Designation: D4141 – 07

StandardPractice for Conducting Black Box and Solar Concentrating Exposures of Coatings[1]

This standard is issued under the fixed designation D4141; 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 two accelerated outdoor exposure procedures for evaluating the exterior durability of coatings applied to substrates.

1.2 The two procedures are as follows:

1.2.1 *Procedure A*—Black Box Exposure.

1.2.2 *Procedure C*—Fresnel Reflector Rack Exposure.

NOTE 1—Procedure B described a Heated Black Box procedure that is no longer in common use.

1.3 This standard does not cover all the procedures that are available to the user for accelerating the outdoor exposure of coatings. Other procedures have been used in order to provide a particular effect; however, the two procedures described here are widely used.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D523 Test Method for Specular Gloss

D660 Test Method for Evaluating Degree of Checking of Exterior Paints

D661 Test Method for Evaluating Degree of Cracking of Exterior Paints

D662 Test Method for Evaluating Degree of Erosion of Exterior Paints

D714 Test Method for Evaluating Degree of Blistering of Paints

D772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints

D823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels

D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

D4214 Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films

D7091 Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals

G7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials

G90 Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight

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

G169 Guide for Application of Basic Statistical Methods to Weathering Tests

3. Terminology

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

4. Summary of Practice

4.1 Several procedures are described that provide acceleration of the degradation that coatings evidence during natural weathering when exposed on an open rack at a fixed angle. The procedures appear in the following order:

4.1.1 *Procedure A*—Exposure on a black box rack facing the equator at 5° from the horizontal.

4.1.2 *Procedure C*—Exposure on a Fresnel reflector rack that provides a high irradiance by following the sun and concentrating sunlight on the test specimens by means of mirrors. The specimens are wet periodically by high purity water spray.

[1] This practice is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.27 on Accelerated Testing.

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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.

4.2 The selection of Procedure A or C is dependent on several factors.

4.2.1 Procedure A is designed to simulate the weathering that occurs on horizontal insulated surfaces. Specimens are typically flat-coated metal panels measuring 10 by 30 cm (4 by 12 in.) or 15 by 30 cm (6 by 12 in.).

NOTE 2—Procedure A is specified in standards used by the automotive industry.

4.2.2 Procedure C is designed to simulate weathering on both automotive and nonautomotive products. Procedure C typically provides faster results than Procedure A on a calendar basis.[3]

5. Significance and Use

5.1 As with any accelerated test, the increase in rate of weathering compared to in service exposure is material dependent. Therefore, no single acceleration factor can be used to relate two different types of outdoor weathering exposures. The durability rankings of coatings provided by these two procedures may not agree when coatings differing in composition are compared. These two procedures should not be used interchangeably.

5.2 The procedures described in this practice are designed to provide greater degradation rates of coatings than those provided by fixed angle open-rack outdoor exposure racks. For many products, fixed angle exposures will produce higher degradation rates than the normal end use of the material.

5.2.1 The use of Procedure A (Black Box) instead of an open-rack direct exposure is a more realistic test for materials with higher temperature end use service conditions.

NOTE 3—*Procedure A (Black Box)*—For many coatings, this procedure provides greater rates of degradation than those provided by 5°, equator-facing, open-rack exposures because the black box produces higher specimen temperatures during irradiation by daylight and longer time of wetness. The black box specimen temperatures are comparable to those encountered on the hoods, roofs, and deck lids of automobiles parked sunlight. The relative rates of gloss loss and color change produced in some automotive coatings by exposures in accordance with Procedure A are given in ASTM STP 781.[4]

NOTE 4—*Procedure C (Fresnel Reflector Rack)*—The acceleration of Procedure C is produced by reflecting sunlight from ten mirrors onto an air-cooled specimen area. In the ultraviolet portion of the solar spectrum, approximately 1400 MJ/m^2 of ultraviolet radiant exposure (295 to 385 nm) is received over a typical one-year period when these devices are operated in a central Arizona climate. This compares with approximately 333 MJ/m^2 of ultraviolet radiant exposure from a central Arizona at-latitude exposure and 280 MJ/m^2 of ultraviolet radiant exposure from a southern Florida at-latitude exposure over the same time period. However, the test described by Procedure C reflects only direct beam radiation onto test specimens. The reflected direct beam sunlight contains a lower percentage of short wavelength ultraviolet radiation than global daylight because short wavelength ultraviolet is more easily scattered by the atmosphere, and because mirrors are typically less efficient at shorter ultraviolet wavelengths. Ultraviolet radiant exposure levels should not be used to compute acceleration factors since acceleration is material dependent.

5.3 The durability of coatings in outdoor use can be very different depending on the location of the exposure because of differences in ultraviolet (UV) radiation, time of wetness, temperature, pollutants, and other factors. Therefore, it cannot be assumed that results from one exposure in a single location will be useful for determining relative durability in a different location. Exposures in several locations with different climates that represent a broad range of anticipated service conditions are recommended.

5.4 Because of year-to-year climatological variations, results from a single exposure test cannot be used to predict the absolute rate at which a material degrades.

NOTE 5—Several years of repeat exposures are typically needed to get an "average" test result for a given location.

5.4.1 The degradation profile for many polymers is not a linear function of exposure time or radiant exposure. When short exposures are used to predict the service life or as indications of durability, the results obtained may not be representative of those from longer exposures.

NOTE 6—Guide G141 provides information for addressing variability in exposure testing of nonmetallic materials. Guide G169 provides information for applying statistics to exposure test results.

