
**Glass in building — Electrochromic
glazings — Accelerated ageing test and
requirements**

*Verre dans la construction — Vitrages électrochromes — Essai de
vieillesse accéléré et exigences*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 160, *Glass in building*, Subcommittee SC 1, *Product considerations*.

This second edition cancels and replaces the first edition (ISO 18543:2017), which has been technically revised.

The main changes compared to the previous edition are as follows:

- the document has been restructured;
- the acceptance criteria for the two classes has been revised;
- fast switching products have been taken into account;
- the concept of photopic transmittance ratio has been abandoned in favour of the one of 85 % of the dynamic range;
- other types of lamps have been allowed provided that they simulate correctly the solar irradiation.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Electrochromic glazings perform several 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 thermal comfort (controlling heat gain), energy efficiency performance, illumination, and glare control, and
- providing for architectural expression.

Therefore, it is important to understand the relative serviceability of these glazings.

This document is intended to provide a means for evaluating the durability of electrochromic glazings.

The test procedures covered in this document includes:

- a) rapid but realistic cycling between high and low light transmission states;
- b) environmental parameters that are typically used in weatherability tests such as simulated solar exposure and high temperature, which are realistic for the intended use of electrochromic glazings.

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Glass in building — Electrochromic glazings — Accelerated ageing test and requirements

1 Scope

This document specifies the accelerated ageing test and requirements for electrochromic glazings intended to either control direct or indirect solar transmission, or both. The electrochromic glazings can be assembled as insulating glass unit, laminated glass or combination of both.

The test method described in this document is only applicable to chromogenic glazings that can be switched between different transmission states using an electrical stimulus. This test method is not applicable to other chromogenic glazings such as photochromic and thermochromic glazings, which do not respond to electrical stimulus.

This test method is applicable to any electrochromic glazing fabricated for use in buildings such as in doors, windows, skylights, exterior wall systems and glazing exposed to solar radiation. The materials used for constructing the electrochromic glazing and for electrochromically changing its optical properties can be inorganic or organic materials.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 12543 (all parts), *Glass in building — Laminated glass and laminated safety glass*

ISO 20492 (all parts), *Glass in buildings — Insulating glass*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

chromogenic glazing

glazing that has the ability to reversibly change either its visible or solar transmission, or both, in response to an external stimulus such as electrical voltage or current, solar radiation or temperature

Note 1 to entry: Active components can be films, coatings, glasses or a combination of them.

3.2

electrochromic glazing

chromogenic glazing (3.1) in which an applied voltage or current is used to reversibly modify either visible or solar transmission characteristics, or both

Note 1 to entry: Active components are usually films, coatings or a combination of them.

3.3

highest transmission state

highest visible light transmittance achieved by the *electrochromic glazing* (3.2)

3.4

lowest transmission state

lowest visible light transmittance achieved by the *electrochromic glazing* (3.2)

3.5

switching time

time taken for *electrochromic glazing* (3.2) to transition to or from the highest and *lowest transmission states* (3.4)

Note 1 to entry: The time to go from the *lowest transmission state* (3.4) to the *highest transmission state* (3.3) can be different from the time needed for the reverse transition.

3.6

switching cycle

transition in light transmittance between two defined light transmittance values starting and ending back at the same point

3.7

lateral uniformity

degree of variation in the amount of irradiance in the x and y directions in the test plane used for exposing *electrochromic glazing* (3.2)

4 Symbols

$V(\lambda)$	spectral luminous efficiency for photopic vision defining the standard observer for photometry (see ISO 23539:2005 ^[1])
τ	visible light transmittance
τ_H	visible light transmittance in the highest transmission state
τ_L	visible light transmittance in the lowest transmission state
t_L	switching time to reduce the transmittance of the glazing
t_H	switching time to increase the transmittance of the glazing
t_{cycle}	total cycle time
Subscripts:	
i	initial stage, prior to accelerated ageing
f	final stage, after accelerated ageing
85	related to 85 % of the difference between the highest transmission state and the lowest transmission state

5 Principle of the test

This test method compares light transmittance before and after artificial ageing.

