Designation: G 53 – 96

Standard Practice for
Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials[1]

This standard is issued under the fixed designation G 53; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice covers the basic principles and operating procedures for using fluorescent ultraviolet (UV) and condensation apparatus to simulate the deterioration caused by sunlight and water as rain or dew.

1.2 This practice is limited to the method of obtaining, measuring, and controlling the conditions and procedures of exposure. It does not specify the exposure conditions best suited for the material to be tested. Specimen preparation and evaluation of the results are covered in ASTM test methods or specifications for specific materials.

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

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

2. Referenced Documents

2.1 *ASTM Standards:*
E 220 Method for Calibration of Thermocouples by Comparison Techniques[2]
E 691 Practice for Conducting an Interlaboratory Study for Determining the Precision of a Test Method[3]
G 7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials[4]
2.2 *CIE Standard:*
No. 20 Recommendations for the Integrated Irradiance and the Spectral Distribution of Simulated Solar Radiation for Testing Purposes[5]

3. Terminology

3.1 *Description of Terms Specific to This Standard:*
3.1.1 *irradiance*—the radiation incident on a surface expressed in W/m². Irradiance is the total of the incident radiation at *all* wavelengths. Forty watt fluorescent lamps of

the UV-B and UV-A types generate similar amounts of irradiance. However, since this irradiance is distributed at different wavelengths, the photochemical effects caused by these different lamps vary greatly. Therefore, irradiance should not be used to compare UV light sources.

3.1.2 *spectral irradiance*—distribution of irradiance as a function of wavelength. It is expressed in W/m² per wavelength band. The spectral irradiance of sunlight is often shown as W/m² per 10 nm band. The spectral irradiance of fluorescent UV lamps should be shown in bands 1 or 2 nm wide. Spectral irradiance is the proper method for comparing sources with different energy distributions.

3.1.3 *spectral energy distribution (SED)*—general term for the characterization of the amount of radiation present at each wavelength. SEDs can be expressed by power in watts, irradiance in W/m², or energy in joules. The shape of the SED would be identical in all of these units. Fluorescent lamps are frequently described by relative SEDs which show the amount of radiation at each wavelength as a percentage of the amount of radiation at the peak wavelength. Figure 1 is a relative SED.

3.1.4 *ultraviolet regions*—CIE Publication No. 20 (1972) divides the ultraviolet spectrum into three regions: UV-A, radiation in wavelengths between 315 nm and 400 nm; UV-B, radiation in wavelengths between 280 nm and 315 nm; and UV-C, radiation in wavelengths shorter than 280 nm.

3.1.5 *fluorescent UV lamp*—lamp in which radiation at 254 nm from a low-pressure mercury arc is transformed to longer wavelength UV by a phosphor. The spectral energy distribution of a fluorescent UV lamp is determined by the
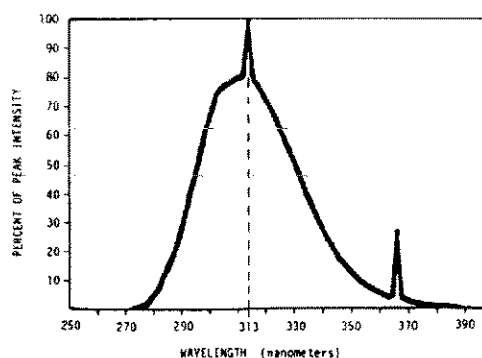
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[1] This practice is under the jurisdiction of ASTM Committee G-3 on Durability of Nonmetallic Materials, and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Environmental Tests.
Current edition approved Jan. 10, 1996. Published April 1996. Originally published as G 53 – 77. Last previous edition G 53 – 95.
[2] *Annual Book of ASTM Standards*, Vol 14.03.
[3] *Annual Book of ASTM Standards*, Vol 14.02.
[4] *Annual Book of ASTM Standards*, Vol 06.01.
[5] Available from Secretary, U.S. National Committee, CIE, National Institute of Standards and Technology, Gaithersburg, MD 20899.

FIG. 1 Typical Relative SED of UV-B Lamp

emission spectrum of the phosphor and the UV transmission of the glass tube.

4. Summary of Practice

4.1 Specimens are alternately exposed to ultraviolet light alone and to condensation alone in a repetitive cycle.

4.2 The UV source is an array of fluorescent lamps, with lamp emission concentrated in the UV range.

4.3 Condensation is produced by exposing the test surface to a heated, saturated mixture of air and water vapor, while the reverse side of the test specimen is exposed to the cooling influence of ambient room air.

4.4 The exposure condition may be varied by selection of: the fluorescent UV lamp; the timing of the UV and condensation exposure; the temperature of UV exposure; and the temperature of condensation exposure and, in the Type B apparatus; the irradiance level.

