INTERNATIONAL

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Standard ~~Test Method~~ Practice for Accelerated Testing for Color Stability of Plastics Exposed to Indoor ~~Fluorescent Lighting and Window-Filtered Daylight~~ Office Environments[1]

This standard is issued under the fixed designation D 4674; 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~~ practice covers ~~an accelerated procedure intended to determine~~ the basic principles and operating procedures~~ta~~ for using fluorescent light to determine color ~~change~~ stability of plastics when materials are exposed in typical office environments~~,~~ where ~~overhead~~ 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.

NOTE 1—There is no equivalent ISO standard.

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 G 154.

NOTE 2—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 G 151. More specific information about methods for determining the change in properties after exposure and reporting these results is described in Practice D 5870.

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 ~~6.~~ 7.

2. Referenced Documents

2.1 *Specification for ASTM Standards:*

[1] This ~~test method~~ 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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D 1729 Practice for Visual Evaluation Appraisal of Colors and Color Differences of Diffusely Illuminated Opaque Materials[2]
D 2244 Method
D 2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates[2]
D 3980 Practice for Interlaboratory Testing of Paint and Related Materials[3]
2.2 *Other Document:*
American Society
D 5870 Practice for Calculating the Property Retention Index of Heating, Refrigerating, Plastics[4]
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[5]
G 113 Terminology Relating to Natural and Airconditioning Engineers, Applications Handbook 1981, Section 1 Artificial Weathering Tests of Nonmetallic Materials[6]
G 141 Guide for Addressing Variability in Exposure Testing on Comfort, Chapter 3.9[4] Nonmetallic Materials[6]

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[2] *Annual Book of ASTM Standards*, Vol 14.02. **06.01**.
[3] Discontinued; see *1997 Annual Book of ASTM Standards* , Vol **06.01**.
[4] Available from the American Society
[4] *Annual Book of Heating, Refrigerating, and Airconditioning Engineers, 1791 Tullie Circle Northeast, Atlanta, GA, 30329. ASTM Standards*, Vol **08.03**.
[5] Apparatus available from Atlas Electric Devices Co., 4114 Ravenswood Ave., Chicago, IL 60613 has been found satisfactory.
[5] *Annual Book of ASTM Standards*, Vol **14.02**.
[6] A 1500-mA lamp is a cool white (CW) fluorescent lamp with a tubular bulb approximately 38 mm in diameter and 1220 mm in length, rated at
[6] *Annual Book of ASTM Standards*, W and designated F48T12 CW/VHO, or its equivalent. F48T12CW/VHO Fluorescent Cool White Lamps, available from North American Philips Lighting Corp., Bloomfield, NJ 07003, have been found satisfactory. Vol **14.04**.

G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests[6]
G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources[6]
G 154 Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials[6]
G 169 Guide for Application of Basic Statistical Methods to Weathering Tests[6]

3. Terminology

3.1 *Definitions*—The definitions given in Terminology G 113 are applicable to this practice.

4. Summary of ~~Test Method~~

~~3.1 This test method~~ Practice

4.1 This practice provides for the exposure of specimens to fluorescent light under controlled environmental conditions. Radiant energy ~~from an array~~ is provided by one of ~~eleven very-high output (VHO) cool, white~~ the following fluorescent light sources: (1) VHO cool-white fluorescent lamps ~~and, simultaneously, to intermittent energy from two soda-lime glass-filtered~~ and glass filtered fluorescent UV ~~sunlamps. The extent of UV irradiation (nominal UV actinic exposure~~ lamps, (2) VHO cool-white fluorescent lamps alone, (3) standard output cool white fluorescent lamps alone, or ~~UVAE) from both sources~~ (4) UVA-351 fluorescent UVA lamps.

4.1.1 Method I is ~~determined separately as~~ intended to simulate the ~~product~~ conditions in an office environment plus a portion of solar UV ~~irradiance at the start of the test~~ radiation transmitted by window glass. Methods II and ~~exposure time, in Watt-hours/m^2 (W–h/m^2).~~

~~3.1.1 The contribution of sunlamp irradiation~~ III are intended to simulate only the ~~total UV actinic exposure~~ indoor lighting component of a typical office environment. Method IV is ~~maintained constant by adjusting~~ intended to simulate only the ~~on/off cycle time~~ effects of ~~the sunlamps.~~

~~3.1.2 The average nominal sunlamp UV actinic exposure is set at 12 %~~ a portion of ~~the value for the VHO lamps.~~ solar UV radiation transmitted through window glass.

