Designation: D 3361 – ~~93~~01

Standard Practice for ~~Operating Light- and Water-Exposure Apparatus (Unfiltered~~ Unfiltered Open-Flame Carbon-Arc ~~Type) for Testing Paint, Varnish, Lacquer,~~ Exposures of Paint and Related ~~Products Using the Dew Cycle~~ Coatings[1]

This standard is issued under the fixed designation D 3361; 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 ~~specific variations in~~ selection of test conditions ~~that are applicable when Method 2 in Practice G 23 is employed~~ for ~~the~~ accelerated exposure testing of ~~paint and related~~ coatings and ~~materials using the dew cycle with~~ related products in unfiltered open-flame carbon-arc devices conducted according to Practice G 151. This practice also covers the preparation of test specimens, the test conditions suited for coatings, and the evaluation of test results.

NOTE ~~1—Another procedure for exposing these products is covered~~ 1—Previous versions of this practice referenced carbon-arc devices described by Practice ~~D 822 in~~ G 23, which described very specific equipment designs. Practice G 23 has been withdrawn and replaced by Practice G 151, which describes performance criteria for all exposure devices that use laboratory light sources.

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 ~~radiation from~~ as the "dew cycle." Practice D 822 describes filtered open-flame ~~carbon arc. The filters in~~ carbon-arc devices, and Practice ~~D 822 remove some of the~~ D 5031 describes enclosed carbon-arc exposures. The radiation from an unfiltered open-flame carbon arc produces shorter wavelengths and higher levels of short wavelength ~~ultraviolet~~ radiation ~~not normally received at the earth's surface.~~

~~1.2 *This*~~ *than either filtered open-flame or enclosed carbon arcs.*

1.3 *This standard does not purport to address all of the safety ~~problems~~, 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:*

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[1] This practice is under the jurisdiction of ASTM Committee ~~D-1~~ 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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D 523 Test Method 358 Specification for Specular Gloss Wood to Be Used as Panels in Weathering Tests of Coatings[2]

D 609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products[2]

D 610 Test 523 Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces Specular Gloss[3]

D 660 Test Method 609 Practice for Evaluating Degree Preparation of Checking of Exterior Paints[2] Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products[3]

D 6610 Test Method for Evaluating Degree of Cracking of Exterior Paints Rusting on Painted Steel Surfaces[2]

D 662 Test Method for 659 Method of Evaluating Degree of Erosion Chalking of Exterior Paints[4]

D 714 Test 660 Test Method for Evaluating Degree of Blistering Checking of Exterior Paints[3]

D 77662 Test Method for Evaluating Degree of Flaking (Scaling) Erosion of Exterior Paints[3]

D 822 Practice 714 Test Method for Conducting Tests on Paint and Related Coatings and Materials Using Filtered Open-Flame Carbon-Arc Light- and Water-Exposure Apparatus[2] Evaluating Degree of Blistering of Paints[3]

D 87723 Test Methods for Producing Films Evaluating Degree of Uniform Thickness Flaking (Scaling) of Paint, Varnish, Lacquer, and Related Products on Test Panels[2] Exterior Paints[3]

D 1005 Test Methods 822 Practice for Measurement of Dry-Film Thickness of Organic Conducting Tests on Paint and Related Coatings and Materials Using Micrometers[2] Filtered Open-Flame Carbon-Arc Light- and Water-Exposure Apparatus[3]

D 1186 Test 823 Test Methods for Nondestructive Measurement Producing Films of Dry Film Uniform Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[2] Paint, Varnish, Lacquer, and Related Products on Test Panels[3]

D 1212 Test 1005 Test Methods for Measurement of Wet Film Dry-Film Thickness of Organic Coatings Using Micrometers[3]

D 1400186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonconductive Nonmagnetic Coatings Applied to a Nonferrous Metal Ferrous Base[3]

D 1729 Practice 1400 Test Method for Visual Evaluation Nondestructive Measurement of Color Differences Dry Film Thickness of Opaque Materials[2] Nonconductive Coatings Applied to a Nonferrous Metal Base[3]

D 1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely Illuminated Opaque Materials[3]

D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting[5]

