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Road vehicles — Tests for rigid plastic safety glazing materials

National foreword

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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 on 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 the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 35, *Lighting and visibility*.

This second edition cancels and replaces the first edition (ISO 15082:1999), which has been technically revised.

Road vehicles — Tests for rigid plastic safety glazing materials

1 Scope

This document specifies commonly used test methods relating to the safety requirements for rigid plastic safety glazing materials in a road vehicle, regardless of the type of plastic of which they are composed.

NOTE 1 Plastic safety glazing materials are classified as rigid or flexible by use of the test described in Annex A.

NOTE 2 Further test methods might be defined in separate standards.

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 48, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

ISO 3538, *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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3536 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 http://www.iso.org/obp

4 Test conditions

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

— ambient temperature: 20 °C ± 5 °C;

— atmospheric pressure: 86 kPa to 106 kPa (860 mbar to 1 060 mbar);

— relative humidity: (60 ± 20) %.

5 Conditioning of test specimens

Unless otherwise specified, all test specimens to be tested shall be conditioned prior to testing under the following conditions and for the following periods of time:

— ambient temperature: 23 °C ± 2 °C for at least 48 h;

— ambient relative humidity: (50 ± 5) % for at least 48 h;

— low temperature: –18 °C ± 2 °C for at least 24 h.

6 Application of tests

For certain types of safety glazing material, it is not necessary to carry out all the tests specified in this document.

7 Optical properties test

Test plastic safety glazing materials in accordance with ISO 3538.

8 Head-form/fragmentation test

8.1 Principle

Determine the fragmentation characteristics of plastic safety glazing materials at ambient temperature.

8.2 Apparatus

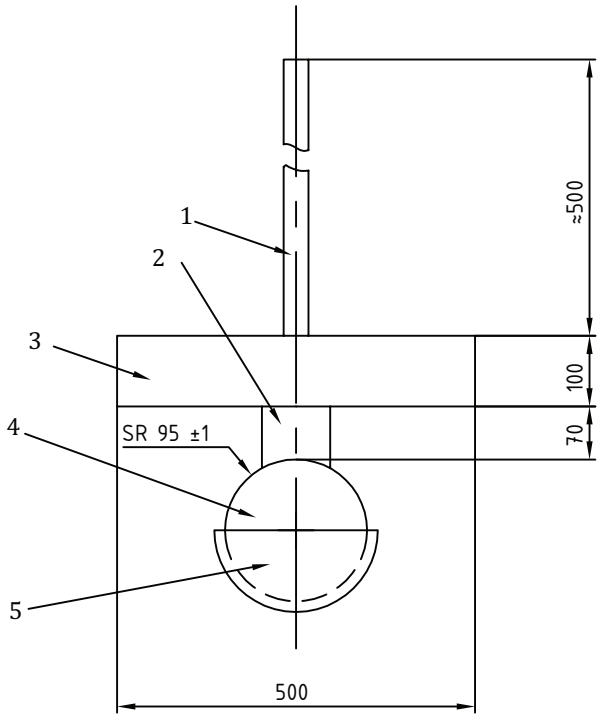
8.2.1 Head-form weight, shall be a spherical or semi-spherical head made of laminated hardwood covered with replaceable felt and with or without a cross-beam made of wood.

Between the spherical part and the cross-beam, there is a neck shaped intermediate piece and on the other side of the cross-beam, a mounting rod.

The dimensions shall be in accordance with Figure 1.

The total mass of the apparatus shall be 10 kg ± 0,2 kg.

Dimensions in millimetres



Key

1 mounting rod
2 intermediate piece
3 cross-beam (optional)
4 head
5 felt cover 5 mm thick

Figure 1 — Head-form weight

8.2.2 Drop.

The means for dropping the head-form weight freely from a height is to be specified, or the means for giving the weight a velocity equivalent to that obtained by the free fall.

When a device to project the head-form weight is used, the tolerance on velocity shall be ±1 % of the velocity equivalent to that obtained by the free fall.