5.5 It is recommended that at least one control material be part of any exposure evaluation. Control materials are used for comparing the performance of the test materials relative to the controls when materials are not being ranked against one another. The control material used should be of similar composition and construction to the test materials and be of known durability. It is preferable to use two control materials, one with relatively good durability and one with poor durability.

6. Test Specimens

6.1 Each test specimen and control specimen shall consist of a uniform coating applied to the surface of a rigid panel. Suitable application procedures are given in Practices D823.

6.2 Use flat specimens, because warpage, waviness, or curvature may seriously affect the measurements of gloss and color and may produce a poor air seal on the black box rack.

6.3 For Procedure C, specimen sizes are typically limited to a maximum of 13 cm (5 in.) in one dimension, and a maximum of 140 cm (55 in.) in the other dimension. However, specimens are typically 7.5 by 13 cm (3 by 5 in.) or 5 by 13 cm (2 by 5 in.). Because air cooling is used to prevent high specimen temperatures, specimens must be flat. A thickness of less than 0.6 cm (0.25 in.) is preferred. This practice may not apply to specimens thicker than 1.3 cm (0.5 in.) because cooling may be questionable.

6.4 Prepare controls for inclusion in each exposure series to act as comparison standards and to provide a means for determining the severity of the exposure conditions encountered by the series. For best results, there should be at least two controls differing in their durability performance.

6.5 Optionally, using Test Method D7091, measure the dry film thickness of the coatings at several different positions on the test specimens.

[3] Zerlaut, G.A., Rupp, M.W., and Anderson, T.E., "Ultraviolet Radiation as a Timing Technique for Outdoor Weathering of Materials," Paper 850378, *Proceedings*, SAE International Congress, Detroit, February 25, 1985.

[4] Symposium on Permanence of Organic Coatings, *ASTM STP 781*, ASTM, 1982.

6.6 Unless otherwise specified, expose at least two replicates. Larger numbers of replicates are recommended.

PROCEDURE A—BLACK BOX EXPOSURE

7. Apparatus

7.1 *Black Box,* constructed of materials in accordance with Practice G7, or its equivalent, and positioned so that the surfaces of the test specimens are 5° from the horizontal, facing the equator (Figs. 1 and 2).

8. Procedure

8.1 Use Practice G147 for specimen handling and conditioning procedures for test specimens.

8.2 If a change in gloss is to be measured, determine the specular gloss value for each unexposed specimen using a properly calibrated glossmeter in accordance with Test Method D523.

8.3 If a change in color is to be measured, determine the delta (change in) color coordinates for each unexposed specimen using Practice D2244. Unless otherwise agreed upon, use the CIE Lab Color Scale. The color measuring instrument shall be stable and properly calibrated.

NOTE 7—As an alternative procedure, reserve unexposed duplicate specimen panels of each coating as file specimens to determine the color change of the exposed specimens. To minimize color drift, store the panels in a dark, room-temperature environment.

8.4 Mount and fasten the specimens on the exposure box. Cover all empty spaces on the black box using black panels so that the entire surface is covered.

NOTE 8—The predominant color of the specimens on the black box should be noted. A black box will attain a lower temperature if all the other specimens are white than if the other specimens are black.

8.4.1 Non-rigid specimens shall be backed to keep specimens from sagging and to ensure that there are no gaps between specimens. The backing material used can be either flattened-mesh expanded metal sheet or solid sheet made from a corrosion-resistant material such as aluminum or stainless steel. If specimens are backed, the backing material used shall be specified in the report.

FIG. 1 Black Box in Use (from Practice G7)

8.5 Expose the test and control specimens for a specified period of time on the basis of one of the following:

8.5.1 Expose for a specified number of days, months, or years with respect to an agreed upon starting date.

8.5.2 Expose for a specified quantity of radiant exposure either total, typically measured from 300 to 3000 nm, or ultraviolet, typically measured from 295 to 385 nm. When solar ultraviolet radiation is measured, use a total ultraviolet radiometer that measures ultraviolet in the wavelength region from 295 to 385 nm. Optionally, ultraviolet can be measured in the wavelength region from 300 to 400 nm. Calibrate the radiometer and readout system in suitable radiometric units, and maintain in at least annual calibration against a standard source of spectral irradiance.

8.5.3 Expose until a specified change has occurred in the test specimens.

8.5.4 Expose until a specified change has occurred in a control exposed with the test specimens.

8.5.5 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 time or radiant exposure.

8.6 Unless otherwise agreed upon, remove the test specimens from the black box and gently wash a portion of the specimen surfaces to remove loose dirt. The same portion of the specimen should be washed at each interval of exposure. A suitable procedure consists of gentle rubbing with a sponge wet with high purity water or a dilute solution of a nonionic detergent, followed by a high purity water rinse. The high-purity water shall meet as a minimum the requirements for water purity contained in Practice G90.

8.7 If required, perform one or more of the following tests on the washed portion of each washed specimen:

8.7.1 Measure the specular gloss in accordance with Test Method D523.

8.7.2 Calculate the color difference in accordance with Practice D2244 based on instrumental measurements of color before and after exposure.

8.7.3 Evaluate checking and cracking rating in accordance with Test Methods D660 and D661.

8.7.4 Evaluate blistering rating in accordance with Test Method D714.

8.7.5 Evaluate erosion rating in accordance with Test Method D662.

8.7.6 Evaluate flaking rating in accordance with Test Method D772.

8.7.7 Use any other agreed upon test methods for evaluating specimens.

8.8 If required, perform a chalk rating in accordance with Test Methods D4214 on an unwashed area of each specimen.