5. Significance and Use

5.1 The use of the apparatus under this practice is intended to simulate the deterioration caused by water as rain or dew and the ultraviolet energy in sunlight. It is not intended to simulate the deterioration caused by localized weather phenomena, such as atmospheric pollution, biological attack, and salt water exposure.

5.2 Variation in results may be expected when operating conditions are varied within the accepted limits of this practice. Therefore, no reference shall be made to results from use of this practice unless accompanied by a report detailing the specific operating conditions in conformance with Section 11.

5.3 Any report correlating results from use of this practice to results from a period of natural weathering shall specify in detail the conditions of natural exposure, since sunlight and water effects upon materials exposed to the weather will vary from year to year and also vary with location, latitude, time of year, temperature, proximity to water sources, etc.

NOTE 1—Practice G 7 lists the information required to describe a particular condition of outdoor exposure.

5.4 Correlations established and reported in conformance with 5.2 and 5.3 shall not be extrapolated to other test conditions permitted by this practice, to other conditions of natural exposure, or to materials other than those tested.

6. Apparatus

6.1 *Test Chamber*, The apparatus employed constructed of corrosion-resistant materials enclosing eight fluorescent UV lamps, a heated water pan, test specimen racks, and provisions for controlling and indicating operating times and temperatures and shall conform to either Type A or Type B apparatus, (e) the irradiance level.

6.1.1 *Type A[6]:* An exposure apparatus where the lamps shall be mounted in two banks of four lamps each as shown in Fig. 2. The lamps in each bank shall be mounted parallel in a flat plane on 70 mm centers.

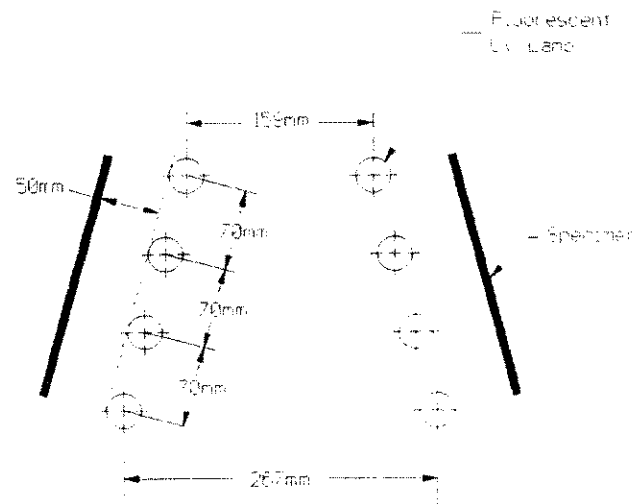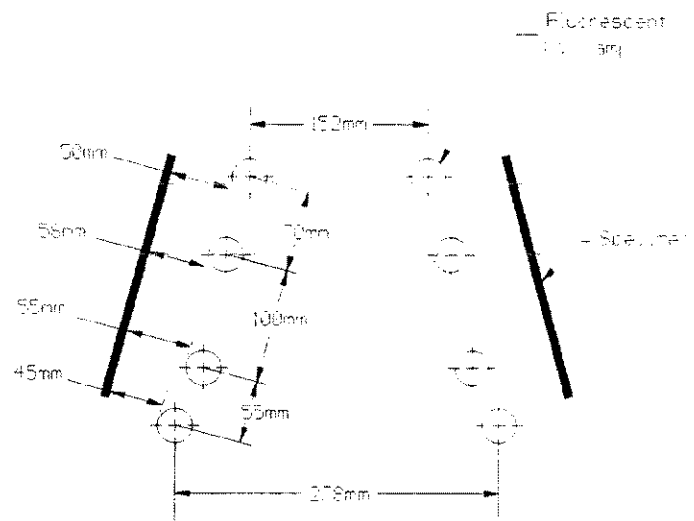6.1.1.1 The test specimens shall be mounted in stationary

FIG. 2 Lamp Placement Schematic—Type A Exposure Apparatus Cross Section

NOTE—Enclosure for apparatus not shown in Figs. 2 and 3.

FIG. 3 Lamp Placement Schematic—Type B Exposure Apparatus Cross Section

racks with the plane of the test surface parallel to the plane of the lamps at a distance of 50 mm from the nearest surface of the lamps, as shown in Fig 2.

6.1.2 *Type B[7]:* An exposure apparatus, as shown in Fig. 3, which is equipped with a radiometer and readout device capable of measuring and controlling the amount of radiant exposure received by the test specimens.

6.1.2.1 The lamps shall be mounted in two bands of four lamps each as shown in Fig. 3.

6.1.2.2 The distance between the test specimen and the light source varies, depending upon where in the sample mounting area the specimen is placed.

