Designation: E2354 – 04

Standard Guide for Assessing the Durability of Absorptive Electrochromic Coatings within Sealed Insulating Glass Units[1]

This standard is issued under the fixed designation E2354; 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 guide provides the recommended sequence for using the referenced ASTM test methods for assessing the durability of absorptive electrochromic coatings (ECCs) within sealed insulating glass units. Cross sections of typical electrochromic windows (ECWs) have three to five-layers of coatings that include one to three active layers sandwiched between two transparent conducting electrodes (TCEs, see Section 3). Examples of the cross-sectional arrangements can be found[2] in "Evaluation Criteria and Test Methods for Electrochromic Windows." (For a list of acronyms used in this Standard, see Appendix X1, Section X1.1).

1.2 This guide is applicable only for layered (one or more active coatings between the TCEs) absorptive ECCs on vision glass (superstrate and substrate) areas planned for use in IGUs for buildings, such as glass doors, windows, skylights, and exterior wall systems. The layers used for electrochromically changing the optical properties may be inorganic or organic materials between the superstrate and substrate.

1.3 The ECCs used in this guide will ultimately be exposed (Test Method E2141) to solar radiation and deployed to control the amount of 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 This guide is not applicable to other types of coatings on vision glass with other chromogenic coatings, for example, photochromic and thermochromic coatings.

1.5 This guide is not applicable to IGUs that will be constructed from superstrate or substrate materials other than glass.

1.6 The test methods referenced in this guide are laboratory test methods conducted under specified conditions.

1.7 The values stated in metric (SI) units are to be regarded as the standard.

1.8 There is no comparable International Standards Organization Standard.

1.9 *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 requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C168 Terminology Relating to Thermal Insulation

E2094 Practice for Evaluating the Service Life of Chromogenic Glazings

E2141 Test Methods for Assessing the Durability of Absorptive Electrochromic Coatings on Sealed Insulating Glass Units

E2188 Test Method for Insulating Glass Unit Performance

E2190 Specification for Insulating Glass Unit Performance and Evaluation

E2240 Test Method for Assessing the Current-Voltage Cycling Stability at 90°C (194°F) of Absorptive Electrochromic Coatings on Sealed Insulating Glass Units

E2241 Test Method for Assessing the Current-Voltage Cycling Stability at Room Temperature of Absorptive Electrochromic Coatings on Sealed Insulating Glass Units

E2355 Test Method for Measuring the Uniformity of an Absorptive Electrochromic Coating on a Glazing Surface

NOTE 1—the following draft standards will be added to this guide after they have been successfully balloted.

ERRR Test Method for Measuring the Stability to Thermal Shock of Sealed Insulating Glass Units with an Operating Absorptive Electrochromic Coating

EZZZ Test Method for Assessing the Stability in High Humidity and Cyclic Temperature Environments of an Absorptive Electrochromic Coating within Sealed Insulating Glass Units

2.2 *Canadian Standard:*

[1] This guide 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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[2] Czanderna, A. W., and Lampert, C. M., "Evaluation Criteria and Test Methods for Electrochromic Windows," *SERI/PR-255-3537*, Solar Energy Research Institute, Golden, CO, July 1990.

[3] 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.

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3. Terminology

3.1 *Definitions*—Refer to Terminology C168 for definitions of general terms.

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *bleached state*—a descriptor for an ECW when no ions reside in the electrochromic layer or after ions have been removed (or inserted, depending on the type of material) from the electrochromic layer(s) and if applicable, the maximum number of ions have been returned to the counterelectrode layer to restore the photopic optical specular transmittance in the bleached state (τ_b) from that of the photopic optical specular transmittance in the colored state (τ_c).

3.2.3 *chromogenic glazing*—is defined in Practice E2094, but also see Appendix X1, Section X1.3.

3.2.4 *colored state*—a descriptor for an ECW after ions have been inserted (or removed, depending on the type of material) into the electrochromic layer and, if applicable, removed from the counterelectrode layer to reduce the photopic optical specular transmittance (of wavelengths from 400 nm to 730 nm) from that in the bleached state (τ_b).

