Standard Practice for Conducting Tests on Sealants Using Artificial Weathering Apparatus[1]

This standard is issued under the fixed designation C 1442; 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 three types of laboratory weathering exposure procedures for evaluating the effect of actinic radiation, heat, and moisture on sealants.

1.2 The exposure sources used in the three types of artificial weathering devices are the filtered xenon arc, fluorescent ultraviolet lamps, and open flame carbon arc based on Practices G 155, G 154, and G 152, respectively.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information only.

1.4 The ISO standard related to this Practice is ISO 11431. Significant differences exist between the procedures. The ISO specimens are exposed through glass and are elongated prior to examination for loss of adhesion or cohesion, or both, following exposure.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 717 Terminology of Building Seals and Sealants

G 113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials

G 141 Guide for Addressing Variability in Exposure Testing of Nonmetallic Materials

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

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources

G 152 Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials

G 154 Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

G 155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

2.2 *ISO Standard:*

ISO 11431 Building Construction—Sealants: Determination of Adhesion/Cohesion Properties After Exposure to Heat and Artificial Light Through Glass and to Moisture[3]

3. Terminology

3.1 *Definitions*—Definitions of the following terms are found in Terminology C 717: *compound, cure, sealant, substrate.* Definitions of the following terms are found in Terminology G 113: *actinic radiation, control material, file specimen, fluorescent ultraviolet lamps, irradiance, open flame carbon arc, radiant exposure, sample, solar radiation-ultraviolet, solar radiation-visible, spectral power distribution, xenon arc*.

4. Summary of Practice

4.1 The test sealant may be applied to a variety of types of substrates or tested as a free film. The configuration depends on the properties to be evaluated following exposure. At least four replicates of each sealant being tested are required. After curing, one replicate of each sealant being tested is retained as an unexposed file specimen and three replicates are exposed to actinic radiation, heat, and moisture. At the end of the exposure period, the test sealant is examined for property change in comparison with the unexposed file specimen and the performance is compared with that of an exposed control material, if used.

4.2 It is recommended that a similar material of known performance under use conditions (a control) be exposed simultaneously with the test specimen for evaluation of the performance of the test materials relative to that of the control under the same laboratory exposure conditions. It is preferable

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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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

to use two control materials, one with relatively poor durability and the other with good durability.

5. Significance and Use

5.1 This practice determines the effects of actinic radiation, elevated temperature, and moisture on sealants and their constituents under controlled laboratory artificial weather test conditions.

5.2 When conducting exposures in devices which use laboratory light sources, it is important to consider *(1)* how well the artificial test conditions will reproduce property changes and failure modes caused by end-use environments on the sealant being tested and *(2)* the stability ranking of sealants. Refer to Practice G 151 for full cautionary guidance regarding laboratory weathering.

5.3 Because of differences in the spectral power distributions of the exposure sources (xenon arc, fluorescent UV lamps, and open flame carbon arc), as well as other conditions used in the three types of laboratory weathering tests, including temperature, type and amount of moisture, and test cycles, these three procedures may not result in the same performance ranking or types of failure modes of sealants. Further, different exposure durations may be required for testing the weathering performance of sealants by the three types of exposures. Comparisons should not be made of the relative stability of sealants exposed in the different types of apparatus.

5.4 Variations in results may be expected when operating conditions are varied within the accepted limits of this practice. Therefore, all test results using this practice must be accompanied by a report of the specific operating conditions as required in Section 10. Refer to Practice G 151 for detailed information on the caveats applicable to use of results obtained according to this practice.

5.5 No laboratory exposure test can be specified as a total simulation of actual use conditions in outdoor environments. The relative durability of materials in actual use conditions can vary in different locations because of differences in UV radiation, time of wetness, relative humidity, temperature, pollutants, and other factors. Results obtained from these laboratory accelerated exposures can be considered as representative of actual use exposures only when the degree of rank correlation has been established for the specific materials being tested and when the failure mode is the same. Exposure of a similar material of known outdoor performance, a control, along with the test specimens provides for evaluation in terms of relative durability under the test conditions, which also greatly improves the agreement in test results among different laboratories.

5.6 The acceleration factor relating the exposure time in a laboratory accelerated test to exposure time outdoors required to produce equivalent degradation is material dependent and can be significantly different for each material and for different formulations of the same material. Therefore, the acceleration factor determined for one material cannot be assumed to be applicable to other materials.

