Designation: D 4141 – 01

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

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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 B* has been deleted from this practice.

1.2.3 *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:*

D 523 Test Method for Specular Gloss[2]

D 660 Test Method for Evaluating Degree of Checking of Exterior Paints[2]

D 661 Test Method for Evaluating Degree of Cracking of Exterior Paints[2]

D 662 Test Method for Evaluating Degree of Erosion of Exterior Paints[2]

D 714 Test Method for Evaluating Degree of Blistering of Paints[2]

D 772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints[2]

D 823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[2]

D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[2]

D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base[2]

D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[2]

D 4214 Test Methods for Evaluating Degree of Chalking of Exterior Paint Films[2]

G 7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials[3]

G 90 Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight[3]

G 113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials[3]

G 141 Guide for Addressing Variability in Exposure Testing of Nonmetallic Materials[3]

G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests[3]

3. Terminology

3.1 The definitions given in Terminology G 113 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 reflecting sunlight on the test specimens by means of mirrors. The specimens are wet periodically by high purity water spray.

4.2 Each of these procedures requires that coated test panels be placed on devices of specified design and be exposed under specified conditions of weathering.

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

4.3.1 Procedure A is designed to simulate the weathering

[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 Tests for Protective Coatings.

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

[3] *Annual Book of ASTM Standards*, Vol 14.04.

that occurs on horizontal automotive surfaces, and is specified in standards used by the automotive industry. 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.).

4.3.2 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.[4]

5. Significance and Use

5.1 As with any accelerated test, the difference in rate of weathering is material dependent and no single exposure factor can be used to compare two different weathering exposures. The durability rankings of coatings provided by these two procedures may not agree when coatings differing widely in composition are compared. These two procedures should not be used interchangeably or used for absolute comparison to each other.

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 2—*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 in unfiltered daylight. 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.[5]

NOTE 3—*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 relative 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. Several years of repeat exposures are 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 relative durability, the results obtained may not be representative of those from longer exposures.

NOTE 4—Guide G 141 provides information for addressing variability in exposure testing of nonmetallic materials. ASTM G03 Committee is developing a standard guide for application of 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 Practice D 823.

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 Methods D 1186 or Test Method D 1400, measure the dry film thickness of the coatings at several different positions on the test specimens.

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

[4] 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.

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

PROCEDURE A—BLACK BOX EXPOSURE

7. Apparatus

7.1 *Black Box*, constructed of materials in accordance with Practice G 7, or its equivalent, and positioned so that the surfaces of the test specimens are 5° from the horizontal, facing the equator.

8. Procedure

8.1 Use Practice G 147 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 D 523.

8.3 If a change in color is to be measured, determine the color coordinates for each unexposed specimen using Test Method D 2244. Unless otherwise agreed upon, use the CIE Lab Color Scale. The color measuring instrument shall be stable and properly calibrated.

NOTE 5—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 6—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.

8.5 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 G 90.

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 D 523.

8.7.2 Calculate the color difference in accordance with Test Method D 2244 based on instrumental measurements of color before and after exposure.

8.7.3 Evaluate checking and cracking rating in accordance with Test Methods D 660 and D 661.

8.7.4 Evaluate blistering rating in accordance with Test Method D 714.

8.7.5 Evaluate erosion rating in accordance with Test Method D 662.

8.7.6 Evaluate flaking rating in accordance with Test Method D 772.

8.8 If required, perform a chalk rating in accordance with Test Methods D 4214 on an unwashed area of each specimen.

PROCEDURE C—FRESNEL REFLECTOR RACK EXPOSURE

9. Apparatus

9.1 *Fresnel Reflector Exposure Rack*, that follows the sun, concentrates sunlight on the test specimens by means of mirrors, and sprays high purity water on the surfaces of test specimens at specified intervals. The rack shall have provisions for cooling the test specimens while they are irradiated. Refer to Practice G 90 for detailed descriptions of the apparatus.

10. Procedure

10.1 Use Practice G 147 for specimen handling and conditioning procedures for test specimens.

10.2 If a change in gloss and color are to be measured, follow 8.2 and 8.3, respectively.

10.3 Mount and fasten the specimens on the exposure device in accordance with Practice G 90.

10.4 Set the water spray control to provide a high purity water spray on the specimens during the night at a frequency of 4 per hour, each spray to be of 3-min duration. Refer to Cycle 3 of Practice G 90 for detailed operating procedures.

10.5 Expose the specimens for a specified period on the basis of either ultraviolet or total radiant exposure. Both ultraviolet and total radiant exposure must be measured and reported using the procedures described in Practice G 90.

10.6 Unless otherwise agreed upon, remove the specimens from the exposure device and gently wash a portion of the specimen surfaces as recommended in 8.6.

10.7 If required, perform on the washed portion of each specimen, the tests outlined in 8.7.

10.8 If required, perform a chalk rating by Test Methods D 4214 on an unwashed portion of each specimen.

11. Interpretation of Results

11.1 Express the change in gloss of each specimen either in terms of units of gloss loss or in percent gloss loss relative to the initial gloss value.

11.2 Express the change in color of each specimen in terms of total color difference, Delta E, using one of the calculations

given in Test Method D 2244.

11.3 Express the amounts of chalking, checking, cracking, or other visual appearance property as outlined in Test Methods D 4214, D 660, D 661, D 662, D 714, or D 772.

12. Report

12.1 Report the following information:

12.1.1 The method of exposure used and its geographical location.

12.1.2 The duration of the exposure and the starting and ending dates of the test.

12.1.3 The measured amount of ultraviolet and total radiant exposure, expressed in MJ/m^2 (required for Procedure C, optional for Procedure A). If measured, report the bandpass used for ultraviolet radiant exposure (that is, 295 to 385 nm or 300 to 400 nm).

12.1.4 If available, the type of controls used and severity of their degradation.

12.1.5 The evaluation measurements performed on each of the exposed specimens:

12.1.5.1 Units of gloss or percent gloss loss,

12.1.5.2 Units of Delta E color change, noting the color space and color scales used, and

12.1.5.3 Ratings for chalking, checking, cracking, erosion, flaking, and blistering.

12.1.6 If requested, report the traceability of calibrations for all environmental measurements reported.

13. Keywords

13.1 durability; exterior exposure tests; outdoor exposure; ultraviolet/light/radiation; weathering