



Designation: E2141 – 21

Standard Test Method for Accelerated Aging of Electrochromic Devices in Sealed Insulating Glass Units¹

This standard is issued under the fixed designation E2141; 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.

1. Scope

1.1 This test method covers the accelerated aging of electrochromic devices (ECD) integrated in insulating glass units.

1.2 The test method is applicable for any electrochromic device incorporated into sealed insulating glass units (IGUs) fabricated for vision glass (superstrate and substrate) areas for use in buildings, such as sliding doors, windows, skylights, and exterior wall systems. The layers used for constructing the EC device and electrochromically changing the optical properties may be inorganic or organic materials.

1.3 The electrochromic (EC) glazings used in this test method are exposed to environmental conditions, including solar radiation. They are employed to control the amount of transmitted radiation by absorption and reflection and, thus, limit the solar heat gain and amount of solar radiation that is transmitted into the building.

1.4 The test method is not applicable to other chromogenic devices, such as, photochromic and thermochromic devices which do not respond to electrical stimulus.

1.5 The test method is not applicable to electrochromic (EC) glazings that are constructed from superstrate or substrate materials other than glass.

1.6 The test method referenced herein is a laboratory test conducted under specified conditions. The test is intended to simulate and, in some cases, to also accelerate actual in-service use of the electrochromic glazing. Results from these tests cannot be used to predict the performance with time of in-service units unless actual corresponding in-service tests have been conducted and appropriate analyses have been conducted to show how performance can be predicted from the accelerated aging tests.

1.7 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

¹ This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.22 on Durability Performance of Building Constructions.

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1.8 *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.*

1.9 *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

- C168 Terminology Relating to Thermal Insulation
- E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
- E631 Terminology of Building Constructions
- E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
- E2953 Specification for Evaluating Accelerated Aging Performance of Electrochromic Devices in Sealed Insulating Glass Units
- G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials
- G155 Practice for Operating Xenon Arc Lamp Apparatus for Exposure of Materials
- G173 Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37° Tilted Surface

2.2 ISO Standard:³

- ISO 9050 Glass in building - Determination of light transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors

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 Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

3. Terminology

3.1 *Definitions*—For definitions of general terms used in this test method related to building construction, thermal insulating materials and natural and artificial weathering tests for nonmetallic materials, refer to Terminologies **E631**, **C168** and **G113**, respectively.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accelerated aging test, n*—a test in which the rate of degradation of building components or materials is intentionally increased from that expected in actual service.

3.2.2 *electrochromic device (ECD), n*—a combination of materials that include materials in which the transmittance, reflectance, and absorbance properties can be altered in response to an applied electrical voltage or current.

3.2.3 *electrochromic (EC) glazing, n*—glazing installed in a building that consists of an ECD with layer(s) of materials in which the optical properties can change in response to an applied electrical field.

3.2.4 *electrochromic layer(s), n*—in an ECD, the layer(s) of material(s) in which the optical properties can change in response to application of an electrical voltage or current, or both.

3.2.5 *electro-optic cycling, n*—the process of applying repetitive voltages or currents, or both, to an ECD for the purpose of reversibly changing the optical properties of the EC glazing from the highest to the lowest transmittance state.

3.2.6 *highest transmittance state, n*—also referred to as the clear state or bleached state, a descriptor for an EC glazing when it is in the transmittance state with the highest photopic specular light transmittance.

3.2.7 *lateral uniformity, n*—the degree of variation in the amount of irradiance in the x and y directions in the test plane used for exposing an EC glazing.

3.2.8 *lowest transmittance state, n*—also referred to as the tinted state, dark state or colored state, a descriptor for an EC glazing when it is in the transmittance state with the lowest photopic specular light transmittance.

3.2.9 *photopic transmittance ratio (PTR), n*—photopic transmittance ratio or $PTR = \tau_H / \tau_L$. The photopic transmittances (τ_H , τ_L) are obtained by integrating the spectra in the wavelength range of 380 to 780 nm using the spectral photopic efficiency I_p (CIE, 1924) as the weighting factor.

3.2.10 *room temperature, n*—ca 22 °C.

3.2.11 *serviceability, n*—the capability of a building product, component, assembly, or construction to perform the function(s) for which it was designed and constructed.