6.2 *Lamps,* shall be medium bipin fluorescent UV lamps with a length of 1220 mm, and a nominal rating of 40 W

[6] Apparatus and lamps from Q-Panel Co., 26200 First St., Cleveland, OH 44145, and from Atlas Electric Devices Co., 4114 N. Ravenswood Ave., Chicago, IL 60613, have been found satisfactory.

[7] Apparatus and lamps from Suga Test Instruments Co. Ltd. 4-14 Shinjuku 5-chome, Shinjuku-ku, Tokoyo, 160, Japan, have been found satisfactory.

when operated from a ballast providing a controlled current of 430 mA at 102V.

6.2.1 Unless otherwise specified, the lamps shall be UV-B lamps with a peak emission at 313 nm and a spectral energy distribution as shown in Fig. 1.

6.2.2 Other fluorescent UV lamps meeting the size and electrical characteristics in 6.2 may be used, provided that the lamp and spectral energy distribution are reported in conformance with Section 11. Differences in lamp energy or spectrum can cause significant differences in test results. Some applications (for example, behind glass) may require alternate lamp types. See Appendix X1 on Lamp Applications for further information on lamp selection.

6.3 *Lamp Spacing and Arrangement*—The lamps shall be mounted in two banks of four lamps each as shown in Fig. 2. The lamps in each bank shall be mounted parallel in a flat plane on 70-mm centers.

6.4 *Specimen Mounting and Arrangement*—The test specimens shall be mounted in stationary racks with the plane of the test surface parallel to the plane of the lamps at a distance of 50 mm from the nearest surface of the lamps, as shown in Fig. 2.

6.4.1 The test specimens shall be exposed within an area 210 mm in height by 900 mm wide on each side of the apparatus located as shown in Fig. 4.

NOTE 2—It is possible to mount specimens above, below, and beside the 210 by 900 mm area, but specimens so mounted will be exposed to lower UV intensities.

6.5 *Condensation Mechanism*—Water vapor shall be generated by heating a water pan extending under the entire sample area and containing a minimum water depth of 25 mm. Specimen racks and the test specimens themselves shall constitute the side walls of the chamber. The back side of the specimens shall be exposed to cooling effects of ambient room air. The resulting heat transfer causes water to condense on the test surface.

6.5.1 The specimens shall be arranged so that condensate runs off the test surface by gravity and is replaced by fresh condensate in a continuous process. Vents along the bottom of the test chamber shall be provided to permit an exchange of ambient air and water vapor to prevent oxygen depletion of the condensate.

6.6 *Water Supply*, with an automatic control to regulate the level in the water pan shall be provided. Distilled, deionized, or potable tap water are equally acceptable for purposes of the test, since the condensation process itself distills water onto the test surface.

6.7 *Cycle Timer*, a continuously operating cycle time, for programming the selected cycle of UV periods and condensation periods.

6.7.1 Hour meters shall be provided to record total time of operation and total time of UV exposure.

6.8 *Specimen Temperature Measurement:*

FIG. 4   Limits of Area of Uniform Intensity

6.8.1 Specimen temperature shall be measured by a thermometer with a remote sensor attached to a black aluminum panel 75 by 100 by 2.5 mm thick. The thermometer shall be precise to ±1°C through a range from 30° to 80°C. The indicator dial shall be located outside the test chamber.

6.8.2 The black aluminum panel with the thermometer sensor shall be positioned in the center of the exposure area so that the sensor is subject to the same conditions as the specimens.

6.9 *Specimen Temperature Control:*

6.9.1 During UV exposure, the selected equilibrium temperature shall be maintained within ±3°C by supplying heated air to the test chamber.

6.9.2 During condensation exposure, the selected equilibrium temperature shall be maintained within ±3°C by heating the water in the water pan.

6.9.3 The UV and condensation temperature controls shall be independent of each other.

6.9.4 Doors shall be located on the room air side of the specimen racks to act as insulation during the UV exposure and to minimize drafts. Such doors shall not interfere with the room air cooling of the specimen during the condensation exposure.

6.10 *Test Chamber Location:*

6.10.1 The apparatus shall be located in an area maintained at a temperature between 20°C and 30°C. The room temperature shall be measured by thermometers mounted on interior walls or column approximately 1500 mm above the floor level and at least 300 mm from any heated apparatus. Three or more thermometers located at various points will show any temperature variation in the area.

6.10.2 It is recommended that the apparatus be located at least 300 mm from walls or other apparatus. Nearby heat sources, such as ovens or heated test apparatus, should be avoided or shielded, because such heat sources can reduce the cooling required for condensation.

6.10.3 The room where the apparatus is located shall be ventilated to remove the heat and moisture produced and to maintain the temperatures specified in 6.10.1. Two to four air changes per hour will normally provide sufficient ventilation.

7. Test Specimens

7.1 Replicate specimens are desirable to provide a record of degradation at different time intervals. Retention of an unexposed specimen is recommended as it is difficult to mask a specimen to prevent exposure to condensation.