The electrochromic glazings shall be exposed to simulated solar radiation during 5 000 h in a temperature-controlled chamber at specimen temperatures as defined in Table 1. During this exposure, the sample shall be switched to at least 85 % of its dynamic range, i.e. the difference between the

highest transmission state and the lowest transmission state, with the shortest possible switching cycle, see [Formula \(1\)](#).

$$\tau_{L,85} = \tau_H - 0,85 \times (\tau_H - \tau_L) \quad (1)$$

In case the switching time is such that more than 50 000 cycles are performed in 5 000 h, an adapted switching cycle may be used, see [8.3](#).

Table 1 — Test classification summary

Conditions of testing	Class 1	Class 2
Specimen temperature	$(85 \pm 7) ^\circ\text{C}$	$(65 \pm 7) ^\circ\text{C}$
Number of switching cycles	Maximum possible with a maximum of 50 000 cycles	Maximum possible with a maximum of 50 000 cycles
Number of hours of exposure	5 000 h	5 000 h
NOTE Class 2 is for electrochromic glass that are not able to switch when above 65 °C.		

The procedure consists of the following steps:

- step 1: initial characterization of the test sample and determination of the cycling conditions:
 - light transmittance at highest ($\tau_{H,i}$) and at lowest ($\tau_{L,i}$) transmission states, at room temperature;
 - switching time from highest to lowest transmission states ($t_{L,i}$) and reverse ($t_{H,i}$), at room temperature;
 - switching time of 85 % of the dynamic range in both directions, at the selected test temperature;
 - calculation of the total switching cycle to be used in step 2;
- step 2: cycling and radiation exposure of the test sample in a chamber maintained at the selected test temperature;
- step 3: final characterization of the test sample:
 - light transmittance at highest ($\tau_{H,f}$) and at lowest ($\tau_{L,f}$) transmission states, at room temperature;
 - switching time from highest to lowest transmission states ($t_{L,f}$) and reverse ($t_{H,f}$), at room temperature.

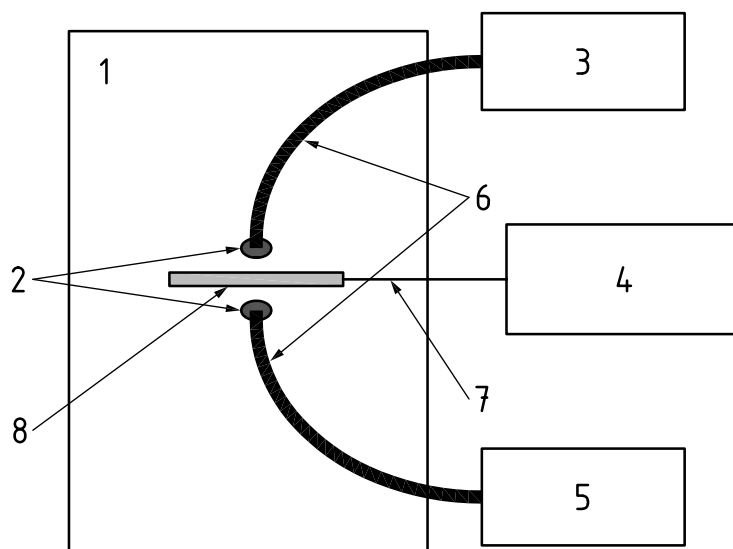
When compared to the initial characteristics, the final characteristics shall meet the requirements given in [Clause 9](#).

6 Description of the test equipment

6.1 Oven (for steps 1 and 3)

An oven shall be used to carry out optical measurements and to define the switching cycle of the electrochromic glazings at the requested temperatures. It shall be large enough for the largest electrochromic glazing to be tested and shall be able to reach the electrochromic glazing testing temperature. The oven shall also be designed to permit using the equipment described in [6.2](#) and [6.3](#) for optical measurements while the electrochromic glazing shall be maintained at the temperature chosen for step 2. Thermocouples shall be used to measure specimen temperature in the oven.

