



Designation: G178 – 16 (Reapproved 2023)

Standard Practice for Determining the Activation Spectrum of a Material (Wavelength Sensitivity to an Exposure Source) Using the Sharp Cut-On Filter or Spectrographic Technique¹

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1. Scope

1.1 This practice describes the determination of the relative actinic effects of individual spectral bands of an exposure source on a material. The activation spectrum is specific to the light source to which the material is exposed to obtain the activation spectrum. A light source with a different spectral power distribution will produce a different activation spectrum.

1.2 This practice describes two procedures for determining an activation spectrum. One uses sharp cut-on UV/visible transmitting filters and the other uses a spectrograph to determine the relative degradation caused by individual spectral regions.

NOTE 1—Other techniques can be used to isolate the effects of individual spectral bands of a light source, for example, interference filters.

1.3 The techniques are applicable to determination of the spectral effects of solar radiation and laboratory accelerated test devices on a material. They are described for the UV region, but can be extended into the visible region using different cut-on filters and appropriate spectrographs.

1.4 The techniques are applicable to a variety of materials, both transparent and opaque, including plastics, paints, inks, textiles and others.

1.5 The optical and/or physical property changes in a material can be determined by various appropriate methods. The methods of evaluation are beyond the scope of this practice.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

NOTE 2—There is no ISO standard that is equivalent to this standard.

¹ This practice is under the jurisdiction of ASTM Committee G03 on Weathering and Durability and is the direct responsibility of Subcommittee G03.01 on Joint Weathering Projects.

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1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

- D256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
- D638 Test Method for Tensile Properties of Plastics
- D822 Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings
- D1435 Practice for Outdoor Weathering of Plastics
- D1499 Practice for Filtered Open-Flame Carbon-Arc Exposures of Plastics
- D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
- D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
- D4141 Practice for Conducting Black Box and Solar Concentrating Exposures of Coatings
- D4329 Practice for Fluorescent Ultraviolet (UV) Lamp Apparatus Exposure of Plastics
- D4364 Practice for Performing Outdoor Accelerated Weathering Tests of Plastics Using Concentrated Sunlight
- D4459 Practice for Xenon-Arc Exposure of Plastics Intended for Indoor Applications
- D4508 Test Method for Chip Impact Strength of Plastics (Withdrawn 2016)³
- D4587 Practice for Fluorescent UV-Condensation Exposures of Paint and Related Coatings

² 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.

³ The last approved version of this historical standard is referenced on www.astm.org.

- D5031 Practice for Enclosed Carbon-Arc Exposure Tests of Paint and Related Coatings
- D6360 Practice for Enclosed Carbon-Arc Exposures of Plastics
- D6695 Practice for Xenon-Arc Exposures of Paint and Related Coatings
- E275 Practice for Describing and Measuring Performance of Ultraviolet and Visible Spectrophotometers
- E313 Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates
- E925 Practice for Monitoring the Calibration of Ultraviolet-Visible Spectrophotometers whose Spectral Bandwidth does not Exceed 2 nm
- G7 Practice for Natural Weathering of Materials
- G24 Practice for Conducting Exposures to Daylight Filtered Through Glass
- G90 Practice for Performing Accelerated Outdoor Weathering of Materials Using Concentrated Natural Sunlight
- G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials
- G147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests
- G152 Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
- G153 Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials
- G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Materials
- G155 Practice for Operating Xenon Arc Lamp Apparatus for Exposure of Materials

3. Terminology

3.1 Definitions given in Terminology G113 are applicable to this practice.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *activation spectrum, n*—the spectral sensitivity of a material specific to the spectral power distribution of the source to which the material is exposed as a function of a specified property measurement.

3.2.1.1 *Discussion*—The activation spectrum of a material exhibits peak sensitivity to the spectral region in which the combination of the radiation intensity, absorption of the radiation by the material and quantum efficiency of degradation produce the maximum damage. Thus, activation spectra show that many materials exhibit greater damage by wavelengths longer than the shortest emitted by the radiation source (see Fig. X1.4 and Fig. X1.8). Since activation spectra relate to the spectral emission properties of the radiation source, the activation spectrum varies with the type of radiation source to which the material is exposed.