7.2 For specimens of insulating materials, such as wood, plastic, or porous laminates, maximum specimen thickness should be 20 mm to allow adequate heat transfer for condensation.

7.3 To provide rigidity, flexible specimens may be attached to a backing panel made of aluminum or other noncorrosive heat conductive material.

7.4 Cut edges of coated steel specimens shall be protected so that rust does not contaminate the test surface.

7.5 Holes in specimens and any openings larger than 1 mm around irregularly shaped specimens shall be sealed to prevent loss of water vapor. Porous specimens, such as textiles or wood shall be backed with a vapor barrier such as metal or plastic.
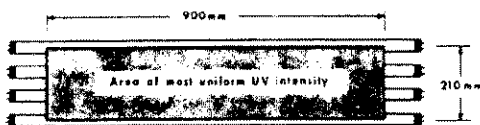
8. Calibration and Standardization

8.1 The thermometer or thermocouple which indicates test temperature shall be calibrated by immersing the sensing element and a liquid-in-glass thermometer in water heated to approximately 70°C and comparing the two temperatures as in Method E 220.

8.2 The formation of condensation may be observed by using clear glass or plastic blanks in the specimen holders or rack. One large sheet of plastic may also be used for this purpose. The condensate that forms on a given area during a period of condensation may be collected and then measured.

8.3 The fading and other changes caused by the fluorescent UV lamps may be observed by exposing lightfastness standards in the apparatus using UV alone without condensation.

8.3.1 The AATCC Blue Wool Lightfastness reference materials[7] may be used to measure the changes caused by UV. The L2 Blue Wool has been found satisfactory for evaluating fluorescent UV lamps.

8.3.2 Other lightfastness reference materials may be used by agreement.

8.4 Reference standards for calibrating the operation of the apparatus in alternate exposure to UV light and condensation may be prepared from painted metal, plastics, or other materials. Painted metal specimens produced by the coil-coating process have been found suitable for such reference standards.

8.5 In addition, for Type B apparatus, the irradiance control system shall be calibrated to the manufacturer's instructions once a year. The radiometer shall be recalibrated when changing to fluorescent UV lamps having a different spectral power distribution.

9. Procedure

9.1 Mount the test specimens in the specimen racks with the test surfaces facing the lamp. When the test specimens do not completely fill the racks, fill the empty spaces with blank panels to maintain the test conditions within the chamber.

9.2 Program the selected test conditions. Operate continuously, repeating the cycle, except for servicing the instrument and inspection of specimens.

9.3 Various test conditions may be used. If no conditions are specified, the following cycle and temperatures are suggested: 4 h UV at 60°C, 4 h Condensation at 50°C.

NOTE 3—Prior versions of this practice recommended a condensation temperature of 40°C in 9.3. When operating in room conditions that do not comply with those set forth in 6.10, a 40°C condensation temperature can result in inadequate condensation. Therefore, a 50°C condensation temperature is now suggested.

9.3.1 Any test temperature that can be maintained within the limits specified in 6.9.1 and 6.9.2 may be used. UV test temperature of 50°C, 60°C, and 70°C are widely used. A condensation test temperature of 50°C is commonly used.

9.3.2 The following time cycles are widely used: 4 h UV/4 h CON, and 8 h UV/4 hr CON. Use UV and condensation periods of at least 2-h duration to allow sufficient time to reach equilibrium.

9.3.3 The severity of the UV exposure is influenced by test temperatures and time cycles. Photochemical reaction begins as soon as the UV lamps are turned on. The rate of UV degradation is proportional to the time of UV exposure or the temperature of UV exposure, or both. UV exposures at temperatures higher than those expected in the service environment can cause abnormal thermal degradation.

9.3.4 Water reactions during condensation exposure are affected by the permeability of the specimen and require time to initiate. The rate of water degradation is increased by increased temperature. However, long hot condensation exposures can cause abnormal degradation. Four-hour condensation exposures are often used for paints on metals, while condensation exposures of 20 h duration may be used on wood.

9.4 *Maintenance*—Periodic maintenance is required to maintain uniform exposure conditions.

9.4.1 *Control of Irradiance*—Because fluorescent UV lamps, like all gas discharge lamps, have a progressive drop in radiation output with continued use, provision shall be made to compensate for lamp aging.

9.4.1.1 *Type A*—After 400 to 450 h of lamp operating time, replace one lamp in each bank of lamps, and rotate the other lamps as shown in Fig. 5. This procedure provides a useful lamp life of 1600 to 1800 h.

9.4.1.2 *Type B:* operate the apparatus using the irradiance level of 20 W/sq. m (270 nm − 700 nm) which is equivalent to Type A apparatus. For other lamps having different spectral power distributions, the equivalent irradiance level can be obtained from the manufacturer. Other irradiance levels specified upon agreement between concerned parties may be used. Provision is made in the apparatus to compensate for lamp aging.

