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Standard Practice for Accelerated Testing for Color Stability of Plastics Exposed to Indoor Office Environments[1]

This standard is issued under the fixed designation D4674; 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 basic principles and operating procedures for using fluorescent light to determine color stability of plastics when materials are exposed in typical office environments where fluorescent overhead lighting and window-filtered daylight are used for illumination and where temperature and humidity conditions are in accordance with American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) recommendations for workers' comfort.

1.2 This practice describes four methods where specimens are exposed to fluorescent light under controlled environmental conditions. Two of the methods use an exposure device that provides for mixing of fluorescent lamps and two of the methods use devices that comply with Practice G154.

NOTE 1—Method I uses cool white fluorescent lamps and window glass filtered fluorescent UVB lamps and is the same method described in previous versions of this standard.

1.3 Specimen preparation and evaluation of the results are covered in ASTM methods or specifications for specific materials. General guidance is given in Practice G151. More specific information about methods for determining the change in properties after exposure and reporting these results is described in Practice D5870.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 Unless otherwise specified, all dimensions are nominal.

1.6 *This practice may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, is 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.* Specific precautionary statements are given in Section 7.

NOTE 2—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials

D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

D3980 Practice for Interlaboratory Testing of Paint and Related Materials (Withdrawn 1998)[3]

D5870 Practice for Calculating Property Retention Index of Plastics

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials

G141 Guide for Addressing Variability in Exposure Testing of Nonmetallic Materials

G147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests

G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources

G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials

G169 Guide for Application of Basic Statistical Methods to Weathering Tests

3. Terminology

3.1 *Definitions*—The definitions given in Terminology G113 are applicable to this practice.

4. Summary of Practice

4.1 This practice provides for the exposure of specimens to fluorescent light under controlled environmental conditions. Radiant energy is provided by one of the following fluorescent light sources: (1) VHO cool-white fluorescent lamps and glass filtered fluorescent UV lamps, (2) VHO cool-white fluorescent

[1] This practice is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.50 on Durability of Plastics.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

lamps alone, (3) standard output cool white fluorescent lamps alone, or (4) UVA-351 fluorescent UVA lamps.

4.1.1 Method I is intended to simulate the conditions in an office environment plus a portion of solar UV radiation transmitted by window glass. Methods II and III are intended to simulate only the indoor lighting component of a typical office environment. Method IV is intended to simulate only the effects of a portion of solar UV radiation transmitted through window glass.

NOTE 3—A comparison of the four listed methods has not been performed, and as such, results obtained from each method cannot be considered as equivalent.

NOTE 4—For more information on the use of fluorescent UV lamps to simulate solar UV radiation behind window glass, refer to Annex A1 of Practice G154.

4.1.2 Do not compare Comparison of results obtained from specimens exposed using the methods described should not be made unless correlation has been established between the methods being compared for the materials being tested.

4.2 Color change is determined periodically throughout the course of the exposure by comparison of the exposed specimens to unexposed specimens, using either visual or instrumental procedures.

5. Significance and Use

5.1 Tests conducted in accordance with this practice are intended to induce property changes associated with use exposure to light and heat in typical office environments. These exposures are not intended to simulate the deterioration caused by localized phenomena such as handling, dirt contamination, etc.

NOTE 5—**Caution:** Caution: Refer to practice G151 for full cautionary guidance applicable to all laboratory weathering devices. Additional information on sources of variability and on strategies for addressing variability by design and data analysis of laboratory accelerated exposure tests is found in Guide G141.

5.2 Variation in results may be expected are possible between the different methods described in this practice. For example, differences in spectral distribution of the lamps used and variations in the irradiance for a single type of lamp can cause significant differences in test results. Therefore, any no reference to the use of this practice should be made unless accompanied by a report prepared in accordance with Section 12 that describes needs to include a reference to the method used.

5.3 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. 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.

6. Apparatus

6.1 *Test Chamber*—Unless otherwise specified, the test chamber shall comply with the requirements of Practice G151.

