Designation: C 1501 – 09

Standard Test Method for Color Stability of Building Construction Sealants as Determined by Laboratory Accelerated Weathering Procedures[1]

This standard is issued under the fixed designation C 1501; 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 test method describes laboratory accelerated weathering procedures using either fluorescent ultraviolet or xenon arc test devices for determining the color stability of building construction sealants.

1.2 Color stability rankings provided by these two procedures may not agree.

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

1.4 There is no equivalent ISO standard for this test method.

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

C 1442 Practice for Conducting Tests on Sealants Using Artificial Weathering Apparatus

D 1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials

D 2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

E 284 Terminology of Appearance

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

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

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

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 *CIE Documents:*

CIE Publication Number 85: 1989, Technical Report-Solar Spectral Irradiance[3]

3. Terminology

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

4. Summary of Test Method

4.1 Specimens for this procedure are prepared in which the sealant to be tested adheres to flat aluminum panels. While any surface can be specified and used, this test method was developed with aluminum panels. At least four replicates of each sealant being tested are required. After curing, one replicate of each sealant being tested is retained as a file specimen and at least three replicates are exposed to actinic radiation, heat and moisture. At the end of the exposure period, the test sealant is examined for color change by comparison to the unexposed file specimen.

4.2 As recommended in ASTM G 151 Section 4.2, unless several test sealants are exposed to determine their relative color stabilities, one or two control sealants of similar composition and construction to the test specimen and having known color stability should be exposed simultaneously with the test

[1] This test method is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.40 on Weathering.

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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] CIE Central Bureau, Vienna, Kegelgasse 27, A-1030 Wien, Austria

specimen to rank the color stability of the latter compared with the color stability of the control(s).

5. Significance and Use

5.1 This test method is intended to induce color changes in sealants, as well as their constituent pigments, associated with end-use conditions, including the effects of sunlight, moisture, and heat. The exposures used in this test method are not intended to simulate the color change of a sealant caused by localized weathering phenomena, such as atmospheric pollution, biological attack, and saltwater exposure.

5.2 When conducting exposures in devices that use laboratory light sources, it is important to consider how well the artificial test conditions will reproduce property changes and failure modes associated with end-use environments for the sealant being tested. Information on the use and interpretation of data from accelerated exposure tests is provided in ASTM G 151.

5.3 When this test method is used as part of a specification, exact procedure, test conditions, test duration and evaluation technique must be specified. Results obtained between the two procedures may vary, because the spectral power distribution of the light sources (fluorescent UV and xenon arc) differ. Sealants should not be compared to each other based on the results obtained in different types of apparatus.

5.4 These devices are capable of matching ultraviolet solar radiation reasonably well. However, for sealants sensitive to long wavelength UV and visible solar radiation, the absence of this radiation in the fluorescent UV apparatus can distort color stability ranking when compared to exterior environment exposure.

NOTE 1—Refer to Practices G 151 for full cautionary guidance regarding laboratory weathering of non-metallic materials.

6. Apparatus

6.1 *Aluminum Panels*—Apply sealant to four aluminum panels, alloy 3003 H14, dimensions, 152mm by 76mm by 0.64mm thick (6 by 3 by 0.025 inches thick), using rectangular Brass Frame described in 6.3. Other substrate materials are acceptable when specified.

6.2 *Spatula*, steel, about 150 mm (6 inches) long.

6.3 *Rectangular Brass Frame*, with outside dimensions of approximately 152mm by 76mm, and inside dimensions 75mm by 65mm by 3.0mm (3 inches long by 2.5 inches wide by 0.125 inches deep).

6.4 *Thin Bladed Knife*.

6.5 *Color Evaluation Apparatus*:

6.5.1 *Lighting Equipment*, to evaluate color difference according to D 1729; or,

6.5.2 *Spectrophotometer*, complying with Practice E 1164; or,

6.5.3 *Colorimeter*, complying with Test Method D 2244.

6.6 *Cleaning Solvent*, isopropyl alcohol.

6.7 *Test Chamber*—Choice of type of apparatus shall be by mutual agreement among the interested parties. Because of differences in test conditions, test results may differ with the type of apparatus used. Consult Practices G 154 and G 155 for differences in the spectral power distributions of the exposure sources and Practice C 1442 for the differences in test parameters in the two types of apparatus specified. The test cycles have 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.

6.7.1 *Fluorescent UV/Condensation Apparatus*—Operate the device in accordance with the procedure in Practice C 1442, Section 7.3.

6.7.2 *Xenon Arc Light Apparatus*—Operate the device in accordance with the procedure in Practice C 1442, Section 7.2.

NOTE 2—CIE Publication No. 85:1989 provides data on solar spectral irradiance for typical atmospheric conditions, which can be used as a basis for comparing laboratory light sources with daylight. For example, global solar irradiance is 0.68 W/(m^2· nm) at 340 nm as presented in CIE 85 table 4.

