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Standard Practice for Enclosed Carbon-Arc Exposure Tests of Paint and Related Coatings[1]

This standard is issued under the fixed designation ~~D5031;~~D5031/D5031M; 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~~ Scope*

1.1 This practice covers the selection of test conditions for accelerated exposure testing of coatings and related products in enclosed carbon arc devices operated according to Practices G151 and G153. This practice also covers the preparation of test specimens, the test conditions suited for coatings, and the evaluation of test results. Table 1 describes commonly used test conditions.

~~NOTE 1—Previous versions of this practice referenced carbon arc devices described by Practice G23, which described very specific equipment designs. Practice G23 has been withdrawn and replaced by Practice G151, which describes performance criteria for all exposure devices that use laboratory light sources, and by Practice G153, which gives requirements for exposing nonmetallic materials in enclosed carbon-arc devices.~~

1.2 This practice does not cover filtered open-flame carbon-arc exposures of paints and related coatings, which is described in Practice ~~D822~~D822/D822M. Another procedure for exposing these products is covered by Practice ~~D3361~~D3361/D3361M, in which the specimens are subjected to radiation from an unfiltered open-flame carbon arc that produces shorter wavelengths and higher levels of short wavelength radiation than filtered open flame or enclosed carbon arcs.

NOTE 1—Practice ~~D3361~~D3361/D3361M requires use of open-flame carbon-arc apparatus with automatic humidity control.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as ~~the~~ standard. The values ~~given in parentheses are for information only.~~stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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]

D358 Specification for Wood to Be Used as Panels in Weathering Tests of Coatings
D523 Test Method for Specular Gloss
D609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products
D610 Practice for Evaluating Degree of Rusting on Painted Steel Surfaces
D659 Method for Evaluating Degree of Chalking of Exterior Paints (Withdrawn 1990)[3]
D660 Test Method for Evaluating Degree of Checking 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
~~D822~~D822/D822M Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings
D823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels
D1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

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

TABLE 1 Test Cycles Commonly Used for Enclosed Carbon-Arc Exposure Testing of Paints and Related Coatings[A]

Cycle Number	Cycle Description	Uninsulated Black Panel Temperature[B] (°C)	(°F)	Typical Uses[C]
1	Continuous light 102 min light only at 50 ± 5 % RH 18 min light and water spray[D] Repeated continuously	63 ± 2.5	145 ± 5	General coatings and historical convention[E]
2	18 h continuous light using: 102 min light only at 50 ± 5 % RH 18 min light and water spray 6 h dark using: 95 % relative humidity (no water spray) Repeated continuously	63 ± 2.5 24 ± 1.5	145 ± 5 75 ± 3	General coatings
3	48 min light at 50 ± 5 % RH 12 min light and water spray Repeated continuously	63 ± 2.5	145 ± 5	Coatings used in original equipment manufacturing
4	4 h light at 50 ± 5 % RH 4 h dark with water spray Repeated continuously	63 ± 2.5	145 ± 5	Exterior pigmented stains
5	12 h light at 50 ± 5 % RH 12 h dark water spray Repeated continuously	63 ± 2.5	145 ± 5	Exterior wood stains and clears
6	8 h light at 50 ± 5 % RH 10 h light and water spray 6 h dark with water spray Repeated continuously	63 ± 2.5	145 ± 5	Marine enamels

TABLE 1 Test Cycles Commonly Used for Enclosed Carbon-Arc Exposure Testing of Paints and Related Coatings[A]

Cycle Number	Cycle Description[B,C]	Uninsulated Black Panel Temperature[B,C,D] °C	°F	Typical Uses[E]
1	Continuous light 102 min light only at 50 ± 10 % RH 18 min light and water spray[G] Repeated continuously	63 ± 2.5	145 ± 5	General coatings and historical convention[F]
2	18 h continuous light using: 102 min light only at 50 ± 10 % RH 18 min light and water spray[G] 6 h dark using: 95 % relative humidity (no water spray) Repeated continuously	63 ± 2.5 24 ± 1.5	145 ± 5 75 ± 3	General coatings
3	48 min light at 50 ± 10 % RH 12 min light and water spray Repeated continuously	63 ± 2.5	145 ± 5	Coatings used in original equipment manufacturing
4	4 h light at 50 ± 10 % RH 4 h dark with water spray Repeated continuously	63 ± 2.5	145 ± 5	Exterior pigmented stains
5	12 h light at 50 ± 10 % RH 12 h dark water spray Repeated continuously	63 ± 2.5	145 ± 5	Exterior wood stains and clears
6	8 h light at 50 ± 10 % RH 10 h light and water spray 6 h dark with water spray Repeated continuously	63 ± 2.5	145 ± 5	Marine enamels

[A] The cycles described are not listed in any order indicating importance, and are not necessarily recommended for the applications listed.