3.2.12 *solar irradiance, n*—as related to natural weathering of materials, the irradiance of the sun incident on the earth's surface, having wavelengths between 295 nm and 4050 nm.

3.2.13 *specular (regular) transmittance, n*—the optical transmittance that does not include light with a diffuse component.

3.2.14 *switching cycle, n*—a transition in visible light transmittance through the whole or part of the EC-IGU's visible

light transmittance range starting at one end of the range (at τ_H or τ_L) and ending back at the same point. For example, one switching cycle can be a transition from the highest transmittance state to the lowest transmittance state and back to the highest transmittance state, or a transition from the lowest transmittance state to the highest transmittance state and back to the lowest transmittance state.

3.2.15 *switching times T_H and T_L , n*—switching time, T_H , is the time it takes for the EC glazing to transition from its highest transmittance state over 80 % of its initial dynamic range (where dynamic range is $\tau_H - \tau_L$). Switching time (T_L) is the time it takes for the EC glazing to transition from its lowest transmittance state across 80 % of its dynamic range (where dynamic range is $\tau_H - \tau_L$).

3.3 *Abbreviations:*

3.3.1 *AM*—air mass

3.3.2 *AWU*—accelerated weathering unit

3.3.3 *DBT*—dry-bulb temperature

3.3.4 *DPM*—digital panel meters

3.3.5 *ECD*—electrochromic device

3.3.6 *IG*—insulating glass

3.3.7 *IGU(s)*—insulating glass unit(s)

3.3.8 *NIR*—near-infrared (radiation)

3.3.9 *PTR*—photopic transmittance ratio

3.3.10 τ_H —specular (regular) transmittance in the *highest transmittance state*

3.3.11 τ_L —specular (regular) transmittance in the *lowest transmittance state*

3.3.12 T_H —time to switch from the highest transmittance state to a transmittance of $\tau_H - 0.8 (\tau_H - \tau_L)$

3.3.13 T_L —time to switch from the lowest transmittance state to a transmittance of $\tau_L + 0.8 (\tau_H - \tau_L)$

3.3.14 *UV*—ultraviolet (radiation)

4. Significance and Use

4.1 EC glazings perform a number of important functions in a building envelope including: minimizing the solar energy heat gain; providing for passive solar energy gain; controlling a variable visual connection with the outside world; enhancing human comfort (heat gain), illumination, and glare control; and providing for architectural expression. It is therefore important to understand the relative serviceability of these glazings.

4.2 This test method is intended to provide a means for evaluating the relative serviceability of EC Glazings as described in Section 1.

4.3 The procedures in this test method include (a) rapid but realistic current-voltage cycling tests emphasizing the electrical properties, and (b) environmental test parameters that are typically used in weatherability tests by standards organizations and are realistic for the intended use of large-area EC IGUs.

