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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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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.

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 *Definitions of Terms Specific to This Standard:*

3.1.1 *irradiance*—the radiation incident on a surface expressed in W/m^2. 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/m^2 per wavelength band. The spectral irradiance of sunlight is often shown as W/m^2 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/m^2, 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. Fig. 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 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.

[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.

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[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.

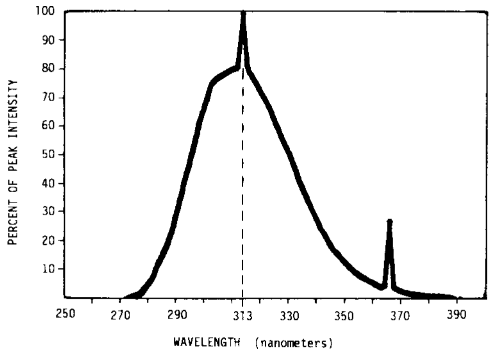


FIG. 1 Typical Relative SED of UV-B Lamp

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.

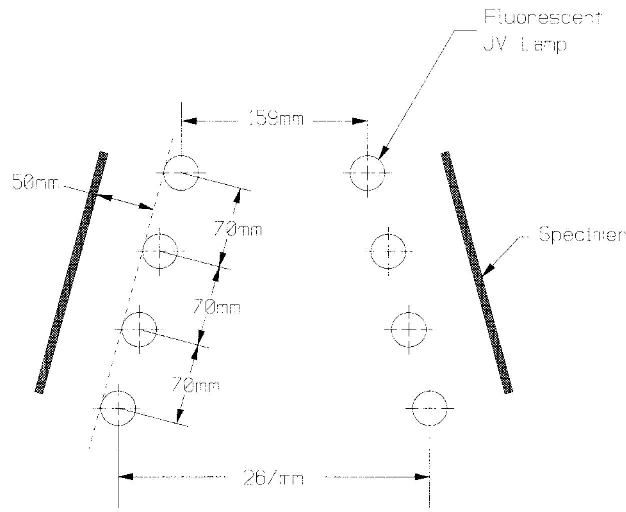


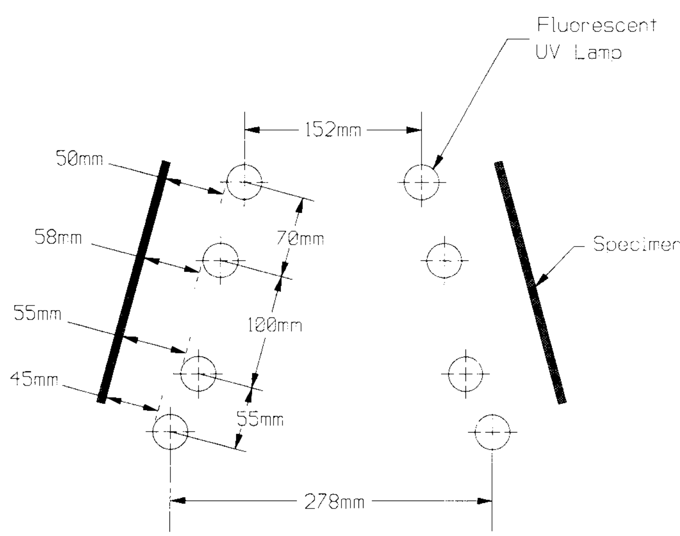
FIG. 2 Lamp Placement Schematic—Type A Exposure Apparatus Cross Section

6.1.1.1 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.

6.1.2 *Type B*[7]*:* An exposure apparatus, as shown in Fig. 3, which is equipped with a radiometer and readout device

[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.



NOTE 1—Enclosure for apparatus not shown in Figs. 2 and 3.

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

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 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.

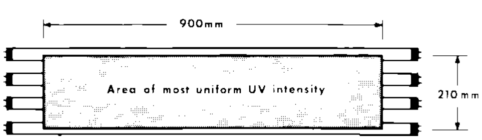


FIG. 4 Limits of Area of Uniform Intensity

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*:

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

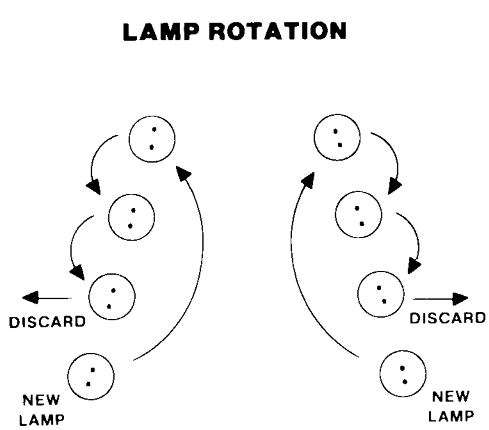


FIG. 5 Lamp Rotation