6.1.1 The test chamber used for Methods I and II shall be designed so that simultaneous operation of VHO cool white and glass filtered UV fluorescent lamps is possible, and shall be equipped with a radiometer complying with the requirements of Practice G151 and calibrated from 250 to 400 nm. Annex Annex A1 contains more information about the design of the apparatus used for Methods I and II.

6.1.2 The test chamber used for Methods III and IV shall conform to the requirements of Practice G154.

6.2 The spectral distribution of the UVB-313, UVA-340, and UVA-351 shall comply with the requirements of practice G154. The spectral power distribution of the cool white lamps used shall comply with the requirements given in Annex Annex A2.

6.3 *Window glass*—Unless otherwise specified the window glass shall be good grade clear, flat, drawn "single strength" sheet glass free of bubbles or other imperfections and between 2.0 and 2.5 mm in thickness. The glass shall be preaged in the device for at least 24 hours prior to use.

6.4 For Methods I and II, place the apparatus in an environment that meets ASHRAE recommendations of 20 to 25.5°C and 40 to 50 % relative humidity. For Methods III and IV follow the requirements of Practice G154 for the area in which the instruments are used.

6.5 *Instrument Calibration*—To ensure standardization and accuracy, the instruments associated with the exposure apparatus (for example, timers, thermometers, UV sensors, and radiometers) require periodic calibration to ensure repeatability of test results. Whenever possible, calibration should needs to be traceable to national or international standards. Unless otherwise specified, calibration schedule and procedure shall be in accordance with manufacturer's instructions.

7. Hazards

7.1 Never look directly at the operating lamps unless wearing UV protective eyewear. The apparatus specified in Section 6 shall be constructed so that the operator will not be exposed to hazardous levels of UV radiation.

7.2 Discard or recycle lamps in accordance with any relevant local ordinances when they are no longer suitable for the tests described.

8. Test Specimens

8.1 The recommended specimen size is a rectangular flat piece 50 by 80 by 4 mm (minimum thickness). This size is adequate for visual or instrumental evaluation. Other specimen dimensions may be used by mutual agreement among the parties concerned but exposed surfaces need to be coplanar for most consistent results.

9. Test Conditions

9.1 Conduct exposures in accordance with one of the following exposure methods.

9.1.1 *Method I:*

9.1.1.1 Use apparatus conforming to the requirements described in Annex Annex A1.

NOTE 6—For Method I, the contribution of fluorescent UV lamp radiation to the total UV actinic exposure is adjusted by changing the percentage of time the specimens are exposed to the various lamp types.

9.1.1.2 This method provides for exposure of specimens to radiant energy from an array of very high output (VHO) cool white fluorescent lamps plus intermittent radiant energy from window glass filtered fluorescent UV lamps. The total UV radiant exposure from both sources is calculated by determining the total UV irradiance from each type of lamp separately and calculating the product of the total UV irradiance and exposure time in Watt-hours/m^2 (W-h/m^2).

9.1.1.3 Place test specimens in the exposure area, leaving at least a 25 mm empty border around the exposure area.

9.1.1.4 Run the device with both the cool white and fluorescent UV lamps on for at least 20 minutes, then turn off the fluorescent UV lamps and record the UV irradiance with only the cool white lamps operating (CWE in W/m^2, 250-400 nm). Calculate the exposure time required for the desired CW_E radiant exposure as follows:

$$CW_t = \frac{CW_H}{CW_E} \quad (1)$$

where:

CW_t = exposure time for cool white lamps,
CW_H = desired UV radiant exposure for cool white lamps alone, and
CW_E = UV irradiance measured with only with the cool white lamps operating.

9.1.1.5 Run the device with only the fluorescent UV lamps on and record the UV irradiance (UVE in W/m^2, 250-400 nm). The UV actinic exposure from the filtered fluorescent UV lamps is set at 12 % of the UV actinic exposure for the cool white lamps. Calculate the total operating time for the fluorescent UV lamps as follows:

$$UV_t = \frac{0.12 \times CW_H}{UV_E} \quad (2)$$

where:

UV_t = exposure time for fluorescent UV lamps,
CW_H = desired UV radiant exposure for cool white lamps alone, and
UV_E = UV irradiance measured with only with the fluorescent UV lamps operating.