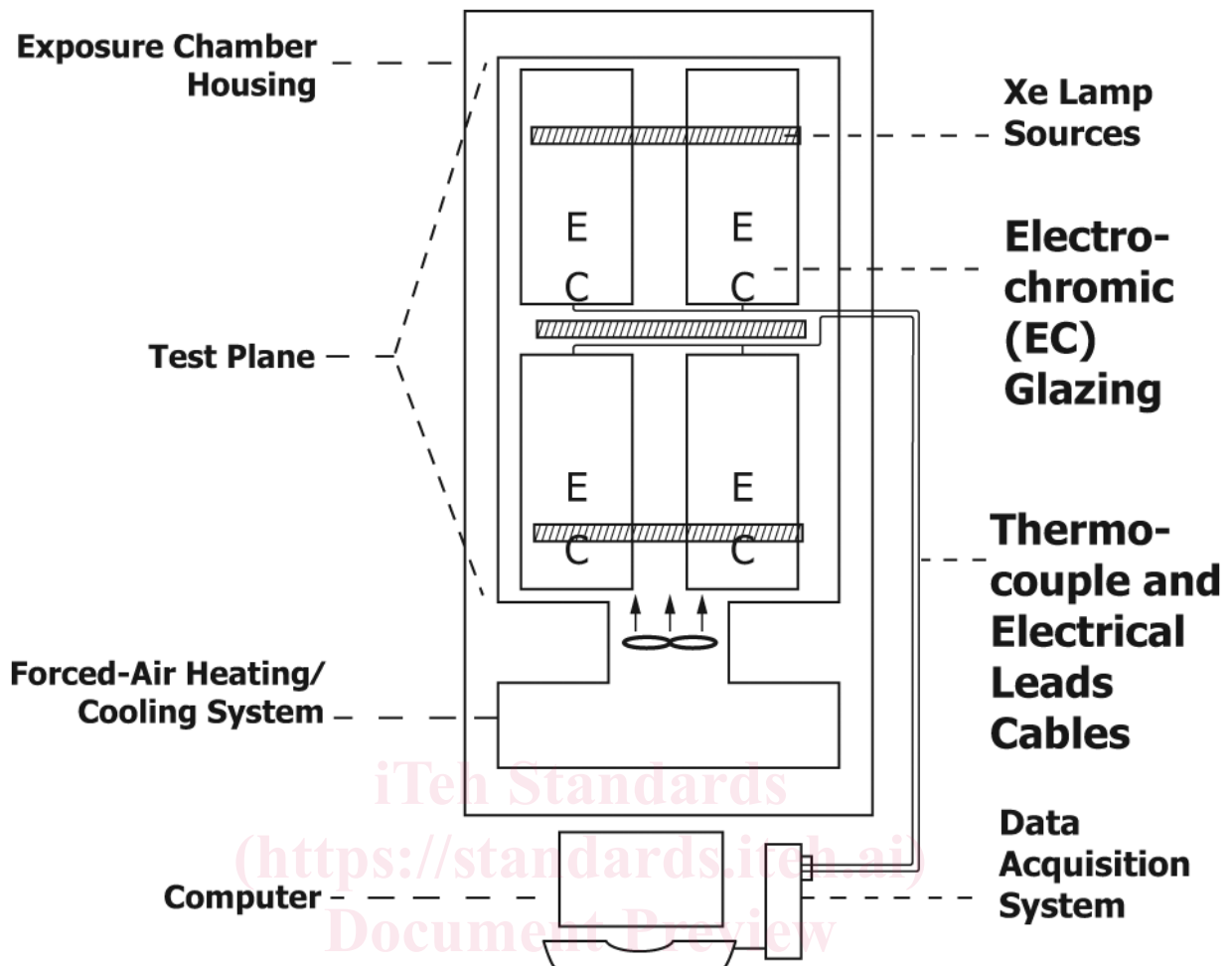


FIG. 1 Top-View Schematic Diagram of the (Essential) Components of an Environmental Test Chamber and Computer-Controlled Electrical Cycling and Data Acquisition System for Accelerated Aging of Electrochromic Glazings

<https://standards.iteh.ai/catalog/standards/sist/68d8fa93-79d4-40ec-946d-89055e68ad40/astm-e2141-21>

5. Apparatus (See Figs. 1 and 2)

5.1 Accelerated Weathering Unit (AWU), consisting of a temperature controlled chamber with properly filtered xenon arc lamps to simulate the spectral power distribution of solar radiation over the UV/visible and NIR wavelength regions (Tables for Reference G173) operated in accordance with Practice G155.

5.1.1 Fig. 1 shows a top-view schematic diagram of the essential features of the environmental test chamber including the layout of the EC IGUs on a test plane of sufficient size to accommodate testing of at least four specimens simultaneously, the location of sufficient xenon-arc lamps above the test plane to deliver the specified radiation intensity, and the necessary connecting thermocouples and cables from the EC IGUs to the computer-controlled cycling and data acquisition system. Chamber dimension shall be large enough to accommodate all specimens.

NOTE 1—It has been found that a chamber of size of 2400 mm high by 2650 mm deep by 4480 mm wide has been useful.

5.1.2 The test plane shall be vertically adjustable and the user shall adjust the distance from the lamps to the specimens to obtain the desired light intensity and lateral uniformity

within the guidelines of this document. Temperature control within the test chamber shall be provided. Conditions inside the closed space shall be controlled for air temperatures from 20 °C to 95 °C ± 0.5 °C. Humidity within the test chamber shall be monitored and shall not exceed 60 %.

5.1.3 Simulated solar radiation shall be provided by spectrally filtered, long-arc xenon arc lamps housed within a reflector system in the ceiling of the test chamber. The lamps may be water cooled. The lamps shall be suitably filtered to provide a match of an AM 1.5 solar spectrum (see Note 2). The lamps may be surrounded by an NIR-absorbing filter, which reduces the heat load in the chamber and allows appropriate temperature control.