3.2.2 *incremental degradation, n*—the increase in degradation in the specimen exposed behind the shorter wavelength cut-on filter of the pair due to the addition of short UV wavelengths transmitted by the filter.

3.2.3 *incremental ultraviolet, n*—the additional short wavelength ultraviolet transmitted by the shorter wavelength cut-on filter of the pair of sharp cut-on UV/VIS transmitting glass filters. It is represented by the *spectral band* (see 3.2.5).

3.2.4 *sharp cut-on UV/VIS transmitting glass filters, n*—filters that screen out the short wavelengths and transmit radiation longer than the cut-on wavelength. The transmittance increases sharply from 5 %, the cut-on wavelength, to 72 % within a spectral range of about 20 nm. They are also referred to as longpass filters.

3.2.5 *spectral band, n*—the spectral region defined by the difference in transmittance of a pair of the sharp cut-on UV/VIS transmitting glass filters. It is also referred to as the *incremental ultraviolet*.

3.2.6 *spectral band pass, n*—the spectral range of the spectral band at the delta 20 % transmittance level. It is the spectral range of the incremental ultraviolet mainly responsible for the incremental degradation.

3.2.6.1 *Discussion*—The definition of this term differs from that commonly applied to the spectral bandpass, also referred to as the spectral bandwidth, of a narrow band filter or the radiant energy leaving the exit slit of a monochromator. These terms are defined as the full width at half-maximum, FWHM, that is, the wavelength range at one half the peak height of the spectral band.

3.2.7 *cumulative spectral sensitivity curve, n*—a plot of the cumulative effect on the optical or physical properties of a material of addition of progressively shorter wavelengths of the source to the longer wavelength exposure with progressive decrease in wavelength of the sharp cut-on UV/visible transmitting filter.

4. Significance and Use

4.1 The activation spectrum identifies the spectral region(s) of the specific exposure source used that may be primarily responsible for changes in appearance and/or physical properties of the material.

4.2 The spectrographic technique uses a prism or grating spectrograph to determine the effect on the material of isolated narrow spectral bands of the light source, each in the absence of other wavelengths.

4.3 The sharp cut-on filter technique uses a specially designed set of sharp cut-on UV/visible transmitting glass filters to determine the relative actinic effects of individual spectral bands of the light source during simultaneous exposure to wavelengths longer than the spectral band of interest.

4.4 Both the spectrographic and filter techniques provide activation spectra, but they differ in several respects:

4.4.1 The spectrographic technique generally provides better resolution since it determines the effects of narrower spectral portions of the light source than the filter technique.

4.4.2 The filter technique is more representative of the polychromatic radiation to which samples are normally exposed with different, and sometimes antagonistic, photochemical processes often occurring simultaneously. However, since the filters only transmit wavelengths longer than the cut-on wavelength of each filter, antagonistic processes by wavelengths shorter than the cut-on are eliminated.

4.4.3 In the filter technique, separate specimens are used to determine the effect of the spectral bands and the specimens are sufficiently large for measurement of both mechanical and

optical changes. In the spectrographic technique, except in the case of spectrographs as large as the Okazaki type (1),⁴ a single small specimen is used to determine the relative effects of all the spectral bands. Thus, property changes are limited to those that can be measured on very small sections of the specimen.

4.5 The information provided by activation spectra on the spectral region of the light source responsible for the degradation in theory has application to stabilization as well as to stability testing of polymeric materials (2).

4.5.1 Activation spectra based on exposure of the unstabilized material to solar radiation identify the light screening requirements and thus the type of ultraviolet absorber to use for optimum screening protection. The closer the match of the absorption spectrum of a UV absorber to the activation spectrum of the material, the more effective the screening. However, a good match of the UV absorption spectrum of the UV absorber to the activation spectrum does not necessarily assure adequate protection since it is not the only criteria for selecting an effective UV absorber. Factors such as dispersion, compatibility, migration and others can have a significant influence on the effectiveness of a UV absorber (see Note 3). The activation spectrum must be determined using a light source that simulates the spectral power distribution of the one to which the material will be exposed under use conditions.