5.7 Results of this procedure will depend on the care that is taken to operate the equipment according to Practices G 152, G 154, and G 155. Significant factors include regulation of the line voltage, freedom from salt or other deposits from water, temperature control, humidity control, where applicable, condition and age of the burners and filters in xenon arc equipment, and age of lamps in fluorescent UV equipment.

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 G 141.

6. Test Specimens

6.1 The size and configuration of the specimens are determined by the specifications of the test method used to evaluate the effect of exposure on the specimens. Where practical, it is recommended that specimens be sized to fit the sample holders supplied with the apparatus.

6.2 Some common specimen configurations may include slab, tensile bar, H-block aymar samples, patties, sheets, drawdowns, preformed joint sealants, prevulcanized elastomeric joint materials, beads, channels, and so forth.

6.3 Specimens configured for movement during exposure to artificial weathering conditions also may be used.

6.4 Follow the procedures described in Practice G 147 for identification and handling of specimens prior to, during and after exposure.

6.5 When destructive tests are used to evaluate weathering stability, ensure that sufficient unexposed file specimens are retained so that the property of interest can be determined on unexposed file specimens each time exposed materials are evaluated.

7. Apparatus

7.1 *Test Chamber*—Choice of apparatus and exposure conditions selected shall be by mutual agreement among the interested parties. Because the different types of exposures may produce different test results, they cannot be used interchangeably without supporting data that demonstrates equivalency of the procedures for the materials tested. The procedures shall be as described in 7.2, 7.3, and 7.4, which are based on test procedures in ASTM and ISO standards and on parameters used in round robin tests on sealants.

7.1.1 The operational fluctuations are allowable deviations from the specified set points for irradiance, temperature and relative humidity during equilibrium operation. They do not imply that the user is allowed to program a set point higher or lower than that specified. If the operational fluctuations are greater than the maximum allowable after the equipment has stabilized, discontinue the test and correct the cause of the problem before continuing.

7.2 *Procedure for Exposure in Xenon Arc Light Apparatus*—Unless otherwise specified, use the following operating conditions and see Practices G 151 and G 155 for requirements that are not given below:

7.2.1 The xenon arc shall be used with daylight type filters to simulate direct exposure to solar radiation and conform with the spectral power distribution in Practice G 155.

7.2.2 The irradiance shall be set at a level not less than 0.35 nor greater than 0.51 $W/(m^2 \cdot nm)$ at 340 nm. The maximum allowable operational fluctuation is ±0.02 $W/(m^2 \cdot nm)$. For equivalent broadband irradiance levels and maximum allowable operational fluctuations at 300–400 nm and 300–800 nm, consult the manufacturer of the apparatus.

7.2.2.1 The irradiance level of 0.51 W/(m^2 · nm) at 340 nm is preferred for reasons given in Appendix X1.1. However, to accommodate users who are required to operate the machine at 0.35 W/(m^2 · nm) at 340 nm for other tests carried out simultaneously, the lower irradiance level is an option. The test duration is specified in terms of radiant exposure and the time is adjusted according to the formula in Annex A1.2 to obtain the same radiant exposure at different irradiance levels. See Appendix X2 for discussion on effect of variation in irradiance level.

7.2.3 The default exposure cycle shall be 102 minutes light only followed by a wet period of 18 minutes light with wetting either by water spray on the front surface or immersion in water. The water spray temperature is typically 21 ± 5°C, but may be lower if ambient water temperature is low and a holding tank is not used to store purified water. For immersion water temperature specifications, consult the manufacturer of the test apparatus.

NOTE 2—Water spray and immersion in water are different kinds of moisture exposures and can produce different results.

7.2.4 The exposure cycle of 2 h light only followed by 2 h light plus wetting either by water spray on the front surface or immersion in water can be used by agreement between concerned parties.

NOTE 3—The test cycle in 7.2.3 has been used by historical convention and may not adequately simulate the effects of outdoor exposure of sealants. Other cycles can be used by mutual agreement of all concerned parties. The cycle specified in 7.2.4, which provides more thorough wetting than the cycle in 7.2.3, was evaluated in ruggedness tests on sealants.

7.2.5 The uninsulated black panel temperature (BPT) shall be set at 70°C with a maximum allowable operational fluctuation of ±2.5°C during the dry period of exposure to the radiation. For the equivalent insulated black panel temperature (black standard temperature, BST), consult the manufacturer of the apparatus.

7.2.6 In equipment that provides for adjustment of the chamber air temperature, the latter shall be set at 48°C with a maximum allowable operational fluctuation of ±2°C.

7.2.7 In xenon arc apparatus that allows for control of relative humidity, it shall be set at 50 % during the dry period of exposure to light. The maximum allowable operational fluctuation is ±5 %.

