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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Practice for Conducting Tests on Paint and Related Coatings and Materials Using Enclosed Carbon-Arc Exposure Apparatus[1]

This standard is issued under the fixed designation D 5031; 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 enclosed carbon-arc devices operated according to Practice G 23. Both types are manufactured with or without automatic humidity control.[2] Table 1 describes commonly used test conditions. Interlaboratory comparisons *must* only be made using the same device type and test conditions.

1.2 The procedures described in this practice were previously included in Practice D 822, which covered the use of both filtered open flame and enclosed carbon arcs for testing paints, varnishes, lacquers, and related products. Practice D 822 describes exposures in filtered open-flame carbon-arc devices only.

NOTE 1—Another procedure for exposing these products is covered by Practice D 3361, in which the specimens are subjected to radiation from an unfiltered open-flame carbon arc that produces much higher levels of short wavelength radiation than filtered open-flame or enclosed carbon arcs. Only automatic humidity controlled open-flame carbon-arc apparatus (Type EH) is applicable to Practice D 3361.

1.3 *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.* For specific hazard statements, see Section 4.

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

Cycle Description	Black Panel Temp,[B] °F (°C)	Typical Uses[C]
102 min light 18 min light and water spray[D,E]	145 ± 5 (63 ± 2.5)	general coatings[B]
18 h using: 102 min light 18 min light and water spray 6 h at 95 ± 4 % relative humidity with no water spray	 145 ± 5 (63 ± 2.5) 75 ± 3	 general coatings
48 min light 12 min light and water spray	145 ± 5 (63 ± 2.5)	original equipment manufactured coatings
4 h light 4 h water spray	145 ± 5 (63 ± 2.5)	exterior pigmented paints
12 h light 12 h water spray	145 ± 5 (63 ± 2.5)	exterior wood stains and clears
8 h light 10 h light and water spray 6 h water spray	145 ± 5 (63 ± 2.5)	marine enamels

[A]The cycles described are not listed in any order indicating importance, and are not necessarily recommended.
[B]Unless otherwise indicated, black panel temperature during light only portion of the cycle.
[C]Typical uses does 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 surface of the test specimens.
[E]Historical convention has established this as a very commonly used test cycle.

2. Referenced Documents

2.1 *ASTM Standards:*

D 358 Specification for Wood to Be Used as Panels in Weathering Tests of Coatings[3]
D 523 Test Method for Specular Gloss[4]
D 609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products[4]
D 610 Test Methods for Evaluating Degree of Rusting on Painted Steel Surfaces[3]
D 659 Method of Evaluating Degree of Chalking of Exterior Paints[4]
D 660 Test Method for Evaluating Degree of Checking of Exterior Paints[4]
D 662 Test Method for Evaluating Degree of Erosion of Exterior Paints[4]
D 714 Test Method for Evaluating Degree of Blistering of Paints[4]
D 772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints[4]

[1] This practice is under the jurisdiction of ASTM Committee D-1 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] Apparatus and carbon arcs manufactured by Atlas Electric Devices Company, 4114 N. Ravenswood Avenue, Chicago, IL 60613, and by Suga Test Instruments Co., Ltd, 4-14 Shinjuku 5-chome, Shinjuku-ku, Tokyo, 160, Japan, have been found satisfactory for this purpose.

[3] *Annual Book of ASTM Standards*, Vol 06.02.

