Designation: D 5071 – 99

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

This standard is issued under the fixed designation D 5071; 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 according to Practices G 151 and G 155. This practice also covers the preparation of test specimens, the test conditions best suited for photodegradable plastics, and the evaluation of test results.

NOTE 1—The previous version of this standard referenced xenon arc devices described by Practice G 26, which described very specific equipment designs. Practice G 26 has been replaced by Practice G 151, which describes performance criteria for all exposure devices that use laboratory light sources and by Practice G 155, which gives requirements for exposing nonmetallic materials in xenon arc devices.

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 2—This practice is technically equivalent to ISO 4892-2 and Practice D 2565 which cover xenon arc exposures of plastics intended for long term use in outdoor applications.

2. Referenced Documents

2.1 *ASTM Standards:*

D 882 Test Methods for Tensile Properties of Thin Plastic Sheeting[2]

D 883 Terminology Relating to Plastics[2]

D 1293 Test Methods for pH of Water[3]

D 2565 Practice for Exposure of Plastics Intended for Outdoor Applications in a Xenon Arc Apparatus[4]

D 3593 Test Method for Molecular Weight Averages and Molecular Weight Distribution of Certain Polymers by Liquid Size-Exclusion Chromatography (Gel Permeation Chromatography (GPC) Using Universal Calibration[4]

D 3826 Practice for Determining Degradation End Point in Degradable Polyolefins Using a Tensile Test[4]

D 3890 Practice for Interlaboratory Testing of Pain and Related Materials[5]

D 5870 Practice for Calculating Property Retention Index of Plastics[4]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[6]

G 26 Practice for Operating Xenon Arc-Type Light Exposure Apparatus With and Without Water for Exposure of Nonmetallic Materials[6]

G 113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials[6]

G 141 Guide for Addressing Variability in Exposure Testing on Nonmetallic Materials[6]

G 147 Practice for Conditioning and Handling of Nonmetallic Materials[6]

G 151 Practice for Exposing Nonmetallic Materials in accelerated Test Devices that Use Laboratory Light Sources[6]

G 155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Nonmetallic Materials[6]

2.2 *Other Standards:*

ISO 4892-2 Plastics—Method of Exposure to Laboratory Light Sources—Part 2, Xenon Arc Sources[7]

Publication C.I.E No. 85 (1989)[8]

DIN 53384 Testing of Plastics: Artificial Weathering or Exposure in Laboratory Exposure Weathering or Exposure in Laboratory Exposure Apparatus to UV Radiation[7]

3. Terminology

3.1 *Definitions*—The definitions given in Terminologies D 883 and G 113 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,

[1] This practice is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.96 on Environmentally Degradable Plastics.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 11.01.

[4] *Annual Book of ASTM Standards*, Vol 08.03.

[5] *Annual Book of ASTM Standards*, Vol 06.01.

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

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

[8] *Publication No. CIE 85, 1st 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.**

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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 simulated daylight (**1,2**)[9] 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 may be no positive correlation of exposure results between this and other laboratory weathering devices.

4.2 Variations in results may 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 G 151 for detailed information on the caveats applicable to use of results obtained according to 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 according to Practice G 155. 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 3—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 G 141.

4.5 Before proceeding with this practice, reference should be made to 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 G 151 and G 155.

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 G 155 for a xenon lamp with daylight filters.

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

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 should be 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. When destructive tests are used for property measurements, a separate set of each test and control material must be prepared for each exposure increment that will be used.

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 Specimens should not be removed from the exposure apparatus for more than 24 h and then returned for additional tests, since this type of interruption may alter results. When specimens are removed from the apparatus exposure for 24 h or more then returned for additional exposure, report the elapsed time in accordance with Section 10.

NOTE 4—Since the stability of the file specimen may 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 may not be valid. Instrumental measurements are recommended whenever possible.

6.5 Follow the procedures described in Practice G 147 for identification and conditioning and handling of specimens of test, control, 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 since the marked 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 5—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.

7.2 Mount the test specimens in the specimen racks with the test surfaces facing the lamp. When the test specimens do not

completely fill the racks, 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 according to 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 G 151.

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 may be used by mutual consent provided that the conditions are reported in conformance with Section 9. Different conditions may result in significant differences in test results.