6.7.3 *Moisture*—The test specimens may be exposed to moisture in the form of water spray, condensation, immersion, or high humidity as agreed on by the mutual parties. Refer to Practice G 151 Section 6.6 for discussion of the various forms of moisture in accelerated test devices.

7. Procedure

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

7.2 Prepare at least four sealant test specimens and at least four of the control material, if used, on aluminum panels. Clean the aluminum panels using cleaning solvent. Allow solvent to dry before applying sealant.

7.3 Position the brass frame on the aluminum panel and overfill the entire frame with conditioned sealant. Strike off flat using the spatula. Immediately separate the sealant from the frame by running a thin bladed knife along the inside of the frame. Lift the frame from the aluminum panel.

7.4 Cure the test specimens at standard conditions for 21 days. Other conditions for curing are acceptable when specified provided they meet the following requirements: *1*) the curing period shall not exceed 21 days, and *2*) 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.

7.5 Place at least three of the cured specimens and the control material if used, in the weathering apparatus with the sealant surface facing the radiation source and positioned at the specified distance from the source. 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 compensation 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.

7.6 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 period.

7.7 Expose the specimens for a mutually agreed upon specified duration in hours or radiant energy. Because of the option of operating the xenon arc apparatus at an irradiance level of 0.35 W/(m^2.nm) at 340 nm as well as 0.51 W(m^2.nm) at 340 nm, test duration is specified in terms of radiant energy. The time in hours at the irradiance level used is determined according to the formula in Annex A1.2.1 in Practice C 1442. Evaluate specimens in the fluorescent UV apparatus at 1,000-hour exposure intervals, where applicable. Evaluate specimens in the xenon arc apparatus operated at an irradiance level of 0.51 W/(m^2.nm) at 340 nm at intervals of 1835 kJ/(m^2.nm) at 340 nm. The minimum exposure duration shall be sufficient to produce a statistically significant change in color in the least color stable building construction sealant.

7.8 After artificial weathering, condition the samples at 23 ± 2°C (73 ± 4°F) and 50% ± 5% relative humidity for at least two hours before color evaluation.

7.9 The color measuring instrument should be set up to read in the CIE L*a*b* color scale with illuminant C or D65 and 10° observer, specular component included. Measure the color values of each test specimen and control, if used, prior to exposure and after each exposure. The edges of the specimens may be trimmed to compensate for shrinkage and provide a secure fit in the color-measuring instrument. Make a minimum of three measurements per specimen, moving or rotating the specimen so as to measure different areas. Using the CIELAB color-difference formula described in Test Method D 2244, calculate $\Delta E *_{ab}$ between each exposed specimen and its file specimen (unexposed counterpart).

7.10 As an alternative to the instrumental color measurement procedure in 7.9 above, evaluate color differences between exposed and unexposed file specimen sealant using D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials.

7.11 Pass/fail evaluations based on either absolute color change after a specified exposure period or comparative stabilities, should be made using the variability determined for the combined exposure and color measurement so that statistically significant pass/fail judgements can be made.

7.12 The duration of exposure required to obtain a specified level of color difference can be determined by interpolation from a plot of $\Delta E *_{ab}$ versus time or cumulative radiant exposure. This approach permits the rate of color change to be determined and weatherability to be more accurately evaluated that in tests based on change after a specified exposure period.

8. Report

8.1 In addition to the items specified in the Report section of Standard Practice G 151, the report shall include the following for each sample tested:

8.1.1 Type, manufacturer and model of laboratory accelerated weathering apparatus,

8.1.1.1 Irradiance level and actual time (number of hours) in weathering apparatus.

8.1.2 Identification of sealant specimen tested, and controls used, if any.

8.1.3 Sealant cure conditions employed,

8.1.4 Qualitative visual color differences as specified in D 1729 or quantitative color difference as specified in D 2244.

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

9. Precision and Bias

9.1 The precision of this test method is based on an interlaboratory study of C 1501, Standard Test Method for Color Stability of Building Construction Sealants as Determined by Laboratory Accelerated Weathering Procedures, conducted in 2005. Results in this study were obtained from eight laboratories reporting fluorescent UV exposure and four laboratories reporting xenon-arc exposure, testing four different sealants. Each participating laboratory reported three replicate test results, at each time interval, for every material. The exposure times ranged from 250 to 3,000 h with color measurements made on the same specimen after each 250-h interval. However, test results for all exposure intervals were not reported by each laboratory. Except for the use of only four laboratories for tests using the xenon arc procedure, Practice E 691 was followed for the design and analysis of the data. The details are given in an ASTM research report.[4]

9.1.1 *Repeatability, Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

9.1.2 *Reproducibility, Limit (R)*—Two test results shall be judged not equivalent if they differ by more then the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

9.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E 177.

9.1.4 The repeatability and reproducibility limits based on averages over all the exposure times for each material exposed in the fluorescent UV and xenon-arc devices are listed in Table 1 and Table 2, respectively. The tables also show the overall averages based on the results for all materials, A through D, and all exposure times evaluated in the round-robin.