NOTE 2—At longer wavelengths, the xenon arc emission is at variance with the AM 1.5 solar spectrum, Tables for Reference G173, because the intensities relative to those in the UV/visible region are higher than in solar radiation. However, this part of the spectrum does not cause photolytically induced degradation.

5.1.4 The EC IGU specimens are located on the vertically moveable test plane beneath the xenon arc lamps. The AWU shall have a means for allowing electrical connections to pass from inside to outside the unit to allow temperature monitoring and electrical control of the EC IGUs.

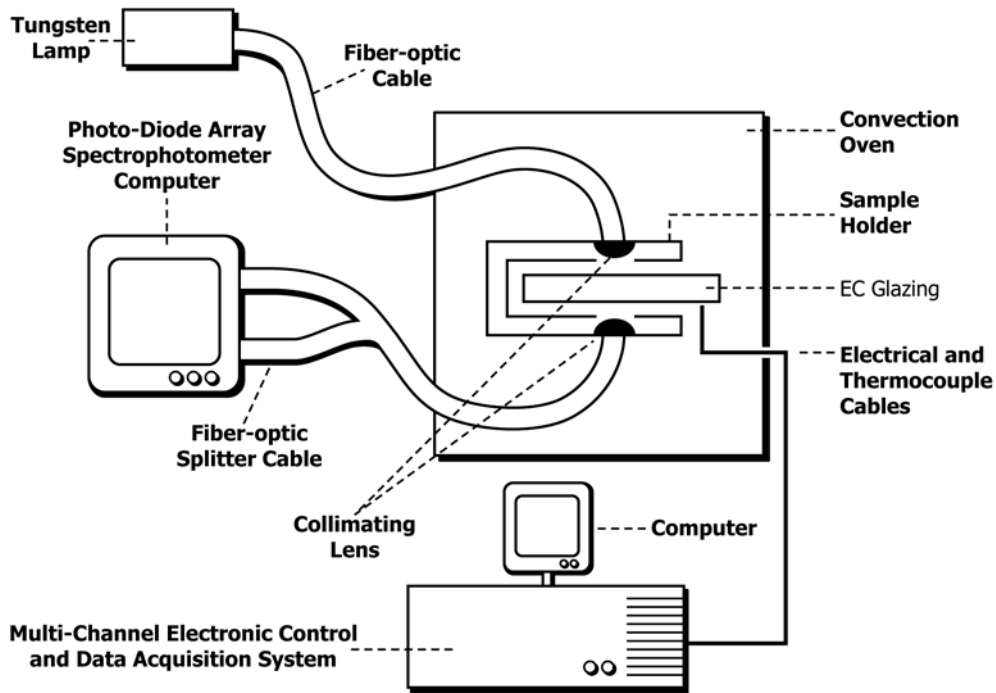


FIG. 2 Schematic of the (Essential) Elements of the Optical Measurement System Used for Recording 300 nm to 780 nm Transmittance Spectra for a Switching Cycle of EC Glazings at Controlled Temperatures

5.2 *EC Cycling Unit*, for imposing voltage or current cycles, or both, to alternately and repeatedly change the transmittance of the EC IGUs.

5.3 *Electrical Leads*, from the EC cycling unit in 5.2 to each EC IGU in the AWU described in 5.1.

5.4 *Computer Controlled Spectrometer*, for obtaining and storing data from the optical characterization of the specimens.

5.4.1 *Spectrometer Light Source*, a tungsten lamp or other suitable lamp source that provides illumination from 380 nm to 780 nm.

5.4.2 *Fiber Optic Cables*, which shall be routed from the lamp source into the EC IGU specimen holder and from the EC IGU specimen holder to the spectrometer. One optical fiber guides the incident light from the lamp source to one side of the specimen; another optical fiber guides the transmitted light to the spectrometer attached to a computer. The fibers shall be optically coupled by properly aligned collimating lens assemblies attached to both the illuminating and the collection fibers.

5.5 *Computer-Controlled, Multichannel Potentiostat*, for switching to and from highest and lowest transmittance states during spectrometer transmittance measurements.