9.4.1.3 To ensure uniform irradiation, pre-aged lamps must be used in the apparatus. Such lamps shall be supplied by the manufacturer.

9.4.1.4 Discard and replace all eight lamps simultaneously after 1600 hours of light-on time. If the lamps are operated at a higher irradiance level than recommended by the manufacturer, the lamp life will be shortened.

9.4.2 Drain water and clean water pan when conducting lamp replacement and rotation procedure. Scum on the top of the water can inhibit water vaporization.

9.5 *Sample Rotation*—The samples' positions within the test area should be rotated on a regular basis in order to minimize any effects from horizontal or vertical variations in UV or temperature. The sample rotation sequence should provide that all samples spend approximately the same
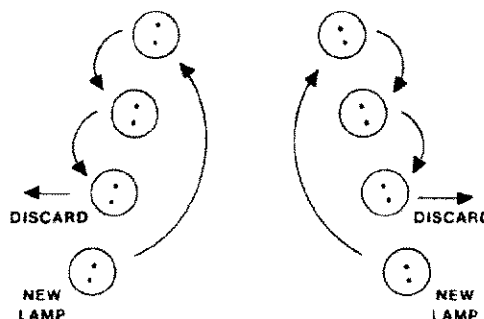
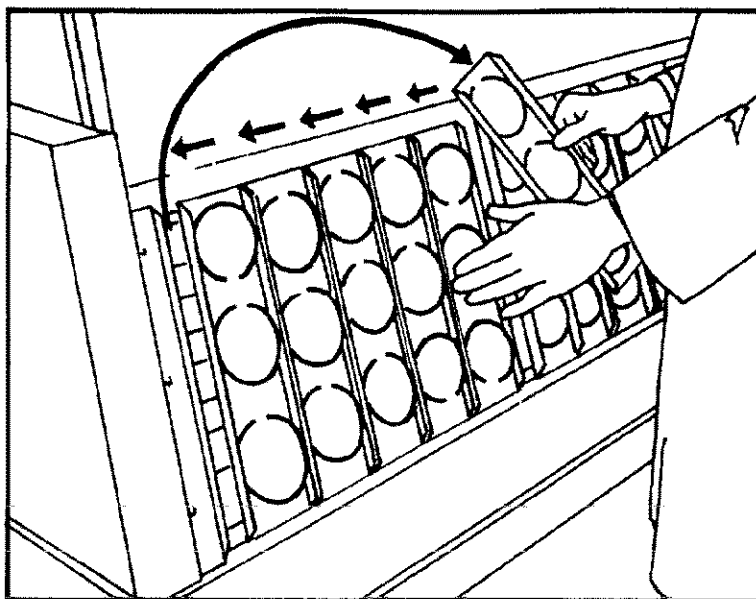**LAMP ROTATION**

FIG. 5 Lamp Rotation

FIG. 6. Daily Horizontal Sample Rotation

amount of exposure time near the center of the exposure area and near the edges of the exposure area. The following rotation sequence is recommended:

9.5.1 *Horizontal Rotation*—Once a day rotate the extreme left hand and extreme right hand samples into the center as shown in Fig. 6.

9.5.2 *Vertical Rotation*—Rotate the samples vertically so that each sample spends the same amount of exposure time in each vertical position in the sample holder. For instance, if two samples are stacked vertically in each sample holder, then the top and bottom sample should switch places halfway through the test method. If four samples are stacked vertically, then the samples should be repositioned vertically

three times during the test method.

9.5.3 Other sample rotation sequences may be used by agreement.

9.6 Inspect specimens daily in tests with a length of 1 week or less. Tests for longer periods should be inspected weekly.

9.6.1 A permanent record of degradation at various times may be obtained by using three replicate specimens and removing the replicates sequentially at intervals equal to one third of the test length.

9.7 Conclude the test when either a mutually agreed-upon number of total test hours or a mutually agreed-upon change has occurred in the test specimen or a standard test spec-

REPORT FORM   ASTM PRACTICE G- 53   FLUORESCENT—UV / CONDENSATION TEST

TEST No. :_____ Date: _____ By: _____

APPARATUS Type and Model			TEST TIME _____ hrs.	
LAMP	MANUFACTURER	TYPE	PEAK EMISSION _____ nm	LOW CUT-OFF (1% of peak) _____ nm
CYCLE	_____ hrs UV at _____ °C: /		_____ hrs COND at _____°C:	
SPECIAL TEST CONDITIONS				
START DATE:	END DATE:	TIMER HRS. START	TIMER HRS. STOP	LAMP SERVICE at _____ hrs.
SPECIMEN SIZE_____			Rotated ☐ Yes ☐ No	
MATERIAL				
PROPERTIES TO BE MEASURED		MEASURING PROCEDURE (ASTM Spec., etc.)		
1. _____				
2. _____				
3. _____				