NOTE 7—Although an office environment sees some UV exposure due to sunlight through window glass, most photodegradation originates from fluorescent lighting. The 12 % is an estimate of a representative office environment.

9.1.1.6 Calculate the fraction of time per hour for which the fluorescent UV lamps are turned off (UV_{OFF}) as follows:

$$UV_{OFF} = \frac{CW_t - UV_t}{UV_t} \quad (3)$$

(1) Replace the cool white lamps if UV_{OFF} is greater than or equal to one.

9.1.1.7 Program the device so that the cool white lamps operate continuously and the fluorescent UV lamps are turned on once per hour for the fraction of time calculated in section 9.1.1.6. Continue the exposure for the total time calculated in section 9.1.1.4.

9.1.1.8 Reposition the specimens at time intervals equal to 25 ± 5 % of the total time calculated in section 9.1.1.4. Move specimens just to the right of the center line of the exposure area to the position farthest to the right in the exposure area and move remaining specimens one position to the left. Move specimens just to the left of the center line of the exposure to the position farthest to the left in the exposure area and move remaining specimens in this half one position to the right.

9.1.1.9 Maintain chamber air temperature between 30 and 40°C during the exposure. If the air temperature exceeds 40°C, the device must be shut off and the cause for the high temperature corrected before exposures can continue.

9.1.1.10 Conduct exposures for a total time agreed upon by all interested parties. Periodically remove test and control specimens for color measurement and relevant physical property tests.

9.1.2 *Method II:*

9.1.2.1 Use apparatus conforming to the requirements of Annex A, but without the fluorescent UV lamps.

9.1.2.2 Place test specimens in the exposure area, leaving at least a 25 mm empty border around the exposure area.

9.1.2.3 Operate the device for at least 20 minutes then record the UV irradiance (CW_{UV}, in W/m^2, 250-400 nm). Calculate the exposure time necessary for the desired cool white UV irradiance exposure in accordance with section 9.1.1.4.

9.1.2.4 Reposition the specimens during the exposure as described in section 9.1.1.8.

9.1.2.5 Maintain chamber air temperature between 30 and 40°C during the exposure. If the air temperature exceeds 40°C, the device must be shut off and the cause for the high temperature corrected before exposures can continue.

9.1.2.6 Conduct exposures for a total time agreed upon by all interested parties. Periodically remove test and control specimens for color measurement and relevant physical property tests.

9.1.3 *Method III:*

9.1.3.1 Use apparatus conforming to the requirements of Practice G154 and equipped with F40T12 cool white lamps. Place specimens in the devices, and fill all spaces not used by test specimens with blank metal panels. Operate the device with lamps on continuously and with the black panel temperature controlled at 50 ± 3°C.

9.1.3.2 *Specimen Repositioning*—Periodic repositioning of the specimens during exposure is not necessary if the irradiance at the positions farthest from the center of the specimen area is at least 90 % of that measured at the center of the exposure area. Irradiance uniformity shall be determined in accordance with Practice G151.

9.1.3.3 Conduct exposures for a total time agreed upon by all interested parties. Periodically remove test and control specimens for color measurement and relevant physical property tests.

9.1.4 *Method IV:*

9.1.4.1 Use apparatus conforming to the requirements of Practice G154 and equipped with UVA 351 lamps that comply with the requirements of Practice G154. Place specimens in the devices, and fill all spaces not used by test specimens with

blank metal panels. Operate the device with lamps on continuously and with the black panel temperature controlled at 50 ± 3°C.

9.1.4.2 *Specimen Repositioning*—Periodic repositioning of the specimens during exposure is not necessary if the irradiance at the positions farthest from the center of the specimen area is at least 90 % of that measured at the center of the exposure area. Irradiance uniformity shall be determined in accordance with Practice G151.

9.1.4.3 Conduct exposures for a total time agreed upon by all interested parties. Periodically remove test and control specimens for color measurement and relevant physical property tests.

9.1.5 Other exposure conditions may be used as long as the exact conditions are detailed in the report. Obtain agreement between all concerned parties for the specific exposure cycle used.