5.6 *Temperature-Controlled Oven*, capable of heating the test specimens to the selected test temperature. The oven will be used to carry out optical measurements of the EC-IGUs at the selected test temperature. It shall be large enough for the largest EC IGU to be tested and shall be able to reach the EC IGU testing temperature. The oven must also be designed to permit using the equipment in 5.4 for optical measurements while the EC IGU is maintained at the temperature chosen for testing in the AWU described in 5.1.

5.7 *Digital Camera*, for taking photographs of the specimens.

5.8 *Video Camera and Recorder*, for taking videos of the specimens.

5.9 *Verified and Calibrated Thermocouples*, for use to measure specimen and chamber temperatures in the AWU and the oven.

6. Test Specimens

6.1 Test specimen size, design, and construction shall be established and specified by the manufacturer, except that the specimens shall be at least $250 \text{ mm} \pm 6 \text{ mm} \times 250 \text{ mm} \pm 6 \text{ mm}$.

6.2 Refer to Specification E2953 for details on specimen quantity and size.

7. Procedure⁴

7.1 *Overview*—The EC IGUs are exposed to simulated solar radiation in a temperature controlled chamber at selected specimen temperatures ranging from 70 °C to 105 °C while the EC IGUs are cyclically switched between low and high transmittance states with the ability to pause during the duty cycles (see Note 3 for further information), depending on the control strategy prescribed by the manufacturer. Accept the prevailing relative humidity in the chamber but ensure that it

⁴ The procedure is based in part on the paper by Czanderna, A., et al., in "Optical Materials Technology for Energy Efficiency and Solar Energy Conversion XV," Lampert, C. M., Granqvist, C., Grätzel, M., and Deb, S. K., eds., *SPIE*, Vol. 3138, 68 (1997).

does not exceed 60 %. The EC IGU specimens are initially characterized optically at room temperature to determine initial performance. Then they are optically characterized in an oven at the selected test temperature in order to determine the time during which the specimens will be in or switching to the lowest transmittance state and the time during which the specimens will be in or switching to the highest transmittance state. This is because some EC products have temperature dependent switching times. The same equipment is used for both room and high temperature optical characterization measurements. After exposure in the AWU, the specimens are again optically characterized at room temperature as they were initially to provide after-aging EC-IGU performance data.

NOTE 3—Control duty cycle refers to the fraction of the total cycle time over which the specimen has a voltage or current, or both, applied that reduces the transmittance of the specimen. A 50 % duty cycle means that a voltage or current, or both, that causes a reduction in transmittance is applied for 50 % of the total cycle time. During the remaining 50 % of the cycle time, a voltage or current, or both, that causes an increase in the transmittance is applied. The applied voltages or currents, or both, to increase and decrease transmittance are as specified in 7.3.4.

7.2 When received, inspect the EC IGUs visually at room temperature, take photographs of any obvious defects or aberrations of the EC specimens in the highest transmittance state or lowest transmittance state, whichever is the unpowered state, and note and record your observations.

7.3 Carry out the initial optical characterization of the EC IGUs at room temperature:

7.3.1 Measure the optical transmittance between 380 nm and 780 nm of all EC IGUs at room temperature in the convection oven, as shown schematically in Fig. 2.

7.3.2 The convection oven shall be allowed to equilibrate with room temperature for measurements at ca. 22 °C. The temperature of the EC IGU shall be monitored with a thermocouple (or other appropriate surface temperature probe or device) attached to the lite that contains the EC layers. The placement should be located on every sample on the center of the outer surface of the glass containing the EC layers with a tape having an emissivity close to that of glass.

7.3.3 Measure transmittances per the spectrometer manufacturer's instructions ensuring that reference spectra for 100 % and 0 % transmittance are taken before each measurement and using at least 5 nm increments. The sample should be positioned or marked at the center of the outer surface of the lite containing the EC device such that the same spot on the sample is measured before and after exposure.

7.3.4 The magnitudes of the voltages or currents, or both, used for switching the EC glazing between transmittance states, shall be applied as specified by the EC glazing manufacturer.

7.3.5 Determine the highest (τ_H) and lowest (τ_L) transmittance and the switching speed of the EC-IGUs.

7.3.5.1 The optical transmittance of the specimen shall be measured over a spectral range covering at least 380 nm to 780 nm in successive intervals during the process of cycling between highest and lowest transmittance states. A time interval of a fraction of the total cycle time for taking each spectrum should be adequate for recording the optical properties of each EC IGU.