7.3 *Procedure for Exposure in Fluorescent UV Apparatus*—Unless otherwise specified, use the following operating conditions and see Practices G 151 and G 154 for requirements that are not given below:

7.3.1 Use fluorescent UVA-340 lamps that comply with the spectral power distribution specifications in Practice G 154.

7.3.2 In apparatus with irradiance control, irradiance shall be set at 0.89 W/(m^2 · nm) at 340 nm.

NOTE 4—The irradiance setting is an attempt to provide irradiance similar to that measured in the fluorescent UV apparatus without irradiance control, when operated at a temperature of 60°C. In previous editions of C 1442, the irradiance set point was 0.77 W/(m^2· nm) at 340 nm. Due to an error in calibration by one manufacturer, the actual irradiance was 0.89 W/(m^2· nm) when the specific manufacturer's equipment was set at 0.77 W/(m^2· nm). Therefore, the correct setting for the recalibrated equipment is 0.89 W/(m^2· nm). However, for users of equipment made by other manufacturers that had been correctly calibrated, running at the new set point will result in a change in the actual irradiance of the test. If in doubt, users should consult the manufacturer of their device for clarification. There can be differences in test results when using different irradiance levels. Refer to Appendix X2 for information regarding the effect of irradiance.

7.3.3 Seal any holes larger than 2 mm in specimens and any opening larger than 1 mm around irregularly shaped specimens to prevent loss of water vapor. Attach porous specimens to a solid backing, such as aluminum, that can act as a vapor barrier.

7.3.4 For specimens that are less than 20 mm thick, including support dimensions, the exposure cycle shall be 8 h UV at an uninsulated black panel temperature set at 60°C followed by 4 h wetting by condensation at an uninsulated black panel temperature set at 50°C. The maximum allowable operational temperature fluctuation is ±2.5°C.

7.3.5 For specimens that are more than 20 mm thick, including support dimensions, the exposure cycle shall be 5 h UV only at an uninsulated black panel temperature set at 60°C followed by 1 h UV plus wetting by water spray on the front surface. The water temperature shall be less than 40°C. The maximum allowable operational temperature fluctuation is ±2.5°C.

NOTE 5—Wetting by condensation is not applicable to specimens having a thickness greater than 20 mm because of inadequate heat transfer.

7.3.6 Initiate exposure at the beginning of the UV period.

7.4 *Procedure for Exposure in Open Flame Carbon Arc Apparatus*—Unless otherwise specified, use the following operating conditions and see Practices G 151 and G 152 for requirements that are not given below.

7.4.1 The open flame carbon arc shall be used with daylight type filters and conform with the spectral power distribution specifications in Practice G 152.

7.4.2 The default exposure cycle shall be 102 minutes light only followed a wet period of 18 minutes light plus water spray on the front surface. The water spray temperature is typically 21 ± 5°C, but may be lower if ambient water temperature is low and a holding tank is not used to store purified water.

7.4.3 The exposure cycle of 2 h light only followed by 2 h light plus water spray on the front surface can be used by agreement between concerned parties.

7.4.4 The uninsulated black panel temperature shall be set at 70°C with a maximum allowable operational fluctuation of ±2.5°C during the dry period of exposure to the radiation.

7.4.5 In equipment that provides for adjustment of the chamber air temperature, the latter shall be set at 48°C with a maximum allowable operational fluctuation of ±2°C.

7.4.6 Relative humidity shall be set at 50 % during the dry period of exposure to light. The maximum allowable operational fluctuation is ±5 %.

8. Conditioning

8.1 Condition sufficient sealant in an original closed container for at least 24 h at standard conditions. Standard conditions are a temperature of 23 ± 2°C (73 ± 3.6°F) and relative humidity of 50 ± 5 %.

9. Procedure

9.1 Prepare at least four sealant test specimens. Unless otherwise agreed upon, cure the test specimens at standard conditions for 21 days. Other conditions for curing are acceptable when specified provided they meet the following requirements: the curing period shall not exceed 21 days, and the temperature during the curing period shall not exceed 50°C (122°F). Keep one test specimen as an unexposed file specimen and store at standard conditions and away from light.

9.2 Place at least three of the cured specimens and the control material, if used, in the artificial weathering apparatus with the sealant surface facing the radiation source.

9.3 *Specimen Mounting and Arrangement*—The test specimens shall be mounted so that the plane of the test surface is at a distance from the lamps consistent with the practice for operation of that apparatus. Refer to the appropriate practice for information about proper specimen mounting.

