Designation: D5272 – 08 (Reapproved 2021)

Standard Practice for Outdoor Exposure Testing of Photodegradable Plastics[1]

This standard is issued under the fixed designation D5272; 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 defines test conditions applicable when Practices D1435 and G7/G7M are employed for the outdoor exposure testing of photodegradable plastics.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—There is no known ISO equivalent to this standard.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D882 Test Method for Tensile Properties of Thin Plastic Sheeting
D883 Terminology Relating to Plastics
D1435 Practice for Outdoor Weathering of Plastics
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Polymers by Liquid Size-Exclusion Chromatography (Gel Permeation Chromatography GPC) Using Universal Calibration (Withdrawn 1993)[3]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
E772 Terminology of Solar Energy Conversion
G7/G7M Practice for Natural Weathering of Materials
G169 Guide for Application of Basic Statistical Methods to Weathering Tests
G183 Practice for Field Use of Pyranometers, Pyrheliometers and UV Radiometers

3. Terminology

3.1 The terminology given in Terminology E772 and Terminology D883 is applicable to this practice.

4. Significance and Use

4.1 When discarded as litter, articles made using photodegradable plastics are subject to attack by daylight (particularly solar-ultraviolet radiation), oxygen, heat, and water. The 5° exposure angle used in this practice represents typical conditions for degradation experienced by litter.

4.2 This practice requires characterization of the duration of exposure in terms of solar-ultraviolet radiation. Solar-ultraviolet radiation varies considerably as a function of location and time of year. This can cause dramatic differences in the time required to produce a specified level of degradation in a polymer. Daro[4] has shown that when the same lot of polyethylene containing an iron-salt prodegradant is exposed at various times of the year in a single location, the time required to produce an average of two chain scissions per molecule varied by over 130 %. Daro, and Zerlaut and Anderson[5] have shown that this variability can be significantly reduced when total solar or solar-ultraviolet radiation, or both, is used to characterize the exposure increments.

4.3 In addition to variations in level of daylight and solar-ultraviolet radiation, there are significant differences in temperature, and moisture stresses between different locations, and between different years, or periods within a single year, at a single location. Because of this variability, results from this test cannot be used to predict the absolute rate at which photodegradable plastics degrade. Results from this test can be used to compare relative rates of degradation for materials exposed at the same time in the same location. Results from

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[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] Daro, A., et al, "Degradation of Polymer Blends IV, Natural Weathering of Low Density and Linear Low Density Polyethylene," *European Polymer Journal*, Vol 26, No. 1, 1990, pp. 47–52.

[5] Zerlaut, G. L., and Anderson, T. A., "Ultraviolet Radiation as a Timing Technique for Outdoor Weathering of Materials," Society of Automotive Engineers, *SAE Technical Paper Number 850348* , 1985.

multiple exposures of a common lot of material (during different seasons over several years) at different sites can be used to compare the relative rates at which a particular photodegradable plastic will degrade in each location.

NOTE 2—An inherent limitation in solar-radiation measurements is that they do not reflect the effects of variations in temperature and moisture exposure, which often can be as important as solar radiation. The same solar-ultraviolet radiation increment will not necessarily give the same changes in properties of the test specimen in different exposure sites. Results from this practice must be regarded as giving only a general indication of the degree of degradability and should always be considered in terms of characteristics of the exposure site as well.

4.4 Where measurement of total solar-ultraviolet radiation is not possible, exposure duration can be determined by the number of days, weeks, or months exposed. When this practice is used, a reference material whose degradation properties have been well established must be exposed at the same time as the other materials being tested. The reference material used must be agreed upon by all interested parties. The time to produce a specified level of degradation for each material in this simultaneous exposure is then compared. It is also a good practice to use reference materials when exposure length is determined by total solar or solar UV radiant exposure.

NOTE 3—A reference material can be a single lot of material which has shown consistent results after a number of exposures. It is not necessary that the composition or properties of the reference material be characterized and certified by a recognized standards agency or group.

5. Apparatus

5.1 Use exposure racks constructed in accordance with the requirements of Practice G7/G7M. Unless otherwise specified, position the exposure racks so that specimens face the equator and so that the exposed surfaces are 5° from the horizontal. If other exposure rack orientations are used, they must be reported.