D 1731 Practices 2244 Test Method for Preparation Calculation of Hot-Dip Aluminum Surfaces for Painting[4] Color Differences from Instrumentally Measured Color Coordinates[3]

D 1732 Practices 2616 Test Method for Preparation Evaluation of Magnesium Alloy Surfaces for Painting[4] Visual Color Difference with a Gray Scale[3]

D 2092 Practices 3980 Practice for Preparation Interlaboratory Testing of Zinc-Coated (Galvanized) Steel Surfaces for Painting[3] Paint and Related Materials[6]

D 42214 Test Methods for Calculation Evaluating Degree of Color Differences from Instrumentally Measured Color Coordinates[2] Chalking of Exterior Paint Films[3]

D 2616 Test Method 5031 Practice for Evaluation of Visual Color Difference with a Gray Scale[2] Conducting Tests on Paint and Related Coatings and Materials Using Enclosed Carbon-Arc Light and Water Exposure Apparatus[3]

D 4214 Test Methods 5870 Practice for Ev Calculating D Propegrty Retention Index of Chalking of Exterior Paint Films[2]

D 4587 Practice for Conducting Tests on Paint and Related Coatings and Materials Using a Fluorescent UV-Condensation Light-and-Water Exposure Apparatus[2] Plastics[7]

E 97 Test Method 691 Practice for Directional Reflectance Factor, 45-deg 0-deg, Conducting an Interlaboratory Study to Determine the Precision of Opaque Specimens a Test Method[8]

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[2] *Annual Book of ASTM Standards*, Vol 06.0T2.

[3] *Annual Book of ASTM Standards*, Vol 06.021.

[4] Discontinued 1989; see *1990 Annual Book of ASTM Standards*, Vol 02.05. 06.01.

[6] Discontinued 1998; see *1997 Annual Book of ASTM Standards*, Vol 14.02. 06.01.

[7] Apparatus and carbon arcs from the Atlas Electric Devices Co., 4114 N. Ravenswood Ave., Chicago, IL 60613, and from Suga Test Instruments Co., Ltd., 5-14-14, Shinjuko, Shinjuko-ko, Tokyo 160, Japan, have been found suitable for this purpose.

[7] *Annual Book of ASTM Standards*, Vol 08.03.

[8] *Annual Book of ASTM Standards*, Vol 14.02.

E 1347 Test Method for Color and Color Difference Measured by ~~Broad-Band Filter Reflectometry[9]~~ Tristimulus (filter) Colorimetry[3]

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[10]

G ~~26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With~~ 113 Terminology Relating to Natural and ~~W~~ Artificial Weathering Tests o~~u~~f Nonmet~~-W~~allic Materials[11]

G 141 Guide for Addressing Variability in Exposure Testing on Nonmetallic Materials[10]

G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests[10]

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources[10]

G 169 Guide for Appliction of Basic Statistical Methods to Weathering Tests[10]

3. ~~Significance and Use~~

~~3.1 Organic coatings on exterior exposure are subjected to attack by degrading elements of the weather, particularly ultraviolet light, oxygen, and water. This practice may be used for evaluating the behavior of films exposed~~Terminology

3.1 The definitions given in ~~apparatus that produces ultraviolet radiation, high temperatures, and water condensation on the films. However, light sources, such as the carbon arc, that emit a significant amount of radiation at wavelengths shorter than those in natural sunlight, may cause results that lead to unrealistic evaluations of weathering properties.~~

~~3.2 This test method produces failure of films at a very rapid rate because the test is run without filters. The unfiltered carbon arc produces light that does not exist at the earth's surface. Failure caused by this light may bear no relationship to failures in natural sunlight. It is essential to have a control material of known performance of a similar vehicle type in every test. Other ASTM Practices that can be operated in a way to produce wavelength spectra with lesser amounts of short wavelength UV include Practices D 822, D 4587, and G 26.~~

~~3.3 Substrates that have good thermal insulating properties should not be used because sufficient condensation cannot be obtained.~~

~~3.4 As no single light exposure apparatus, with or without water, can be specified as a direct simulation of natural exposure, this practice does not imply expressly, or otherwise, a specific correlation with outdoor exposure. It has, however, been useful in some instances.~~

~~3.5 Since climatic conditions vary with respect to time, geography, and topography, it may be expected that the effects of natural exposure will vary accordingly. All materials~~ Terminology G 113 are ~~not affected equally by the same environment. Results obtained by use of this practice should not be represented as equivalent~~ applicable to ~~those of any outdoor weathering test unless the degree of quantitative correlation has been established for the material in question.~~

~~3.6 Variations in results may be expected when operating conditions among similar type instruments vary within accepted limits of~~ this ~~standard procedure.~~ practice.

