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Road vehicles — Safety glazing materials — Test methods for electro-switchable glazing

Véhicules routiers — Vitrages de sécurité — Méthodes d'essai pour vitrages électro-commutables

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Contents

Foreword

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 35, *Lighting and visibility*.

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Introduction

This document outlines the test method to evaluate properties of electro-switchable glazing during the switching period and under stable states of luminous transmittance.

There are various principles of electro-switchable glazing that can be used to produce safety glazing for road vehicles. See Annex A for a description of these principles. The luminous transmittance states that the electro-switchable glazing can be switched to and the time it takes to switch between these states are major concerns for consumers and the market. The lifetime of these different electro-switchable glazing is influenced by humidity, temperature and radiation. The various principles differ in terms of performance, but they can be improved applying appropriate voltage or current or applying more complex circuits.

Road vehicles — Safety glazing materials — Test methods for electro-switchable glazing

1 Scope

This document provides the test methods for regular luminous transmittance, switching time, haze, insulation resistance, humidity resistance, low temperature resistance, colour uniformity, switching cycles and radiation durability for electro-switchable glazing used on road vehicles.

This document applies to switchable glazing in response to applied voltage or current.

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 3538:1997, *Road vehicles — Safety glazing materials — Test methods for optical properties*

ISO 4892-2:2013, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 6469-3:2021, *Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety*

ISO/CIE 11664-6, *Colorimetry — Part 6: CIEDE2000 colour-difference formula*

ISO 13837:2021, *Road vehicles — Safety glazing materials — Method for the determination of solar transmittance*

ISO 14782:2021, *Plastics — Determination of haze for transparent materials*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
electro-switchable glazing
glazing comprised of one or more panes of material whose transmittance properties can be altered in response to an applied voltage or current

3.2
highest transmittance state
stable state as glazing switched to highest *regular luminous transmittance* (3.4) under specific conditions

Note 1 to entry: This is also referred to as the clear state or bleached state.

3.3
lowest transmittance state
stable state as glazing switched to lowest *regular luminous transmittance* (3.4) under specific conditions

Note 1 to entry: This is also referred to as the tinted state, dark state, or coloured state.

3.4
regular luminous transmittance
light transmittance from 380 nm to 780 nm measured perpendicularly to the glazing without considering diffused light

3.5
tinting time
period of *electro-switchable glazing* (3.1) switching from *highest transmittance state* (3.2) to *lowest transmittance state* (3.3)

3.6
switching cycle
electro-switchable glazing (3.1) switched from lowest/*highest transmittance state* (3.2) to highest/*lowest transmittance state* (3.3) and back to lowest/highest transmittance state with each process finished once

4 Test methods

4.1 Ambient conditions

Unless otherwise specified, the tests shall be conducted under the following conditions:

a) ambient temperature: (23 ± 5) °C;

b) atmospheric pressure: $8{,}06 \times 10^4$ Pa to $1{,}06 \times 10^5$ Pa (860 mbar to 1 060 mbar);

c) relative humidity:(60 ± 20) %.

4.2 Regular luminous transmittance

4.2.1 Purpose of test

The purpose of this test is to determine regular luminous transmittance of electro-switchable glazing in different transmittance states.

4.2.2 Apparatus

4.2.2.1 Control system, which shall be provided by the manufacturers for switching the device under test (DUT) to a different state. The control system and parameters shall be pre-set to make the specimen switch same as finished product.

4.2.2.2 Regular luminous transmittance measuring system, which is described in ISO 3538:1997, 5.1.2.

4.2.3 Measuring state

The regular luminous transmittance of any state that the glazing can be switched to, may be measured.

4.2.4 Device under test

One specimen or finished product may be used as the DUT.

4.2.5 Procedure

Before measuring regular luminous transmittance, switch the DUT for at least five cycles.

Then, switch the whole DUT to required state and keep it in that state for about 5 min. Measure regular luminous transmittance of the DUT according to ISO 3538:1997, 5.1.3.

4.2.6 Expression of results

Record the regular luminous transmittance and the corresponding state of DUT. The value shall be rounded to 0,1 %.

4.3 Switching time

4.3.1 Purpose of test

The purpose of this test is to determine the switching time between different states of electro-switchable glazing.