5.2 Use one of the following rack constructions for exposing photodegradable plastic specimens:

5.2.1 *Exposure Rack A*—Positionable mounting bars used for attaching specimens shall be arrayed over a regular mesh expanded-metal (aluminum or stainless steel) sheet backing. Use 16–18 gage metal with approximately 0.5-in. openings. It is recommended that the surface area of the expanded metal be 60 to 70 % open. Use a noncorroding material for the mounting bars. 6061T6 aluminum or untreated wood are typical materials used for the mounting bars. Fig. 1 is a top view showing typical rack construction.

5.2.2 *Exposure Rack B*—Unpainted exterior-grade plywood forms the rack surface to which specimens are directly attached. Replace the plywood when there is any evidence of delamination or fiber separation which could produce sharp edges and damage exposed specimens. Medium-density overlay (MDO) or high-density overlay (HDO) plywood are satisfactory substrates and will require less frequent replacement than plywood with no overlay.

NOTE 4—There is less air circulation around the specimens when Rack B exposures are used. Degradation rates from exposures using Rack B will be somewhat faster than those using Rack A because specimen temperatures will be higher. Comparisons between materials should only be made with exposures conducted at the same time and using the same rack type.

5.3 *Solar Radiometers:*

5.3.1 *Ultraviolet Radiometer*—Unless otherwise specified, use a total UV radiometer that measures ultraviolet radiation from 295 to 385 mm. Operate the radiometer in accordance with Practice G183. Narrow band radiometers (for example, with 20 nm bandpass) can also be used if agreed upon by all interested parties. Operate narrow band radiometers in accordance with Practice G183.

NOTE 5—The use of narrow band filter UV radiometers having selective spectral sensitivity may not be sensitive to all variations of solar-ultraviolet radiation. Monitoring at a narrow band (for example, 20 nm) may not relate to the total photodegradation of the plastic material, which is a result of a complex interaction of many factors, including sensitivity across a broad wavelength region.

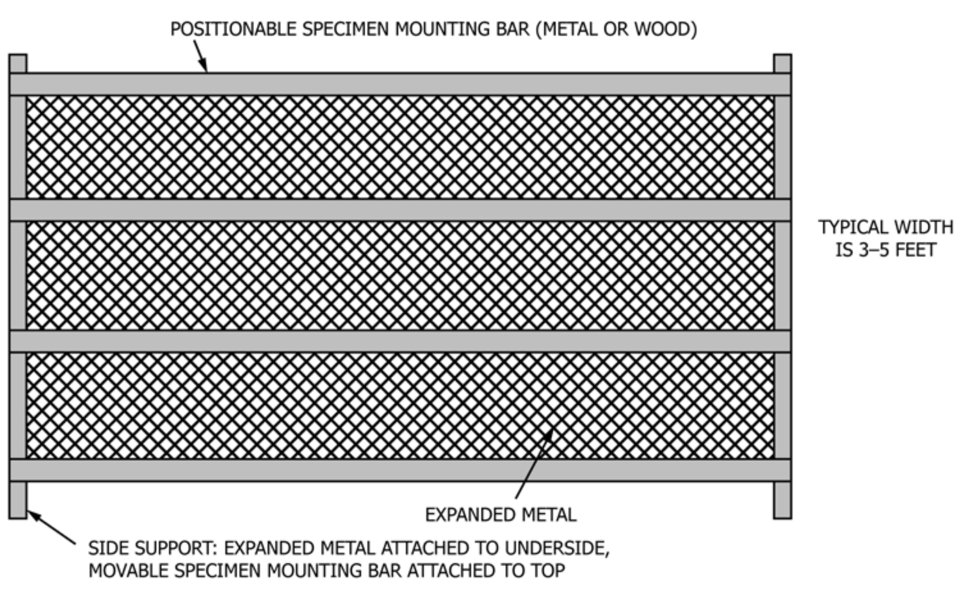

FIG. 1 Typical Rack Construction for Exterior Exposures of Photodegradable Plastics

6. Sampling

6.1 Sample using a statistically acceptable procedure agreed upon by interested parties.

7. Procedure

7.1 Attach the ends of specimens of photodegradable plastic to be exposed to the positionable mounting bars or plywood rack. Films or specimens that are nearly flat can be attached using a pressure sensitive tape with a durable adhesive and backing. Staples may be used with plywood racks or with wood mounting bars. Specimens with odd shapes can be attached directly to the expanded metal or plywood using nonferrous bolts and large washers or by any other suitable method. Ensure that the test specimens are inscribed or otherwise labeled with an identifying number, letter, or symbol. Expose at least three replicate specimens for each material and exposure increment used.