4. ~~A~~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.~~1~~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 pre~~-EH A~~pared according to Section 10 that describes the specific operating conditions used. Refer to Practice G 151 for detailed information on the caveats applicable to use of results obtained according to this practice.

NOTE ~~1~~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 G 141.

4.2.1 The spectral power distribution of light from an unfiltered open-flame carbon ~~arc),~~ 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 according to Practice ~~G~~ D 822 or D 5031 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.

~~[9] Discontinued; see *1992 Annual*~~

[9] *Annual Book of ASTM Standards,* Vol ~~14.02.~~ 02.05.

[10] Discontinued 2000; see *1999 Annual Book of ASTM Standards,* Vol 14.04.

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

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.[12,13] 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. 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. ~~Hazards~~

~~5.1 **Warning—**Never look directly at the carbon arc because ultraviolet radiation can damage the eye. Most carbon arc~~Apparatus

5.1 Use filtered open-flame carbon-arc apparatus ~~machines are equipped~~ with ~~door safety switches, but users of old equipment must be certain~~ automatic humidity control that conforms to ~~turn~~ the ~~operate switch off before opening~~ requirements defined in Practice G 151.

5.2 Do not place any filters between the ~~test chamber door.~~

~~5.2 This light source generates ozone~~ open flame carbon arc and ~~nitrous oxides. Exhaust from~~ the ~~cabinet should be vented to the atmosphere.~~ 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.

7. Test Specimens

~~6.1 Unless otherwise agreed upon, choose panels that meet~~

7.1 Apply the ~~applicable base panel requirements specified in Practices D 609, D 1730, D 1731, D 1732, or D 2092. Select panel sizes suitable for exhibiting the failure mode~~ coating to ~~be observed.~~

~~6.2 Apply the coatings to~~ flat (plane) panels with the ~~base panel material,~~ 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 ~~the~~ user.

~~6.3 Unless otherwise agreed upon, coat~~

7.2 Panel specifications and methods of preparation include but are not limited to Practices D 609 or D 1730, or Specification D 358. Select panel sizes suitable for use with the exposure apparatus.

7.3 Coat test panels in accordance with Test Methods D 823 ~~a, then~~d measure the film thickness in accordance with an appropriate procedure selected from Test Methods D 1005, D 1186, ~~D 1212,~~ or D 1400. Nondestructive methods are preferred because panels so measured ~~do not~~ need ~~to~~ not be repaired.

~~6.4 Unless otherwise specified, before~~

7.4 Prior to exposing coated panels in the apparatus, condition them at ~~73.5~~ 23 ± ~~3.5°F (23~~ 2°C (73 ± ~~2°C)~~ 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. Procedure~~

~~7.1 Mount the~~

7.4.1 Other procedures for preparation of test specimens ~~vertically both above and below~~ may be used if agreed upon by all interested parties.

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

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[12] 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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[13] Ketola, W., and Fischer, R., "Characterization and Use of Reference Materials in Accelerated Durability Tests," *VAMAS Technical Report No. 30*, NIST, June 1997.

7.6 Unless otherwise specified, expose at least three replicate specimens ~~from upper to lower rack to provide uniform exposure conditions over their surface. Specimens should be exposed approximately as many hours in~~ of each test and control material.

7.7 Follow the ~~top rack as~~ procedures described in ~~the bottom rack, but need not be inverted.~~

~~7.2 Operate in accordance with~~ Practice ~~G 23. The black panel temperature shall reach a maximum~~ G 147 for identification and conditioning and handling of ~~145 ± 9°F (63 ± 5°C) during the light-on-without-water-spray period~~ specimens of ~~the test cycle~~ test, control, and reference materials prior to, during, and after exposure.

