



Designation: G 154 – 00

Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials¹

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1. Scope

1.1 This practice covers the basic principles and operating procedures for using fluorescent UV light, and water apparatus intended to reproduce the weathering effects that occur when materials are exposed to sunlight (either direct or through window glass) and moisture as rain or dew in actual usage. This practice is limited to the procedures for obtaining, measuring, and controlling conditions of exposure. A number of exposure procedures are listed in an appendix; however, this practice does not specify the exposure conditions best suited for the material to be tested.

NOTE 1—Practice G 151 describes performance criteria for all exposure devices that use laboratory light sources. This practice replaces Practice G 53, which describes very specific designs for devices used for fluorescent UV exposures. The apparatus described in Practice G 53 is covered by this practice.

1.2 Test specimens are exposed to fluorescent UV light under controlled environmental conditions. Different types of fluorescent UV light sources are described.

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 and ISO 4892-1. More specific information about methods for determining the change in properties after exposure and reporting these results is described in ISO 4582.

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

1.5 *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.*

1.6 This standard is technically similar to ISO 4892-3 and ISO DIS 11507.

2. Referenced Documents

2.1 ASTM Standards:

D 3980 Practice for Interlaboratory Testing of Paint and Related Materials²

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method³

G 53 Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials⁴

G 113 Terminology Relating to Natural and Artificial Weathering Tests for Nonmetallic Materials⁴

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources⁴

2.2 CIE Standard:

CIE-Publ. No. 85: Recommendations for the Integrated Irradiance and the Spectral Distribution of Simulated Solar Radiation for Testing Purposes⁵

2.3 ISO Standards:

ISO 4582, Plastics—Determination of the Changes of Colour and Variations in Properties After Exposure to Daylight Under Glass, Natural Weathering or Artificial Light⁶

ISO 4892-1, Plastics—Methods of Exposure to Laboratory Light Sources, Part 1, Guidance⁶

ISO 4892-3, Plastics—Methods of Exposure to Laboratory Light Sources, Part 3, Fluorescent UV lamps⁶

ISO DIS 11507, Paint and Varnishes—Exposure of Coatings to Artificial Weathering in Apparatus—Exposure to Fluorescent Ultraviolet and Condensation Apparatus⁶

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard*—As used

² Discontinued 1998. See 1998 Annual Book of ASTM Standards, Vol 06.01.

³ Annual Book of ASTM Standards, Vol 14.02.

⁴ Annual Book of ASTM Standards, Vol 14.04.

⁵ Available from Secretary, U.S. National Committee, CIE, National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899.

⁶ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

¹ This practice is under the jurisdiction of ASTM Committee G-3 on Weathering and Durability and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Exposure Tests.

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in this practice, the term *sunlight* is identical to the terms *daylight* and *solar irradiance, global* as they are defined in Terminology G 113.

4. Summary of Practice

4.1 Specimens are exposed to repetitive cycles of light and moisture under controlled environmental conditions.

4.1.1 Moisture is usually produced by condensation of water vapor onto the test specimen or by spraying the specimens with demineralized/deionized water.

4.2 The exposure condition may be varied by selection of:

- 4.2.1 The fluorescent lamp,
- 4.2.2 The lamp's irradiance level,
- 4.2.3 The type of moisture exposure,
- 4.2.4 The timing of the light and moisture exposure,
- 4.2.5 The temperature of light exposure, and
- 4.2.6 The temperature of moisture exposure, and
- 4.2.7 The timing of a light/dark cycle.

4.3 Comparison of results obtained from specimens exposed in same model of apparatus should not be made unless reproducibility has been established among devices for the material to be tested.

4.4 Comparison of results obtained from specimens exposed in different models of apparatus should not be made unless correlation has been established among devices for the material to be tested.

5. Significance and Use

5.1 The use of this apparatus is intended to induce property changes associated with the end use conditions, including the effects of the UV portion of sunlight, moisture, and heat. These exposures may include a means to introduce moisture to the test specimen. Exposures are not intended to simulate the deterioration caused by localized weather phenomena, such as atmospheric pollution, biological attack, and saltwater exposure. Alternatively, the exposure may simulate the effects of sunlight through window glass. Typically, these exposures would include moisture in the form of condensing humidity.

NOTE 2—Caution: Refer to Practice G 151 for full cautionary guidance applicable to all laboratory weathering devices.

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 the use of this practice unless accompanied by a report detailing the specific operating conditions in conformance with the Section 10.

5.2.1 It is recommended that a similar material of known performance (a control) be exposed simultaneously with the test specimen to provide a standard for comparative purposes. It is recommended that at least three replicates of each material evaluated be exposed in each test to allow for statistical evaluation of results.