NOTE 6—Pressure sensitive tapes with aluminum foil backing and acrylic pressure sensitive adhesives have been found to be suitable for attaching flat films and specimens to the exposure rack.

7.2 Ensure that the UV radiometer is mounted at an angle of 5° from the horizontal, facing the equator. If specimens are exposed at a different angle, mount the UV radiometer at the same angle as the specimens.

7.3 Mount the specimens on the exposure rack for the time desired to produce the prescribed level of total solar-ultraviolet radiation. It is recommended that a series of exposure increments be used for each material being tested to determine the rate of degradation as a function of total solar or solar-ultraviolet radiant energy dose. Table 1 shows monthly and annual average total solar-ultraviolet radiation incident on 5° surfaces in representative humid subtropical and desert climates.

7.4 If total ultraviolet radiant energy is used to determine exposure increments, measure the increments using the instrumentation in accordance with 5.3.1. Express total solar-ultraviolet exposures in joules per square metre, with data reported to four significant figures. If agreed on by all interested parties, the ultraviolet radiant energy in specified narrow wavelength intervals (or bands) that closely conform to spectral regions where the plastic material is most sensitive may also be employed to follow exposure increments.

7.5 After specimens are exposed for the desired amount of total solar-ultraviolet radiation, measure the specified property or properties. Typical properties measured are molecular weight (in accordance with Test Method D3593) and tensile strength and elongation (in accordance with Test Methods D882). For polyolefins, degree of oxidation can be monitored using a carbonyl index, which is the ratio of carbonyl infrared absorbance at approximately 1715 cm^{-1} to an invariant absorbance characteristic of the polymer (for example, C-H stretch at approximately 3000–2840 cm^{-1}). The degradation end point of polyolefins can be determined by a tensile test in accordance with Practice D3826. Measure the same properties of an unexposed specimen of each material being tested. If a reference material is used, determine its properties and express the time to degradation for all other materials as a function of the time to produce a specific degree of degradation in the reference material.

NOTE 7—Guide G169 provides information about using statistical analysis techniques to compare properties of exposed and unexposed specimens.

TABLE 1 Average Monthly Solar-Ultraviolet Radiation (295 to 385 nm) on a 5° Surface[A]

NOTE 1—The climate data for Miami also meets the criteria for a tropical summer rain climate given in the Koppen Climate Classification System.

Month	Average Solar-Ultraviolet Radiation (MJ/m^2, 295–385 nm)	
	Subtropical Climate Miami, FL (26°N latitude)	Desert Climate Phoenix, AZ (34°N latitude)
January	19.6	16.6
February	21.6	19.5
March	28.4	29.0
April	32.2	36.1
May	33.3	41.1
June	28.6	41.7
July	29.8	40.3
August	27.6	37.7
September	24.7	32.1
October	23.5	25.7
November	18.7	18.0
December	17.5	15.3
Annual	305.5	352.5

[A]Data in this table are the averages for monthly total solar UV radiation data reported from 1985 to 2005.

8. Report

8.1 Report the following information for each material exposed:

8.1.1 Complete identification and description (for example, dimensions) of material tested.

8.1.2 Location of exposure and type of exposure rack used.

8.1.2.1 Any exposure angle other than 5°.

8.1.3 Dates exposure started and completed.

8.1.3.1 Total time exposed (expressed in days, weeks, or months).

8.1.4 Solar-ultraviolet radiant exposure:

8.1.4.1 If total ultraviolet radiation is used, it shall be expressed in joules per square metre. Record manufacturer and model of UV radiometer employed, date of last calibration, and calibrating laboratory.

8.1.5 General appearance and results of tests used to characterize the properties on unexposed samples of each material being exposed.

8.1.6 General appearance and results of tests used to characterize the properties of specimens from each exposure increment. Report the average and standard deviation from each test used to measure properties of replicate specimens.

8.1.7 Complete description or reference to characterization tests used to evaluate material properties.

9. Precision and Bias

9.1 It is not practicable to specify the precision of the procedure in this practice because it is dependent upon the ASTM test methods used to determine the specific properties being measured. The precision and bias for the individual test