NOTE ~~1—Although office machines see some UV exposure due to sunlight, most originates~~ 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 ~~lighting. The 12 % is an estimate~~ UV lamps to simulate solar UV radiation behind window glass, refer to Annex A1 of Practice G 154.

4.1.2 Do not compare Comparison of results obtained from specimens exposed using tahe methods descrivbed shoffiuld not be made unless correlation has beenv establirshed between the methods being compared for the materials being tested.

~~3~~4.2 Color change is determined periodically throughout the course of the exposure by comparison of the exposed specimens to ~~the masked or~~ unexposed specimens, using either visual or instrumental procedures.

~~3.3 The final color change should be evaluated in less than 24 h after the test is completed, preferably in less than 1 h, to eliminate possible misleading consequences of postactinic reaction. (Color change initiated by accelerated exposure may continue after removal of specimens from exposure to radiation.)~~

~~4. Significance and Use~~

~~4.1 This test method is intended to produce the color changes that may occur in plastics upon exposure to irradiation from typical office lighting by simulating these office conditions.~~

~~4.1.1 It is recognized that the rate of photodegradation of plastics will vary significantly due to factors such as processing conditions, initial color, pigment loading, the presence/type of flame retardants and other additives, etc. Consequently, correlation of accelerated test results with actual end-use performance must be determined individually for each resin system.~~

~~4.1.2 Variations in exposure time, temperature and humidity may also affect results.~~

5. ~~Apparatus [5]~~

~~5.1 The test chamber shall be constructed of UV reflective aluminum~~Significance and Use

5.1 Tests conducted in accordance with ~~a clear, chromate conversion coating. An arched reflector~~ this practice are intended to induce property changes associated with ~~a radius of 330 mm serves as the chamber roof. The reflector also contains two apertures that hold soda-lime glass panels which filter the sunlamps. The vertical distance from the exposed surface of the specimen~~ use exposure to light and heat in typical office environments. These exposures are not intended to simulate the ~~lamp surface shall be 140 ± 3 mm at the midpoint~~ deterioration caused by localized phenomena such as handling, dirt contamination, etc.

NOTE 5—**Caution:** Caution: Refer to practice G 151 for full cautionary guidance applicable to all laboratory weathering devices. Additional information on sources of ~~the arch. See Figs. 1 and 2.~~

~~5.1.1 Eleven 1500-mA cool white VHO fluorescent lamps (CW)[6] shall be mounted in three groups~~ variability and on ~~the inner surface~~ strategies for addressing variability by design and data analysis of ~~the reflector. The angular spacing between lamps~~ laboratory accelerated exposure tests is found in ~~each group shall~~ Guide G 141.

5.2 Variation in results may be 8°, 45 min. See Figs. 1 and 2.

5.1.2 A 430-mA fluorescent sunlamp (FS)[7] shall be mounted directly above each of expected are possible between the two apertures at a position 26° 15 min from the vertical plane intersecting the longitudinal axis different methods described in this practice. For example, differences in spectral distribution of the test chamber. Each lamp must be mounted behind a soda-lime glass filter (2.4 ± 0.2 mm thick). (See Fig. 1, lamps 12 used and 13).

5.2 The specimen table shall have variations in the same reflecting surface as the lamp reflector. It shall have irradiance for a vertical adjustment to control specimen-to-lamp distance. The table shall accommodate two specimen trays, each having an area single type of approximately 0.13 m^2 (630 by 210 mm) separated by a median containing a center port for lamp can cause significant differences in test results. Therefore, any no reference to the cosine receptor (light sensor) use of the radiometer.

5.3 To assure uniform test conditions, it is important that all lamps shall this practice should be made unless accompanied by a report prepared in accordance with 5.1.1 and 5.1.2. All 1500-mA lamps shall be cool white. Both 430-mA lamps shall be fluorescent F40T12UVB sunlamps.

5.4 The apparatus shall be used only in an environment which meets ASHRAE recommendations of 20 Section 12 that describes needs to 25.5°C ambient temperature and 40 include a reference to 50 % relative humidity.

