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

This standard is issued under the fixed designation D4141/D4141M; 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 weather resistance 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.~~use and has been removed as of the 2014 revision of this standard.

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 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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

1.6 *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]

[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.

***A Summary of Changes section appears at the end of this standard**

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, Coatings 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
E772 Terminology of Solar Energy Conversion
G7 Practice for Natural Weathering of Materials
G90 Practice for Performing Accelerated Outdoor Weathering of 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~~Terminologies G113 and E772 are applicable to this practice.

4. Summary of Practice

4.1 ~~Several~~Two 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~~ tilted toward 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~~ sun's daily path and concentrating ~~sunlight~~ radiation from the sun on the test specimens by means of mirrors. The specimens are wet periodically by ~~high purity~~ high-purity water spray.

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.~~ surfaces, such as exterior automotive coatings. 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.~~any application of exterior coatings. 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~~ in-service exposure is material dependent. Therefore, no single acceleration factor can be used to relate two different types of outdoor weathering exposures. The weather resistance 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

[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.

~~fixed angle open-rack~~ 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. 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 specimen wetness. The black box specimen temperatures are comparable to those encountered on the hoods, roofs, and deck lids of automobiles parked in 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]

5.2.2 The acceleration of degradation by weathering as described in 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~~ Approximately 1400 MJ/m^2 of ultraviolet radiant exposure (295 to ~~385 nm)~~ 385 nm) is received over a typical one-year period when samples are exposed on 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~~ 280 MJ ~~MJ/m~~/m^2 of ultraviolet radiant exposure from a southern Florida at-latitude exposure over ~~the same~~an equivalent time period. However, the test described by Procedure C reflects only direct beam radiation onto test specimens. The reflected direct beam of 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 weather resistance of coatings in outdoor use can be very different depending on the geographic 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 weather resistance in a different location. Exposures in several locations with different climates that represent a broad range of anticipated service conditions are ~~recommended.~~recommended to determine weathering resistance and/or service life.

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 3—~~Several~~ Three or more years of repeat ~~exposures~~ exposures, starting at various times of the year, are typically needed to get an "average" test result for a given location.

5.4.1 The degradation profile for many ~~polymers~~coatings is not a linear function of exposure time or radiant exposure. When short exposures are used as indications of weather resistance, the results obtained may not be representative of those from longer exposures.

NOTE 4—Guide G141 provides information for addressing variability in exposure testing of nonmetallic materials. Guide G169 provides information for applying statistics to exposure test results.

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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 weather resistance. It is preferable to use two control materials, one with relatively good weather resistance and one with poor weather resistance.

6. Test Specimens

6.1 Each test specimen and control specimen shall consist of a uniform coating applied to the surface of a flat panel because warpage, waviness, or curvature may seriously affect the measurement of gloss and color. Flat, rigid specimens are preferred. Non-rigid specimens shall be backed to ensure a proper seal on the black box rack (Procedure A), or to ensure proper cooling (Procedure C). Suitable application procedures are given in Practices D823.

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

6.2 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.]~~ 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.

6.3 It is recommended that ~~controls~~ control specimens be prepared 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~~ control specimens differing in their weather resistance performance.

6.4 It is recommended that the dry film thickness of the coatings be measured at several different positions on the test specimens in accordance with Test Method D7091.

6.5 Unless otherwise specified, expose ~~at least two replicates. Larger numbers of replicates are recommended.~~a minimum of two replicates.

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~~ tilted toward 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 (1976) L*a*b* (CIE Lab) Color Scale, illuminant D65, and the 1964 10° Standard Observer Function with specular reflection included. The color measuring instrument shall be stable and properly calibrated.

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

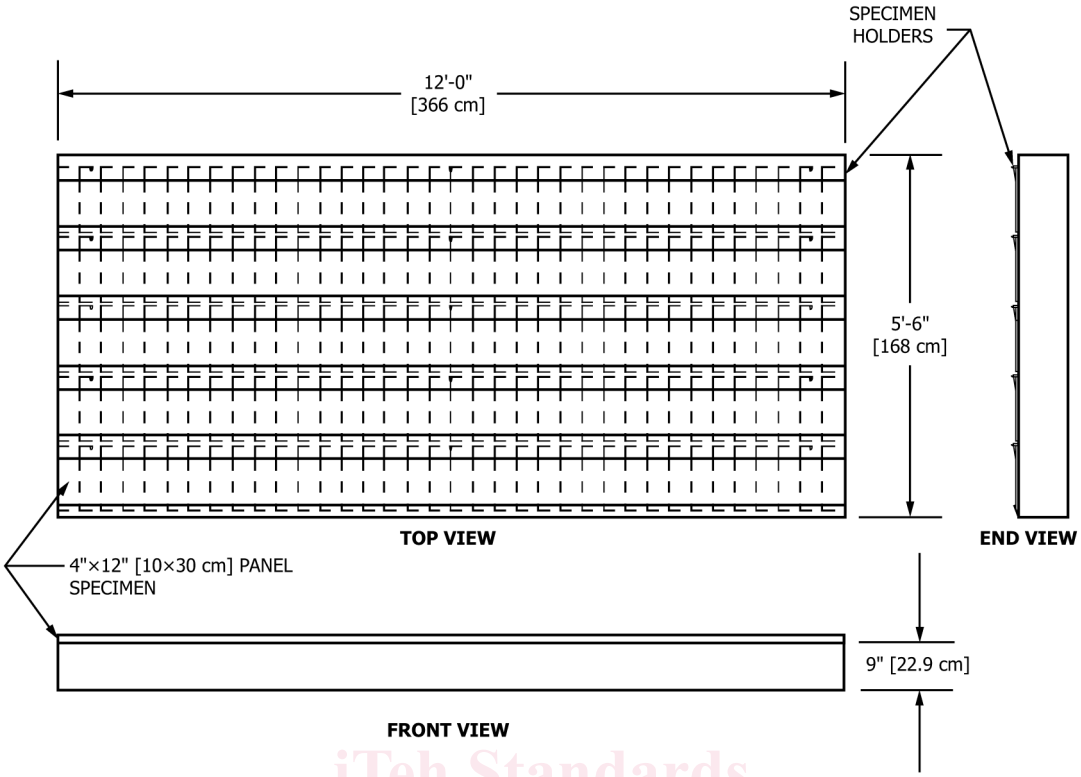

FIG. 2 Black Box Diagram (from Practice G7)

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. For example, a black box will attain a lower temperature if all the specimens are white than if some specimens are ~~black.~~black, since lighter colored specimens typically have a higher spectral reflectance than darker colors.

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.

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,~~ total solar, 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~~ calibrate at intervals recommended by the radiometer manufacturer against a standard source of spectral irradiance.

8.5.3 Expose until a specified change in an optical, mechanical, or chemical property has occurred in the test specimens.

8.5.4 Expose until a specified change in an optical, mechanical, or chemical property has occurred in a control exposed with the test specimens.