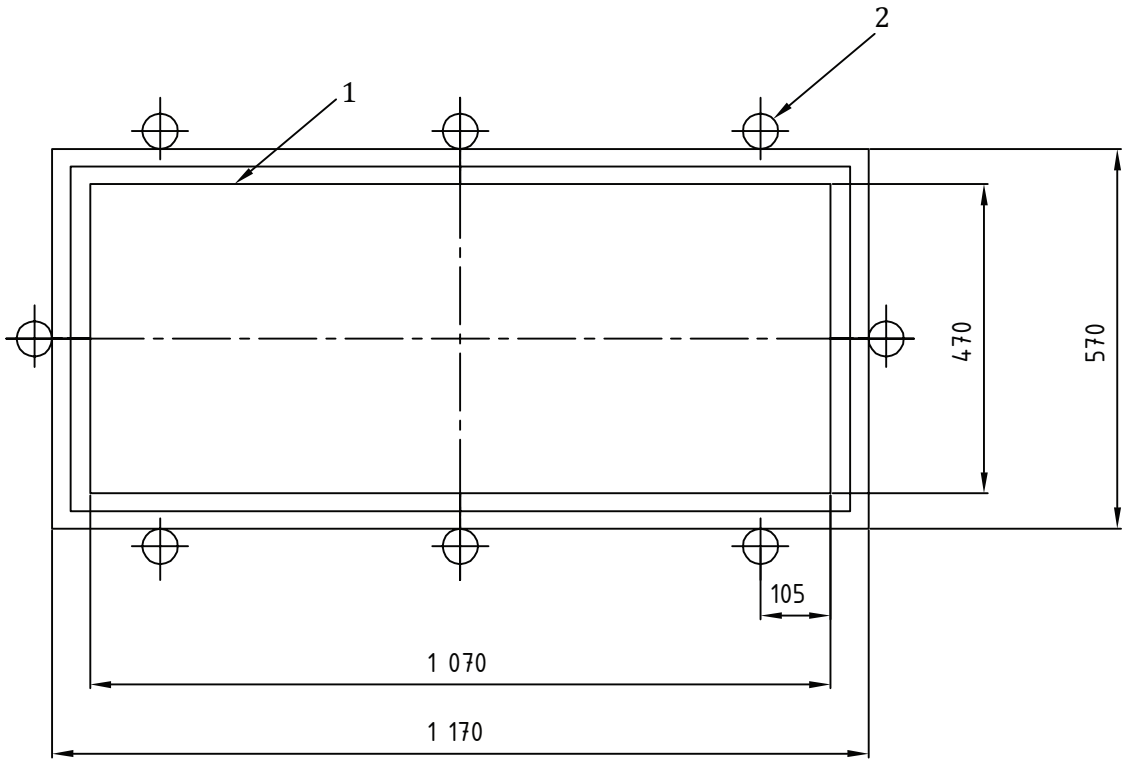
8.2.3 Supporting fixture for testing flat test specimens, as show in Figure 2.

The fixture is composed of two steel frames, with 50 mm wide machined edges, fitting one over the other and faced with rubber gaskets about 3 mm ± 0,5 mm thick, and 15 mm ± 1 mm wide, of hardness 70 IRHD, measured in accordance with ISO 48. The upper frame is pressed against the lower frame by at least eight bolts; the minimum recommended torque for M20 bolts is 30 Nm. Alternatively, other pressing techniques may be used, e.g. hydraulic or pneumatic pressing (see 8.4).

8.3 Test specimens

Test specimens shall be flat rectangles with length 1 100 mm $^{+5}_{-2}$ mm and width 500 mm $^{+5}_{-2}$ mm.

Dimensions in millimetres



Key

1 rubber gasket

2 bolt

Figure 2 — Support for head-form tests

8.4 Procedure

Place a conditioned test specimen in the supporting fixture (Figure 2); the torque on the bolts, or the amount of hydraulic or pneumatic pressure, shall ensure that the movement of the test specimen during the test will not exceed 2 mm. The plane of the test specimen shall be substantially perpendicular to the incident direction of the head-form weight.