5.4.1 The lamps and ballasts shall be forced-air cooled to maintain the air temperature in the method used.

5.3 Reproducibility of test chamber results between 30 and 40°C.

5.4.2 The apparatus shall be equipped with a thermostatic sensor that will cause the lamps laboratories has been shown to be turned off should good when the upper temperature limit stability of materials is evaluated in the specimen area be exceeded.

5.5 The apparatus shall be equipped with timing devices and time meters terms of performance ranking compared to control on-time for the 1500-mA lamps, other materials or to control on/off cycling for a control. Therefore, exposure of a similar material of known performance (a control) at the 430-mA lamps, and to record total same time as the test materials is strongly recommended. It is recommended that at least three replicates of operation for each type of lamp.

5.6 The apparatus shall include a properly calibrated radiometer to measure irradiance in the exposure chamber. The light detector shall material be located centrally in the exposure table; it shall have a bandpass from 250 exposed to 400 nm and be a cosine response receptor. allow for statistical evaluation of results.

6. Safety Precautions

6.1 Never look directly atApparatus

6.1 *Test Chamber*—Unless otherwise specified, the operating sunlamps unless wearing UV protective eyewear. The apparatus specified in Section 5 test chamber shall comply with the requirements of Practice G 151.

6.1.1 The test chamber used for Methods I and II shall be constructed designed so that simulthaneous operation of VHO cool white and glass fil ntered UV fluorescent lamps is possible, and shall be exquipped with a radiometer complying with the requirements of Practice G 151 and calibrated from 250 to hazardous levels 400 nm. Annex Annex A1 contains more information about the design of UV radiation. Access the apparatus used for Methods I and II.

6.1.2 The test chamber used for Methods III and IV shall conform to the la requirements of Practice G 154.

6.2 The spectral distribution of the UVB-313, UVA-340, and UVA-351 shall be protected by safety switches that turn comply with the requirements of practice G 154. 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 gaining access. The use.

6.4 For Methods I and II, place the apparatus shall have a circuit breaker switch controlling electric power 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 apparatus.

6.2 Sunlamps should be discarded when they are no longer suitable requirements of Practice G 154 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 not needs to be used for any other purpose. traceable to national or international standards. Unless otherwise specified, calibration schedule and procedure shall be in accordance with manufacturer's instructions.

7. Test Specimens

7.1 The recommended specimen size is a rectangular flat piece 50 by 80 by 4 mm (maximum thickness). This size is adequate for visual or instrumental evaluation. Other specimen dimensions may be used by mutual agreement amongHazards

[7] A 430-mA lamp is a fluorescent sunlamp (FS)

[7] Simms, J.A., *Journal* of similar dimension to the cool white lamp described in Footnote 5, rated at 40 W and designated as F40T12UVB, or its equivalent. F40T12UVB Fluorescent UV Sunlamps are also available from North American Philips Lighting Corp. *Coatings Technology*, Vol. 50, 1987, pp. 45–53.

7.1 Never look directly at the parties concerned but exposed surfaces should operating lamps unless wearing UV protective eyewear. The apparatus specified in Section 6 shall be coplanar.

7.2 It is recommended constructed so that one half of each test specimen be masked with aluminum foil, tightly wrapped to prevent exposure of the covered side. The entire specimen may operator will not be exposed if an unexposed control is used to judge color shift, or if the color hazardous levels of the test specimen is measured instrumentally and recorded prior to exposure.

7.2.1 Use of aluminum foil-masked specimens may result UV radiation.

7.2 Discard or recycle lamps in a higher irradiance level due to increased reflectivity of accordance with any relevant local ordinances when they are no longer suitable for the specimen area. tests described.

8. Preparation of Apparatus

8.1 Verify proper lamp function before starting any test.

8.2 Verify the UV irradiance level of each type of lamp before starting Test Specimens

8.1 The recommended specimen size is a test. Carry out verification of irradiance with samples in place; otherwise reflectance of 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 bare aluminum tray will give erroneous results. Radiometer readings at the start 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 test should not be less than 6.0 W/m^2 for following exposure methods.

9.1.1 *Method I*:

9.1.1.1 Use apparatus conforming to the 1500-mA lamps and 1.0 W/m^2 for requirements described in Annex Annex A1.

NOTE 6—For Method I, the 430-mA lamps.

9. Conditioning

9.1 Specimen conditioning is unnecessary for this test beyond a visual inspection for uniformity contribution of color and fluorescent UV lamp radiation to the totabl UV actinic exposure is adjusted by changing the percentage of surface irregularities which could adversely affect color measurement.