10. Procedure

10.1 Prepare specimens in accordance with relevant standards and identify each in accordance with Practice G147.

10.2 Determine which property or properties of the test and control specimens will be evaluated. If non-destructive tests are used, measure the property or properties on each test and control specimen prior to exposure and after each exposure increment. Use of instrumental measurements is recommended whenever possible. Retain a supply of unexposed file specimens of all materials evaluated.

10.2.1 When destructive tests are used, a separate set of specimens will be needed for each exposure increment. It is recommended that sufficient file specimens be retained so that the property of interest can be determined on unexposed file specimens each time the exposed materials are evaluated.

NOTE 8—Since the stability of file specimen may also be time-dependent, users are cautioned that over prolonged exposure periods, or where small differences in the order of acceptable limits are anticipated, comparison of exposed to file specimens may not be valid.

10.3 *Mounting of Test Specimens*—Attach the specimens to the specimen tray or specimen holders in the equipment in such a manner that the specimens are not subject to any applied stress. To assure uniform exposure conditions, fill all of the spaces, using blank panels of corrosion resistant material.

10.4 Evaluation of color and appearance changes of exposed materials shall be made based on comparisons to unexposed specimens of the same material that have been stored in the dark.

10.5 Unless otherwise specified, do not mask or shield Masking or shielding the face of test specimens with an opaque cover for the purpose of showing the effects of exposure on one panel. Misleading results may be obtained by using this method, since the masked portion of the specimen is still exposed to temperature and humidity that in many cases will affect results.

10.6 *Exposure to Test Conditions*—Unless otherwise specified, expose specimens in accordance with one of the methods described in Section 9. Maintain these conditions throughout the exposure. Interruptions to service the apparatus and to inspect specimens shall be minimized.

10.7 *Inspection*—If it is necessary to remove a test specimen for periodic inspection, take care not to handle or disturb the test surface. After inspection, the test specimen shall be returned to the test chamber with its test surface in the same orientation as previously tested.

10.8 *Apparatus Maintenance*—The test apparatus requires periodic maintenance to maintain uniform exposure conditions. Perform required maintenance and calibration in accordance with manufacturer's instructions.

10.9 Color changes initiated by accelerated exposure may continue after removal of the specimens from exposure to radiation. Unless otherwise specified, evaluate the final color change within 24 hours after the test is completed, preferably less than one hour, to eliminate possible misleading consequences of post actinic exposure reaction. (Color change initiated by accelerated exposure may continue after removal of specimens from exposure to radiation.)

11. Periods of Exposure and Evaluation of Test Results

11.1 In most cases, periodic evaluation of test and control materials is necessary to determine the variation in magnitude and direction of property change as a function of exposure time or radiant exposure.

11.2 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.

11.2.1 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 use, 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.

11.2.2 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.

11.2.3 The relation between time to failure in an exposure conducted in accordance with this practice and service life in its end use environment requires determination of a valid acceleration factor. Do not use arbitrary acceleration factors relating time in an exposure conducted in accordance with this practice and time in its end use 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 real time and laboratory accelerated exposures so that results used to relate times to failure in each exposure can be analyzed using statistical methods.

NOTE 9—An example of a statistical analysis using multiple-laboratory and exterior exposures to calculate an acceleration factor is described by

Simms[4]. See Practice G151 for more information and additional cautions about the use of acceleration factors.

11.3 After each exposure increment, evaluate or rate changes in exposed test specimens in accordance with applicable ASTM test methods.

11.3.1 For some materials, changes may continue after the specimen has been removed from the exposure apparatus. In such cases, it is best if measurements (visual or instrumental) should be are made within a standardized time period or as agreed upon between the interested parties. The standardized time period needs to consider conditioning prior to testing.

11.4 Use of results from exposures conducted in accordance with this practice in specifications:

11.4.1 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 in accordance with this practice, base the specified property level on results from round-robin experiments run to determine the test reproducibility from the exposure and property measurement procedures. Conduct these round robins in accordance with Practice E691 or Practice D3980 and include a statistically representative sample of all laboratories or organizations who would normally conduct the exposure and property measurements.