NOTE 3—In a study by ASTM G03.01, the activation spectrum of a copolyester based on exposure to borosilicate glass-filtered xenon arc radiation predicted that UV absorber A would be superior to UV absorber B in outdoor use because of stronger absorption of the harmful wavelengths of solar simulated radiation. However, both additives protected the copolyester to the same extent when exposed either to xenon arc radiation or outdoors.

4.5.2 Comparison of the activation spectrum of the stabilized with that of the unstabilized material provides information on the completeness of screening and identifies any spectral regions that are not adequately screened.

4.5.3 Comparison of the activation spectrum of a material based on solar radiation with those based on exposure to other types of light sources provides information useful in selection of the appropriate artificial test source. An adequate match of the harmful wavelengths of solar radiation by the latter is required to simulate the effects of outdoor exposure. Differences between the natural and artificial source in the wavelengths that cause degradation can result in different mechanisms and type of degradation.

4.5.4 Published data have shown that better correlations can be obtained between natural weathering tests under different seasonal conditions when exposures are timed in terms of solar UV radiant exposure only rather than total solar radiant exposure. Timing exposures based on only the portion of the UV identified by the activation spectrum to be harmful to the material can further improve correlations. However, while it is an improvement over the way exposures are currently timed, it does not take into consideration the effect of moisture and temperature.

⁴ The boldface numbers in parentheses refer to the list of references at the end of this standard.

4.6 Over a long test period, the activation spectrum will register the effect of the different spectral power distributions caused by lamp or filter aging or daily or seasonal variation in solar radiation.

4.7 In theory, activation spectra may vary with differences in sample temperature. However, similar activation spectra have been obtained at ambient temperature (by the spectrographic technique) and at about 65 °C (by the filter technique) using the same type of radiation source.

5. Activation Spectrum Procedure Using Sharp Cut-On Filter Technique

5.1 Spectral Bands of Irradiation:

5.1.1 Select glass types for the sharp cut-on UV/visible transmitting glass filters which provide a spectral shift of approximately 10 nm at 40 % transmittance between filter pairs when ground to appropriate thicknesses. It may be necessary to use filters from more than one source. The exact thickness to which each filter is ground is governed by the incremental ultraviolet transmitted by the shorter wavelength filter of the pair. Adjust the thicknesses so that the incremental ultraviolet is within 10 % of the average of the incremental ultraviolet of all filter pairs. The method for determining the incremental ultraviolet is described in 5.1.3.

NOTE 4—Typically, 12 or 13 filters with cut-on wavelengths ranging from 265 nm to 375 nm are used to determine the effects of 10 spectral bands, each approximately 20 nm wide, in the solar UV region. A larger set of filters can be used to reduce the width of each spectral band, but it would extend the time required to produce degradation by each of the spectral regions. The filter size is normally 2 in. by 2 in., but other sizes up to 6 in. by 6 in. can be used.

NOTE 5—The spectral transmittance curves of a typical set of filters are shown in Figs. X1.1 and X1.2 in the Appendix.

NOTE 6—Due to variations in the melt of each glass type, the filter types and thicknesses used for one filter set may not be applicable to other sets.

5.1.2 Spectral Transmittance Data:

5.1.2.1 Use a UV/visible spectrophotometer that produces either digital data or an analog curve to measure the spectral transmittance of each filter from the spectral region of complete blocking at the short wavelength end to maximum transmittance at the long wavelength end.

5.1.2.2 Determine the wavelength calibration and linearity of the spectrophotometer as described in either Practices E275 or E925. Check the 0 % and 100 % baselines and adjust, if necessary, according to manufacturer's recommendations. If the 100 % baseline is not flat in the spectral region in which the filters are measured, correct the data. In the case of analog curves, use sufficient chart expansion to allow accurate transmittance values to be read from the chart at 2 nm intervals.

5.1.3 Incremental Ultraviolet:

5.1.3.1 From Digitized Data:

(1) The delta % transmittance for each filter pair and resultant spectral bands can often be obtained instrumentally when using a computerized spectrophotometer for the digitized data.

5.1.3.2 From Analog Data:

(1) Tabulate the % transmittance of each filter at 2 nm intervals and calculate the delta % transmittance for each pair