4.3.2 Apparatus

4.3.2.1 Spectrophotometer, which has the time drive function and whose time interval can be switched to 1 s or shorter. An equivalent photometer can be used, but the light output shall be filtered to 550 nm ± 5 nm or other required wavelengths, and the measurements shall be recorded per second or shorter.

4.3.2.2 Control system, which shall be provided by the manufacturers for switching the DUT to a different state. The control system and parameters shall be pre-set to make the specimen switch same as finished product.

4.3.3 Device under test

One specimen or finished product may be used as the DUT. When a specimen is used, the shape of the specimen shall be able to cover a square whose sides are 290 mm in length.

4.3.4 Procedure

4.3.4.1 Use the time drive function of the spectrophotometer to measure light transmittance at 550 nm ± 5 nm or other required wavelengths when measuring switching time.

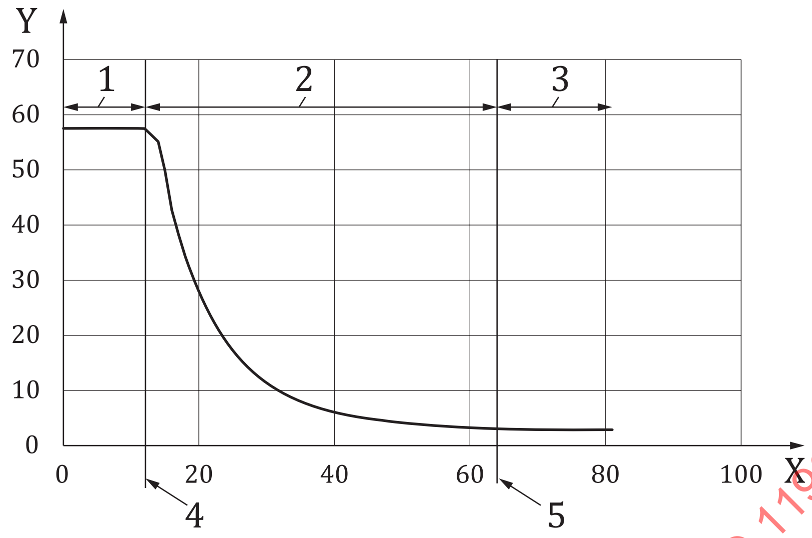
4.3.4.2 Keep the whole DUT in the bleached state for at least 5 min. Then, switch the DUT to the tinted state. Record light transmittance at 550 nm ± 5 nm during the whole switching period. When the entire DUT reaches the tinted state, record for at least 30 s if the switching time is more than 10 s, or record for at least 10 s if the switching time is less than 10 s. See Figure 1 for an example of electro-switchable glazing with a tinting time of more than 10 s. See Figure 2 for an example of electro-switchable glazing with a tinting time of less than 10 s.

4.3.4.3 Keep the whole DUT at the tinted state for at least 5 min. Then, switch the DUT from the tinted state to the bleached state, record the data same as 4.3.4.2.

4.3.4.4 The moment the tinted or bleached state is reached shall be defined between the customer and manufacturer. The following are two example methods for defining the moment the tinted or bleached state is reached:

a) for a switching time of more than 10 s: when variation in light transmittance at 550 nm ± 5 nm in the next 10 s is smaller than 0,1 %;

b) for a switching time of less than 10 s: when variation in light transmittance at 550 nm ± 5 nm in the next 1 s is smaller than 0,1 %.



Key

X time [s]

Y 550 nm light transmittance [%]

