Designation: D5071 – 06 (Reapproved 2013)

Standard Practice for Exposure of Photodegradable Plastics in a Xenon Arc Apparatus[1]

This standard is issued under the fixed designation D5071; 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 specific procedures and test conditions that are applicable for xenon arc exposure of photodegradable plastics conducted in accordance with Practices G151 and G155. This practice also covers the preparation of test specimens, the test conditions best suited for photodegradable plastics, and the evaluation of test results.

1.2 *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 4892-2 and Practice D2565 which cover xenon arc exposures of plastics intended for long term use in outdoor applications.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D882 Test Method for Tensile Properties of Thin Plastic Sheeting

D883 Terminology Relating to Plastics

D1293 Test Methods for pH of Water

D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications

D3593 Test Method for Molecular Weight Averages/ Distribution of Certain Polymers by Liquid Size-Exclusion Chromatography (Gel Permeation Chromatography GPC) Using Universal Calibration (Withdrawn 1993)[3]

D3826 Practice for Determining Degradation End Point in Degradable Polyethylene and Polypropylene Using a Tensile Test

D3890 Test Method for Number of Strokes to Prime a Mechanical Pump Dispenser

D5870 Practice for Calculating Property Retention Index 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

G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

G169 Guide for Application of Basic Statistical Methods to Weathering Tests

2.2 *Other Standards:*

ISO 4892-2 Plastics—Method of Exposure to Laboratory Light Sources—Part 2, Xenon Arc Sources[4]

Publication C.I.E. No. 85 (1989)[5]

DIN 53384 Testing of Plastics: Artificial Weathering or Exposure in Laboratory Exposure Weathering or Exposure in Laboratory Exposure Apparatus to UV Radiation[4]

3. Terminology

3.1 *Definitions*—The definitions given in Terminologies D883 and G113 are applicable to this practice.

4. Significance and Use

4.1 Materials made from photodegradable plastics are intended to deteriorate rapidly when exposed to solar radiation, oxygen, heat, moisture and other degrading elements of the weather. This practice is used for evaluating the photodegradability of plastics when exposed in an apparatus that produces

[1] This practice is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.96 on Environmentally Degradable Plastics and Biobased Products.

Current edition approved April 1, 2013. Published April 2013. Originally approved in 1991. Last previous edition approved in 2006 as D5071 - 06. DOI: 10.1520/D5071-06R13.

[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.

[5] *Publication No. CIE 85, 1 st Ed., 1989 Technical Report*, "Solar Spectral Irradiance," available from U.S. National Committee CIE, Mr. Thomas M. Lemons, TLA-Lighting Consultants, Inc., 72 Loring Ave., Salem, MA 01970.

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

simulated daylight (**1**,**2**)[6] and controlled temperature and moisture. 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 salt water exposure. There can be no positive correlation of exposure results between this and other laboratory weathering devices.

4.2 Variations in results can be expected when operating conditions are varied within the accepted limits of this practice. Therefore, all test results using this practice must be accompanied by the specific operating conditions required in Section 9. Refer to Practice G151 for detailed information on the caveats applicable to use of results obtained in accordance with this practice.

4.3 The results of laboratory exposure cannot be directly extrapolated to estimate absolute rate of deterioration by the environment because the acceleration factor is material dependent and can be significantly different for each material and for different formulations of the same material. However, exposure of a similar material of known outdoor performance, a control, at the same time as the test specimens allows comparison of the durability relative to that of the control under the test conditions. Evaluation in terms of relative durabilities also greatly improves the agreement in test results among different laboratories (**3**).

4.4 Test results will depend on the care that is taken to operate the equipment in accordance with Practice G155. Significant factors include regulation of line voltage, freedom from salt or other deposits from water, temperature and humidity control and condition and age of the burners and filters.

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.

4.5 Before proceeding with this practice, it is common practice to reference the specifications of the material being tested. Any test specimen preparation, conditioning, dimensions, or testing parameters, or combination thereof, covered in the material specification shall take precedence over those mentioned in this practice. If there are no material specifications, then the default conditions apply.

5. Apparatus

5.1 The exposure apparatus employed shall use as the source of radiation a xenon arc lamp and apparatus which conforms to the requirements defined in Practices G151 and G155.

5.1.1 Unless otherwise specified, the spectral power distribution (SPD) of the xenon lamp shall conform to the requirements of Table 1 in Practice G155 for a xenon lamp with daylight filters.