9.2 Pre-age time the lamps by leaving them on specimens are exposed to the various lamp types.

9.1.1.2 This method provides for a minimum exposure of 48 h prior specimens to initial test. Replace all 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 falls below the limits specified in 8.2.

10. Procedure

10.1 Make an initial color determination prior to loading specimens.

10.2 Open specimen drawer from each type of lamp separately and load specimen trays. Arrange 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 rows beginning in the middle and exposure area, leaving at least a minimum 25-mm 25 mm empty border around the edge of exposure area.

9.1.1.4 Run the trays. Each tray will accommodate 21 to 22 samples of the 50 by 80-mm size recommended in 7.1.

10.2.1 Adjust the specimens or specimen table so that the surfaces of all test specimens are within 3 mm of being coplanar device with both the cosine receptor.

10.3 Close the specimen drawer cool white and verify lamp irradiance level in accordance with 8.2.

10.3.1 Turn fluorescent UV lamps on both sets of lamps. After for at least 20 minutes, then turn off FS the fluorescent UV lamps and record the CW UV irradiance (radiometer reading) with only the cool white lamps operating (CWE in W/m^2, 250-400 nm). Calculate the exposure time required for the desired cool white UV Actinic Exposure (UVAE) CW_E radiant exposure as follows:

CW Exposure, h = CW UVAE/CW Irradiance

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

(*Example*: CW Exposure, h = 3240/10.8 = 300 h)

CW E

where:
3240 W-h/m^2

where:

CW^t = example of an often-agreed-upon exposure, and

10.8exposure time for cool white lamps,
CW_H = desired UV radiant expomsure for cool white lamps alone, and
CW_E = UV irradiance measured with only with the cool white lamps operating.

10.3.2 Turn off

9.1.1.5 Run the CW device with only the fluorescent UV lamps and turn on and record the FS lamps. Record the radiometer reading (W/m 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 FS lamp on-time operating time for the fluorescent UV lamps as follows:

$$\text{FS On} - \text{time, h} = 12\ \%\ \text{CW UVAE/FS Irradiance}$$

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

$$(Example\text{: FS On} - \text{time, h} = (0.12)(3240)/2.0 = 194\text{ h})$$

where:
2.0
where:
UV_t = radiometer readingexposure 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 FS fluorescent UV lamps operating.

10.4 Calculate the off-time interval/cycle for the FS lamps by subtracting the FS on-time from the CW exposure time and dividing by the FS on-time.

$$\left(Example\text{: } \frac{300 - 194}{194} = \frac{106}{194}\, 0.546\text{ off} - \text{time h/cycle}\right) \quad (3)$$

NOTE 2—If 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 radiometer reading fraction of time per hour for which the 1500-mA fluorescent UV lamps is too low, are turned off (UV_{OFF}) as follows:

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

(1) Replace the off-time interval/cycle will be cool white lamps if UV_{OFF} is greater than 1.0. The FS lamp timer can not be programmed with an off-time interval/cycle greater than 1.0. A different combination of 1500-mA or equal to one.

9.1.1.7 Program the device so that the cool white lamps operate continuously and 430-mA the fluorescent UV lamps s are turned on once per hour for the fraction of time calcul bated 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 achieve an off-time interval/cycle less than 1.0.

10.4.1 Program 25 ± 5 % of the FS lamp cycling timer total time calculated in section 9.1.1.4. Move specimens just to a 1-h time-on interval/cycle.

10.4.2 Program the FS lamp timer right of the center line of the exposure area to the off-time interval/cycle calculated position farthest to the right in 10.4.

10.4.3 Replace the CW lamps if exposure area and move remaining specimens one position to the total on-time for left. Move specimens just to the FS exceeds left of the CW center line of the exposure time.

10.4.4 Do not add additional to the position farthest to the left in the exposure area and move remaining specimens in this half onee position to the test has begun.

10.5 Start 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 which will assure prompt agreed upon by all interested parties. Periodically remove test and control specimens for color measurement w 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 is completed.

10.5.1 The CW lamps should be on continuously throughout specimens in the entire exposure area, leaving at least a 25 mm empty border around the exeposure area.