The head-form weight shall strike the test specimen, from a height to be specified, within 40 mm of its centre on that face which represents the inside face of the plastic safety glazing material when mounted on the vehicle, and shall be allowed to make only one impact.

The felt cover shall be replaced after 12 tests or when damaged.

8.5 Expression of results

Evaluate the fracture characteristics of the plastic safety glazing material by recording whether the test specimen did not break and the head-form was supported, or the test specimen broke and the head-form was supported, or the test specimen broke and the head-form was not supported. Record the drop height for each impact test.

In the event of fracture, evaluate the plastic safety glazing material by recording the smallest angle between two adjacent sides of resulting fragments and the area, longest dimension, and weight of the largest fragment. Record this data for the fragments remaining in the supporting fixture and for those that are dislodged from the supporting fixture.

9 Head-form test with deceleration measurement

9.1 Principle

Assessment of the minimum strength and fragmentation characteristics of plastic safety glazing materials under impact from a blunt, bulky object at ambient temperature. The danger of skull-brain-injuries is assessed by simultaneous determination of the HIC (head injury criterion)-values.

Tests can be performed on flat specimens or on complete panes.

9.2 Test conditions

Unless otherwise specified, the test shall be carried out under the following conditions:

— ambient temperature: 20 °C ± 5 °C;

— atmospheric pressure: 86 kPa to 106 kPa (860 mbar to 1 060 mbar);

— relative humidity: (60 ± 20) %.

9.3 Conditioning of test pieces

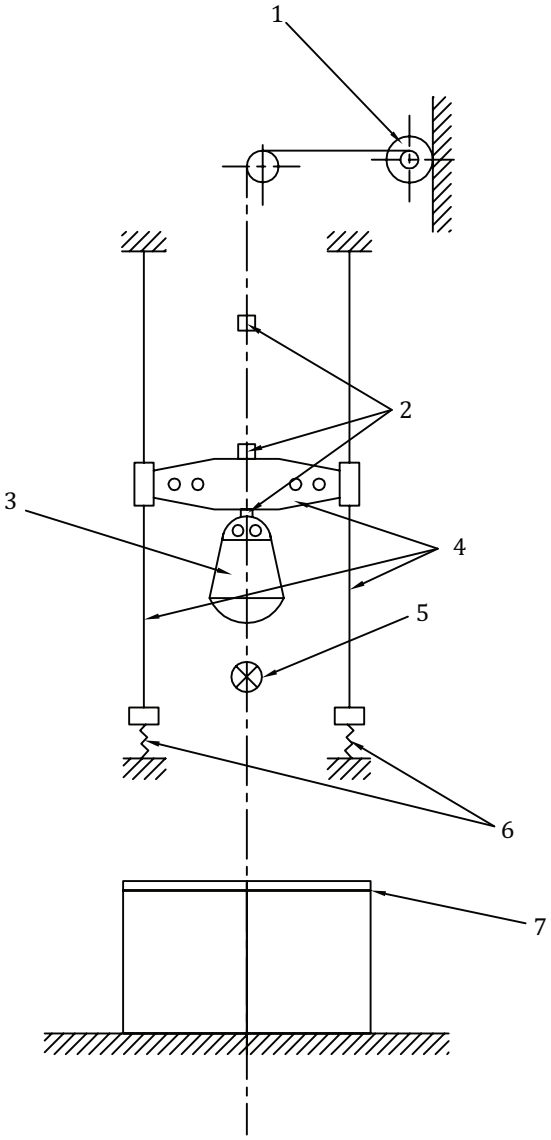
Unless otherwise specified, the test pieces to be tested shall be conditioned prior to testing under the following conditions and for the following periods of time:

— ambient temperature: 23 °C ± 2 °C for at least 48 h;

— ambient relative humidity: (50 ± 5) % for at least 48 h.

9.4 Apparatus

To perform the head-form test with deceleration measurement, a test apparatus according to Figure 3 can be used. The head-form (see 9.4.1 and Figure 4) is fixed to the cross arm of the guide system and moved to the required drop height by means of a lifting device. To start the drop test the cross arm with the head-form is released. After passing the height-adjustable light barrier the head-form is released from the cross arm, the cross arm's fall is dampened and the head-form drops onto the test piece. Instead of the data transmission via cables, wireless data transmission (e.g. radio transmission) may be used. In this case,the guide system can be omitted because of no risk of obstruction of the free vertical drop by any cables.