11.4.2 If a standard or specification for use between two or three parties require a definite property level after a specific time or radiant exposure in an exposure test conducted in accordance with this practice, base the specified property level on 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 minimum level of property after the exposure that is mutually agreeable to all parties.

11.4.3 When reproducibility in results from an exposure test conducted in accordance with this practice has not been established through round-robin testing, specify performance requirements for materials in terms of comparison (ranked) to a control material used.

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

NOTE 10—Fischer illustrates use of rank comparison between test and control materials in specifications.[5] The precision and bias section of this standard shows how rank correlation was used to compare the between lab results for materials tested in accordance with Method I.

NOTE 11—Guide G169 shows examples using analysis of variance to compare materials.

12. Report

12.1 The report shall include the following:

12.1.1 Material identification and source (if known).

12.1.2 Exposure apparatus type.

12.1.3 Total exposure time, h.

12.1.4 Exposure method used (I, II, III or IV).

12.1.5 Radiant dosage and wavelength in which it was measured (CWH for Methods I and II).

12.1.6 Quantity and types of lamps used.

12.1.7 *For Methods I and II:*

12.1.7.1 Initial and final CW Irradiance (CW_E)

12.1.7.2 Initial and final UV Irradiance (UV_E)

12.1.7.3 Hours CW Light time (CW_t)

12.1.7.4 Hours UV Light time (UV_t)

12.1.7.5 UV off time interval (UV_{OFF} – Method I only)

12.1.8 *Basis for evaluation:*

12.1.8.1 Results from visual or instrumental tests used to evaluate specimens,

12.1.8.2 Results from visual or instrumental tests used to evaluate masked areas or file specimens,

12.1.9 Description of the method used for visual or instrumental analysis of the specimens,

12.1.10 If instrumental color measurements are used, the type of equipment and color-difference equation must be stated.

13. Precision and Bias

13.1 *Precision*

13.1.1 The repeatability and reproducibility of results obtained in exposures conducted in accordance with this practice will vary with the materials being tested, the material property being measured, and with the variability in temperature and irradiance within and between exposure devices. In a round-robin on Method I conducted in 1986,[6] laboratories reported color (CIE L, a, b) and ΔE for eight materials. Five replicate specimens of each material were tested. Seven laboratories participated in the round-robin, but variability in color measurement or exposure conditions, or both resulted in data from only four laboratories being used for statistical analysis in accordance with Practice E691. The precision data for the eight materials tested by the four laboratories is shown in Table 1.

13.1.2 Using the precision data obtained in the round-robin, two samples of material Aa tested in a single device cannot be judged to be different (at a 95 % confidence level) unless the ΔE between the unexposed and exposed specimens differs by more than 0.59. Similarly, two samples of material Aa tested in different laboratories unless the ΔE difference is larger than 1.05 units. The reproducibility data in Table 1 show how the precision varies with material and the tolerances needed to account for variability in exposure and property measurement. The variability shown in this round-robin studies restricts the use of "absolute standards" such as requiring a specific property level after a specific exposure period.

13.1.3 The same round-robin study demonstrated that the ΔE values for the eight materials could be ranked with a high level of reproducibility between laboratories. Table 2 shows the average ΔE for the eight materials reported by the seven labs that participated in the round-robin. Table 3 shows the

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

[5] Fischer, R., Ketola, W., "Impact of Research on Development of ASTM Durability Testing Standards," Durability Testing of Non-Metallic Materials, ASTM STP 1294, Robert Herling, ed., American Society for Testing and Materials, Philadelphia 1995.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D20–1135.

TABLE 1 Precision Data for ΔE of Eight Materials Exposed for Time T100 in Round-Robin Exposures Conducted in Accordance with Method I of This Practice

Material	Average ΔE	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
Aa	1.99	0.21	0.37	0.59	1.05
Ab	1.61	0.11	0.42	0.31	1.19
Ba	1.53	0.10	0.17	0.28	0.48
Bb	0.39	0.08	0.19	0.23	0.54
Ca	9.25	0.30	1.24	0.85	3.51
Cb	1.07	0.29	0.44	0.82	1.25
Da	3.63	0.25	0.83	0.71	2.35
Db	0.33	0.07	0.26	0.20	0.74