9.1.2.3 Operate the device for brief periods at least 20 minutes then record the UV irradiance (CW_{UV}, in which W/m^2, 250-400 nm). Calculate the samples are removed exposure time necessary for color measurement the desired cool white UV irradiance exposure in accordance with 10.6. Verify that section 9.1.1.4.

9.1.2.4 Reposition the FS l 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 reproducible cycle of 1 h on followed 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 calculated time off.

10.5.2 Having determined requirements of Practice G 154 and verified equipped with F40T12 cool white lamps. Place specimens in the test duration devices, and FS cycle intervals, do fill all spaces not make adjustments in test/cycle time during used by test specimens with blank metal panels. Operate the test. If device with lamps fail during the test, replace them on continuously and restart the entire test with new specimens.

10.5.3 Rotate 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 time intervals equal to 25 ± 5 % 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 G 151.

9.1.3.3 Conduct exposures for a total test time agreed upon by moving those in the innermost row (adjacent 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 median) to the outermost row requirements of Practice G 154 and equipped with UVA 351 lamps that comply with the same specimen tray. Move requirements of Practice G 154. Place specimens in the devices, and fill all remaining rows one row position closer to spaces not used by test specimens with blank metal panels. Operate the median.

10.6 Evaluate device with lamps on continuously and with the color change black panel temperature controlled at 50 ± 3°C.

9.1.4.2 *Specimen Repositioning*—Periodic repositioning of the test specimens during exposure is not necessary if the irradiance at several intervals throughout the course 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 Method D 2244 or Practice D 1729. In addition to the initial reading, take color measurements when G 151.

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 upon identify each in accordance with Practice G 147.

10.2 Determine which property or properties of the test and comntrol specimens will be evaluatied. If non. A ddestructive tests are used, measure the property or properties on ealch 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 3—Colorfastness under these exposure conditions should 8—Since the stability of file specimen may also be timev-dependent, users alre cautioned that over prolonged exposure periods, or where small differences in terms 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 lowest nominal UV actinic exposure required specimens to the specimen tray or specimen holders in the equeipment in such a prescribed objectionable color change. Since discoloration is seldom linear with respect manner that the specimens are not subject to dose or time, it is also important to observe any applied stress. To assure uniform exposure conditions, fill all of the rate spaces, using blank panels of discoloration. Plots corrosion resistant material.

10.4 Evaluation of color change (for example, ΔE and i 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 both) versus exposure are useful. (See Appendix X1.)

10.6.1 Remove shield Masking or shielding the face of test specimens from with an opaque cover for the test chamber only after turning off purpose of showing the main power, thereby stopping effects of exposure on one panel. Misleading results may be obtained by using this method, since the CW lamp countdown timer. The time required for color measurement during 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 affect to handle or disturb the total exposure time. To avoid post-actinic changes of samples taken at intermediate points of test surface. After inspection, the test cycle, complete color measurements specimen shall be returned to the test chamber with its test surface in the same orientation as rapidly as possible. Following each color measurement, return previously tested.

10.8 *Apparatus Maintenance*—The test apparatus requires peeriodic maintensance to the appropriate locations maintain uniform exposure conditions. Perform required maintenance and calibration in accordance with manufacturer's instrumctions.

10.9 Color changes initiated by accelerated exposure until the test is completed.

10.6.2 If immediate evaluation may continue after removal of the final, post-exposure specimens from exposure to radiation. Unless otherwise specified, evaluate the final color change is not possible, refrigerate within 24 hours after the test specimens at − 15 to − 20°C is completed, preferably less than one hour, to minimize eliminate possible effects misleading consequences of post- actinic exposure reaction. In any case, make measurement within 5 days (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 completion.

10.6.3 Terminology for describing and control materials is necessary to determine the observed color variation in magnitude and direction of property change shall be established by mutual agreement among the parties concerned.

10.6.4 Instrumental evaluation as a function of color difference exposure time or radiant exposure.

11.2 The time or radiant exposure necessary to produce a defined change in CIE L*a*b (CIE LAB) units in accordance with Method D 2244 shall a material property can be used to evaluate or rank the preferred 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 describing the color change purpose of a specific test if agreed upon between an unexposed control specimen and the exposed specimen 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 masked test materials or between the test material and u the control material.