Key

1 lifting device
2 release device
3 drop body (head-form)
4 guide system
5 light barrier
6 dampers
7 test-piece support

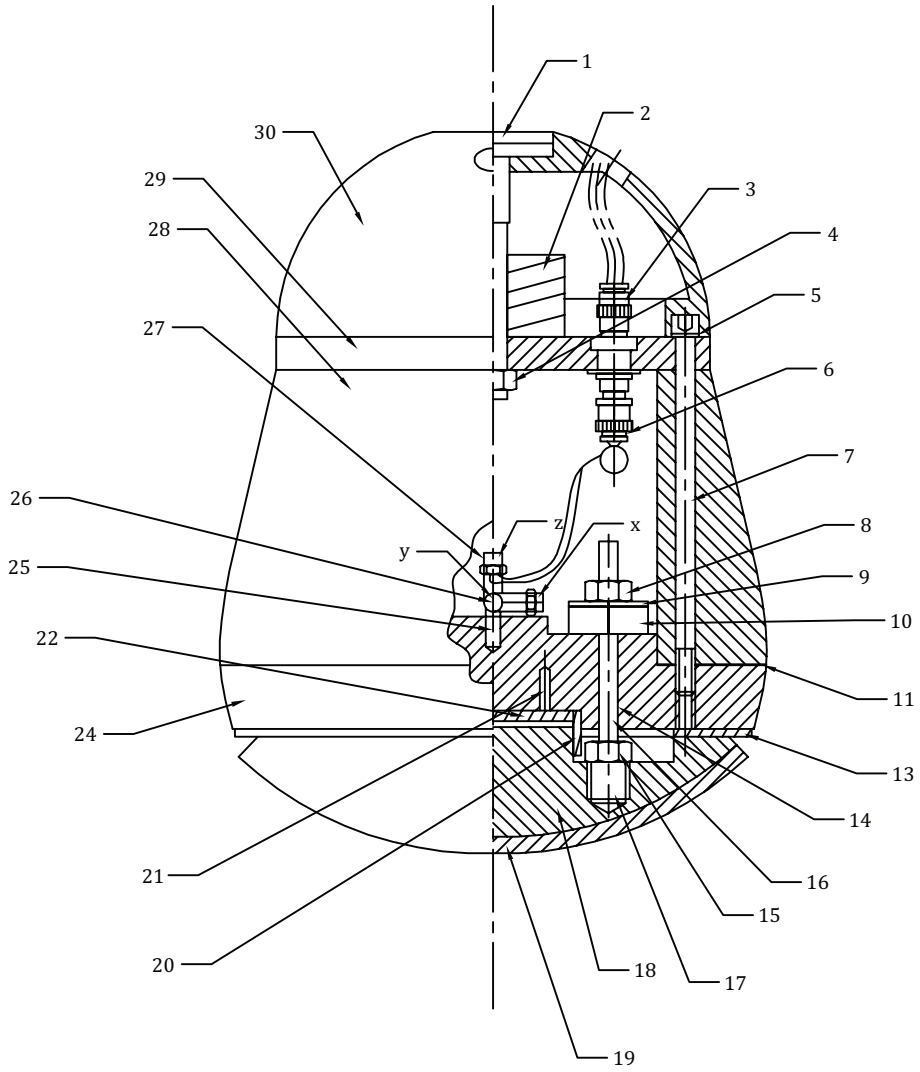
Figure 3 — Principal sketch of a test apparatus for the head-form test with deceleration measurement

9.4.1 Head-form weight. Head-form [as shown in Figure 4 for data transmission via co-axial (BNC) cables] with total mass of 10,0 kg + 0,2/-0,0 kg, which allows the simultaneous determination of HIC-values.