1 bleached state

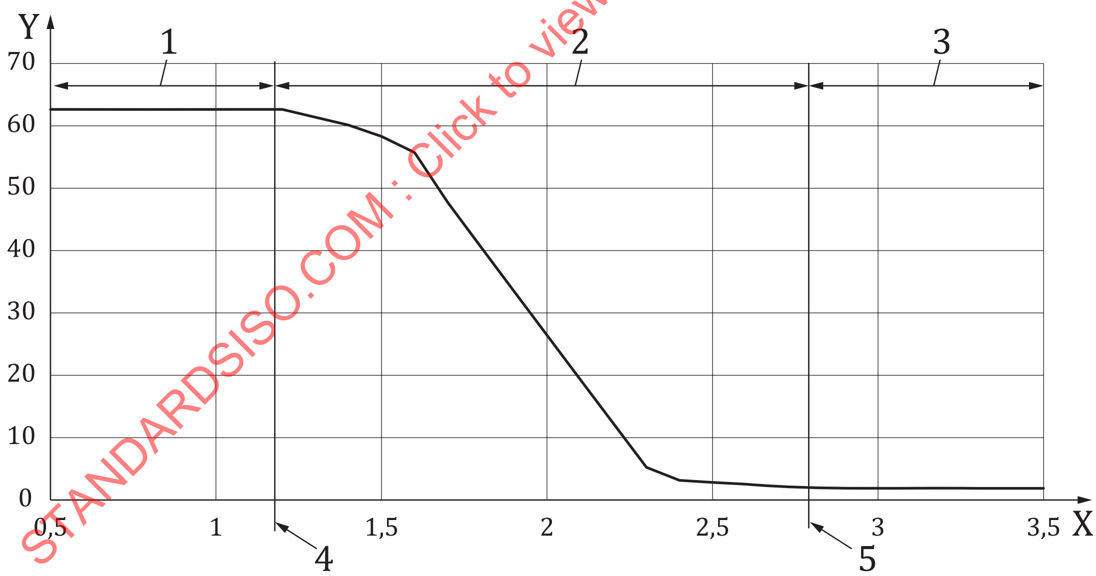
2 tinting time

3 tinted state

4 switching start moment

5 switching stop moment

Figure 1 — Example for tinting time more than 10 s



Key

X time [s]

Y 550 nm light transmittance [%]

1 bleached state

2 tinting time

3 tinted state

4 switching start moment

5 switching stop moment

Figure 2 — Example for tinting time less than 10 s

4.3.5 Expression of results

Record the time between the moment the switching started and the moment the tinted or bleached state is reached.

The value shall be rounded to 1 s when the switching time is more than 10 s and rounded to 0,1 s when the switching time is less than 10 s.

4.4 Haze

4.4.1 Purpose of test

The purpose of this test is to determine the haze value of electro-switchable glazing in different transmittance states.

4.4.2 Apparatus

4.4.2.1 Control system, which shall be provided by the manufacturers for switching the device under test (DUT) to a different state. The control system and parameters shall be pre-set to make the specimen switch same as finished product.

4.4.2.2 Haze meter, as described in ISO 14782:2021, Clause 5.

4.4.3 Measuring state

The haze of any state that the glazing can be switched to, may be measured. The parameters for switching glazing to any transmittance state shall be provided by manufacturer.

4.4.4 Device under test

One specimen or finished product may be used as the DUT. When a specimen is used, the shape of the specimen shall be able to cover a square whose sides are 290 mm in length.

4.4.5 Procedure

Before measuring haze, switch the DUT for at least five cycles.

Then, switch the whole DUT to required state and keep the DUT at that state for about 5 min. Measure the haze of the DUT according to ISO 14782:2021, Clause 8.

4.4.6 Expression of results

Record haze and the corresponding state of the DUT. The value shall be rounded to 0,1 %.

4.5 Insulation resistance

4.5.1 Purpose of test

The purpose of this test is to determine whether electro-switchable glazing can withstand the effects of high voltage. This test only applies to a product that connects to the circuit conforming to Class B and the corresponding requirements defined in ISO 6469-3:2021, Clause 4.

4.5.2 Apparatus

Withstanding voltage tester, with at least output voltage 500 V.

4.5.3 Device under test

One specimen or finished product may be used as the DUT.

4.5.4 Procedure

4.5.4.1 Dry weather

Place the DUT at ambient temperature, i.e. (20 ± 5) °C, and at a relative humidity of (60 ± 10) % for 24 h.

Use tin foil to cover the edge of the DUT. Use a finger, apply a force of at least 5 N to smooth the tin foil to ensure it has close contact with the edge of the DUT.

