Designation: D3361/D3361M – 13

Standard Practice for Unfiltered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings[1]

This standard is issued under the fixed designation D3361/D3361M; 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 the selection of test conditions for accelerated exposure testing of coatings and related products in unfiltered open-flame carbon-arc devices conducted according to Practice G151 and G152. This practice also covers the preparation of test specimens, the test conditions suited for coatings, and the evaluation of test results.

1.2 This practice covers unfiltered open-flame carbon-arc exposures of paints and related coatings, and covers the exposure cycle that has been commonly referred to as the "dew cycle." Practice D822/D822M describes filtered open-flame carbon-arc devices, and Practice D5031/D5031M describes enclosed carbon-arc exposures. The radiation from an unfiltered open-flame carbon arc produces shorter wavelengths and higher levels of short wavelength radiation than either filtered open-flame or enclosed carbon arcs.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values 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D358 Specification for Wood to Be Used as Panels in Weathering Tests of Coatings (Withdrawn 2014)[3]

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D659 Method for Evaluating Degree of Chalking of Exterior Paints (Withdrawn 1990)[3]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/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

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

D3980 Practice for Interlaboratory Testing of Paint and

[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**

Related Materials (Withdrawn 1998)[3]
D4214 Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films
D5031/D5031M Practice for Enclosed Carbon-Arc Exposure Tests of Paint and Related Coatings
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
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
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 1—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 unfiltered open-flame 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 unfiltered open-flame carbon-arcs can be much different from that produced by exposures to other types of laboratory light sources. Typically, exposures conducted according to this practice will produce degradation faster than similar exposures conducted in accordance with Practice D822/D822M or D5031/D5031M and may cause different types of degradation.

4.2.2 Interlaboratory comparisons are valid only when all laboratories use the same type of carbon-arc 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 in accordance with Practice G152. 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.*

5. Apparatus

5.1 Use filtered open-flame carbon-arc apparatus with automatic humidity control that conforms to the requirements defined in Practices G151 and G152.

5.2 Do not place any filters between the open flame carbon arc and the test specimens.

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 This light source generates ozone and nitrous oxides. Vent exhaust from the exposure device to the atmosphere.

6.3 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.

6.4 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.

[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.

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 Test Methods 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] and 50 ± 5 % 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 min

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 2—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 Unless otherwise specified, operate the device using the following exposure cycle so that the allowable deviations about the set points given with each set point below 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.

NOTE 3—Each set point and the corresponding operational fluctuations given in this section represent an operational control point for equilibrium conditions at a single location in the cabinet, which may not necessarily represent the uniformity of those conditions throughout the cabinet. ASTM Committee G03 is working to refine these operational fluctuations and address the uniformity issue.

NOTE 4—Set points and operational fluctuations are listed as set point ± operational fluctuation in this standard. 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.

8.1.1 Sixty min light only with black panel temperature controlled at 63 ± 5°C [145 ± 9°F] and relative humidity controlled at 50 ± 10 %.

NOTE 5—The black panel temperature is for equilibrium conditions. There will be a period immediately after the dark cycle where the black panel temperature will be less than the control limits given.

8.1.2 Sixty min dark with water spray on the back of test specimens. During this dark cycle the chamber air temperature shall be controlled at 32 ± 3°C [90 ± 5°F] and the relative humidity shall be controlled at 95 ± 10 %.

8.1.3 Adjust the water spray so that the only water on the face of the test specimens is from the dew formation caused by the chilled water sprayed on the back of the specimens. The temperature of the water sprayed on the back of the specimens shall be controlled at 7.2 ± 2°C [45 ± 4°F].

8.2 Practice D822/D822M lists other exposure cycles that may be used.

8.3 Place test specimens in the device according to the manufacturer's recommendations. It is recommended that all unused spaces in the specimen exposure area be filled with blank metal panels.