7.3.5.2 The photopic transmittance of the devices shall be obtained by integrating the spectra in the wavelength range of 380 nm to 780 nm using the spectral photopic efficiency $I_p(\lambda)$ (CIE, 1924) as the weighting factor.⁵ The procedure for integration can be found in ISO 9050.

7.3.5.3 Allow the samples to reach their lowest transmittance and highest transmittance states during these measurements. Wait for 30 min from the start of the transition for the specimens to reach their extreme states or until the rate of change of transmittance is less than 0.4 %T per min, whichever yields the shortest time.

7.3.5.4 Plot the transmittance spectra measured during switching as a function of wavelength. Typical transmittance spectra recorded during a full switching cycle are shown in Fig. 3, in which the optical spectra of the glazings are plotted as a function of wavelength.

7.4 Use the oven and spectrometer to measure the optical transmittance as a function of time of the specimens at the selected test temperature.

7.4.1 The magnitudes of the voltages or currents, or both, used for switching the EC glazing between transmittance states during the long-term cycling tests at temperatures ranging from 70 °C to 105 °C, shall be applied as specified by the EC glazing manufacturer.

7.4.2 Heat each EC IGU in a convection oven at the specified specimen test temperature. Determine the switching times for obtaining a PTR of at least 5, starting from and returning to the highest transmittance state by measuring the transmittance as a function of time using the spectrometer as described in 7.3.5. For specimens that have a PTR lower than 5, determine the switching time to transition through 85 % of the specimen's dynamic range (where dynamic range is $\tau_H - \tau_L$).

7.4.3 Use these switching times to program the multichannel potentiostat with specific voltage or current profiles, or both, for cyclic testing at the test temperature in the AWU. The control duty cycle shall be 50 % with a voltage or current, or both, applied that causes an increase in transmittance or in the highest transmittance state, and 50 % with a voltage or current, or both, applied that causes a decrease in transmittance or in the lowest transmittance state (see Note 3).

7.5 Set up the AWU.

7.5.1 Adjust the lamp to specimen distance to obtain a reading of 1000 W/m² over the spectral range 300 nm to 3000 nm on the digital panel meter (DPM) to represent a 1 sun illumination. Ensure that the uniformity of the illumination at the test plane of the specimens is at least ± 8 %. See Annex A1 for a description of how to adjust the illumination uniformity.

7.5.2 Adjust the chamber temperature to obtain the desired testing temperature of the EC IGU (see 7.7 for definition of testing temperature). For example, with a chamber air temperature of 60 °C, the average EC IGU surface temperature reaches a steady-state temperature of about 85 °C depending on the specimen size, optical PTR-ratio reached during EC cycling,

⁵ Kingslake, R., *Applied Optics and Optical Engineering: Volume 1 Light: Its Generation and Modification*, Table II, Chapter 1, Academic Press, New York, NY, 1965.

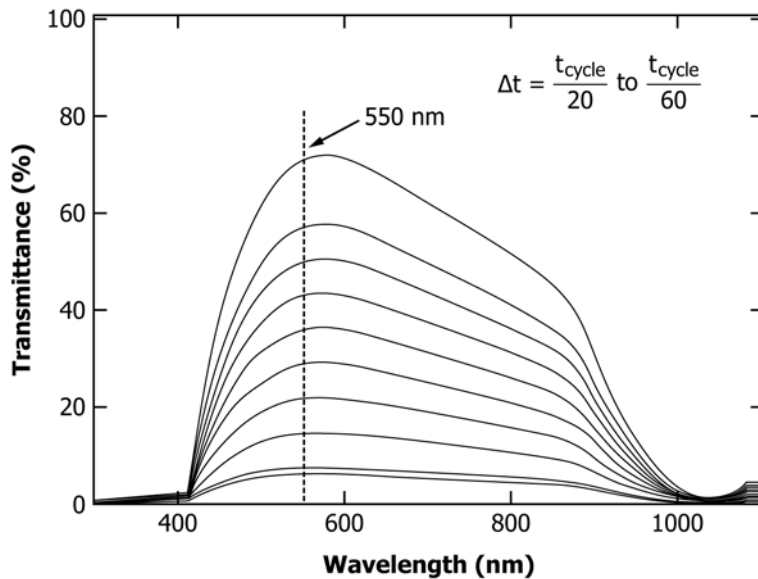


FIG. 3 Example Transmittance Spectra When Transitioning Reversibly Between Highest and Lowest Transmittance States at Intervals Ranging from $t_{\text{cycle}}/20$ to $t_{\text{cycle}}/60$ for an Example EC IGU

location of the glazing in the test plane, and the EC IGU construction. Ensure that the relative humidity does not exceed 60 %.