[B] Unless otherwise specified, operate the device so that the allowable deviations about the set points given in Table 1 are within the specified limits specified in the corresponding entry. If the actual operating conditions do not agree with the machine settings after the equipment has stabilized, discontinue the test and correct the cause of the disagreement before continuing.

[C] Set points and operational fluctuations are listed as set point ± operational fluctuation in Table 1. They are sometimes listed in separate columns. The set point is the target condition for the sensor used at the operational control point as programmed by the user. Operational fluctuations are deviations from the indicated set point at the control point indicated by the readout of the calibrated control sensor during equilibrium operation and do not include measurement uncertainty. At the operational control point, the operational fluctuation can exceed no more than the listed value at equilibrium. Therefore, when a standard calls for a particular set point, the user programs that exact number. The operational fluctuations specified with the set point do not imply that the user is allowed to program a set point higher or lower than the exact set point specified.

[D] Unless otherwise indicated, black panel temperatures apply during the light-only portion of the cycle. The equilibrium black panel temperature is obtained without a spray period. For light intervals less than 30 min, the black panel temperature might not reach equilibrium.

[E] Typical uses do not imply that results from exposures of these materials according to the cycle described will correlate to those from actual use conditions.

[D] Unless otherwise specified, water spray refers to water sprayed on the exposed surfaces of the test specimens.

[F] Historical convention has established this as a very commonly used test cycle. This cycle may not adequately simulate the effects of outdoor exposure.

[G] Unless otherwise specified, water spray refers to water sprayed on the exposed surfaces of the test specimens.

D1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base (Withdrawn 2006)[3]

D1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base (Withdrawn 2006)[3]
D1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials
D1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting
D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
D2616 Test Method for Evaluation of Visual Color Difference With a Gray Scale
~~D3361~~D3361/D3361M Practice for Unfiltered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings
~~D3980 Practice for Interlaboratory Testing of Paint and Related Materials (Withdrawn 1998)[3]~~
D4214 Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films
D5870 Practice for Calculating Property Retention Index of Plastics
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E1347 Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry
~~G23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials (Withdrawn 2000)[3]~~
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
G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources
G152 Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
G153 Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
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. Significance and Use

4.1 The ability of a paint or coating to resist deterioration of its physical and optical properties caused by exposure to light, heat, and water can be very significant for many applications. This practice is intended to induce property changes associated with end-use conditions, including the effects of sunlight, moisture, and heat. The exposure used in this practice is not intended to simulate the deterioration caused by localized weather phenomena such as atmospheric pollution, biological attack, and saltwater exposure.

4.2 *Cautions*—Variation in results may be expected when different operating conditions are used. Therefore, no reference to the use of this practice shall be made unless accompanied by a report prepared according to Section 10 that describes the specific operating conditions used. Refer to Practice G151 for detailed information on the caveats applicable to use of results obtained according to this practice.

NOTE 2—Additional information on sources of variability and on strategies for addressing variability in the design, execution, and data analysis of laboratory accelerated exposure tests is found in Guide G141.

4.2.1 The spectral power distribution of light from an enclosed carbon arc is significantly different from that produced in light and water exposure devices using other carbon-arc configurations or other light sources. The type and rate of degradation and the performance rankings produced by exposures to enclosed carbon arcs can be much different from those produced by exposures to other types of laboratory light sources.

4.2.2 Interlaboratory comparisons are valid only when all laboratories use the same type of carbon arc, filters, and exposure conditions.

4.3 Reproducibility of test results between laboratories has been shown to be good when the stability of materials is evaluated in terms of performance ranking compared to other materials or to a control.[4,5] Therefore, exposure of a similar material of known performance (a control) at the same time as the test materials is strongly recommended. It is recommended that at least three replicates of each material be exposed to allow for statistical evaluation of results.

4.4 Test results will depend upon the care that is taken to operate the equipment according to Practice G153. Significant factors include regulation of line voltage, freedom from salt or other deposits from water, temperature and humidity control, and conditions of the electrodes.