FIG. 7   Sample Report Form

imen. For convenience in inspecting and concluding tests during normal working hours, the following test durations are recommended:

96 h = 4 days	672 h = 4 weeks
168 h = 1 week	1008 h = 6 weeks
336 h = 2 weeks	1512 h = 9 weeks
504 h = 3 weeks	2016 h = 12 weeks

10. Interpretation of Results

10.1 This practice is intended to simulate the deterioration caused by natural weathering. However, the rate of degradation in natural weathering varies from year to year. Laboratory accelerated weathering is more consistent in rate. Therefore, in comparing natural and laboratory weathering one should not attempt to predict the number of hours of laboratory exposure that might equal a year of natural weathering. Even if the details of the natural exposure are fully reported as required by 5.3, any time to time comparison would apply only to a given year at a particular site.

10.2 It is possible to correlate the deterioration resulting from a period of natural weathering, such as 1 year, to the deterioration resulting from a period of laboratory accelerated weathering. Spearman rank correlation, which is discussed in most basic statistical texts, has proved to be a useful method for this. A minimum of seven variables must be ranked by both test methods to obtain statistical validity from Spearman rank correlation. Ranking 10 to 15 variables by both methods will improve the reliability of such correlations.

10.3 It is frequently not possible to predict how many hours or weeks of accelerated testing will yield the best correlation to some period of outdoor testing. Therefore, laboratory tests should be measured periodically, such as weekly or biweekly, so that the correlation coefficient may be calculated at several points during the accelerated test.

11. Report

11.1 Report the following information:

11.1.1 Manufacturer and model of fluorescent UV/condensation apparatus,

11.1.2 Manufacturer's designation for the fluorescent UV lamp, the wavelength (nm) at which peak emission occurs, and the short wavelength at which 1 % of peak emission occurs (for example, FS-40 313/280 nm),

11.1.3 Cycle of UV exposure time and temperature, condensation time and temperature (for example 4 h UV/60°C, 4 h CON/50°C),

11.1.4 Total exposure time,

11.1.5 Special conditions of test, such as rotation of test specimens, and

11.2 A sample report form is shown in Fig. 7.

12. Precision and Bias

12.1 *Precision:*

12.1.1 The repeatability and reproducibility of results obtained in exposures conducted according to this practice will vary with the materials being tested, the material property being measured, and the specific test conditions and cycles that are used. In round-robin studies[8] conducted by ASTM subcommittee G3.03, the 60° gloss values of replicate PVC tape specimens exposed in different laboratories using identical test devices and exposure cycles showed significant variability. The variability shown in these round-robin studies restricts the use of "absolute standards" such as requiring a specific property level after a specific exposure period.

12.1.1.1 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 according to this practice, the specified property level shall be based on results obtained in a round-robin that takes into consideration the variability due to the exposure, and the test method used to measure the property of interest. The round-robin shall be conducted according to Practice E 691 and shall include a statistically representative sample of all laboratories or organizations who would normally conduct the exposure and property measurement.

12.1.1.2 If a standard or specification for use between two or three parties requires a definite property level after a specific time or radiant exposure in an exposure test conducted according to this practice, the specific property level shall be based on statistical analysis of results from at least two separate, independent exposures in each laboratory. The design of the experiment used to determine the specification shall take into consideration the variability due to the exposure, and the test method used to measure the property of interest.

12.1.2 The same round-robin studies demonstrated that the gloss values for a series of materials could be ranked with a high level of reproducibility between laboratories. When reproducibility in results from an exposure test conducted according to this practice have not been established through round-robin testing, performance requirements for materials shall be specified in terms of comparison (ranked) to a control specimen. The control specimen shall be exposed simultaneously with the test specimen(s) in the same device. The specific control material used shall be agreed upon by the concerned parties. Expose replicates of the test specimen and the control specimen so that statistically significant performance difference can be determined.

12.2 *Bias:*

12.2.1 Bias can not be determined because no acceptable standard weathering reference materials are available.

13. Keywords

13.1 condensation; cycles; environmental; exposure; fluorescent; light; nonmetallic; simulation; ultraviolet; weathering test

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[8] Fischer, R. M., "Results of Round Robin Studies of Light- and Water-Exposure Standard Practices," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202,* Warren D. Ketola and Douglas Grossman, Eds, American Society for Testing and Materials, Philadelphia, 1993.

APPENDIXES

(Nonmandatory Information)

X1. LAMP APPLICATIONS

X1.1 A variety of lamps can be used in fluorescent UV-condensation devices. The particular application determines which lamp should be used. The lamps discussed in this appendix differ in the total amount of UV energy emitted and in their wavelength spectrum. Differences in lamp energy or spectrum may cause significant differences in test results. Consequently it is extremely important to report lamp type in accordance with 11.1.2.