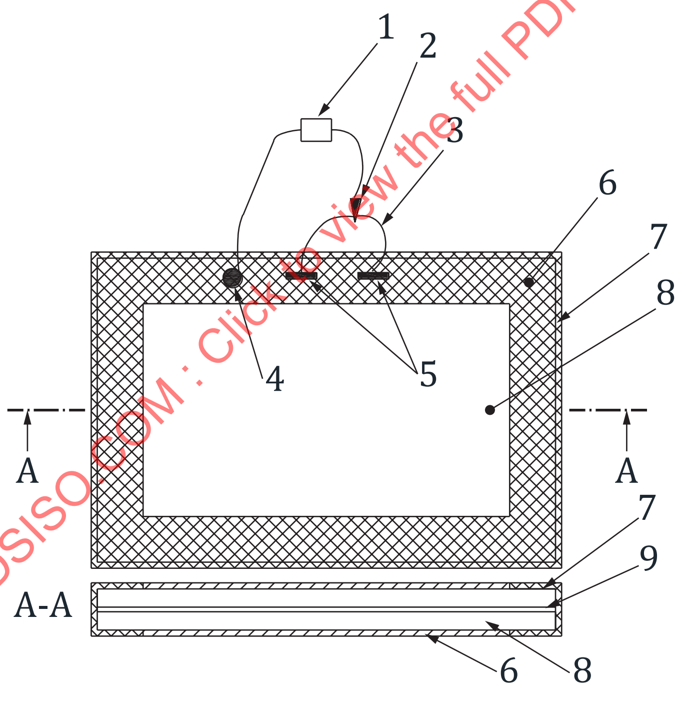
Short circuit the two electrodes of the DUT and then connect these two electrodes to the positive electrode of the voltage tester.

Touch the tin foil to the negative electrode of the voltage tester.

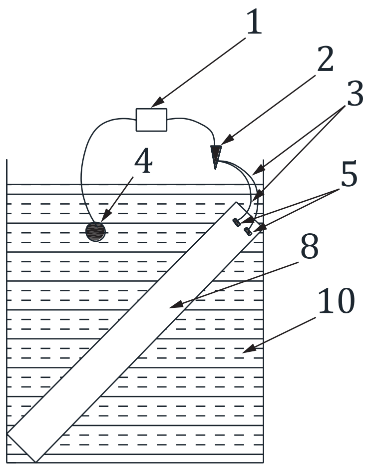
Adjust the voltage tester to 500 V. Keep this voltage for 2 min and measure the insulation resistance.

The circuit loop of this test is shown in Figure 3 a).

After measuring the insulation resistance, touch the electrodes of the DUT to the tin foil on the glazing edge to discharge the DUT.



a) Insulation resistance test under dry weather



b) Insulation resistance test under damp weather

Key

1 withstanding voltage tester
2 positive electrode
3 conducting wires
4 negative electrode
5 two electrodes of DUT
A-A section view
6 tin foil
7 edge of glazing
8 DUT
9 interlayer of the DUT
10 water

Figure 3 — Insulation resistance test

4.5.4.2 Damp weather

Put the DUT in water with a resistance lower than 35 Ω·m and at (22 ± 3) °C. Make sure the whole DUT is immersed in the water, but that the metal part of the conducting wire is not in direct contact with the water.

Short circuit the two electrodes of the DUT and then connect them to the positive electrode of the voltage tester.

Put the negative electrode of the voltage tester in the water.

Adjust the voltage tester to 500 V. Keep this voltage for 2 min, then measure the insulation resistance.

The circuit loop of this test is shown on Figure 3 b).

After measuring the insulation resistance, connect the electrodes of DUT to the water to discharge the DUT.

4.5.5 Expression of results

Record the insulation resistance of the DUT.

4.6 Humidity resistance

4.6.1 Purpose of test

The purpose of this test is to determine whether electro-switchable glazing can withstand the effects of high humidity for two weeks.

4.6.2 Apparatus

4.6.2.1 High humidity chamber, which can maintain temperature at 50 °C ± 2 °C and relative humidity at (95 ± 4) % for at least two weeks. Precautions shall be taken to prevent condensation dripping from the walls and ceiling of the test chamber on the test specimens.

4.6.2.2 Regular luminous transmittance measuring system, which is described in ISO 3538:1997, 5.1.2.

4.6.2.3 Control system, which shall be provided by the manufacturers for switching the DUT to a different state. The control system and parameters shall be pre-set to make the specimen switch same as finished product. The control system shall be able to cyclically switch the DUT from one transmittance state to another.

4.6.3 Device under test

One specimen or finished product may be used as the DUT. When a specimen is used, the effective switching area of the specimen shall be able to cover a square whose sides are 290 mm in length.