11.2.2 The minimum exposkure time used shall be that necessary to produce a substantial change in the property of an exposed specimen, unless agreed upon by 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 4—The preferred method uses reflectance measurement with integrating-sphere geometry, specular component included, 9—An example of a statistical analysis using multiple-laboratory and exterinor exposures to calculateg an acceleration factor is described by Simms[7]. See Practice G 151 for CIE 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 generall use requires a definite property level after a specific time or radiant exposure in an exposure t Cest 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 E 691 or Practice D 3980 and include a statistically representative sample of all laboratories or organizations who would normally conduct the 1931 (2°) 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 UV 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 instrument source should be excluded. It should also be noted 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 in color measurements can occur, particularly be determined.

NOTE 10—Fischer illustrates use of rank comparison between test and control materials in specifications.[8] The precision and bias section of this standard shows how rank correlation was used to compare the between lab res,ults for materials tested in accordance with Menthod I.

NOTE 11—Guide G 169 shows examples using different types analysis of instruments.

11. variance to compare materials.

12. Report

112.1 The report shall include the following:

112.1.1 Material identification and source (if known).

112.1.2 Exposure apparatus type.

11.1.3 Initial

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 UV irradiance, W/m^2.

11.1.4 Initial Irradiance (CW_E)

12.1.7.2 Initial and final FS UV irradiance, W/m^2.

11.1.5 Total exposure time, h.

11.1.6 Total FS on-time, h.

11.1.7 FS off-time interval.

11.1.8 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*:

112.1.8.1 VResults from visual or instrumental, tests used to evaluate specimends,

112.1.8.2 MaskRedsults from visual or unexposed controls.

11.1.9 Exposure required instrumental tests used to produce a prescribed color change evaluate masked areas or a plot file specimens,

12.1.9 Description of color change as a function of UV actinic exposure (W-h/m^2) using either the method used for visual or instrumental measurement analysis of color: J/m^2 = 2.78 × 10^{-4} W–h/m^2.

11.1.9.1 If the specimens,

12.1.10 If instrumental color measurements are used, the type of equipment, any deviations from the requirements in Note 4, equipment and color-difference equation used must be stated.

123. Precision and Bias

12.1 An interlaboratory test program was undertaken in 1986.[8] Some laboratories reported five replicate

[8] Supporting data available from

[8] Fischer, R., Ketola, W., "Impact of Research on Development of ASTM headquarters. Request RR: D20-1162. Durability Testing Standards," Durability Testing of Non-Metallic Materials, ASTM STP 1294, Robert Herling, ed., American Society for Testing and Materials, Philadelphia 1995.

13.1 *Precision*

13.1.1 The repeatability and reproducibility of results obtain fed in exposures conducted in accordance with this practice will vary with the materials being tested, the maeterial property being measured, and with the variability in a light color (such as white) temperature and irradiance within and between exposure devices. In a round-robin on Method I conducted in 1986,[9] laborkatories reported color (such as brown). CIE units (L, (CIE L, a, b) and ΔE values were measured by spectrometer at for eight materials. Five replicate specimens of each time interval (T_o, T_{25}, T_{50}, T_{75}, and T_{100}). Due to data material were tested. Seven laboratories participated in the round-robin, but variability in color measurement problems occurring with three laboratories, statistical analysis was confined to or exposure conditions, or both resulted in data from only four laboratories.

12.2 Coefficients of variation (CV) laboratories being used for ΔE at 25 % of test cycle (T_{25}) were as follows:

Material		CV_R(%)[A]	CV_L(%)[B]
FRABS	light	11.4	14.4
	dark	45.6	43.3
Polycarbonate	light	5.2	5.2
	dark	44.6	76.8
Modified PPE	light	8.9	32.9
	dark	19.8	28.2
UV stabilized PPE	light	12.6	10.9
	dark	17.0	31.5

[A] Within Labs.
[B] Between Labs.

12.3 Coefficients of variation (CV) statistical analysis in accordance with Practice E 691. The precision data for ΔE at end of test cycle (T_{100}) were as follows:

Material		CV_R(%)[A]	CV_L(%)[B]
FRABS	light	13.6	13.7
	dark	8.9	13.9
Polycarbonate	light	7.0	6.8
	dark	88.9	9.6
Modified PPE	light	3.2	13.3
	dark	13.9	26.8
UV stabilized PPE	light	7.5	19.9
	dark	28.8	53.9

[A] Within Labs.
[B] Between Labs.

12.4 It should be noted that significant variation the eight materials tested by the four laboratories is shown in Table 1.