A schematic of an oven is given in [Figure 1](#).

**Key**

1	convection oven	5	spectrometer
2	lens	6	spectrometer fibre optic cables
3	spectrometer lamp source	7	thermocouple and electrical leads
4	electrochromic switching control system	8	electrochromic sample

Figure 1 — Schematic of an oven used to determine the switching cycle for use in the test chamber — Plan view

6.2 Spectrometer (for steps 1 and 3)

A spectrometer shall be used for obtaining and storing data from the optical characterization in the range 380 nm to 780 nm of the specimens in the highest and lowest transmission states.

The lamp source can be a tungsten lamp or other lamp source that provides illumination from 380 nm to 780 nm.

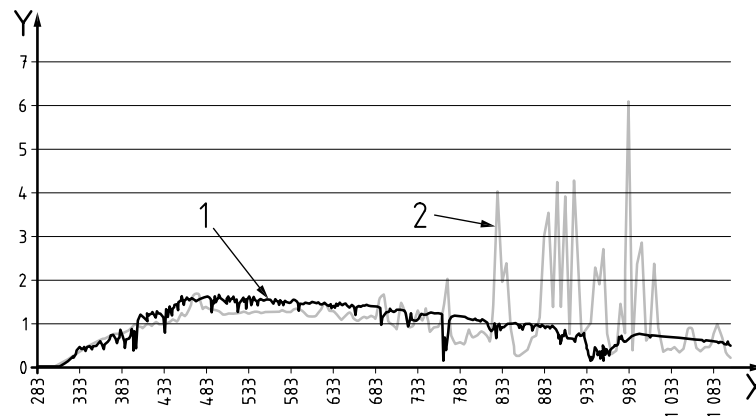
Fibre optic cables extend from the lamp source into the electrochromic glazing specimen holder and from the electrochromic glazing specimen holder to the spectrometer. One optical fibre guides the incident light from the lamp source to one side of the specimen; another optical fibre guides the transmitted light to the spectrometer attached to a computer. The fibres shall be optically coupled by properly aligned collimating lens assemblies attached to both the illuminating and the collecting fibres.

6.3 Switching control system (for steps 1 and 3)

The switching to and from highest and lowest transmission states during spectrophotometer transmittance measurements can be done by means of a computer-controlled multichannel potentiostat or by manufacturer-supplied control system.

6.4 Test chamber (for step 2)

The test chamber shall be temperature-controlled and shall contain lamps that have been filtered appropriately in order to simulate the spectral power distribution of solar radiation over the ultraviolet, visible and near infrared wavelength regions. As an example, [Figure 2](#) shows the spectral irradiance of an appropriately filtered xenon arc source compared to the global Air Mass 1,5 spectrum.



Key

X wavelength of the radiation in nm

Y irradiance in $\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$

1 spectral power distribution of Air Mass 1,5 solar irradiation

2 irradiance of an appropriately filtered xenon arc lamp which is used to simulate the spectral power distribution of solar radiation

Figure 2 — Irradiance of an appropriately filtered xenon arc lamp compared to the spectral power distribution of air mass 1,5 solar irradiation