4.5 *All references to exposures in accordance with this practice must include a complete description of the test cycle used.*

[4] Fischer, R., "Results of Round-Robin Studies of Light- and Water-Exposure Standard Practices," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*, ASTM, 1993.
[5] Ketola, W., and Fischer, R., "Characterization and Use of Reference Materials in Accelerated Durability Tests," *VAMAS Technical Report No. 30*, NIST, June 1997.

5. Apparatus

5.1 Use enclosed carbon-arc apparatus that conforms to the requirements defined in Practices G151 and G153.

5.2 Unless otherwise specified, the spectral power distribution of the enclosed carbon arc shall conform to the requirements in Practice G153 for the enclosed carbon arc.

6. Hazards

6.1 **Warning—**In addition to other precautions, never look directly at the carbon arc because UV radiation can damage the eye. Most carbon-arc machines are equipped with door safety switches, but users of old equipment must be certain to turn off the power to the carbon arc before opening the test-chamber door.

6.2 The burning carbon rods used in these devices become very hot during use. Make sure to allow at least 15 min for the arcs to cool after the device is turned off before attempting to change the carbon rods.

6.3 Carbon residue and ash are known respiratory irritants. Wear an appropriate high-efficiency dust respirator, gloves, and safety glasses when handling or changing carbon rods. Make sure to wash any carbon residue from hands or arms prior to eating or drinking.

7. Test Specimens

7.1 Apply the coating to flat (plane) panels with the substrate, method of preparation, method of application, coating system, film thickness, and method of drying consistent with the anticipated end use, or as mutually agreed upon between the producer and user.

7.2 Panel specifications and methods of preparation include but are not limited to Practices D609 or D1730, or Specification D358. Select panel sizes suitable for use with the exposure apparatus.

7.3 Coat test panels in accordance with Practices D823, then measure the film thickness in accordance with an appropriate procedure selected from Test Methods D1005, D1186, or D1400. Nondestructive methods are preferred because panels so measured need not be repaired.

7.4 Prior to exposing coated panels in the apparatus, condition them at 23 ± 2°C ~~(73 ± 3°F)~~[73 ± 3°F] and ~~50 ± 5 %~~ 50 ± 10 % relative humidity for one of the following periods in accordance with the type of coating:

Baked coatings	24 h
Radiation-cured coatings	24 h
All other coatings	7 days

7.4.1 Other procedures for preparation of test specimens may be used if agreed upon by all interested parties.

7.5 Mount specimens in holders so that only the minimum specimen area required for support by the holder is covered. Do not use this covered area of the specimen as part of the test area.

7.6 Unless otherwise specified, expose at least three replicate specimens of each test and control material.

7.7 Follow the procedures described in Practice G147 for identification and conditioning and handling of specimens of test, control, and reference materials prior to, during, and after exposure.

7.8 Do not mask the face of a specimen for the purpose of showing on one panel the effects of various exposure times. Misleading results may be obtained by this method, since the masked portion of the specimen is still exposed to temperature and humidity cycles that in many cases will affect results.

7.9 Retain a supply of unexposed file specimens of all materials evaluated.

7.9.1 When destructive tests are run, it is recommended that a sufficient number of file specimens be retained so that the property of interest can be determined on unexposed file specimens each time exposed materials are evaluated.

NOTE 3—Since the stability of the file specimen may also be time dependent, users are cautioned that over prolonged exposure periods, or where small differences in the order of acceptable limits are anticipated, comparison of exposed specimens with the file specimen may not be valid. Nondestructive instrumental measurements are recommended whenever possible.

7.10 Specimens should not ordinarily be removed from the exposure apparatus for more than 24 h, then returned for additional tests, since this does not produce the same results on all materials as tests run without this type of interruption. When specimens are removed from the exposure apparatus for 24 h or more, then returned for additional exposure, report the elapsed time as noted under Section 10.

8. Procedure

8.1 Table 1 lists several exposure cycles that are used for enclosed carbon arc exposures of nonmetallic materials. Obtain mutual agreement between all concerned parties for the specific exposure cycle used. Additional intervals and methods of wetting, by spray, condensation, or both, may be substituted upon agreement among the concerned parties.

NOTE 4—Each set point and ~~its tolerances~~ the corresponding operational fluctuations found in Table 1 represent an operational control point for