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

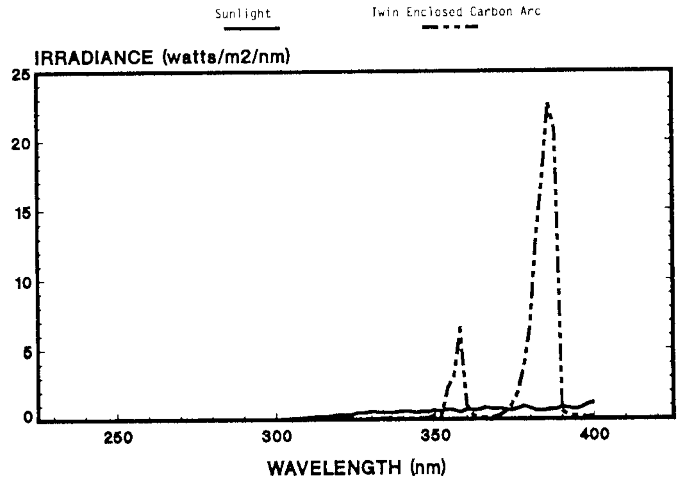
D 822 Practice for Conducting Tests on Paint and Related Coatings and Materials using Filtered Open-Flame Carbon-Arc Light and Water Exposure Apparatus[4]
D 823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[4]
D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers[4]
D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[4]
D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base[4]
D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials[4]
D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting[5]
D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[4]
D 2616 Test Method for Evaluation of Visual Color Difference with a Gray Scale[4]
D 3361 Practice for Operating Light- and Water-Exposure Apparatus (Unfiltered Open-Flame Carbon-Arc Type) for Testing Paint, Varnish, Lacquer, and Related Products Using the Dew Cycle[4]
D 3980 Practice for Interlaboratory Testing of Paint and Related Materials[4]
D 4214 Test Methods for Evaluating Degree of Chalking of Exterior Paint Films[4]
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of Test Methods[6]
E 1347 Test Method for Color and Color Difference Measured by Tristimulus (filter) Colorimetry[4]
G 23 Practice for Operating Light- and Water-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[6]
G 113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials[6]

3. Terminology

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

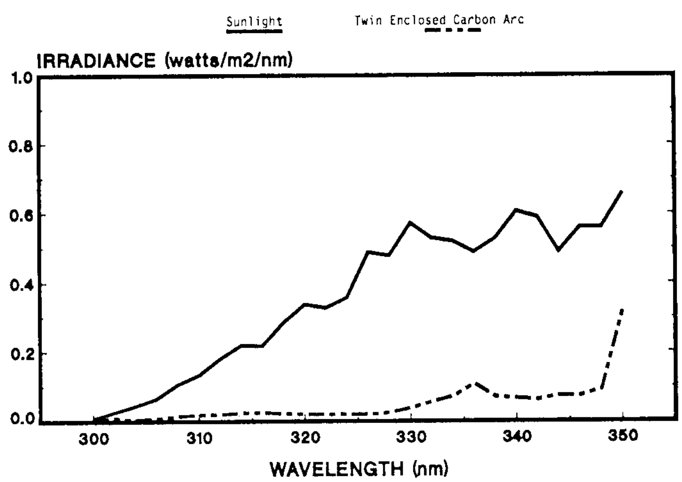
4. Significance and Use

4.1 Organic coatings on exterior exposure are subjected to attack by degrading elements of the weather, particularly ultraviolet light, oxygen, and water. This practice is intended to evaluate coating films for their stability in an apparatus that exposes specimens to ultraviolet (UV) light, heat, and moisture. If the spectral power distribution of the light source used for exposure tests does not adequately simulate that of terrestrial solar radiation, it may produce a different type of degradation and distort the ranking of materials obtained in outdoor exposures. Fig. 1 and Fig. 2 compare representative spectral power distributions of the enclosed carbon-arc with that of terrestrial sunlight.



NOTE 1—The enclosed carbon-arc irradiance was measured at the sample plane at a position centered between the two carbon arcs. Sunlight was measured in Phoenix, AZ, at the summer solstice with clear sky at solor noon using a double grating monochromator (1-nm bandpass) with a quartz cosine receptor on an equatorial follow-the-sun mount. Because of momentary fluctuations in intensity due to flickering of the carbon-arc flame, the spectral power distribution shown in this figure is relative and is not to be used to calculate or estimate total radiant exposure for tests in enclosed carbon-arc devices.

FIG. 1 Representative Spectral Power Distributions (250–400 nm) for Twin Enclosed Carbon Arcs and Terrestrial Sunlight



NOTE 1—Measurements were made as described in Fig. 1. Because of momentary fluctuations in intensity due to flickering of the carbon-arc flame, the spectral power distribution shown in this figure is representative and is not meant to be used to calculate or estimate total radiant exposure for tests in enclosed carbon-arc devices.

FIG. 2 Representative Spectral Power Distributions (300–350 nm) for Twin Enclosed Carbon Arcs and Terrestrial Sunlight

4.1.1 Exposures in enclosed carbon-arc devices have been historically used to simulate the effects of terrestrial sunlight. As shown in Fig. 1 and Fig. 2, the UV spectral power distribution of the light from these devices is significantly different from that of terrestrial sunlight. The primary emission of the enclosed carbon-arc produces is in two relatively narrow peaks between 350 and 400 nm. The intensity of the enclosed carbon arc is less than that of terrestrial solar radiation at virtually all other wavelengths.