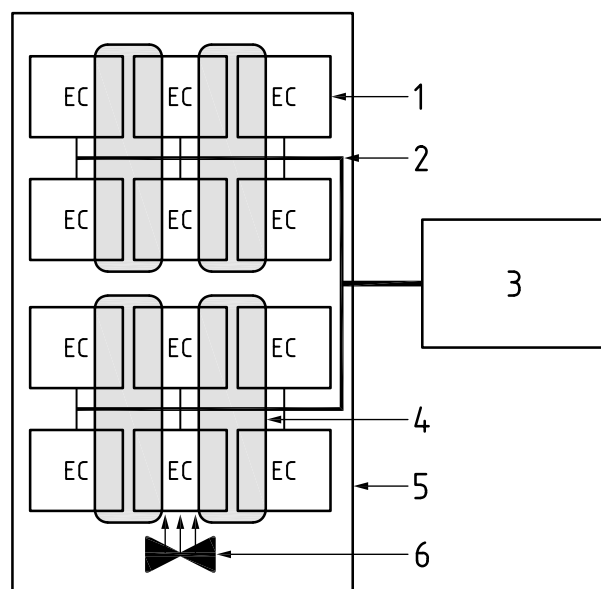
NOTE 1 At longer wavelengths, the xenon arc emission is at variance with the air mass 1,5 solar spectrum because the intensities relative to those in the ultraviolet/visible region are higher than in solar radiation. However, this part of the spectrum does not cause photolytic-induced degradation.

To prevent unintended degradations, peaks occurring in the range 300 nm to 780 nm should be avoided.

Figure 3 shows an example top-view of the essential features of the test chamber, including the layout of the electrochromic glazings on a test plane, the location of the lamps above the test plane and the necessary connecting cables from the electrochromic glazings to the computer-controlled cycling and data acquisition system. Chamber dimension shall be large enough to accommodate all specimens.

The intensity of the irradiance at the specimens shall be adjustable to obtain the desired light intensity and lateral uniformity within the guidelines of this document (see 6.4).

NOTE 2 This can be achieved by adjusting the distance between the specimens and the lamps.



Key

- | | | | |
|---|---|---|-----------------------------------|
| 1 | electrochromic glazings | 4 | lamp sources |
| 2 | electrical leads and thermocouples | 5 | chamber enclosure |
| 3 | electrochromic cycling unit and data acquisition system | 6 | forced-air heating/cooling system |

Figure 3 — Example plan view of the essential features of the test chamber

Temperature control within the test chamber shall be provided. Conditions inside the closed space shall be controlled for air temperatures from 20 °C to the maximum temperature of the test +10 °C. The relative humidity within the test chamber shall not exceed 60 % to avoid condensation.

Simulated solar irradiance shall be provided by the appropriate number of spectrally filtered and cooled 6 500 W lamps, housed within a reflector system in the ceiling of the test chamber. The lamps shall be suitably filtered to provide a match of an Air Mass 1,5 solar spectrum from 300 nm to 900 nm (see Figure 2). The water-cooled lamps shall be surrounded by a near infrared-absorbing filter, which reduces the heat load.

The chamber shall be designed to achieve a radiation intensity over the spectral range of 300 nm to 3 000 nm of $(1\,000 \pm 40) \text{ W/m}^2$ at the specimens. The lateral uniformity of irradiance across the test plane shall be no more than $\pm 8 \%$.

NOTE 3 For the determination of the total irradiance level, pyranometers according to the specifications in ISO 9060^[2] and the sensitivity to the spectral range from 300 nm to 3 000 nm can be used.

The electrochromic glazing specimens shall be located on the test plane beneath the lamps. The test chamber 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 electrochromic glazings.

NOTE 4 A suitable lamp source and filter combination is a 3 500 W/6 500 W xenon burner (part number 20-6500-00) with an inner quartz filter (part number 20650600 and an outer filter of CIRA/Sodalime (Part Number 2065200) from Atlas^{®1)}.

Thermocouples shall be used to measure specimen and chamber temperatures in the test chamber.

1) CIRA and Sodalime are trade names of a product supplied by Atlas. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

6.5 Electrochromic cycling unit (for step 2)

The electrochromic cycling unit shall impose either voltage or current cycles, or both to alternately and repeatedly change the transmittance of the electrochromic glazings while in the test chamber.

NOTE The functions of the electrochromic cycling unit and of the switching control system (6.3) can be performed by the same equipment and can be the manufacturer of the supplied control system.