6. Apparatus

6.1 *Laboratory Light Source*—The light source shall be fluorescent UV lamps. A variety of fluorescent UV lamps can be used for this procedure. Differences in lamp intensity or spectrum may cause significant differences in test results. A

detailed description of the type(s) of lamp(s) used should be stated in detail in the test report. The particular testing application determines which lamp should be used. See Appendix X1 for lamp application guidelines.

NOTE 3—Do not mix different types of lamps. Mixing different types of lamps in a fluorescent UV light apparatus may produce major inconsistencies in the light falling on the samples, unless the apparatus has been specifically designed to ensure a uniform spectral distribution.

NOTE 4—Many fluorescent lamps age significantly with extended use. Follow the apparatus manufacturer's instructions on the procedure necessary to maintain desired irradiance (1,2).

6.1.1 Actual irradiance levels at the test specimen surface may vary due to the type or manufacturer of the lamp used, or both, the age of the lamps, the distance to the lamp array, and the air temperature within the chamber and the ambient laboratory temperature. Consequently, the use of a radiometer to monitor and control the radiant energy is recommended.

6.1.2 Several factors can affect the spectral power distribution of fluorescent UV lamps:

6.1.2.1 Aging of the glass used in some types of lamps can result in changes in transmission. Aging of glass can result in a significant reduction in the short wavelength UV emission of some lamp types,

6.1.2.2 Accumulation of dirt or other residue on lamps can affect irradiance,

6.1.2.3 Thickness of glass used for lamp tube can have large effects on the amount of short wavelength UV radiation transmitted, and

6.1.2.4 Uniformity and durability of phosphor coating.

6.1.3 *Spectral Irradiance:*

NOTE 5—Fluorescent UVA lamps are available with a choice of spectral power distributions that vary significantly. The more common may be identified as UVA-340 and UVA-351. These numbers represent the characteristic nominal wavelength (in nm) of peak emission for each of these lamp types. The actual peak emissions are at 343 and 350 nm, respectively.

6.1.3.1 *Spectral Irradiance of UVA-340 Lamps for Daylight UV*—The spectral power distribution of UVA-340 fluorescent lamps shall comply with the requirements specified in Table 1.

NOTE 6—The main application for UVA-340 lamps is for simulation of the short and middle UV wavelength region of daylight.

6.1.3.2 *Spectral Irradiance of UVA-351 Lamps for Daylight UV Behind Window Glass*—The spectral power UV behind window glass of UVA-351 fluorescent lamps shall comply with the requirements specified in Table 2.

NOTE 7—The main application for UVA-351 lamps is for simulation of the short and middle UV wavelength region of daylight which has been filtered through window glass (3).

6.1.3.3 *Spectral Irradiance of UVB-313 Lamps*—The spectral power distribution of UVB-313 fluorescent lamps shall comply with the requirements specified in Table 2.

NOTE 8—Fluorescent UVB lamps have the spectral distribution of radiation peaking near the 313-nm mercury line. They emit significant amounts of radiation below 300 nm, the nominal cut on wavelength of global solar radiation, that may result in aging processes not occurring outdoors. Use of this lamp is not recommended for sunlight simulation. See Table 3.

6.2 *Test Chamber*—The design of the test chamber may

TABLE 1 Relative Spectral Power Distribution Specification for UVA-340 Lamps for Daylight UV

Bandpass, nm	Fluorescent UVA-340 Lamp ^A	Sunlight ^E
Ultraviolet Wavelength Region		
Irradiance as a percentage of total irradiance from 260 to 400 nm		
260–270	0.0 %	0
271–280	0.0 %	0
281–290	0.0 %	0
291–300	< 0.2 %	0
301–320	6.2–8.6 %	5.6 %
321–340	27.1–30.7 %	18.5 %
341–360	34.2–35.4 %	21.7 %
361–380	19.5–23.7 %	26.6 %
381–400	6.6–7.8 %	27.6 %
Ultraviolet and Visible Wavelength Region		
Irradiance as a percentage of total irradiance from 300 to 800 nm ^C		
300–400	87.3 % ^D	11 % ^E
401–700	12.7 % ^D	72 % ^E

^AUVA-340 data—The ranges given are based on spectral power distribution measurements made for lamps of different ages and operating at different levels of controlled irradiance. The ranges given are based on three sigma limits from the averages of this data.

^BSunlight data—The sunlight data is for global irradiance on a horizontal surface with an air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.81 at 300 nm and 0.62 at 400 nm.

^CData from 701 to 800 nm is not shown.

^DUVA-340 data—Because the primary emission of fluorescent UV lamps is concentrated in the 300- to 400-nm bandpass, there are limited data available for visible light emissions of fluorescent UV lamps. Therefore, the data in this table are based on very few measurements and are representative only.

^ESunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm.

vary, but it should be constructed from corrosion resistant material and, in addition to the radiant source, may provide for means of controlling temperature and relative humidity. When required, provision shall be made for the spraying of water on the test specimen for the formation of condensate on the exposed face of the specimen or for the immersion of the test specimen in water.

6.2.1 The radiant source(s) shall be located with respect to the specimens such that the uniformity of irradiance at the specimen face complies with the requirements in Practice G 151.

6.2.2 Lamp replacement, lamp rotation, and specimen repositioning may be required to obtain uniform exposure of all specimens to UV radiation and temperature. Follow manufacturer’s recommendation for lamp replacement and rotation.

6.3 *Instrument Calibration*—To ensure standardization and accuracy, the instruments associated with the exposure apparatus (for example, timers, thermometers, wet bulb sensors, dry bulb sensors, humidity sensors, UV sensors, and radiometers) require periodic calibration to ensure repeatability of test results. Whenever possible, calibration should be traceable to national or international standards. Calibration schedule and procedure should be in accordance with manufacturer’s instructions.

6.4 *Radiometer*—The use of a radiometer to monitor and control the amount of radiant energy received at the sample is recommended. If a radiometer is used, it shall comply with the requirements in Practice G 151.

TABLE 2 Relative Spectral Power Distribution Specification for UVA-351 Lamps for Daylight UV Behind Window Glass

Bandpass, nm	Fluorescent UVA-351 Lamp ^A	Estimated Window Glass Filtered Sunlight ^E
Ultraviolet Wavelength Region		
Irradiance as a percentage of total irradiance from 260 to 400 nm		
260–270	0.0 %	0 %
271–280	0.0 %	0 %
281–290	0.0 %	0 %
290–300	< 0.1 %	0 %
301–320	0.9–3.3 %	0.1–1.5 %
321–340	18.3–22.7 %	9.4–14.8 %
341–360	42.7–44.5 %	23.2–23.5 %
361–380	24.8–28.2 %	29.6–32.5 %
381–400	5.8–7.6 %	30.9–34.5 %
Ultraviolet and Visible Wavelength Region		
Irradiance as a percentage of total irradiance from 300 to 800 nm ^C		
300–400	90.1 % ^D	9.0–11.1 % ^E
401–700	9.9 % ^D	71.3–73.1 % ^E

^AUVA-351 data—The ranges given are based on spectral power distribution measurements made for lamps of different ages and operating at different levels of controlled irradiance. The ranges given are based on three sigma limits from the averages of this data.

^BSunlight data—The sunlight data is for global irradiance on a horizontal surface with an air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.081 at 300 nm and 0.62 at 400 nm. The range is determined by multiplying solar irradiance by the upper and lower limits for transmission of single strength window glass samples used for studies conducted by ASTM Subcommittee G03.02.

^CData from 701 to 800 nm is not shown.

^DUVA-351 data—Because the primary emission of fluorescent UV lamps is concentrated in the 300- to 400-nm bandpass, there are limited data available for visible light emissions of fluorescent UV lamps. Therefore, the data in this table are based on very few measurements and are representative only.

^ESunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm. The range is determined by multiplying solar irradiance by the upper and lower limits for transmission of single strength window glass samples used for studies conducted by ASTM Subcommittee G03.02.

6.5 *Thermometer*—Either insulated or un-insulated black or white panel thermometers may be used. The un-insulated thermometers may be made of either steel or aluminum. Thermometers shall conform to the descriptions found in Practice G 151.

6.5.1 The thermometer shall be mounted on the specimen rack so that its surface is in the same relative position and subjected to the same influences as the test specimens.

6.5.2 Some specifications may require chamber air temperature control. Positioning and calibration of chamber air temperature sensors shall be in accordance with the descriptions found in Practice G 151.

NOTE 9—Typically, these devices control by black panel temperature only.

6.6 *Moisture*—The test specimens may be exposed to moisture in the form of water spray, condensation, or high humidity.

6.6.1 *Water Spray*—The test chamber may be equipped with a means to introduce intermittent water spray onto the test specimens under specified conditions. The spray shall be uniformly distributed over the samples. The spray system shall be made from corrosion resistant materials that do not contaminate the water used.