[5] *Annual Book of ASTM Standards*, Vol 02.05.
[6] *Annual Book of ASTM Standards*, Vol 14.02.

4.1.2 The spectral power distribution of light from an enclosed carbon-arc is significantly different from that produced in light and water exposure devices using open-flame carbon-arcs or other light sources. The rate and type of degradation produced in exposures to enclosed carbon-arcs can be much different from that produced in exposures to other types of laboratory light sources.

4.2 No artificial exposure test can be specified as a complete simulation of actual use conditions in outdoor environments. Results obtained from exposures conducted according to this practice may be considered as representative of actual outdoor exposures only when the degree of rank correlation has been established for the specific materials being tested. The relative durability of materials in actual outdoor service can be very different in different locations because of differences in UV radiation, time of wetness, temperature, pollutants, and other factors. Therefore, even if results from a specific artificial test conducted according to this practice are found to be useful for comparing the relative durability of materials exposed in a particular exterior environment, it cannot be assumed that they will be useful for determining relative durability for a different environment.

4.3 Even though it is very tempting, calculation of an" acceleration factor" relating "*x*" hours of exposures in a laboratory accelerated test to "*y*" months or years of exterior exposure or actual use conditions is *not recommended*. Different materials and formulations of the same material can have significantly different acceleration factors. The acceleration factor calculated also varies depending on the variability in rate of degradation in the laboratory accelerated test and in outdoor or actual use exposures.

4.3.1 Although the use of an acceleration factor is not recommended, laboratories that calculate such a factor for a particular material shall base their findings on data from a sufficient number of separate exterior and artificial exposures so that results used to relate times to failure in each exposure can be analyzed using statistical methods.[7] It must be noted that any acceleration factor is specific to the material and formulation tested and cannot be extrapolated to other materials or formulations. In addition, use of an acceleration factor assumes that the degradation mechanism is the same in both exterior and artificial exposures. It is important to note that exterior exposure and artificial exposure degradation mechanisms can be different.

4.4 This practice is best used to compare the relative performance of materials tested at the same time in the same exposure device. Because of possible variability between the same type of exposure devices, comparing the amount of degradation in materials exposed for the same duration or radiant energy at separate times, or in separate devices running the same test condition, is not recommended. This practice should not be used to establish a "pass/fail" approval of materials after a specific period of exposure unless performance comparisons are made relative to a control material exposed simultaneously, or the variability in the test is quantified so that statistically significant pass/fail judgments can be made.

4.5 It is strongly recommended that at least one control material be exposed with each test for the purpose of comparing the performance of the test materials relative to that of the control. The control material should be of similar composition and construction and be chosen so that its failure modes are the same as that of the coating material being tested. It is preferable to use two control materials, one with relatively good durability and one with relatively poor durability.

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

5. Apparatus

5.1 *Enclosed Carbon-Arc Device*, that meets the requirements of Practice G 23.

6. Hazards

6.1 **Precaution—**In addition to other precautions, never look directly at the carbon arc because ultraviolet 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 the OPERATE switch OFF 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.[8] 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 Practice D 609, Specification D 358, or Practices D 1730. Select panel sizes suitable for use with the exposure apparatus.

7.3 Coat test panels in accordance with Test Methods D 823 and measure the film thickness in accordance with an appropriate procedure selected from Test Methods D 1005, D 1186, or D 1400. 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 73 ± 3°F (23 ± 2°C) and 50 ± 5 % relative humidity for one of the following periods in accordance with the type of coating:

[7] An example of such a statistical analysis is described in Simms, J. A., *Journal of Coatings Technology*, Vol 50, No. 748, 1987, pp. 45–53.

[8] 6000 Series Respirator and #2040 High Efficiency Filters manufactured by 3M, St. Paul, MN, or equivalent respirator/filter combination, have been found satisfactory for this purpose.

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

NOTE 2—The procedures and specifications described in 7.2 through 7.4 are recommended but others may be used if agreed upon by all interested parties.

7.5 The use of at least three replicates of each test material and each reference or control material is recommended in order to allow statistical evaluation of results.

8. Procedure

8.1 Mount the test specimens both above and below a horizontal plane at the center of the single arc or centered between the two enclosed carbon arcs. When the exposure interval does not exceed 24 h, locate each specimen equidistant from the horizontal plane at the center of the single arc or centered between the arcs.