X2. DIRECT EXPOSURES

X2.1 *UV-B Lamps:*

X2.1.1 The UV-B region (280–315 nm) includes the shortest wavelengths found in sunlight at the earth's surface and is responsible for most polymer damage. UV-B lamps are commonly used lamps in fluorescent UV-condensation devices. For most applications, they produce the fastest polymer degradation. There are two commonly available types of UV-B lamps that meet the requirements of 6.2.1. They emit different amounts of total energy, but both peak at 313 nm and produce the same UV wavelengths in the same relative proportions. In tests utilizing the same cycles and temperatures, shorter times to failure are observed when the lamp with higher UV irradiance is used. Furthermore, tests using the same cycles and temperatures with these two lamps may exhibit differences in *ranking* of materials, due to difference in the proportion of UV to moisture and temperature.
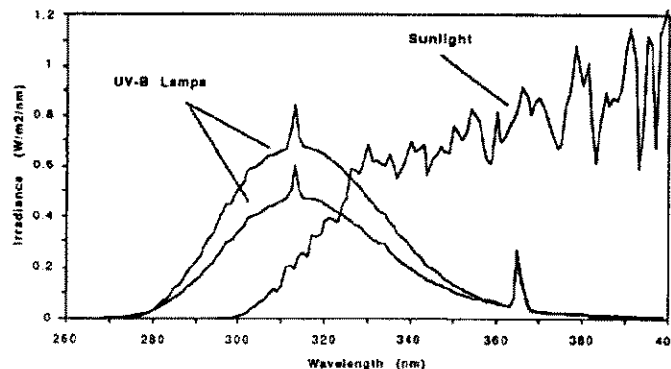
X2.1.2 All UV-B lamps emit UV below the normal sunlight cut-on. This short wavelength UV can produce rapid polymer degradation and often causes degradation by mechanisms that do not occur when materials are exposed to sunlight. This may lead to anomalous results. Figure X2.1 shows the spectral power distribution (SPD) of typical UV-B lamps compared to the SPD of noon, summer sunlight.

X2.2 *UV-A Lamps:*

X2.2.1 For certain applications, the longer wavelength spectrum emitted by UV-A lamps is useful. Because UV-A lamps typically have little or no UV output below 300 nm (which is considered the "cut-on" wavelength for terrestrial sunlight), they usually do not degrade materials as rapidly as UV-B lamps, but they may allow enhanced correlation with actual outdoor weathering. Tests using UV-A lamps have been found useful for comparing different polymers, textiles and UV stabilizers. Figure X2.2 illustrates the SPD of one commonly used type of fluorescent UV-A lamp compared to noon, summer sunlight. This lamp has a peak emission at 340 nm.

X2.2.2 The other commonly used type of UV-A lamp has peak at 351 nm, and is mostly used for behind glass simulations because it lacks some of the short UV-B wavelengths found in sunlight. UV-A lamps with different SPD's can produce very different test results.

NOTE—All SPD's in this appendix are representative SPD's only, and are not meant to be used to calculate or estimate total radiant exposure for tests in fluorescent UV devices. SPD's were measured using a spectroradiometer with a double grating monochromator (1 nm band pass) with a quartz cosine receptor. Sunlight was measured in Phoenix, AZ at solar noon at the summer solstice with a clear sky, with the spectroradiometer on an equatorial follow-the-sun mount. The fluorescent UV SPD's were measured at the sample plane in the center of the allowed sample area.

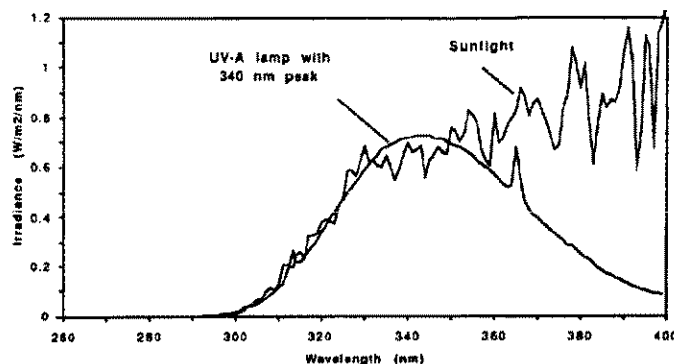FIG. X2.1 Typical UV-B Lamps versus Sunlight

FIG. X2.2 UV-A Lamp with 340 nm Peak versus Sunlight

X3. SIMULATIONS OF EXPOSURES TO SUNLIGHT BEHIND GLASS

X3.1 For simulations of behind glass exposure applications, UV-A lamps are recommended.