7.6 Mount the EC IGUs in the AWU.

7.6.1 Place the EC IGU specimens horizontally onto the test plane. The IGU shall be oriented such that the exterior lite, as installed in the field, is facing the light source. Make suitable electrical connections from the EC cycling unit and data acquisition system to the wires of each EC glazing.

NOTE 4—Specimens may be raised from the surface of the test plane to allow for proper air circulation if required to maintain adequate temperature control. The test plane must be lowered an equal distance in order to maintain the proper incident light energy on the lite closest to the light source.

7.6.2 Tape thermocouples (0.13 mm diameter) to the center surface of the specimens (to the lite containing the EC) with 8 mm square pieces of tape as defined in 7.3.2. The thermocouple leads may also be taped away from the center of the specimen using up to two additional 8 mm square pieces of aluminum tape to provide strain relief to prevent the thermocouple from being pulled off the glass surface. Mate the thermocouples to thicker extension wires leading to the remote electronics via subminiature connectors. If the EC IGU is oriented with the EC containing lite furthest away from the light source, the thermocouple on that lite shall be shielded from the incident radiation by a 5 cm by 5 cm piece of aluminized tape applied to the surface closest to the lamp array to prevent it from heating up due to absorbing the radiation from the lamp array.

7.7 Cycle the EC IGUs in the AWU at elevated temperature and under simulated solar exposure. Note that the “testing” temperature shall be that of the lite containing the ECD in the lowest transmittance state; the average EC IGU temperature will be less because of a typical decrease of about 5 °C when the EC IGU is in the highest transmittance state.

7.7.1 Before cycling at the test temperature, electro-optically cycle all the EC IGU specimens in the AWU at room temperature to verify the integrity of the electronic control and data acquisition system, as well as the continuity of the electrical and thermocouple connections.

7.7.2 With the specimen in the highest transmittance state, activate the Xenon arc lamps and adjust the dry-bulb temperature (DBT) to adjust the chamber air temperature and thus provide adjustment of the specimen temperature.

7.7.2.1 The DBT serves as the controlling parameter for the internal forced-air heating and cooling system. It is set at a temperature less than the specified specimen temperature, so as to achieve the latter, which is reached by the combined heat transfer from absorption of the radiant energy of the source and conduction. The specimen temperature depends on the manufactured EC IGU construction, PTR during EC cycling, specimen size, and location in the AWU test plane, as well as whether the EC IGU is in the lowest or highest transmittance state.

7.7.2.2 When the EC specimen in the highest transmittance state approaches the desired testing temperature, begin the EC cycling of the EC IGU using the voltage/current profile at the specified test temperature obtained by earlier oven pretesting (7.4). Make minor adjustments to the DBT setting to account for the inevitable rise in temperature of the specimens resulting from absorption in the lowest transmittance state. Specimen temperatures may increase or decrease by several degrees Celsius during cycling the specimen through the lowest and highest transmittance states, respectively.

7.7.2.3 Record the specimen temperatures and electro-optic cycling data using the data acquisition system and periodically monitor to ensure proper operation of the AWU, associated apparatus, and the computer.

7.8 Interim Visual and Optical Characterizations:

7.8.1 Program the electro-optic cycling of the EC glazings and the functions of the AWU to shut down periodically after 2000 h and 4000 h and finally after 50 000 cycles and at least 5000 h have elapsed. Periodic shutdowns at other times are also allowed. After each shut down, disconnect the thermocouple and electrical leads to the specimen from the cabling, remove the specimens, and re-measure the optical transmittance in the highest and lowest transmittance states at room temperature as in 7.3. (See Note 5.)

NOTE 5—Because of difference in switching cycle times of different specimen sets based on for example, sample size or material type, exposure times may exceed the minimum of 5000 h in order to achieve 50 000 cycles. Variation in exposure time should be considered when interpreting the results of this test method.