9.1.5 Any judgment in accordance with 9.1.1 and 9.1.2 would normally have an approximate 95 % probability of being correct, however the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of laboratories reporting results guarantees that there will be

[4] Supporting data available from ASTM Headquarters, request RR:C24-1056.

TABLE 1 Repeatability and Reproducibility Averages Based on ΔE for all Exposure Times in the Fluorescent UVA-340 Device

Material	Repeatability Standard Deviation, S_r	Reproducibility Standard Deviation, S_R	Repeatability Limit, *r*	Reproducibility Limit, *R*
A	0.40	0.66	1.12	1.86
B	0.79	0.88	2.21	2.47
C	0.46	0.56	1.29	1.57
D	0.51	1.11	1.45	3.11
Average A-D	0.54	0.80	1.52	2.25

TABLE 2 Repeatability and Reproducibility Averages Based on ΔE for All Exposure Times in the Xenon-Arc Device

Material	Repeatability Standard Deviation, S_r	Reproducibility Standard Deviation, S_R	Repeatability Limit, r	Reproducibility Limit, R
A	0.47	1.16	1.30	3.26
B	0.44	0.83	1.23	2.31
C	0.23	0.28	0.63	0.80
D	0.90	1.21	2.51	3.38
Average A-D	0.51	0.87	1.42	2.44

times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95 % probability limit would imply. The repeatability limit and the reproducibility limit should be considered as general guides, and the associated probability of 95 % as only a rough indicator of what can be expected.

9.2 *Bias*—At the time of this study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

9.3 The precision statement was determined through statistical examination of 563 results, from eight laboratories, on four materials. These four sealants were described as the following:

Sealant A: Light Gray One-Component Moisture Cured Polyurethane

Sealant B: White Polyurethane

Sealant C: White Acrylic Latex

Sealant D: Dark Gray Two-Part Polyurethane

To judge the equivalency of two test results, it is recommended to choose the sealant closest in characteristics to the test sealant.

10. Keywords

10.1 artificial accelerated weathering; sealant; color change; color stability

APPENDIX

(Nonmandatory Information)

X1. INSTRUMENTAL COLOR MEASURMENTS

X1.1 A discussion of color measurement instrumentation is provided below to aid in the interpretation of quantitative color difference measurements.

X1.2 *Color Change*—The color of an object, either measured or perceived, is dependent on a number of factors. These include the illuminating light source, the viewing angle and the type of machine used to measure the color. In the case of a human observer, the observer's experience with similar observations plays a role as well. This is due to both physical and psychological variations and limitations in each individual. A less experienced observer may have subconscious tendencies towards preferring a specific color or believing that a color difference of one type may be more desirable than another. Also, the concentration of rods and cones in the retina effects an individual's ability to perceive color.

X1.3 A number of instrumental methods exist for determining color and change in color as determined by comparison either with a file specimen or with the measurements obtained on the test specimen before exposure. A system widely used, and used in this discussion, is the CIE 1976 L*a*b* Uniform Color Space, abbreviated CIELab. This system is defined as a simplified uniform color space where L* is on a scale of 0 to 100 and indicates dark to light (lightness); a* is expressed from positive, red, to negative, green, values; b* is expressed from positive, yellow, to negative, blue, values. From these values, the magnitude of color difference, ΔE^*_{ab}, is calculated as follows:

$$\Delta E^*_{ab} = [(L^*1 - L^*0)^2 + (a^*1 - a^*0)^2 \ + (b^*1 - b^*0)2]^{\frac{1}{2}} \qquad (X1.1)$$

where:

L^*_1, a^*_1, *and* b^*_1, = refer to the test specimen after exposure

L^*_0, a^*_0, *and* b^*_0, = refer to the test specimen before exposure

X1.4 The magnitude of ΔE^*_{ab} gives no indication of the character of the change. These are reported as the magnitude and direction of change of the hue, chroma, saturation or lightness from a reference point. Chalking will increase the difference in the L* value while bringing those of a* and b* closer to 0. A yellowing will increase the b* difference but may have little impact on the other variables. Both phenomenon may produce similar ΔE^*_{ab} values without discerning which is occurring. In all other comparisons, a visual standard should be kept to compare the relative change.

X1.5 However, for this test method only the magnitude of the change is of importance since a change in color may be perceived as aesthetically unpleasing. Generally, ΔE^*_{ab} values of less than 1.0 indicate only a slight change in color from the unexposed file specimen. The human eye may not perceive changes in this range. Values ranging from 1.0 to about 3.0 indicate a perceptible change and may usually be considered acceptable. When the ΔE^*_{ab} value is above 3.0, the change is readily perceived by the human eye. Whether these values are unacceptable is dependent on the application and the original color of the material.

X1.6 To further understand color and appearance, ASTM E 284Standard Terminology of Appearance and ASTM D 2244 Standard Test Method for Calculation of Color Differences From Instrumentally Measured Color Coordinates should be reviewed.