The components of the head-form according to Figure 4 are listed in Table 1. In the middle of the base plate (24), the tri-axial mounting block (26) is mounted in the centre of gravity to hold the acceleration gauges (27). The acceleration gauges shall be arranged vertically to each other.

The basin (18) and cover (19) situated under the base plate (24) share, to a great extent, the elastic properties of the human skull. The elastic properties of the head-form on impact are determined by the hardness and the thickness of the intermediate ring (13) and the basin.

If wireless data transmission is used instead of transmission via co-axial cables, it shall be ensured that those electronic components additionally installed in the head-form do not influence mass, gravity centre point and spring force of the head-form. Those electronic components shall be installed on the base plate (24) only. A mass correction, if necessary, is also restricted to the base plate at that surface which faces the hollow space within the head-form. If additional miniature components for controlling of the electronic modules are required (e.g. micro switches, loading sockets for voltage supply), these may replace the co-axial cables. In this case, the original holes in the cover plate (29) and the protective cap (30) shall be used for the installation and wiring.



Key

1	magnetic holding device	17	screwed insert
2	vibration damper	18	basin
3	HF connector BNC	19	cover
4	hexagonal nut	20	guide bush
5	disc	21	counter sunk crew
6	transition piece	22	damping disc
7	cylinder screw	24	base plate
8	hexagonal nut	25	set screw with hexagon socket
9	disc	26	tri-axial mounting block
10	rubber ring	27	acceleration gauge
11	damping ring	28	wood component
13	intermediate ring	29	cover plate
14	guide tube	30	protective cap
15	hexagonal nut		
16	threaded bolt		

Figure 4 — 10 kg head-form

9.4.2 Measuring device, for recording and evaluation of the measured deceleration curves $ax_{(t)}$, $ay_{(t)}$ and $az_{(t)}$, transmitted from the head-form acceleration gauges via cables or wireless: acceleration gauges, measuring and recording instruments according to ISO 6487, channel-amplitude class CAC 5000 m/s^2 and channel-frequency class CFC 1 000Hz.

Table 1 — List of components for the 10 kg head-form shown in Figure 4

Position no.	Number of pieces	Standard notation	*Material*	*Remarks*
1	1	Magnetic holding device	Steel: EN 10025–2-E295GC	—
2	1	Vibration damper	Rubber/steel	Diameter: 50 mm Thickness: 30 mm Thread: M10
3[a]	4	HF connector BNC	—	Coupler-coupler (EN 122120)
4	1	Hexagonal nut ISO 10511-M10–05	—	—
5	6	Disc ISO 7090-6-200HV	—	—
6[a]	3	Transition piece Pos.No. 3 – Pos.No. 27	—	—
7	6	Cylinder screw ISO 4762-M6x140–8.8	—	Torque about 12 Nm
8	3	Hexagonal nut ISO 10511-M8–05	—	Torque about 4 Nm (see 9.5)
9	3	Disc	Steel EN 10025–2-E295GC	Hole diameter: 8 mm Outer diameter: 35 mm Thickness: 1,5 mm
10	3	Rubber ring	Rubber, hardness 60 IRHD (ISO 48)	Hole diameter: 8 mm Outer diameter: 30 mm Thickness: 10 mm
11	1	Damping ring	Gasket paper	Hole diameter: 120 mm Outer diameter: 199 mm Thickness: 0,5 mm
12	—	—	—	—
13	1	Intermediate ring	Butadiene-rubber, hardness about 60 IRHD (ISO 48)	Hole diameter: 129 mm Outer diameter: 192 mm Thickness: about 6 mm (see 9.5)
14	3	Guide tube	Polytetrafluoroethylene (PTFE)	Inner diameter: 8 mm Outer diameter: 10 mm Length: 40 mm
15	3	Hexagonal nut ISO 10511-M8–05	—	—
16	3	Threaded bolt DIN 976–1– M8x90–B–8.8	—	—

[a] These components are unnecessary in case of wireless data transmission. In this case, other components for data transmission are installed in the head-form (e.g. radio-transmitter) (see 9.4.1).

