Designation: D 5272 – 92 (Reapproved 1999)

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

This standard is issued under the fixed designation D 5272; 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 D 1435 and G 7 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 and health practices and determine the applicability of regulatory limitations prior to use.*

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

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 1435 Practice for Outdoor Weathering of Plastics[2]

D 1898 Practice for Sampling of Plastics[2]

D 3593 Test Method for Molecular Weight Averages and Molecular Weight Distribution of Certain Polymers by Liquid Size-Exclusion Chromatography (Gel Permeation Chromatograph GPC) Using Universal Calibration[3]

D 3826 Practice for Determining Degradation End Point in Degradable Polyolefins Using a Tensile Test[3]

E 772 Terminology Relating to Solar Energy Conversion[4]

G 7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials[5]

3. Terminology

3.1 The terminology given in Terminology E 772 and Terminology D 883 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[6] 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[7] 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 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

[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 08.02.

[4] *Annual Book of ASTM Standards*, Vol 12.02.

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

[6] 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.

[7] 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.

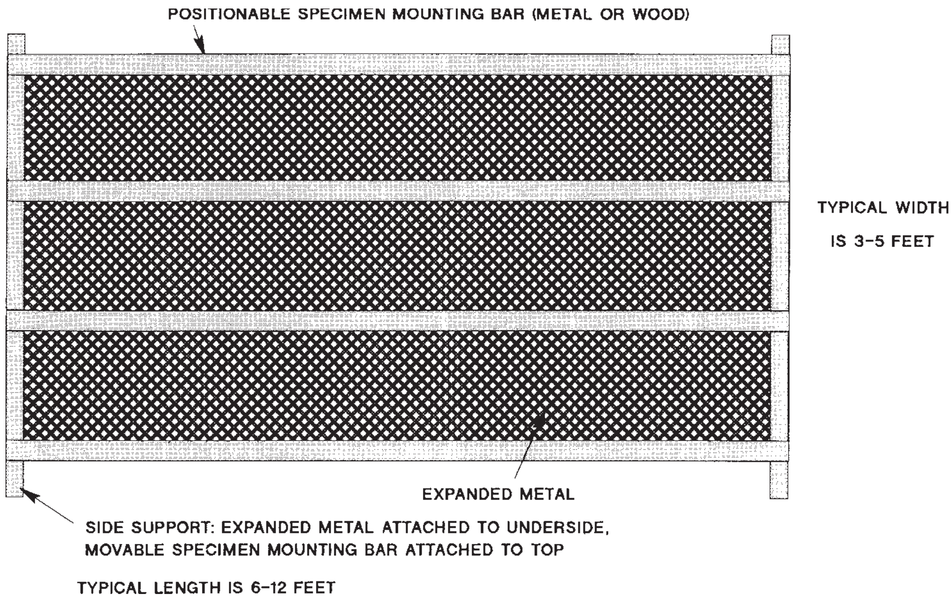

FIG. 1 Typical Rack Construction for Exterior Exposures of Photodegradable Plastics

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 G 7. 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*—A total ultraviolet (UV) radiometer that measures ultraviolet radiation in the wavelength region from 295 to 385 nm should be used.[8] Calibrate the radiometer in suitable radiometric units, preferably in watts per square metre per volt (Wm^{-2} V^{-1}), and shall be maintained in at least semiannual calibration against a standard source of special irradiance.[9] Narrow band radiometers (for example, with 20 nm bandpass) can also be used if agreed upon by all interested parties. Narrow band radiometers must also be calibrated at least semiannually against a standard source of spectral irradiance. A certificate of calibration shall be provided with all total solar-ultraviolet or narrow band irradiance measurements. It is recommended that calibrations be traceable to a recognized national standards agency such as the National Institute for Science and Technology in the United States.

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.

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[8] Model TUVR Total Ultraviolet Radiometer manufactured by the Eppley Laboratory, 12 Sheffield Ave., Newport, RI 02804, has been found to be suitable for this purpose when maintained in frequent calibration.

[9] Suitable calibrations may be obtained from some manufacturers, and from the Eppley Laboratory, 12 Sheffield Ave., Newport, RI 02804.

6. Sampling

6.1 Sample in accordance with Practice D 1898.

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

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	16.9	16.4
February	19.6	19.4
March	23.6	28.5
April	31.7	36.3
May	33.8	41.3
June	32.0	40.4
July	31.0	39.1
August	28.3	37.2
September	26.2	30.9
October	23.2	24.5
November	16.0	17.8
December	16.1	14.5
Annual	301.4	346.3

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.[10] 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. Make sure 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.

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

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 to determine the level of degradation. Typical properties measured are molecular weight (in accordance with Test Method D 3593) and tensile strength and elongation (in accordance with Test Methods D 882). 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 D 3826. 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.

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 methods can be used in the analysis of data from exposures used to assess the differences in materials.

9.2 Because of the variability in solar radiation, temperature, and moisture levels between sites and between different times at the same site, results from this practice should only be used to compare relative rates of degradation for materials *exposed at the same time in the same location using the same exposure rack construction.*

[10] Number 425 aluminum foil tape from 3M, Building 220-8E, 3M Center, St. Paul, MN 55144 (612-736-1413) is satisfactory.

10. Keywords

10.1 aging; degradable plastic; exterior exposure; outdoor exposure; photodegradation; ultraviolet radiation; weathering