7.8.2 Visually inspect the EC IGU specimens and photograph any detectable degradation with the digital camera. Note and record any visually detectable degradation of the specimens in the highest and lowest transmittance states. (See Note 6.)

NOTE 6—The visual uniformity tests should be made when the EC IGU is held at a constant transmittance. To establish a given transmittance state for assessing the uniformity of the EC IGU, the manufacturers should be asked to provide control information (voltage or current, or both, time) that will result in a constant transmittance of the EC IGU in the lowest and highest transmittance states, and this information should be used.

NOTE 7—The seals in an IGU can degrade if the test temperature is too high resulting in a visible obstruction to the glass compared to the original sample. In this case, no assessment of the EC glazing shall be made.

7.8.3 Record the optical measurements and other observations, and reinsert the EC IGU specimens into the AWU for the next series of cyclic testing, that is, another 2000 h or 1000 h as appropriate.

7.8.4 Repeat the procedure in 7.7 and 7.8 until a total of 50 000 switching cycles and at least 5000 h under test conditions are achieved.

7.9 Final Characterization:

7.9.1 *Final Optical Characterization*—After the specimens have amassed 50 000 switching cycles and 5000 h under test conditions, optically characterize the specimens at room temperature following the procedure in 7.3.

7.9.2 *Video Documentation*—Mount each EC IGU that has been aged next to an un-tested specimen from the same lot of all those tested. Record the dynamic response for 5 switching cycles between highest and lowest transmittance states using the video camera.

7.9.3 *Final Visual Inspection*—Perform the final visual inspection, take photographs, and record all evidence of visually detectable degradation.

8. Analysis for Performance

8.1 *Photopic Transmittance*—Use 3.3 (Light Transmittance) and Table 1 (Weighting Functions) of ISO 9050 to determine the photopic transmittance of the lowest and highest transmittance states.

8.2 *Switching Speed*—Calculate the switching time from the highest transmittance state (τ_H) to the lowest transmittance state (τ_L) and from the lowest (τ_L) to the highest transmittance state (τ_H).

9. Observations

9.1 Observe and document the following:

9.1.1 Specimen breakage.

9.1.2 Specimen degradation that is evident visually in the highest transmittance state.

9.1.3 Specimen degradation that is evident visually in the lowest transmittance state.

9.1.4 Specimen degradation that is evident from photographs in the highest transmittance state.

9.1.5 Specimen degradation that is evident from photographs in the lowest transmittance state.

9.1.6 Specimen degradation that is evident from the videos in the highest transmittance state.

9.1.7 Specimen degradation that is evident from the videos in the lowest transmittance state.

10. Report

10.1 The following information shall be provided in the test report.

10.1.1 A complete description of the test specimen(s) including size, the make-up of the EC insulating glass unit tested, including a description of the EC pane and the non-EC pane, the cavity dimension and any additional films or coatings, or both, product name, code/identifier, manufacturer, date received, date testing was completed.

10.1.2 The number of samples.

10.1.3 The orientation of the EC lite with respect to the light source during testing (that is, was it tested in an exterior EC lite or room side EC lite configuration).

10.1.4 The photopic transmittance in the lowest and highest transmittance states of the specimen(s) both before and after the accelerated test was conducted.

10.1.5 Switching times T_L and T_H before and after test.

10.1.6 Additional measurements and analyses performed on the specimen(s) and the results.

10.1.7 The number of switching cycles completed.

10.1.8 The number of hours completed.

10.1.9 The average test temperature and range (this is the average of the specimen temperatures in the lowest transmittance states).

10.1.10 Any observations made in Section 9.

10.2 Additional information such as technical drawings, photographs, and videos shall be included or referenced in the test report.

11. Precision and Bias⁶

11.1 *Precision*—The precision of this test method is based on an interlaboratory study of ASTM E2141-06, Standard Test Methods for Assessing the Durability of Absorptive Electrochromic Coatings on Sealed Insulating Glass Units, conducted in 2012. A single laboratory participated in this study, testing 14 sealed tungsten oxide-based electrochromic insulating glass units from two manufacturers (five from one manufacturer and nine from another). Every “test result” represents an individual

⁶ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:E06-1005. Contact ASTM Customer Service at service@astm.org.