TABLE 3 Relative Spectral Power Distribution Specification for UVB-313 Lamps

Bandpass, nm	Fluorescent UVB-313 Lamp ^{A,B}	Sunlight ^C
Ultraviolet Wavelength Region ^A		
Irradiance as a percentage of total irradiance from 260 to 400 nm		
260–270	< 0.1 %	0
271–280	0.1–0.7 %	0
281–290	3.2–4.4 %	0
291–300	10.7–13.7 %	0
301–320	38.0–44.6 %	5.6 %
321–340	25.5–30.9 %	18.5 %
341–360	7.7–10.7 %	21.7 %
361–380	2.5–5.5 %	26.6 %
381–400	0.0–1.5 %	27.6 %
Ultraviolet and Visible Wavelength Region		
Irradiance as a percentage of total irradiance from 300 to 800 nm ^D		
300–400	88.5 % ^E	11 % ^F
401–700	11.5 % ^E	72 % ^F

^AUVB-313 data—Some UVB lamps have measurable emittance at the 254-nm mercury line. This may affect test results for some materials.

^BUVB-313 data—The ranges given are based on spectral power distribution measurements made for lamps of a different ages and operating at different levels of controlled irradiance. The ranges given are based on three sigma limits from the averages of this data. Lamps that meet this specification are available from different manufacturers. These lamps may have significantly different irradiance levels (that is, total light output), but still have the same relative spectral power distribution.

^CSunlight data—The sunlight data is for global irradiance on a horizontal surface with a air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.081 to 300 nm and 0.62 at 400 nm.

^DData from 701 to 800 nm is not shown.

^EUVB-313 data—Because the primary emission of fluorescent UV lamps is concentrated in the 300- to 400-nm bandpass, there is limited data available for visible light emissions of fluorescent UV lamps. Therefore, the data in this table are based on very low measurements and are representative only.

^FSunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm.

6.6.1.1 *Spray Water Quality*—Spray water shall have a conductivity below 5 µS/cm, contain less than 1-ppm solids, and leave no observable stains or deposits on the specimens. Very low levels of silica in spray water can cause significant deposits on the surface of test specimens. Care should be taken to keep silica levels below 0.1 ppm. In addition to distillation, a combination of deionization and reverse osmosis can effectively produce water of the required quality. The pH of the water used should be reported. See Practice G 151 for detailed water quality instructions.

6.6.2 *Condensation*—The test chamber may be equipped with a means to cause condensation to form on the exposed face of the test specimen. Typically, water vapor shall be generated by heating water and filling the chamber with hot vapor, which then is made to condense on the test specimens.

6.6.3 *Relative Humidity*—The test chamber may be equipped with a means to measure and control the relative humidity. Such instruments shall be shielded from the lamp radiation.

6.7 *Specimen Holders*—Holders for test specimens shall be made from corrosion resistant materials that will not affect the test results. Corrosion resistant alloys of aluminium or stainless steel have been found acceptable. Brass, steel, or copper shall not be used in the vicinity of the test specimens.

6.8 *Apparatus to Assess Changes in Properties*—The necessary apparatus required by ASTM or ISO relating to the determination of the properties chosen for monitoring shall be used (see also ISO 4582).

7. Test Specimen

7.1 Refer to Practice G 151.

8. Test Conditions

8.1 Any exposure conditions may be used as long as the exact conditions are detailed in the report. Appendix X2 shows some representative exposure conditions. These are not necessarily preferred and no recommendation is implied. These conditions are provided for reference only.

9. Procedure

9.1 Identify each test specimen by suitable indelible marking, but not on areas used in testing.

9.2 Determine which property of the test specimens will be evaluated. Prior to exposing the specimens, quantify the appropriate properties in accordance with recognized ASTM or international standards. If required (for example, destructive testing), use unexposed file specimens to quantify the property. See ISO 4582 for detailed guidance.

9.3 *Mounting of Test Specimens*—Attach the specimens to the 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 if necessary.

NOTE 10—Evaluation of color and appearance changes of exposed materials shall be made based on comparisons to unexposed specimens of the same material which have been stored in the dark. Masking or shielding the face of test specimens with an opaque cover for the purpose of showing the effects of exposure on one panel is not recommended. Misleading results may be obtained by this method, since the masked portion of the specimen is still exposed to temperature and humidity that in many cases will affect results.

9.4 *Exposure to Test Conditions*—Program the selected test conditions to operate continuously throughout the required number of repetitive cycles. Maintain these conditions throughout the exposure. Interruptions to service the apparatus and to inspect specimens shall be minimized.

9.5 *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 G 151.

9.5.1 If irradiance at positions farther from the center of the exposure area is between 70 and 90 % of that measured at the center, one of the following three techniques shall be used for specimen placement.

9.5.1.1 Periodically reposition specimens during the exposure period to ensure that each receives an equal amount of radiant exposure. The repositioning schedule shall be agreed upon by all interested parties.

9.5.1.2 Place specimens only in the exposure area where the irradiance is at least 90 % of the maximum irradiance.

9.5.1.3 To compensate for test variability randomly position replicate specimens within the exposure area which meets the