TABLE 2 Average ΔE for Five Replicates of Each Material Exposed to Time T100 in Accordance to Method I Reported by Laboratories Participating in Round-Robin on This Practice

Material	Lab 1	Lab 2	Lab3	Lab 4	Lab 5	Lab 6	Lab 7	Lab Ave
Aa	2.36	1.88	3.66	1.67	1.29	2.14	1.77	2.11
Ab	1.73	1.54	2.14	1.32	1.20	1.26	1.86	1.58
Ba	1.64	1.66	1.33	1.45	1.77	1.45	1.64	1.56
Bb	1.56	0.28	1.22	1.69	0.25	0.11	1.12	0.47
Ca	9.94	9.96	10.81	8.46	8.40	7.49	8.83	9.13
Cb	1.16	0.96	1.38	0.79	0.93	0.59	1.55	1.05
Da	4.35	4.80	4.57	3.12	3.28	3.38	2.74	3.75
Db	0.71	0.20	0.70	0.26	0.35	0.15	0.60	0.42

TABLE 3 Rank Order for Eight Materials Based on ΔE Obtained in Exposure in Accordance with Method I of This Practice (1 = Smallest ΔE, 8 = Largest ΔE)

Material	Lab 1	Lab 2	Lab3	Lab4	Lab 5	Lab 6	Lab 7	Lab Ave
Aa	6	6	6	6	5	6	5	6
Ab	5	4	5	4	4	4	6	5
Ba	4	5	3	5	6	5	4	4
Bb	1	2	2	1	1	1	2	2
Ca	8	8	8	8	8	8	8	8
Cb	3	3	4	3	3	3	3	3
Da	7	7	7	7	7	7	7	7
Db	2	1	1	2	2	2	1	1

TABLE 4 Rank Correlation Coefficients between Individual Labs and between a Lab and the Rank Based on Average ΔE for All Labs

	Lab 1	Lab 2	Lab3	Lab4	Lab 5	Lab 6	Lab 7	Lab Ave
Lab 1	1.0000	0.9995	0.9995	0.9997	0.9992	0.9997	0.9995	0.9997
Lab 2	0.9995	1.0000	0.9992	0.9997	0.9995	0.9997	0.9992	0.9997
Lab 3	0.9995	0.9992	1.0000	0.9990	0.9982	0.9990	0.9995	0.9997
Lab 4	0.9997	0.9997	0.9990	1.0000	0.9997	1.0000	0.9990	0.9995
Lab 5	0.9992	0.9995	0.9982	0.9997	1.0000	0.9997	0.9987	0.9990
Lab 6	0.9997	0.9997	0.9990	1.0000	0.9997	1.0000	0.9990	0.9995
Lab 7	0.9995	0.9992	0.9995	0.9990	0.9987	0.9990	1.0000	0.9997
Lab Ave	0.9997	0.9997	0.9997	0.9995	0.9990	0.9995	0.9997	1.0000

rank ordering based on the average ΔE and Table 4 shows the rank correlation coefficients between individual labs for each lab compared to the average for all labs.

13.2 *Bias*

13.2.1 Bias cannot be determined because no acceptable standard weathering reference materials are available.

ANNEXES

(Mandatory Information)

A1. Requirements for Apparatus Used for Methods I and II

A1.1 The interior of the test chamber shall be constructed using UV reflective aluminum with a clear chromate or non-chrome conversion coating.

A1.2 The test chamber shall consist of a flat area used for exposure of specimens and an arched "roof" on which are placed 1500 mA F48T12/CW/VHO cool white fluorescent lamps. The arched roof shall contain two apertures where 430 mA fluorescent UV lamps are placed behind a soda lime glass filter that is 2.4 ± 0.2 mm thick.

A1.3 The apparatus shall be equipped with timing devices and timing meters to control on time for the 1500 mA cool white and 430 mA fluorescent UV lamps and to record the total operating time for each type of lamp. The spectral power distribution of the fluorescent UV lamps shall conform to the requirements of the UVA-340 or UVB 313 lamps given in Practice G154. Fig. A1.1 shows a typical instrument configuration. The dimensions shown produce a configuration where irradiance uniformity within the exposure area meets the requirements of Practice G151. Other configurations and dimensions can be used if uniform conditions can be achieved.

