and operational fluctuations could either be listed independently of each other, or they could be listed in the format: Set point ± operational fluctuations. The set point is the target condition for the sensor used at the operational control point as programmed by the user. Operational fluctuations are deviations from the indicated set point at the control point indicated by the readout of the calibrated control sensor during equilibrium operation and do not include measurement uncertainty. At the operational control point, the operational fluctuation can exceed no more than the listed value at equilibrium. Therefore, when a standard calls for a particular set point, the user programs that exact number. The operational fluctuations specified with the set point do not imply that the user is allowed to program a set point higher or lower than the exact set point specified.

7.4.1.1 Continuous light with equilibrium uninsulated black panel temperature controlled to 63 ± 3°C (145 ± 9°F), consisting of the following alternating intervals:

7.4.1.2 102 minutes light only followed by 18 minutes of light with water sprayed on the test specimens.

7.4.1.3 Unless otherwise specified in devices which allow for control of relative humidity, control the relative humidity at a 50 ± 5 % equilibrium during the light-only interval.

7.4.1.4 Unless otherwise specified, in devices which allow for control of air chamber temperature, control the chamber temperature at 44 ± 2°C (111 ± 4°F).

NOTE 8—The equilibrium black panel temperature is obtained without a spray period. For light intervals less than 30 min, the maximum black panel temperature may not reach equilibrium.

NOTE 9—The test cycle described in 7.4.1 is also referred to as the "102-18 cycle" and may not adequately simulate the effects of outdoor exposure.

7.5 *Water Purity:*

7.5.1 The purity of water used for specimen spray is very important. Without proper treatment to remove cations, anions, organics, and particularly silica, exposed panels will develop spots or stains that may not occur in exterior exposures.

7.5.2 Follow the requirements for water purity described in Practice G151.

7.5.3 If specimens are found to have deposits or stains after exposure in the apparatus, the water purity must be checked to determine if it meets the requirements of 7.5.2. On some occasions, exposed specimens can be contaminated by deposits from bacteria that can grow in the purified water used for specimen spray. If bacterial contamination is detected, the entire system used for specimen water spray must be flushed with chlorine and thoroughly rinsed prior to resuming exposures.

7.5.4 The typical temperature of water used for specimen spray is 21 ± 5°C (70 ± 9°F). However, if ambient temperature is low and a holding tank is not used to store purified water, the temperature of water used for specimen spray may be below the typical range given.

7.5.5 When the water purity requirements are met and there is disagreement between parties on the extent of problems caused by stain or deposit, run referee tests in at least one other laboratory that can meet the water quality requirements described in 7.5.

7.5.6 For devices with humidity control, it is recommended that deionized water be used when generating water vapor to control humidity.

7.6 Some tests for lightfastness are run without any specimen wetting. When this type of test is required, omit the period where water is sprayed on specimens.

8. Periods of Exposure and Evaluation of Test Results

8.1 In most cases, periodic evaluation of test and control materials is necessary to determine the variation in magnitude and direction of property change as a function of exposure time or radiant exposure.

8.2 The time or radiant exposure necessary to produce a defined change in a material property can be used to evaluate or rank the stability of materials. This method is preferred over evaluating materials after an arbitrary exposure time or radiant exposure.

8.2.1 Exposure to an arbitrary time or radiant exposure may be used for the purpose of a specific test if agreed upon between the parties concerned or if required for conformance to a particular specification. When a single exposure period is used, select a time or radiant exposure that will produce the largest performance differences between the test materials or between the test material and the control material.

8.2.2 The minimum exposure time used shall be that necessary to produce a substantial change in the property of interest for the least stable material being evaluated. An exposure time that produces a significant change in one type of material cannot be assumed to be applicable to other types of materials.

8.2.3 The relation between time to failure in an exposure conducted in accordance with this practice and service life in an outdoor environment requires determination of a valid acceleration factor. Do not use arbitrary acceleration factors relating time in an exposure conducted in accordance with this

practice and time in an outdoor environment because they can give erroneous information. The acceleration factor is material-dependent and is only valid if it is 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.

NOTE 10—An example of a statistical analysis using multiple-laboratory and exterior exposures to calculate an acceleration factor is described by Simms.[7] See Practice G151 for more information and additional cautions about the use of acceleration factors.

8.3 After each exposure increment, evaluate or rate changes in exposed test specimens in accordance with the applicable ASTM test methods.

NOTE 11—For some materials, changes may continue after the specimen has been removed from the exposure apparatus. Measurements (visual or instrumental) should be made within a standardized time period or as agreed upon between the interested parties. The standardized time period needs to consider conditioning prior to testing.