8.4 If the irradiance uniformity within the exposure area does not meet the requirements of Practice G151 for exposure without repositioning, use one of the procedures described in Practice G152 to ensure that specimens receive as uniform a radiant exposure as possible.

8.4.1 If specimen repositioning is used, and no repositioning schedule is specified, use the following procedure for specimen repositioning:

8.4.1.1 Once per week, move all holders in the top half of the specimen exposure area to the bottom half and move all holders in the bottom half of the exposure area to the top half. Do not reposition the specimens within the holder.

NOTE 6—Incident energy at the top and bottom of the specimen rack is often only 70 % of that at the center. This condition requires that the procedures described in 8.4 be followed to ensure uniformity of radiant exposure.

8.5 *Water Purity:*

8.5.1 The purity of water used is very important. Without proper treatment to remove cations, anions, organics, and particularly silica, exposed panels will develop spots or stains that may not occur in exterior exposures.

8.5.2 Follow the requirements for water purity described in Practice G151.

8.5.3 If specimens are found to have deposits or stains after exposure in the apparatus, the water purity must be checked to determine if it meets the requirements of 8.5.2. On some occasions, exposed specimens can be contaminated by deposits from bacteria that can grow in the purified water used for specimen spray. If bacterial contamination is detected, the entire system used for specimen water spray must be flushed with chlorine and thoroughly rinsed prior to resuming exposures.

8.5.4 When the water purity requirements are met and there is disagreement between parties on the extent of problems caused by stain or deposit, run referee tests in at least one other laboratory that can meet the water quality requirements described in 8.5.

8.5.5 For devices with humidity control, it is recommended that deionized water be used when generating water vapor to control humidity.

8.6 Some tests for lightfastness are run without any specimen wetting. When this type of test is required, omit the period where water is sprayed on specimens.

8.7 Identification of any control specimen used shall accompany the report.

9. Periods of Exposure and Evaluation of Test Results

9.1 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 exposure time or radiant exposure.

9.2 The time or radiant exposure necessary to produce a defined change in a material property can be used to evaluate or rank the stability of materials. This method is preferred over evaluating materials after an arbitrary exposure time or radiant exposure.

9.2.1 Exposure to an arbitrary time or radiant exposure may be used for the purpose of a specific test if agreed upon between the parties concerned or if required for conformance to a particular specification. When a single exposure period is used, select a time or radiant exposure that will produce the largest performance differences between the test materials or between the test material and the control material.

9.2.2 The minimum exposure time used shall be that necessary to produce a substantial change in the property of interest for the least stable material being evaluated. An exposure time that produces a significant change in one type of material cannot be assumed to be applicable to other types of materials.

9.2.3 The relation between time to failure in an exposure conducted according to this practice and service life in an outdoor environment requires determination of a valid acceleration factor. Do not use arbitrary acceleration factors relating time in an exposure conducted according to this practice and time in an outdoor environment because they can give erroneous information. The acceleration factor is material dependent and is only valid if it is based on data from a sufficient number of separate exterior and laboratory accelerated exposures so that results used to relate times to failure in each exposure can be analyzed using statistical methods.

NOTE 7—An example of a statistical analysis using multiple laboratory and exterior exposures to calculate an acceleration factor is described by J.A. Simms.[6] See Practice G151 for more information and additional cautions about the use of acceleration factors.

9.3 After each exposure increment, determine the changes in exposed specimens. Test Methods D523, D610, D659, D660, D662, D714, D772, D2244, D2616, D4214, E1347, or Practice D1729 may be used. Consider product use requirements when selecting appropriate methods.

9.3.1 Other methods for evaluating test specimens may be used if agreed upon between all interested parties.

NOTE 8—For some materials, changes may continue after the specimen has been removed from the exposure apparatus. Measurements (visual or instrumental) should be made within a standardized time period or as agreed upon between interested parties. The standardized time period needs to consider conditioning prior to testing.

9.4 It is recommended that the following procedure be followed when results from exposures conducted according to this practice are used in specifications.