3.2.5 *control parameters for an electrochromic coating (ECC)*—the time dependent voltage or current profile that is supplied by the manufacturer of the ECW in which the voltage or current is applied to the ECC for achieving the desired cyclic changes from the bleached state to the colored state and back to the bleached state.

3.2.6 *durability*—the capability of maintaining the serviceability of a product, component, assembly, or construction over a specified time.

3.2.7 *electrochromic coating (ECC)*—the multilayered materials that include the electrochromic layers, other layers, and transparent conducting oxide layers required for altering the optical properties of the coating.

3.2.8 *electrochromic layer(s)*—the material(s) in an ECW that alter its optical properties in response to the insertion or removal of ions, for example, Li^+ or H^+.

3.2.9 *electrochromic window (ECW)*—a device with an ECC consisting of several layers of electrochromic and attendant materials, which are able to alter their optical properties in response to a change in an applied electric field. The changeable optical properties include transmittance, reflectance, and absorptance result in changes in the solar heat gain, visible transmittance, and U-factor of the window.

3.2.10 *fenestration*—the placement of openings in a building, that is, a window, door, or skylight and its associated interior or exterior elements such as shades or blinds.

3.2.11 *ion conducting layer*—the material in an ECC through which ions are transported between the electrochromic layer and the ion storage layer and electron transport is minimized.

3.2.12 *ion storage layer or counter electrode layer*—the material in an ECC that serves as a reservoir for ions that can be inserted into the electrochromic layer.

3.2.13 *performance parameters*—the photopic transmittance ratio (PTR), of at least 5:1 (PTR = τ_b/τ_c) between the bleached (for example, τ_b of 60 to 70 %) and colored (for example, τ_c of 12 to 14 %) states; coloring and bleaching times of a few minutes; switching with applied voltages from ~1 to 3 V; and open-circuit memory of a few hours, for example, contemporary ECWs typically have open circuit memories of 6 to 24 h.

3.2.14 *sealed insulating glass unit*—is defined in Test Method E2190 but see also Appendix X1, Section X1.3.

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

3.2.16 *service life (of a building component or material)*—the period of time after installation during which all properties exceed minimum acceptable values when routinely maintained.

3.3 For additional useful definitions for terminology used in this standard, see Appendix X1, Section X1.3.

4. Significance and Use

4.1 This guide provides a recommended systematic sequence for using the referenced test methods for evaluating the durability of ECWs as described in section 1.2.[2,4] (See Appendix X1, Section X1.4.)

4.2 This guide provides a summary of the durability issues addressed by each of the series of standards that are necessary for establishing a service lifetime of electrochromic coatings (ECCs) in insulating glass units (IGUs). When fully implemented in buildings in the U.S., ECCs in IGUs have the potential of saving 4 to 5 % of our current energy consumption for all uses—not just buildings. Many of the standards that have been and are being developed for the durability of sealed insulating glass units are clearly relevant and important parts of the long-term national mission of replacing currently used windows with IGUs with ECCs, and these are cited in the referenced standards. IGUs with ECCs will, of necessity, have to be able to pass the applicable standards listed in Appendix X1, Section X1.4, as well as an ASTM standard on wind loading for IGUs. Passing these will not be sufficient because the operating temperatures of ECCs in IGUs is likely to be 90°C (194°F) at the center-of glass, whereas the highest temperature used in Test Methods E773 or E2188 is 60°C (140°F). Listings of existing and proposed standards are given in Table 1 and in Appendix X1, Section X1.4.

5. Background

5.1 Observations and measurements have shown that some of the performance parameters of ECWs have a tendency to deteriorate over time. In selecting the materials, device design, and glazing for any application, the ability of the glazing to perform over time is an indication of that glazing's durability. The ability of the product to perform over time, at or better

[4] Czanderna, A. W., Benson, D. K., Jorgensen, G. J., Zhang, J-G., Tracy, C. E., and Deb, S. K., "Durability Issues and Service Lifetime Prediction of Electrochromic Windows for Buildings Applications," *NREL/TP-510-22702*, National Renewable Energy Laboratory, Golden, CO, May 1997; *Solar Energy Materials and Solar Cells*, 56, 1999, pp. 419-436.