9.3.1 Specimens should be confined to an exposure area in which the irradiance is at least 90 % of the irradiance at the center of the exposure area. Unless it is known that irradiance uniformity meets this requirement, use one of the procedures described in Practice G 151, Section 5.1.4, to ensure equal radiant exposure on all specimens or to compensate for differences within the exposure chamber. If the specimens do not completely fill the racks, fill the empty spaces with blank metal panels to maintain the test conditions within the chamber.

9.4 The apparatus shall be operated continuously. However, if the test needs to be interrupted to perform routine maintenance or inspection, it should be during a dry stage. Specimens should not be removed from the exposure apparatus for more than 24 h and then returned for additional exposure because this does not produce the same results on all materials as tests run without this type of interruption. When specimens have to be removed for more than 24 h, report the elapsed time.

9.5 After artificial weathering, condition the samples at 23 ± 2°C (73 ± 3.6°F) and 50 ± 5 % relative humidity for at least 2 h.

9.6 Use one of the following methods as a basis for the duration of exposure under this procedure and consult Practice G 151 for guidance on Periods of Exposure and Evaluation of Test Results. The exposure duration shall be sufficient to produce a statistically significant change of the property evaluated in a material known to give poor performance when used in the application of interest. Information on the test method reproducibility is required for a pass/fail evaluation based on a specific property change after a specified exposure time or radiant exposure.

9.6.1 Use a mutually agreed upon specified time period or amount of radiant exposure. The amount of radiant exposure rather than time is specified for xenon arc tests to obtain equivalent radiant exposures at the different levels of irradiance allowed. See Annex A1 for the relation between time and radiant exposure at the irradiance setting used;

9.6.2 Use the time period or amount of radiant exposure required to produce a mutually agreed upon defined change in a property of the sealant. This method provides a more accurate evaluation of weatherability than the method based on change after a specified exposure period.

9.7 At the end of the exposure period, evaluate the appropriate properties in accordance with recognized ASTM procedures and report the results in accordance with Practice G 151.

10. Report

10.1 The report shall make reference to this ASTM practice and, in addition to the items specified in Practice G 151, the report shall include the following for each sample tested:

10.1.1 Identification of the sealant specimen tested, and control material, if used, including a description of the origin of the sealant, that is, laboratory production facility, product code, color code or name, and lot number, if applicable;

10.1.2 The substrate used, if any;

10.1.3 Sealant cure conditions employed;

10.1.4 the type of laboratory weathering test used and manufacturer and model of artificial weathering apparatus; and

10.1.5 The irradiance level and actual time (in hours) the specimens were exposed in the weathering device.

10.1.6 Variations, if any, from the specified test procedure.

11. Precision and Bias

11.1 The repeatability and reproducibility of results obtained in exposures conducted according to this practice will vary with the materials tested, the material property measured, and the specific test conditions and cycles used. It is essential to determine reproducibility of the exposure/property measurement process when using results from exposures conducted according to this practice in product specifications.

12. Keywords

12.1 accelerated weathering; actinic radiation; artificial accelerated weathering; durability; exposure; fluorescent UV lamps; light; open flame carbon arc; sealant; temperature; ultraviolet; UV-radiation; weathering; xenon arc

ANNEX

(Mandatory Information)

A1. Xenon Arc Radiant Exposure Versus Time

A1.1 Xenon Arc Irradiance Setting

A1.1.1 The recommended irradiance at the set point is 0.51 $W/(m^2 \cdot nm)$ at 340 nm. However, to accommodate testing in xenon arc machines set at 0.35 $W/(m^2 \cdot nm)$ at 340 nm for other specimens being tested at the same time, the option is given of testing sealants at the lower irradiance level. Therefore, for xenon arc tests, the test duration is specified in terms of radiant exposure rather than time (see 9.6.1) in order to provide equivalent radiant exposures at the different irradiance levels.

A1.2 Times for Equivalent Radiant Exposures at Different Xenon Arc Irradiance Levels

A1.2.1 The relation between radiant exposure in Joules and time in hours is based on the irradiance level and the following equivalency: 1 Watt = 3600 Joules/hour.

The general equation relating radiant exposure in kiloJoules (kJ) to time in hours is:

$$\text{Watts} \times 3.6\ \text{kJ/hr} \times \text{hours of exposure} = \text{kiloJoules} \quad (A1.1)$$

For example, at an irradiance level of 0.35 $W/(m^2 \cdot nm)$ at 340 nm, the radiant exposure in 500h is 630 $kJ/(m^2 \cdot nm)$ at 340 nm. At an irrradiance level of 0.51 $W/(m^2 \cdot nm)$ at 340 nm, 630 $kJ/(m^2 \cdot nm)$ at 340 nm is obtained in 343 h of exposure.