8.2 To ensure uniform exposure conditions for all specimens, reposition them vertically within their holders in a sequence that will provide each specimen with equivalent exposure periods in each location. For exposure intervals not exceeding 100 h, reposition specimens daily. For longer exposures, reposition specimens weekly. Other methods of achieving uniform total irradiation may be employed if mutually agreed upon between all concerned parties.

8.3 Table 1 lists test-cycle conditions commonly used for evaluation of paints, varnishes, lacquers, and related coatings.

8.4 It is recommended that the temperature of the water used for specimen spray be 60 ± 9°F (16 ± 5°C). Water used for specimen spray must meet the purity levels specified in Practice G 23 in order to avoid unrealistic water spotting.

8.5 When mutually agreed upon, cycles other than those listed in Table 1 may be used. The term *cycle* is defined as the set of exposure conditions (light, light plus water spray, dark periods) that are repeated.

9. Periods of Exposure

9.1 Use one of the following methods to determine the duration of the exposure under this practice:

9.1.1 A mutually agreed upon specified number of total hours.

9.1.2 The number of total hours of exposure required to produce a mutually agreed upon amount of change in either the test specimen or an agreed upon control or reference material.

10. Evaluation of Specimens After Exposure

10.1 Evaluate or rate changes in exposed test specimens in accordance with Test Methods D 523, D 610, D 659, D 660, D 662, D 714, D 772, D 2244, D 2616, D 4214, E 1347, or Practice D 1729. Consider product use requirements when selecting appropriate methods.

10.2 Evaluate test specimens by ranking their performance relative to a control or reference material exposed at the same time.

10.3 Plot properties of test specimens and controls as a function of exposure time and compare rate of change with that of the control or reference material. When this method of evaluation is used, the control or reference material must be exposed at the same time and in the same device as the test specimens.

10.4 Other methods for evaluating test specimens may be used if mutually agreed on by all interested parties.

11. Report

11.1 Report the following information:

11.1.1 Complete description of exposure procedure used, including:

11.1.1.1 Light/light plus water/dark cycle used, type of device used (single or twin enclosed carbon arc),

11.1.1.2 Operating black panel temperature during all portions of exposure cycle,

11.1.1.3 Operating relative humidity, and

11.1.1.4 Temperature of water used for water spray.

11.1.2 Total hours of test.

11.1.3 Test specimen preparation.

11.1.4 Identification of controls used.

11.1.5 Results of evaluation test or tests performed on specimens and control or standard samples.

12. Precision and Bias

12.1 *Precision*:

12.1.1 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. In round-robin studies[9] conducted by ASTM subcommittee G3.03, the 60° gloss values of replicate polyvinylchloride (PVC) tape specimens exposed in different laboratories using identical test devices and exposure cycles showed significant variability. The variability shown in these round-robin studies restricts the use of "absolute specifications" such as requiring a specific property level after a specific exposure period.

12.1.1.1 If a standard or specification *for general use* requires a definite property level after a specific time or radiant exposure in an exposure test conducted according to this practice, the specified property level shall be based on results obtained in a round-robin that takes into consideration the variability due to the exposure, and the test method used to measure the property of interest. The round-robin shall be conducted according to Practices E 691 or D 3980 and shall include a statistically representative sample of all laboratories or organizations who would normally conduct the exposure and property measurement.

12.1.1.2 If a standard or specification for use *between two or three parties* requires a definite property level after a specific time or radiant exposure in an exposure test conducted according to this practice, the specified property level shall be based on statistical analysis of results from at least two separate, independent exposures in each laboratory. The design of the experiment used to determine the specification shall take into consideration the variability due to the exposure, and the test method used to measure the property of interest.

12.1.2 The round-robin studies cited in 12.1.1 demonstrated

[9] Fischer, R. M., "Results of Round-Robin Studies of Light-and Water-Exposure Standard Practices," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*, Warren D. Ketola and Douglas Grossman, Editors, ASTM, 1993.

that the gloss values for a series of materials could be ranked with a high level of reproducibility between laboratories. When reproducibility in results from an exposure test conducted according to this practice have not been established through round-robin testing, performance requirements for materials shall be specified in terms of comparison (ranked) to a control material. The control specimens shall be exposed simultaneously with the test specimen(s) in the same device. The specific control material used shall be agreed upon by the concerned parties. Expose replicates of the test specimen and the control specimen so that statistically significant performance differences can be determined.

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

13. Keywords

13.1 accelerated; aging; carbon-arc; degradation; durability; exposure; ultraviolet