13.1.2 Using the test precision data occurs early obtained in the test cycle, as shown by the coefficients round-robin, two samples of variation material Aa tested in 12.2. This may a single device cannot be due judged to changes in 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 discoloration for many materials near 25 % of material Aa tested in different laboratories unless the test. Therefore, one must use caution when evaluating materials for color change using a short (<100 h) test cycle. A marked improvement ΔE difference is larger than 1.05 units. The renproducibility data in Table 1 show how the coefficients of variation precision varies with material and the tolerances needed to account for ΔE at variability in exposure and property measurement. The variability shown in this

[9] Fig. 3 was generated using software available from Laboratory MicroSystems, Inc., P.O. Box 336, Troy, NY 12181.
[9] 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

round-robin studies restricts the~~ end~~ use of~~ a full test cycle,~~ "absolute standards" such as~~ noted in 12.3. Therefore it is recommended that~~ requiring a~~ full cycle, based on the example in Section 10, be used. Overall, at T_{100} the largest variations were noted with those materials~~ specific property level after a specific exposure period.

13.1.3 The same round-robin study demonstrated that~~ had~~ the~~ smallest color change, for example,~~ ΔE~~ < 0.4. The most reproducible data occurred with those~~ values for the eight materials~~ having~~ could be ranked with a~~ ΔE > 0.5. Although the reproducibility~~ high level of reproducibility between laboratories. Table 2 shows the~~ most color stable~~ average ΔE for the eight materials~~ is poorer than~~ reported by the~~ others, from a practical standpoint it is not considered significant because of~~ seven labs that participated in the~~ smallness of~~ round-robin. Table 3 shows the~~ data being measured and~~ rank ordering based on the~~ instrument limitations.~~

~~12.5 The~~ average ΔE and~~ standard deviation at end of test (T_{100}) reported from~~ Table 4 shows the rank correlation coefficients between individual labs for each lab~~ was as follows:~~

~~Material~~		~~Lab 1~~	~~Lab 2~~	~~Lab 3~~	~~Lab 4~~
~~FRABS~~	~~light~~	~~2.36 (±0.36)~~	~~1.88 (±0.39)~~	~~1.67 (±0.05)~~	~~2.14 (±0.12)~~
	~~dark~~	~~1.73 (±0.10)~~	~~1.54 (±0.19)~~	~~1.32 (±0.06)~~	~~1.26 (±0.13)~~
~~Polycarbonate~~	~~light~~	~~1.64 (±0.10)~~	~~1.66 (±0.05)~~	~~1.45 (±0.12)~~	~~1.45 (±0.15)~~
	~~dark~~	~~0.16 (±0.11)~~	~~0.28 (±0.29)~~	~~0.17 (±0.04)~~	~~0.11 (±0.02)~~
~~Modified PPE~~	~~light~~	~~9.94 (±0.36)~~	~~9.96 (±0.42)~~	~~8.46 (±0.14)~~	~~7.49 (±0.08)~~
	~~dark~~	~~1.16 (±0.20)~~	~~0.96 (±0.11)~~	~~0.79 (±0.04)~~	~~0.59 (±0.05)~~
~~UV stabilized PPE~~	~~light~~	~~4.35 (±0.41)~~	~~4.80 (±0.28)~~	~~3.12 (±0.23)~~	~~3.38 (±0.21)~~
	~~dark~~	~~0.65 (±0.19)~~	~~0.40 (±0.10)~~	~~0.23 (±0.01)~~	~~0.21 (±0.04)~~

compared to the average for all labs.

13.2 *Bias*—~~Since~~

13.2.1 Bias cannot be determined because no~~ absolute method is available~~ acceptable standard weathering reference materials are available.

ANNEXES

(Mandatory Information)

A1. Requirements for comparison, no statement of bias can be presented Apparatus Used for Methiods I and II

A1.1 The interior of the test method.

12.7 No statement can chamber shall be made about either precision constructed using UV reflective aluminum with a clear chromate or bias when visual measurement is non-chrome conversion coating.

A1.2 The test chamber shall consist of a flat area used for exposure of specimens and an arche td "roof" on which are placed 1500 mA F48T12/CW/VHO cool white fluoresulcent lamps. The archelyd roof shall contain two apertures whethre 430 mA fluor thescent UV lamps are placed behisnd a conformance 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 the criteria control on time for success specified in the procedure.

