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# Standard Practice for Accelerated Testing for Color Stability of Plastics Exposed to Indoor Office Environments<sup>1</sup>

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## 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.

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 G154.

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 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, 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. Specific precautionary statements are given in Section 7.*

<sup>1</sup> 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. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- 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<sup>3</sup>
- 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 Light Apparatus for UV 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

<sup>2</sup> 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.

<sup>3</sup> Withdrawn.

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<sup>2</sup>(W-h/m<sup>2</sup>).

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 ( $CW_E$  in W/m<sup>2</sup>, 250-400 nm). Calculate the exposure time required for the desired  $CW_E$  radiant exposure as follows:

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

where:

$CW_i$  = 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 ( $UV_E$  in W/m<sup>2</sup>, 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:

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

where:

$UV_i$  = 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:

$$UV_{OFF} = \frac{CW_i - UV_i}{UV_i} \quad (3)$$

(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  $25 \pm 5$  % 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<sup>2</sup>, 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  $50 \pm 3^\circ\text{C}$ .

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  $50 \pm 3^\circ\text{C}$ .

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<sup>4</sup>. 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.

<sup>4</sup> Simms, J.A., *Journal of Coatings Technology*, Vol. 50, 1987, pp. 45–53.