8.4 Use of results from exposures conducted in accordance with this practice in specifications:

8.4.1 If a standard or specification for general use requires a definite property level after a specific time or radiant exposure in an exposure test conducted in accordance with this practice, base the specified property level on results from round-robin experiments run to determine the test reproducibility from the exposure and property measurement procedures. Conduct these round-robins in accordance with Practice E691 or Practice D3980 and include a statistically representative sample of all laboratories or organizations who would normally conduct the exposure and property measurement.

8.4.2 If a standard or specification for use between two or three parties requires a definite property level after a specific time or radiant exposure in an exposure test conducted in accordance with this practice, base the specified property level on two independent experiments run in each laboratory to determine the reproducibility for the exposure and property measurement process. The reproducibility of the exposure/property measurement process is then used to determine the minimum level of property after the exposure that is mutually agreeable to all parties.

8.4.3 When reproducibility in results from an exposure test conducted in accordance with this practice has not been established through round-robin testing, specify performance requirements for materials in terms of comparison (ranked) to a control material. All specimens shall be exposed simultaneously in the same device. All concerned parties must agree on the specific control material used.

8.4.3.1 Conduct analysis of variance to determine whether any differences between test materials and control materials is statistically significant. Expose replicates of the test specimen and the control specimen so that statistically significant performance differences can be determined.

NOTE 12—Fischer illustrates the use of rank comparison between test and control materials in specifications.[8]

NOTE 13—Guide G169 includes examples showing use of analysis of variance to compare materials.

9. Report

9.1 Report the following information:

9.1.1 Complete identification and description (for example, dimensions) of test material and any control material used.

9.1.2 Type and model of exposure device.

9.1.3 Type of light source.

9.1.4 Type and age of filters at the beginning of the exposure, and whether any of the filters were replaced during the period of exposure.

9.1.5 If the exposed face of a specimen does not fall within the exposure device's specimen plane, report the distance from specimen to light source. For three-dimensional specimens extending beyond the specimen plane (in front of, or behind the specimen plane, or both), report the minimum and maximum distance from the exposed face of the specimen to the light source.

9.1.6 If measured, irradiance in $W/(m^2 \cdot nm)$, or radiant exposure in $J/(m^2 \cdot nm)$, at the sample plane, and the wavelengths in which the measurements were made. For broad band measurements, irradiance in W/m^2, or radiant exposure in J/m^2 and the wavelength region in which the measurements were made.

9.1.6.1 Do not report irradiance or radiant exposure unless direct measurement of irradiance was made during the exposure.

9.1.7 Elapsed exposure time.

9.1.8 Light- and dark-water humidity cycle employed.

9.1.9 Type of black panel (uninsulated or insulated) used and set point of the black panel temperature. If light and dark periods are employed, report the set point for each period. Report any deviations from the operational fluctuations specified.

9.1.10 If relative humidity is controlled, report relative humidity set point. If light and dark periods are employed, report the relative humidity set point for each period. Report any deviations from the operational fluctuations specified.

9.1.11 If chamber (air) temperature is controlled, report chamber (air) temperature set point, If light and dark periods are employed, report the chamber (air) temperature set point for each period. Report any deviations from the operational fluctuations specified.

9.1.12 Type of spray water, if used, and total solids and silica level of water used for specimen spray, if above limits specified in 7.5.

9.1.13 Type of spray nozzle.

9.1.14 If used, specimen, repositioning procedure.

9.1.15 Date, results of physical property tests, identification of laboratory conducting the exposure and property tests, (if different labs conduct the exposures and property tests, identify both).

[7] Simms, J.A., *Journal of Coatings Technology*, Vol 50, 1987, pp. 45-53.

[8] Fischer, R., and Ketola, W., "Impact of Research on Development of ASTM Durability Testing Standards," *Durability Testing of Nonmetallic Materials, ASTM STP 1294*, Robert Herling, ed., American Society for Testing and Materials, Philadelphia, 1995.

9.1.15.1 Where retention of characteristic property is reported, Practice D5870 contains examples of these calculations.

10. Precision and Bias

10.1 *Precision*—The repeatability and reproducibility of results obtained in exposures conducted in accordance with this practice will vary with the materials being tested, the material property being measured, and the specific test conditions and cycles that are used. It is essential to determine reproducibility of the exposure/property measurement process when using the results from exposures conducted in accordance with this practice in product specifications.

10.2 *Bias*—Bias cannot be determined because no acceptable standard weathering reference materials are available.

11. Keywords

11.1 carbon-arc; degradation; exposure; light exposure; open-flame carbon-arc; ultraviolet

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue, D1499 - 05, that may impact the use of this standard. (July 15, 2013)

(1) Harmonized significance and use test with other relevant carbon arc standards.

(2) Introduced text recommending the use of deionized water for humidity control in devices with this feature.