NOTE A1.1—Typical spectral power distributions for the UVA-340 and UVB-313 lamps filtered by window glass can be found in Appendix X1 of Practice G154.

A1.4 The specimen table shall have the same reflecting surface as the lamp reflector. It shall have a vertical adjustment to control specimen-to-lamp distance.

A1.5 The apparatus shall include a properly calibrated radiometer to measure irradiance at the center of the exposure area. The radiometer shall be capable of recording irradiance between 250 and 400 nm with appropriate cosine response.

A1.6 The apparatus shall be equipped with fans or other means of cooling to maintain air temperature in the exposure chamber between 30 and 40°C while the apparatus is operating. The apparatus shall be equipped with a thermostatic sensor that will cause lamps to turn off if the upper temperature limit within the exposure area is exceeded.

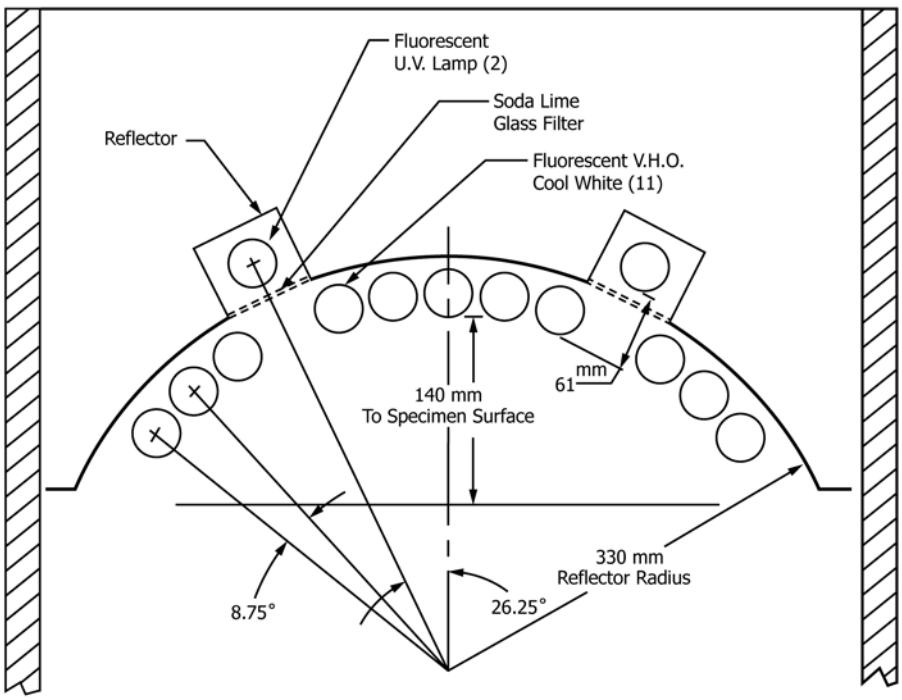

FIG. A1.1 Cross Section Diagram of Representative Test Apparatus for Methods I and II.

A2. Spectral Power Distributions and Tabular Data for Fluorescent Cool White Lamps

A2.1 Spectral Irradiance of Cool White Fluorescent Lamps—The spectral power distribution of cool white fluorescent lamps shall comply with the requirements specified in Table A2.1.

TABLE A2.1 Specification for Cool White Lamps (Irradiance Expressed as a Percent of Integrated Irradiance from 300-400 nm or from 300-700 nm)

(nm)	minimum	maximum
	As percent of 300–400 nm irradiance	
<300	0.0 %	1.4 %
300–320	4.0 %	28.0 %
321–360	0.0 %	14.0 %
361–400	65.0 %	90.0 %
	As percent of 300–700 nm irradiance	
300–400	0.0 %	5.0 %
401–700	94.0 %	100.0 %

NOTE 1—The sum of the percentages given in the "minimum" and "maximum" will not necessarily add up to 100 % because they represent limits based on measurements made on a number of different cool white lamps. However, the data for any individual lamp will add up to 100 %.