6. Test Specimens

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 is covered. This unexposed surface must not be used as part of the test area. To provide rigidity, flexible specimens are typically attached to, or backed by, a panel made of aluminum, 0.025-in. (0.64-mm) thick.

6.2 Unless otherwise specified, prepare at least three replicate specimens of each test and control material to be exposed.

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

6.3.1 When destructive tests are used, it is recommended that a sufficient number of file specimens be retained so that the property of interest can be determined on the file specimens each time the exposed materials are evaluated.

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

6.5 Do not mask the face of a specimen for the purpose of showing on one panel the effects of various exposure times. Accurate results are not guaranteed since the masked portion of the specimen is still exposed to temperature and humidity cycles that, in many cases, will affect results.

6.6 In some materials, specimen thickness markedly affects the test results. Thickness of test and control specimens shall be within ±10 % of the nominal dimensions.

NOTE 3—Thickness of a specimen is especially important when mechanical properties are being investigated.

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 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, either reposition in accordance with the schedule agreed upon by all concerned parties, or randomly position replicate specimens and determine the average change in property. Determine irradiance uniformity in accordance with Practice G151.

[6] The boldface numbers in parentheses refer to a list of references at the end of this standard.

7.4 Table 1 describes three cycles that have been used for xenon arc exposure of photodegradable plastics. Unless otherwise specified, use Cycle 1 for exposure of materials that will be tested for toxicity after exposure. Obtain mutual agreement among all concerned parties for the specific exposure cycle to be used. Other test conditions can be used by mutual consent provided that the conditions are reported in conformance with Section 9. Different conditions can result in significant differences in test results.

7.4.1 Unless otherwise specified, operate the device so that the allowable deviation about the set point conditions given in Table 1 is within the limits specified in Table 2. 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.

7.5 Unless otherwise specified, do not remove specimens from the exposure apparatus for more than 24 h and then returned for additional testing, since this type of interruption can alter results. Report any elapsed time in accordance with Section 9.

NOTE 4—Since the stability of the file specimen can also be time-dependent, users are cautioned that over prolonged exposure periods, or when small differences in the order of acceptable limits are anticipated, comparison of exposed specimens with the file specimen are not guaranteed to be valid. Instrumental measurements are recommended whenever possible.

7.6 *Water Purity:*

7.6.1 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 are not typical in exterior exposures.

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

7.6.3 If specimens are found to have deposits or stains after exposure in the apparatus, check the water purity to determine if it meets the requirements of 7.6.2. On some occasions, exposed specimens are contaminated by deposits from bacteria that grow in the purified water used for specimen spray. If bacterial contamination is detected, flush the entire system used for specimen water spray with chlorine and thoroughly rinse prior to resuming exposures.

TABLE 1 Test Cycles Commonly Used for Xenon Arc Exposure of Photodegradable Plastics[A]

Cycle Number	Cycle Description[B,C,D]	Uninsulated Black Panel Temperature (°C)[C,D,E]	Typical Irradiance[B,C,D]	Typical Uses[F]
1	Continuous light	63	0.35 W/(m^2 · nm) at 340 nm 41.5 W/(m^2 · nm) from 300 – 400 nm 365 W/(m^2 · nm) from 300 – 800 nm	Required when exposed specimens will be used for toxicity tests
2	Continuous light using 102 min light only and 18 min light and water spray[G]	63	0.35 W/(m^2 · nm) at 340 nm 41.5 W/(m^2 · nm) from 300 – 400 nm 365 ± 20 W/(m^2 · nm) from 300 – 800 nm	Exposures when a slight moisture stress is desired[H]
3	18 h continuous light using 102 min light only and 18 min light and water spray[G]	63	0.35 W/(m^2 · nm) at 340 nm 41.5 W/(m^2 · nm) from 300 – 400 nm 365 W/(m^2 · nm) from 300 – 800 nm	Recommended when a dark period with high moisture stress is required
	6 h dark using: 95 % relative humidity (no water spray) repeated continuously	38		