4.6.4 Procedure

Measure the initial regular luminous transmittance of the DUT (at least the highest transmittance state and lowest transmittance state) in accordance with 4.2.

Place the DUT into the high humidity chamber.

Connect the DUT to the switching control system.

Maintain the temperature at 50 °C ± 2 °C and relative humidity at (95 ± 4) % in the chamber for two weeks. Meanwhile, use the switching control system to cyclically switch the DUT between the lowest and the highest transmittance states. If the DUT's switching time of half cycle is less than 30 s, after the DUT is switched to the lowest/highest transmittance state, adjust the switching control system to keep the DUT at the lowest/highest state to make the half cycle last at least 30 s. The half cycle is the time it takes for the DUT to switch from the lowest transmittance state to the highest, or from the highest transmittance state to the lowest.

If several DUTs are tested at the same time, adequate spacing shall be provided between the DUTs.

After two weeks, take the DUT out of the chamber. Place the DUT at ambient temperature for at least 4 h.

Measure the regular luminous transmittance at the initial states.

Switch the DUT for at least five cycles to check any detectable defects.

4.6.5 Expression of results

Record any visually detectable defects.

Calculate the difference between the measurements of regular luminous transmittance at the same states of the DUT before and after the period of high humidity.

4.7 Low temperature resistance

4.7.1 Purpose of test

The purpose of this test is to determine whether electro-switchable glazing can withstand low temperatures for at least 4h.

4.7.2 Apparatus

4.7.2.1 Low temperature chamber, which can reach −20 °C with stability ±2 °C.

4.7.2.2 Regular luminous transmittance measuring system, which is described in ISO 3538:1997, 5.1.2.

4.7.2.3 Control system, which shall be provided by the manufacturers for switching the DUT to a different state. The control system and parameters shall be pre-set to make the specimen switch same as finished product.

4.7.3 Device under test

One specimen or finished product may be used as the DUT. When a specimen is used, the effective switching area of the specimen shall be able to cover a square whose sides are 290 mm in length.

4.7.4 Procedure

Measure the initial regular luminous transmittance of the DUT (at least the highest transmittance state and lowest transmittance state) in accordance with 4.2.

Place the DUT into the low temperature chamber and cool the DUT to (-20 ± 2) °C. Keep the temperature stable for at least 24 h.

Take the DUT out of the chamber. Place the DUT at ambient temperature for at least 4 h.

Measure the regular luminous transmittance at the same states as the initial measurements.

Switch the tested DUT for at least five cycles to check any detectable defects.

4.7.5 Expression of results

Record any visually detectable defects.

Calculate the difference between the measurements of regular luminous transmittance at the same states of the DUT before and after cooling.

4.8 Colour uniformity

4.8.1 Purpose of test

The purpose of this test is to determine whether the colour of electro-switchable glazing is uniform at different states.

4.8.2 Apparatus

4.8.2.1 Spectrophotometer or colorimeter, the sample space of the spectrophotometer shall be large enough to measure any point of a 300 mm square glazing. The colorimeter shall be portable.

4.8.2.2 Control system, which shall be provided by the manufacturers for switching the DUT to a different state. The control system and parameters shall be pre-set to make the specimen switch same as finished product. Five control systems to control five DUTs individually or one control system to control all five DUTs shall be provided.

4.8.3 Device under test

Five specimens or finished products may be used as DUTs. When a specimen is used, the effective switching area of the specimen shall be able to cover a square whose sides are 290 mm in length.

4.8.4 Measuring state

The colour uniformity of at least the highest and lowest transmittance states shall be measured.

4.8.5 Procedure

4.8.5.1 Reflectance colour difference for single panel

Switch the DUTs to required state and keep for at least 5 min.

Select one panel randomly from the five DUTs. Measure the reflectance colorimetry (CIE 1976 L^*, a^*, b^* colour space) according to ISO 13837:2021, 5.3.8 at five points as shown in Figure 4. Test three points at least 100 mm away from each other, if these five points cannot be easily tested, or if the DUT is too small to get these five points. If it is still not possible to choose three points from the DUT, it is not necessary to test the difference in colour of a single panel.

Calculate the reflectance colour difference between the central point (point 5) and the other points according to ISO/CIE 11664-6.