7.4.1 Unless otherwise specified, control the irradiance to produce either: (*1*) 0.35 ± 0.02 W/m^2 at 340 nm, (*2*) 41.5 ± 2.5 W/m^2 between 300 and 400 nm, or (*3*) 365 ± 20 W/m^2 between 300 and 800 nm. If the exposure device is not equipped with irradiance control, follow the device manufacturer's recommendations to produce this irradiance, or other specified irradiance level.

7.4.2 Unless otherwise specified, the equilibrium temperature of an uninsulated black panel thermometer is 63 ± 2.5°C.

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

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

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 may not occur in exterior exposures.

7.6.2 Follow the requirements for water purity described in Practice G 151.

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.

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 G 151.

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 may 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

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

Cycle Number	Cycle Description[B]	Uninsulated Black Panel Temperature (°C)[C]	Typical Irradiance	Typical Uses[D]
1	Continuous light	63 ± 2	0.35 ± 0.02 W/m^2 at 340 nm 41.5 ± 2.5 W/m^2 from 300 – 400 nm 365 ± 20 W/m^2 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[E]	63 ± 2	0.35 ± 0.02 W/m^2 at 340 nm 41.5 ± 2.5 W/m^2 from 300 – 400 nm 365 ± 20 W/m^2 from 300 – 800 nm	Exposures when a slight moisture stress is desired[F]
3	18 h continuous light using 102 min light only and 18 min light and water spray[E]	63 ± 2	0.35 ± 0.02 W/m^2 at 340 nm 41.5 ± 2.5 W/m^2 from 300 – 400 nm 365 ± 20 W/m^2 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 ± 2		

[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 G 155 for a xenon lamp with daylight filters.
[C] 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. For light intervals less than 30 min, the maximum black panel temperature may not reach equilibrium.
[D] "Typical Uses" does not imply that results from exposures of these materials according to the cycle described will correlate to those from actual use conditions.
[E] Unless otherwise specified, water spray refers to water sprayed on the exposed surface of the specimen.
[F] This cycle has been used for plastics by historical convention and may not adequately simulate of the effects of outdoor exposure. Other cycles may be used by mutual agreement.

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 according to 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 according to 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 6—An example of a statistical analysis using multiple laboratory and exterior exposures to calculate an acceleration factor is described in Ref. (**4**). See Practice G 151 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 according to applicable ASTM test methods. The degradation end point of polyolefins can be determined by a tensile test conducted in accordance with Practice D 3826. Other properties that can be measured are molecular weight in accordance with Test Method D 3593, and tensile strength and elongation in accordance with Test Method D 882.

NOTE 7—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 interested parties. Consider conditioning prior to testing, when determining the standardized time period.

8.4 *Use of Results from Exposures Conducted According to 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 according to 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 according to Practices E 691 or D 3980 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 according to 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 according to 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 8—Use of rank comparison between test and control materials in specifications is illustrated in Ref. (**5**).

NOTE 9—ASTM Committee G-3 on Weathering and Durability is developing a standard guide for application of basic statistical methods to weathering tests, that will include 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 required, and only if direct measurement of irradiance was made during the exposure, irradiance in W/m^2 or radiant exposure in J/m^2 at the sample plane, and the wavelength region in which the measurements were made,

9.1.6 Elapsed exposure time,

9.1.7 Cycle employed,

9.1.8 Type of black panel used and operating black panel temperature,

9.1.9 Operating relative humidity, if used,

9.1.10 Type of spray water, if used, and total solids and silica level of water used for specimen spray, if above limits specified in 7.4.

9.1.11 Type of spray nozzle,

9.1.12 Specimen repositioning procedure, and

9.1.13 Results of property tests, including a reference to relevant ASTM standards used, or a description of the method used to measure the property reported. Calculate retention of characteristic property according to Practice D 5780 when it is reported.

10. Precision and Bias

10.1 *Precision*—The repeatability and reproducibility of results obtained in exposure conducted according to 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 according to 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.

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(**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

This section identifies the location of selected changes to this practice. For the convenience of the user, Committee D-20 has highlighted those changes that may impact the use of this practice. This section may include descriptions of the changes or the reasons for the changes, or both.

D 5017 – 99:

(*1*) Complete rewrite of the previous version.

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