9.4.1 If a standard or specification for *general use* requires a defined property level after a specific time or radiant exposure in an exposure test conducted according to this practice, base the specified property level on results from round-robin experiments run to determine the test reproducibility for the exposure and property measurement procedures. Conduct these round robins according to Practice E691 or D3980 and include a statistically representative sample of all laboratories or organizations that would normally conduct the exposure and property measurement.

9.4.2 If a standard or specification for *use between two or three parties* requires a defined property level after a specific time or radiant exposure in an exposure test conducted according to this practice, base the specified property level on at least two independent experiments run in each laboratory to determine the reproducibility for the exposure and property measurement process. The reproducibility of the exposure/property measurement process is then used to determine the maximum or minimum level of property after the exposure that is mutually agreeable to all parties.

9.4.3 When reproducibility in results from an exposure test conducted according to this practice has not been established

[6] Simms, J.A., *Journal of Coatings Technology*, Vol 50, 1987, pp. 45-53.

through round-robin testing, specify performance requirements for materials in terms of comparison (ranked) to a control material. All specimens shall be exposed simultaneously in the same device. All concerned parties must agree on the specific control material used.

9.4.3.1 Conduct analysis of variance to determine whether the differences between test materials and any control materials used are statistically significant. Expose replicates of the test specimen and the control specimen so that statistically significant performance differences can be determined.

NOTE 9—Fischer illustrates use of rank comparison between test and control materials in specifications.[7]

NOTE 10—Guide G169 includes examples showing use of analysis of variance to compare materials.

10. Report

10.1 Report the following information:

10.1.1 Type and model of exposure device.

10.1.2 Type of light source.

10.1.3 Average distance from specimens to light source.

10.1.4 Type of black panel (uninsulated or insulated) used.

10.1.5 If required, irradiance in $W/(m^2 \cdot nm)$, or radiant exposure in J/m^2, at the sample location, and the wavelength region in which the measurements were made.

10.1.5.1 Do not report irradiance or radiant exposure unless direct measurement of spectral irradiance was made during the exposure.

10.1.6 Elapsed exposure time.

10.1.7 Light and dark-water-humidity cycle employed.

10.1.8 Operating black panel temperature.

10.1.9 Operating relative humidity.

10.1.10 Type of spray water, if water spray was used.

10.1.10.1 Total solids and silica level of water used for specimen spray (if above limits specified in 8.5).

10.1.11 Type of spray nozzle.

10.1.12 Specimen repositioning procedure.

10.1.13 Results of property tests. Where retention of characteristic property is reported, calculate results according to Practice D5870.

NOTE 11—In some cases, exposures are conducted by a contracting agency but property tests are conducted by the contracting party. In these cases, the agency that conducts the exposures cannot report results from property tests.

11. Precision and Bias

11.1 *Precision*—The repeatability and reproducibility of results obtained in exposures conducted according to this practice will vary with the materials being tested, the material property being measured, and the specific test conditions and cycles that are used.

11.2 *Bias*—Bias can not be determined because no acceptable standard weathering reference materials are available.

12. Keywords

12.1 carbon arc; degradation; dew cycle; exposure; light exposure; ultraviolet; weathering

[7] Fischer, R., Ketola, W., "Impact of Research on Development of ASTM Durability Testing Standards," *Durability Testing of Non-Metallic Materials, ASTM STP 1294*, ASTM, 1995.

SUMMARY OF CHANGES

Committee D01 has identified the location of selected changes to this standard since the last issue (D3361 – 01 (2006)) that may impact the use of this standard. (Approved October 1, 2013.)

(1) Deleted references to obsolete standard (Practice G23).

(2) Referenced Practice G152 (in addition to Practice G151) for guidance on proper operation and maintenance of the test equipment.

(3) Changed allowable operational fluctuation for humidity control from ±5 % to ±10 %, harmonized with other industry standards.

(4) Introduced text clarifying the use of operational fluctuations.