APPENDIX

(Nonmandatory Information)

X1. JUDGING RELATIVE 1500 mA cool white and 430 mA fluorescent UV COLOR STABILITY BY THIS TEST METHOD

X1.1 Color change due lamps and to record the total operating time for each type of lamp. The spectral power distribution of the fluorescent UV photodegradation is known lamps shall conform to be a nonlinear function the requirements of both UV the UVA-340 or UVB 313 lamps given in Practice G 154. Fig. A1.1 shows a typical instrument configuration. The dimensions shown produce a configuration where irradiance and uniformity within the exposure area meets the requirements of Practice G 151. Other configurations and dimensions can be used if uniform conditions can be achieved.

NOTE A1.1—Typical spectral power distributions for many materials. Consequently, it is recommended that colorfastness the UVA-340 and UVB-313 lamps filtered by window glass can be judged found in terms Appendix X1 of Practice G 154.

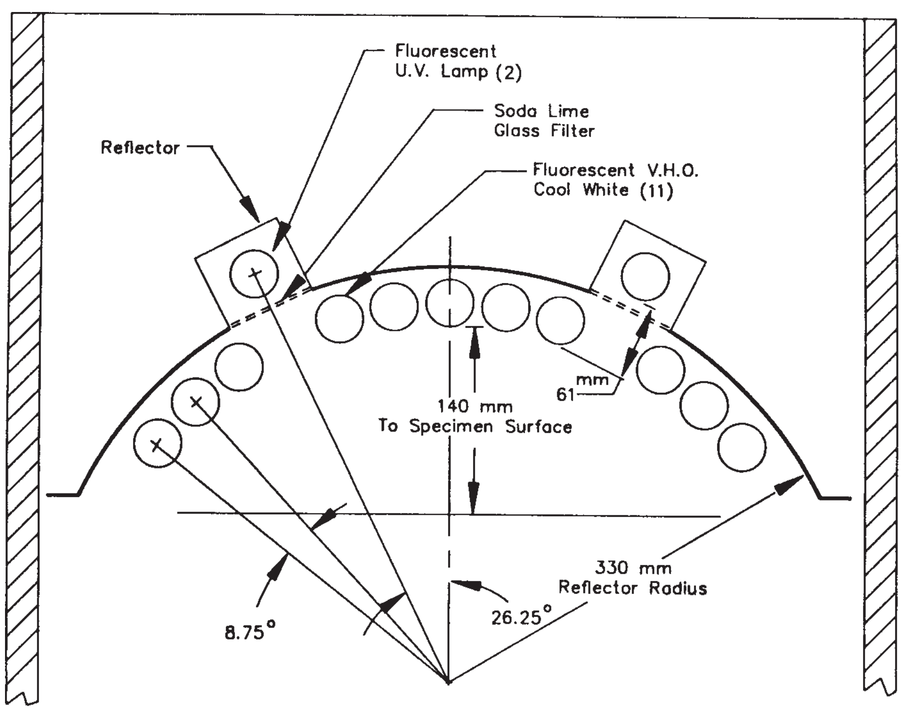

FIG. A1.1 Cross Section Diagram of Representative Test Apparatus for Methods I and II.

A1.4 The specimen table shall have the nominal UV actinic exposure (irradiance × exposure time) required same reflecting surface as the lamp reflector. It shall have a vertical adjustment to effect control specimen-to-lamp distance.

A1.5 The apparatus shall include a prescribed objectionable color change, rather than properly calibrated radiometer to measure irradiance at the degree center of color change obtained after an arbitrary the exposure time.

X1.2 Fig. 3 shows an example 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 total color change (CIE ΔE) versus UV actinic exposure (W–h/m^2) for two materials where an objectionable color change has been arbitrarily defined as CIEΔ E = 2.0.[9] Material A exhibits an objectionable color change in 563 W–h/m^2, chamber between 30 and 40°C while Material B did so after a UV actinic exposure of 1588 W–h/m^2. Using the recommended criterion for judging relative color stability, Material B apparatus is superior to A by 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.

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

A2.1 Spectral Irradiance of about 2.8 under these accelerated test conditions. For further interpretation Cool White Fluorescent Lamps—The spectral power distribution of cool white fluorescent lamps shall comply with the results requirements specified in terms of a possible correlation to real-world performance, see Section 4. 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 %.