APPENDIXES

(Nonmandatory Information)

X1. IRRADIANCE SPECIFICATION FOR XENON ARC EXPOSURE

X1.1 Justification for the Xenon Arc Recommended Irradiance Setting of 0.51 $W/(m^2 \cdot nm)$ at 340 nm

X1.1.1 *Harmonization with ISO Standards*

In ISO standards that contain laboratory accelerated weathering tests, the xenon arc irradiance level is generally specified as 550 W/m^2 in the spectral region 290–800 nm. It is the irradiance of the reference solar spectrum recommended in the Publication of the International Commission on Illumination, CIE No. 20 (TC-2.2) 1972 for simulation in accelerated laboratory testing devices. The xenon arc irradiance of 550 W/m^2 at 290–800 nm translates to 0.51 $W/(m^2 \cdot nm)$ at 340 nm.

X1.1.2 *Representative of Solar Irradiance at Benchmark Exposure Sites*

Spectral solar irradiance measured as a function of time of day in Miami, Florida and Phoenix, Arizona between April and September show that for approximately three or four hours before and after noon, the irradiance at 340 nm is at least 0.50 $W/(m^2 \cdot nm)$. The irradiance at these locations at noon under optimum atmospheric conditions is 0.68 $W/(m^2 \cdot nm)$ at 340 nm on the surface of the specimens. Thus, the xenon arc irradiance of 0.51 $W/(m^2 \cdot nm)$ at 340 nm is representative of solar irradiance levels to which sealants are exposed in commonly used outdoor benchmark exposure sites.

X2. EFFECT OF EXPOSURE AT DIFFERENT IRRADIANCE LEVELS

X2.1 Specimens receiving equivalent radiant exposures at different irradiance levels will be exposed to elevated temperature and moisture for different lengths of time. Heat and moisture are important factors in the weathering process in conjunction with solar and solar-simulated radiation. For specimens that are particularly sensitive to heat or moisture, differences in time of exposure to these factors can theoretically affect test results. Also, the influence of these weather factors may differ at different irradiance levels. Due to variations in the response of materials to increase in irradiance, studies have shown that for the same increase in irradiance (63 %), its effect on rate of degradation was not the same for all materials ((1), (2)). However, in a study on several types of polymer materials, for equivalent radiant exposures the color change was the same at double and triple the normal irradiance (3). Also, good correlation with outdoor exposure in terms of the relative stabilities of various types of materials have been reported for exposures at triple the normal irradiance level ((4), (5)). For more information on the effect of different irradiance levels in fluorescent UV devices, see Reference (1).

References

(1) Gregory R. Fedor and Patrick J. Brennan, "Irradiance Control in Fluorescent UV Exposure Testers," in *Accelerated and Outdoor Durability Testing of Organic Materials,* ASTM STP 1202, Warren D. Ketola and Douglas Grossman, Eds., American Society of Testing and Materials, Philadelphia, 1994, pgs. 199–215.

(2) Gregory R. Fedor and Patrick J. Brennan, "Comparisons Between Natural Weathering and Fluorescent UV Exposures: UVA-340 Lamp Test Results," in *Durability Testing of Nonmetallic Materials,* ASTM STP 1294, Robert J. Herling, Ed., American Society for Testing and Materials, Philadelphia, 1996, pgs. 91–105.

(3) Jorg Boxhammer, "Shorter Test Times for Thermal- and Radiation-Induced Aging of Polymer Materials 1: Acceleration by Increased Irradiance and Temperature in Artificial Weathering Tests," *Polymer Testing*, 20(7), 719–724, 2001.

(4) Kurt P. Scott, "Viability of High Irradiance Xenon Arc Weathering Tests," in *Accelerated and Outdoor Durability Testing of Organic Materials,* ASTM STP 1202, Warren D. Ketola and Douglas Grossman, Eds., American Society of Testing and Materials, Philadelphia, 1994, pgs. 216–231.

(5) Shigeru Suga and Shigeo Suga, "New Accelerated Light Fastness Test with Super High Irradiance Using a Xenon Arc Lamp," in *Accelerated and Outdoor Durability Testing of Organic Materials,* ASTM STP 1202, Warren D. Ketola and Douglas Grossman, Eds., American Society of Testing and Materials, Philadelphia, 1994, pgs. 232–246.