[A] The cycles described are not listed in any order indicating importance, and are not necessarily recommended for the applications shown.
[B] As stated in 5.1.1, the SPD of the xenon lamp shall conform to the requirements of Practice G155 for a xenon lamp with daylight filters.
[C] Unless otherwise specified, operate the apparatus to maintain the specified operational fluctuations in Table 2 for the parameters in this table. 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.
[D] 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. 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.
[E] Unless otherwise indicated, black panel temperature applies during the light only portion of the cycle. The equilibrium black panel temperature is obtained without a spray period. In some instances, for light intervals less than 30 min, the maximum black panel temperature does not reach equilibrium.
[F] "Typical Uses" does not imply that results from exposures of these materials in accordance with the cycle described will correlate to those from actual use conditions.
[G] Unless otherwise specified, water spray refers to water sprayed on the exposed surface of the specimen.
[H] This cycle has been used for plastics by historical convention and an adequate simulation of the effects of outdoor exposure is not guaranteed. Other cycles can be used by mutual agreement.

TABLE 2 Operational Fluctuations on Exposure Conditions

Parameter	Maximum Allowable Deviation from the Set Point at the Control Point Indicated by the Readout of the Calibrated Control Sensor During Equilibrium Operation
Black Panel Temperature	±2.5°C
Chamber Air Temperature	±2°C
Relative Humidity	±5 %
Irradiance (monitored at 340 nm)	±0.02 W/(m^2 · nm)
Irradiance (monitored at 300–400 nm)	±2 W/m^2
Irradiance (monitored at 300–800 nm)	±20 W/m^2

7.6.4 When the water purity requirements above 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 Practice G151.

7.6.5 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 can be below the typical range given.

8. Period 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 can be used for the purpose of a specific test if agreed upon by 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 time to failure in each exposure can be analyzed using statistical methods.

NOTE 5—An example of a statistical analysis using multiple laboratory and exterior exposures to calculate an acceleration factor is described in Ref. (**4**). 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 applicable ASTM test methods. The degradation end point of polyolefins can be determined by a tensile test conducted in accordance with Practice D3826. Other properties that can be measured are molecular weight in accordance with Test Method D3593, and tensile strength and elongation in accordance with Test Method D882.

NOTE 6—For some materials, changes can continue after the specimen has been removed from the exposure apparatus. Measurements (visual or instrumental) are typically made within a standardized time period or as agreed upon between interested parties. Consider conditioning prior to testing, when determining the standardized time period.

8.4 *Use of Results from Exposures Conducted 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 Practices E691 or D3980 and include a statistically representative sample of all laboratories or organizations that 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. Expose all specimens 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 are statistically significant. Expose replicates of the test specimen

and the control system so that statistically significant performance differences can be determined.

NOTE 7—Use of rank comparison between test and control materials in specifications is illustrated in Ref. (5).

NOTE 8—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 material tested 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 there were any filter changes 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. Report any deviations from the operational fluctuations specified in Table 2,

9.1.7 Elapsed exposure time,

9.1.8 Light and dark water spray 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 in Table 2,

9.1.10 If relative humidity is controlled, report relative humidity set point. If light and dark periods employed, report the relative humidity set points for each period. Report any deviations from the operational fluctuations specified in Table 2,

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 in Table 2,

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 7.6,

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), and

9.1.15.1 Where retention of a 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 exposure 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 degradable plastics; exposure; photodegradable; ultraviolet radiation; xenon arc

REFERENCES

(1) Hirt, R.C., Schmitt, R.G., Searle, N.S., and Sullivan, A.P., "Ultraviolet Spectral Energy Distributions of Natural Sunlight and Accelerated Test Light Sources", *Journal of Optical Society of America*, 50, No. 7, 1960, pp. 706–13.

(2) Boettner, E.A., and Miedler, L.J., "Simulating the Solar Spectrum With a Filtered High Pressure Xenon Lamp", Applied Optics. 2, No. 1, January 1963 , pp. 105–108.

(3) 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 Douglass Grossman, eds., American Society for Testing and Materials, Philadelphia, 1993.

(4) Simms, J.A., "Acceleration Shift Factor and Its Use in Evaluating Weathering Data," *Journal of Coatings Technology*, Vol 59, 1987, pp. 45–53.

(5) Fischer, R., Ketola, W., "Impact of Research on Development of ASTM Durability Testing Standards," *Durability Testing of Non-Metallic Materials, ASTM STP 1294*, Robert Herling, ed., American Society for Testing and Materials, Philadelphia, 1995.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D5071 - 06) that may impact the use of this standard. (April 1, 2013)

(1) Performed five-year review and reapproved without changes.