X3.2 *Filtering Effect of Glass*—Glass of any type àcts as a filter on the sunlight spectrum. Ordinary glass is essentially transparent to light above about 370 nm. However, the filtering effect becomes more pronounced with decreasing wavelength. The shorter, more damaging UV-B wavelengths are the most greatly affected. Window glass completely filters out the most damaging wavelengths below about 310 nm. For purposes of illustration, only one type of window glass is used in the accompanying graphs. It should be noted that glass transmission characteristics will vary due to manufacturer, production lot, thickness, or other factors.

X3.3 *UV-B Lamps:*

X3.3.1 Most of the emission of UV-B lamps is in the shorter wavelengths that are filtered very efficiently by glass. Because of this, very little energy from this type of lamp will reach specimens mounted behind glass in the test chamber. Figure X3.1 shows a UV-B lamp unfiltered, a UV-B lamp through window glass, and sunlight through window glass. Window glass filters out 80 % of the total energy from UV-B lamps. As a result of attenuating the short wavelengths, it also shifts the peak spectrum toward the longer wavelengths. The short wavelength cut-on for both sunlight through glass and the UV-B through glass is at about 310 nm, depending on the glass lot.

X3.3.2 UV-B lamps should not be used to test materials that are exposed to sunlight through glass. *Unfiltered* exposure to UV-B lamps is much too severe a test when compared to sunlight through glass.

X3.4 *UV-A Lamps:*

X3.4.1 Most of the energy emitted from UV-A lamps is able to pass through typical window glass. Figure X3.2 compares the SPD's for sunlight filtered through a typical window glass, a UV-A lamp with a peak output of 340 nm, and the same UV-A lamp filtered by the same window glass.
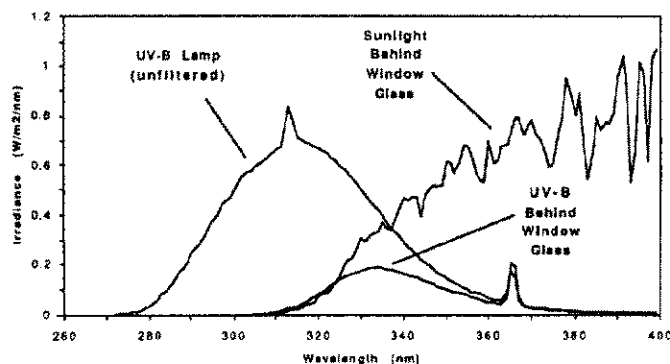

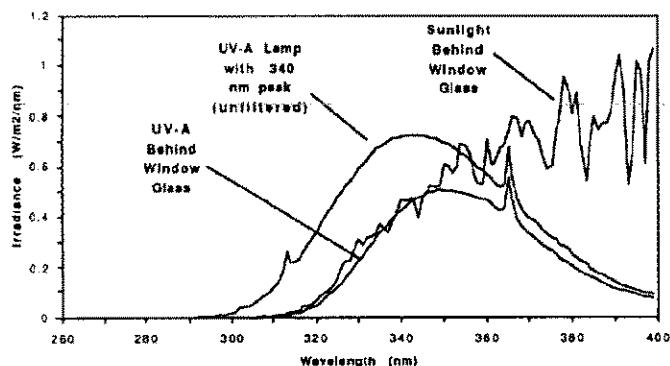FIG. X3.1 Sunlight Behind Glass versus UV-B Lamp and UV-B Lamp Behind Glass

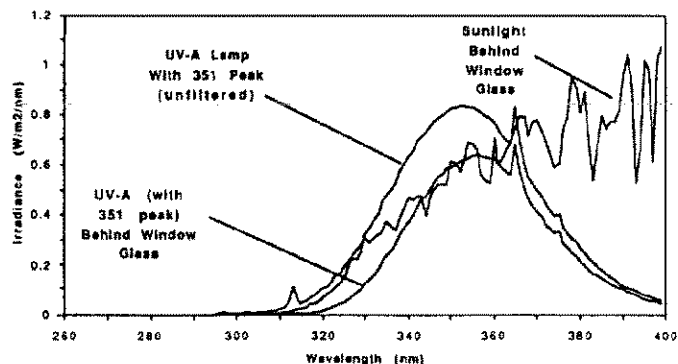FIG. X3.2 Sunlight Behind Glass versus 340 nm Lamp and 340 nm Lamp Behind Glass

FIG. X3.3 Sunlight Behind Glass versus 351 nm Lamp and 351 nm Lamp Behind Glass

X3.4.2 Figure X3.3 compares the SPD's for sunlight filtered through a typical window glass, a UV-A lamp with a peak output of 351 nm, and the same UV-A lamp filtered by the same window glass.

X3.4.3 For many applications, exposure to unfiltered UV-A lamps with a peak output at 351 nm provides a good simulation for sunlight filtered through typical window glass. If specimens must be exposed behind glass in the test chamber, tests using lamps with a peak emission at 340 nm are recommended.