4.8.5.2 Reflectance colour difference for batch

Switch DUTs to required state and keep for at least 5 min.

Measure the reflectance colorimetry (CIE 1976 L^*, a^*, b^* colour space) at a central point (point 5) of the five DUTs.

Calculate the difference between the maximum and minimum values of a^* as X. Calculate the difference between the maximum and minimum values of b^* as Y.

When $X \geq Y$, select the DUT with the maximum or minimum a* value as the reference DUT. When $X \leq Y$, select the DUT with the maximum or minimum b* value as the reference DUT.

Calculate the reflectance colour difference between the reference DUT and the other four DUTs.

4.8.5.3 Transmittance colour difference

If the transmittance colour difference is required, measure the transmittance colour difference as per 4.8.5.1 and 4.8.5.2. If it is not possible to measure the transmittance colour at these points, the customer and the manufacturer shall decide on the alternative measuring points.

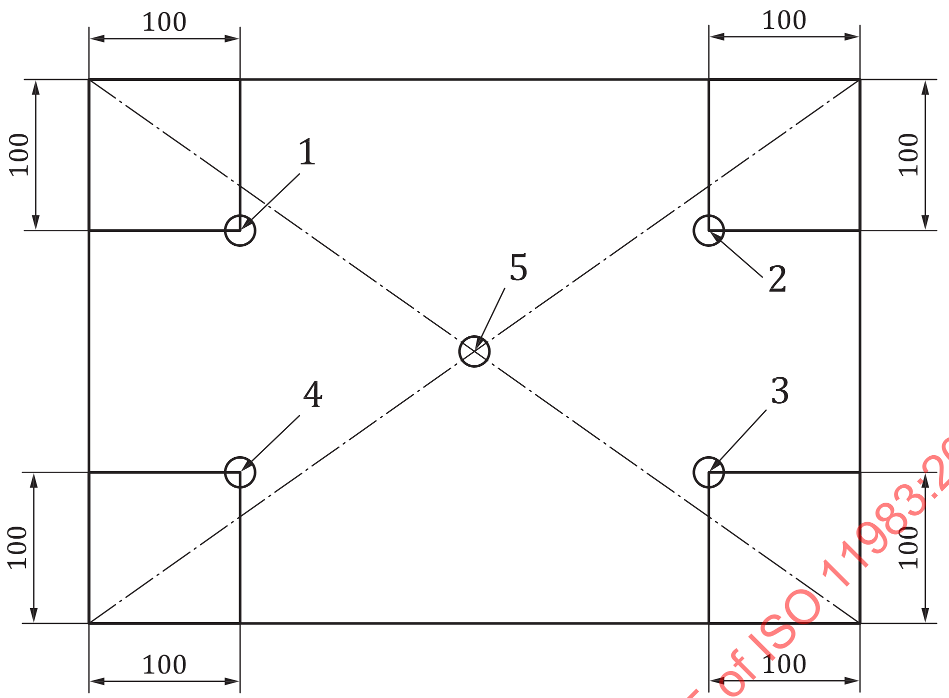
4.8.6 Expression of results

The maximum value of the colour difference on one DUT shall be considered the single panel colour difference.

The maximum value of the colour difference of the five DUTs shall be considered the batch colour difference.

The value shall be rounded to 0,1.

Dimensions in millimetres



Key

1 measuring point 1

2 measuring point 2

3 measuring point 3

4 measuring point 4

5 measuring point 5 — geometric central point

Figure 4 — Measuring points

4.9 Switching cycles

4.9.1 Purpose of test

The purpose of this test is to determine whether electro-switchable glazing will perform well after switching for required cycles.

4.9.2 Apparatus

4.9.2.1 High and low temperature chamber, which can maintain −20 °C and 85 °C with stability ±2 °C.

4.9.2.2 Regular luminous transmittance measuring system, which is described in ISO 3538:1997, 5.1.2.

4.9.2.3 Control system, which shall be provided by the manufacturers for switching the DUT to a different state. The control system and parameters shall be pre-set to make the specimen switch same as finished product. The control system shall be able to cyclically switch the DUT between different transmittance states.

4.9.3 Device under test

One specimen or finished product may be used as the DUT for each test temperature. When a specimen is used, the effective switching area of the specimen shall be able to cover a square whose sides are 290 mm in length.