7.8 Do not mask the ~~equilibrium relative humidity~~ face of a specimen for the ~~air in~~ purpose of showing on one panel the ~~test chamber shall~~ effects of various exposure times. Misleading results may be ~~50 ± 5 %. The chamber temperature shall be 90 ± 5°F (32 ± 3°C) during~~ obtained by this method, since the ~~light-off-with-water-spray period~~ masked portion of the specimen is still exposed to temperature and ~~the relative~~ humidity cycles that in many cases will affect results.

7.9 Retain a supply of ~~the air shall be 95 ± 5 %.~~

~~7.3 The water from the rack spray shall strike the back~~ 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 ~~only water~~ property of interest can be determined on unexposed file specimens each time exposed materials are evaluated.

NOTE 3—Since the ~~face~~ stability of the file specimen may also be time-dependent, users are cautioned that over prolonged exposure periods, or where small differences in the ~~dew formation caused by the chilled water on the back~~ order of ~~the panels. The temperature~~ acceptable limits are anticipated, comparison of exposed specimens with the ~~water shall~~ file specimen may not be ~~45 ± 4°F (7.2 ± 2°C). The water~~ valid. Nondestructive instrumental measurements are recommended whenever possible.

7.10 Specimens should ~~have less than 20 ppm of solids.~~

~~7.4 Operate~~ 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 ~~a cycle of 60 min dark with water-back spray and 60 min light~~ all materials as tests run without ~~w~~ 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, use the following exposure cycle:

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 ± 5 %.

NOTE 4—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 ± 5 %.

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).

NOTE 5—Each set point and its tolerances 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 tolerances and address the uniformity issue.

8.2 Practice D 822 lists other exposure cycles that may be used.

8.~~1~~3 ~~U~~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 G 151 for exposure without repositioning, use one of the ~~following methods~~ procedures described in Practice G 151 to ~~d~~ 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 ~~under this practice:~~

~~8.1.1 A mutually agreed upon specified number~~ area to the bottom half and move all holders in the bottom half of the exposure area to the top half. Do ~~o~~ not reposition the specimens within the holder.

NOTE 6—Incident energy at the top and ~~dark hours),~~

~~8.1.2 Number~~ bottom of ~~total hours~~ 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 G 151.

8.5.3 If specimens are found to have deposits or stains after exposure in the apparatus, the ~~q~~ water purity must be checked to

produce a mutually agreed upon amount determine if it meets the requirements of 8.5.2. On some occasions, exposed specimens can be contaminated by deposits from bacteria that can gerow in either the purified water usted 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 lagboratory that can meet the water quality requirements described in 8.5.

8.5.5 For devices with hupmidity 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 Evaluate conditions

9.1 In most cases, periodic evaluation of exposed test specimens by means 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.[14] See Practice G 151 for more information and additional cautions about the use of acceleration factors.

9.3 After each exposure increment, determine the following standards: changes in exposed specimens. Test Methods D 523, D 610, D 659, D 660, D 661, D 662, D 714, D 772, D 2244, D 2616, D 4214, and E 97 and Practices D 1729. Select methods in accordance with E 1347, or Practice D 1729 may be used. Consider product use requirements.

9.2 Because of possible variations in results as described in 3.5, no reference 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 obtained 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 E 691 or D 3980 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 unless accompanied by Section 10 or unless otherwise specified has not been established through round-robin testing, specify performance requirements for

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

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.[15]

NOTE 10—Guide G 169 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 ~~apparatus used and type~~ exposure device.

10.1.2 Type of ~~carbon arc,~~

~~10.1.2 Total hours of test (dark plus~~ 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.~~3~~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~~s~~,.

10.1.~~4~~9 Operating relative ~~humidities,~~

~~10.1.5 Test specimen preparation,~~

~~10.1.6 Results~~ humidity.

10.1.10 Type of ~~evaluation tests, and~~

~~10.1.7 Identification~~ spray water, if water spray was used.

10.1.10.1 Total solids and silica level of ~~standards~~ 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 characteri~~v~~stic property is re~~v~~ported, calculate results according to Practice D 5870.

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

~~11.1 light-exposure; ultraviolet light/radiation~~

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

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[15] 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.