6.6 Image capturing equipment (optional)

A digital camera and video camera can be used for visual documentation.

7 Test specimen

7.1 Description of the test specimen

The test specimen design and construction shall be representative of the product design.

The minimum specimen size shall be $(250 \pm 5) \text{ mm} \times (250 \pm 5) \text{ mm}$.

Five samples shall be provided and four shall be tested together. The fifth sample shall be kept as a non-tested reference sample. See [Clause 11](#) for reporting requirements.

For samples in an insulating glass unit, capillary tubes may be used to provide edge pressure relief for the insulating glass units at the testing temperatures.

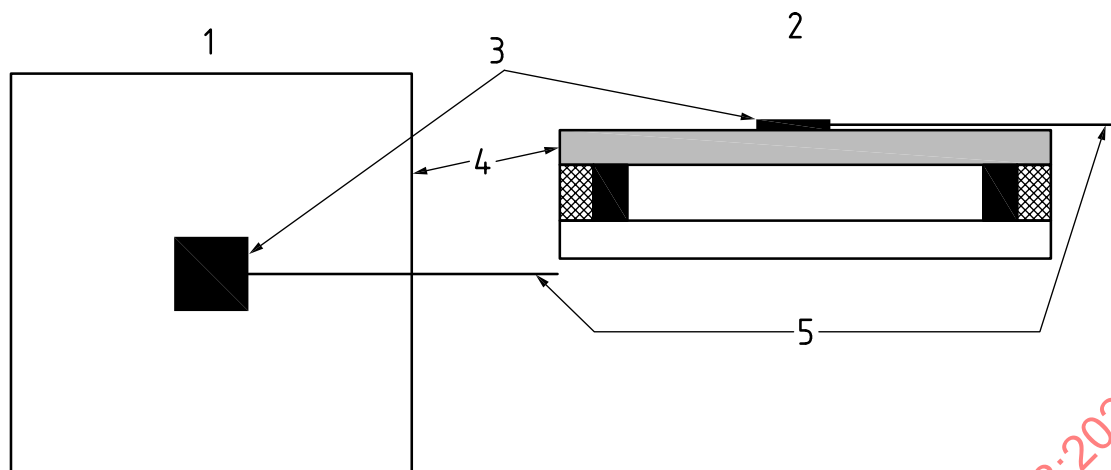
The edge seals of the insulating electrochromic glass unit or the edges or edge seals of laminated electrochromic glazings, where relevant, may be protected from radiation exposure by an appropriate material such as aluminium tape or foil up to 16 mm from the edge of the glass, provided that in the actual application the edges or edge seals are also protected from radiation.

7.2 Preparation of the test specimen

Before testing, the electrochromic glazings shall be inspected visually. Photographs of any obvious defects or aberrations of the electrochromic specimens shall be taken in the highest transmission state and lowest transmission state, and observations shall be recorded.

Thermocouples (0,13 mm diameter) shall be taped to the centre surface of the glass component with electrochromic properties with 8 mm × 8 mm pieces of aluminium tape (see [Figure 4](#)). If this component is the one furthest away from the radiation source, special care shall be taken to ensure thermocouple is appropriately shielded from the light source. Other appropriate surface temperature probe or device can also be used.

[Figure 4](#) shows an example with insulating glass unit, but the same principle applies for monolithic or laminated electrochromic glazing.



Key

- | | | | |
|---|--|---|---|
| 1 | plan view of the electrochromic glazing sample | 4 | glass component containing the electrochromic |
| 2 | side view of the electrochromic glazing sample | 5 | thermocouple wire |
| 3 | aluminium tape | | |

NOTE [Figure 4](#) is not to scale.

Figure 4 — Schematic placement of the thermocouple on an electrochromic glazing sample

The thermocouple leads may also be taped away from the centre of the specimen using up to two additional 8 mm × 8 mm pieces of aluminium tape to provide strain relief to prevent the thermocouple from being pulled off the glass surface.

8 Initial optical characterization of the test sample (step 1)

8.1 General

The electrochromic glazing specimens shall be characterized at room temperature and at the selected test temperature, using the same equipment for both series of measurements.

8.2 Initial optical characterization of the electrochromic glazings at room temperature

The convection oven described in [6.1](#) shall be allowed to equilibrate with room temperature for measurements at approximately 22 °C. The temperature of the electrochromic glazing shall be monitored by a thermocouple as described in [7.2](#).

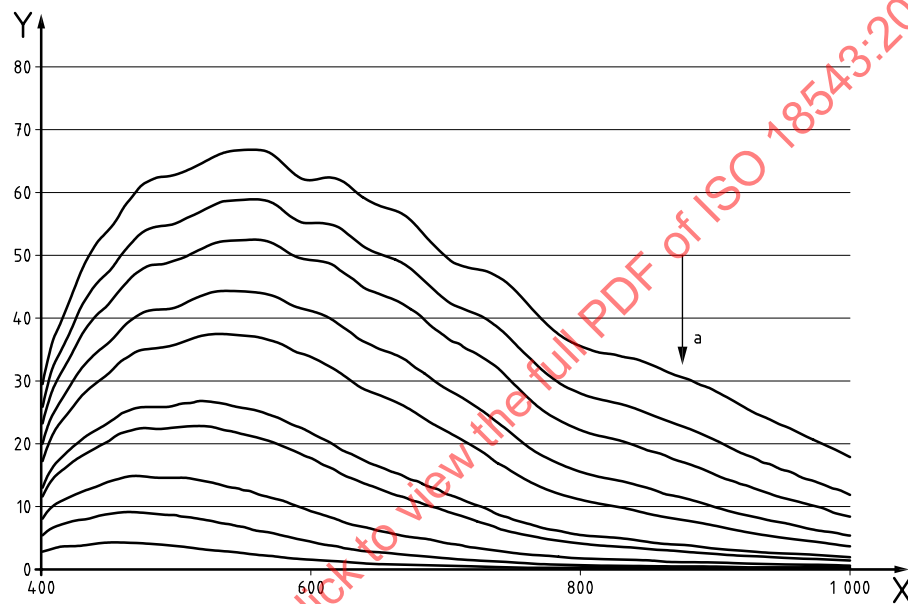
The highest ($\tau_{H,i}$) and lowest ($\tau_{L,i}$) transmittance of the electrochromic glazings shall be determined as follows:

- Reference spectra for 100 % and 0 % transmittance shall be taken before each measurement using at least 5 nm increments.
- The light transmittance of the specimen shall be measured at one point near the centre of glass, over a spectral range covering at least 380 nm to 780 nm in successive time intervals during the process of cycling between highest and lowest transmission states. Ensure that the measurement is away from the area that is covered by the thermocouple attachment or shielding.

NOTE 1 A time interval of a fraction of the total electrochromic cycle time for taking each spectrum is adequate to record the optical properties of each electrochromic glazing.

- c) The light transmittance of the glazings shall be obtained by integrating the spectra in the wavelength range of 380 nm to 780 nm using the spectral luminous efficiency for photopic vision $V(\lambda)$ as the weighting factor^[3]. The procedure for integration is found in ISO 9050.
- d) The samples shall reach their lowest transmission and highest transmission states during these measurements. The control protocols applied for switching the electrochromic glazing between transmission states and holding at lowest and highest transmission states shall be as specified by the electrochromic glazing manufacturer. 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 % of τ per minute (whichever yields the shortest time).

NOTE 2 Typical transmittance spectra recorded during a full switching cycle are shown in Figure 5, in which the optical spectra of the glazings are plotted as a function of wavelength.



Key

- X wavelength, in nm
 Y light transmittance, in %
 a Direction of reducing transmission.

Figure 5 — Typical transmittance spectra recorded during a full switching cycle in which the optical spectra of the glazings are plotted as a function of wavelength

8.3 Light transmittance measurement as a function of time at the selected test temperature

Each electrochromic glazing shall be heated in a convection oven at the selected test temperature.

The sample shall be cycled through 85 % of its dynamic range (where dynamic range is $\tau_{H,i}$ to $\tau_{L,i}$). That is, the sample shall be cycled starting from $\tau_{H,i}$ through to a transmittance of:

$$\tau_{L,85} = \tau_{H,i} - 0,85 (\tau_{H,i} - \tau_{L,i})$$

The switching times for obtaining a light transmittance of $\tau_{L,85}$, starting from and returning to the highest transmission state shall be determined by measuring the transmittance as a function of time using the spectrometer as described in 8.2.

- $t_{L,85}$, the switching time to reduce the transmittance of the glazing from $\tau_{H,i}$ to $\tau_{L,85}$ is the highest of the values measured on the five samples.

- $t_{H,85}$, the switching time to increase the transmittance of the glazing from $\tau_{L,85}$ to $\tau_{H,i}$ is the highest of the values measured on the five samples.

The value of $t_{L,85}$ and $t_{H,85}$ can be different.

- If the electrochromic cycling unit can replicate this difference, the duty cycle t_{cycle} can be taken as the sum of $t_{L,85}$ and $t_{H,85}$.
- If it is not the case, t_{cycle} shall be two times the maximum of $t_{L,85}$ and $t_{H,85}$ and the time to increase or decrease the transmission will be equal.

For electrochromic glazing that can achieve more than 50 000 cycles in 5 000 h, the time spent in both highest and lowest transmission states shall be equal and the cycling shall occur evenly and continuously throughout the 5 000 h. In that case, both $t_{L,85}$ and $t_{H,85}$ will be equal to 6 min.

9 Cycling and radiation exposure of the test sample (step 2)

9.1 Mounting of the electrochromic glazings in the test chamber

The electrochromic glazing specimens shall be placed onto the test plane. The surface of the glazing unit facing the light source shall be the surface facing the exterior when the glazing is installed in the building. Suitable electrical connections shall be made from the electrochromic cycling unit and data acquisition system to the wires of each electrochromic glazing.

NOTE The test plane can either be horizontal or vertical. The critical requirement is that the illumination and uniformity meet the requirements of this document.

Before cycling at the test temperature, the electrochromic glazing specimens shall be submitted to switching cycle in the test chamber 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.

9.2 Setting up the test chamber

The chamber temperature shall be adjusted to obtain the desired surface temperature of the electrochromic glazing in the lowest transmission state. The temperature of the electrochromic glazing is the temperature measured at the centre of the surface of the glass component with the electrochromic properties when in the lowest transmission state, irrespective of the orientation of the sample relative to the radiation source.

EXAMPLE With a chamber air temperature of 60 °C, the centre of electrochromic glazing surface in the lowest transmission state reaches a steady-state temperature of about 85 °C depending on the specimen size, lowest transmission state reached during voltage cycling, location of the glazing in the test plane, and the electrochromic glazing construction.

NOTE The average electrochromic glazing temperature will be less because of a typical decrease of about 5 °C when the electrochromic glazing is in the high transmission state.

9.3 Cycling the electrochromic glazings in the test chamber at elevated temperature and under simulated solar exposure

With the specimen in the highest transmission state, the xenon arc lamps shall be activated. When the electrochromic specimen approaches the desired testing temperature, the voltage cycling of the electrochromic glazing shall be started, using the cycle defined in 8.3. Adjustments shall be made to the chamber air temperature to account for the inevitable rise in temperature of the specimens resulting from absorption in the lowest transmission state.

Specimen temperatures and cycling data shall be recorded using the data acquisition system and periodic monitoring shall be done to ensure proper operation of the test chamber and associated experimental apparatus.