Table 1 *(continued)*

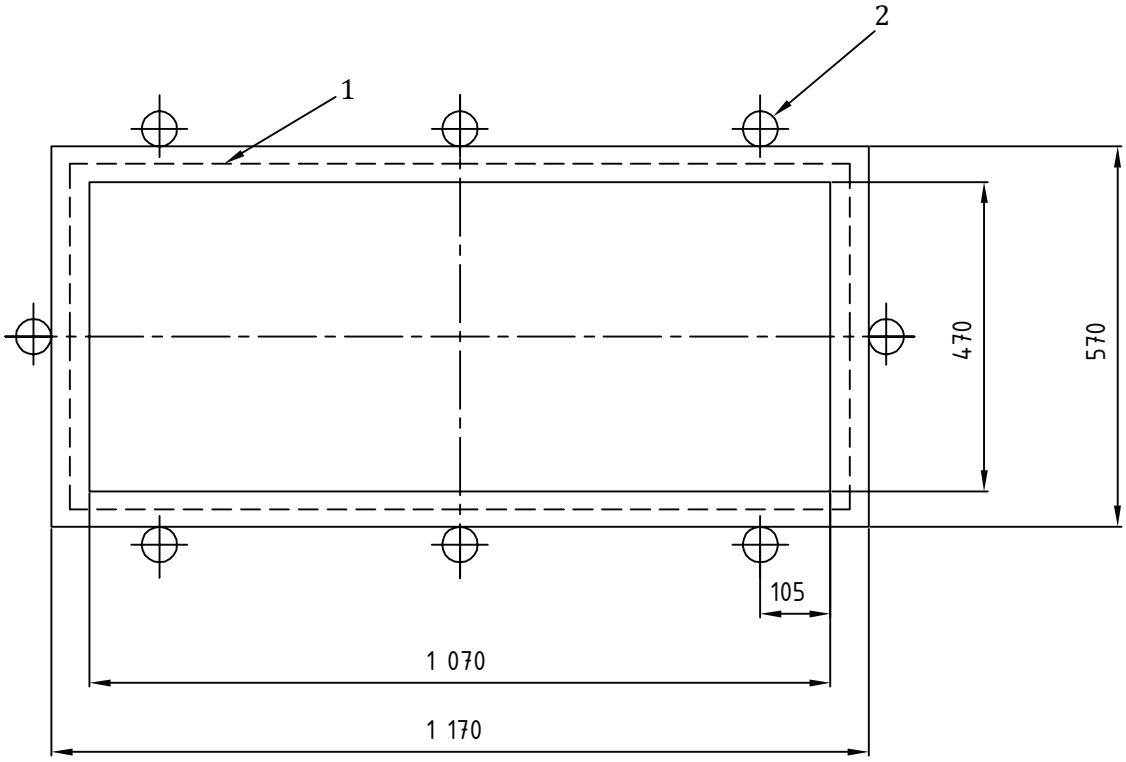
Position no.	Number of pieces	Standard notation	*Material*	*Remarks*
17	3	Screwed insert	Cast alloy EN 1982-CuZn39Pb1Al-C-GP	Dimensions M8 × 12 (DIN 7965)
18	1	Basin	Polyamide 12 (ISO 1874-1)	—
19	1	Cover	Butadiene-rubber	Thickness: 6 mm Rib on one side
20	1	Guide bush	Steel EN 10025–2-E295GC	—
21	4	Counter sunk screw ISO 2009-M5x10–5.8	—	—
22	1	Damping disc	Gasket paper	Diameter: 65 mm Thickness: 0,5 mm
23	—	—	—	—
24	1	Base plate	Steel EN 10025–2-E295GC	—
25	1	Set screw with hexagonal socket	Class of strength 45H (ISO 898-5)	—
26	1	Tri-axial mounting block	—	—
27	3	Acceleration gauge	—	See 9.4.2
28	1	Wood component	Hornbeam, glued in layers	—
29	1	Cover plate	Alloy EN 573–3 ; EN AW-5019 (EN AW-AlMg5)	—
30	1	Protective cap	Polyamide 12 (ISO 1874-1)	—

[a] These components are unnecessary in case of wireless data transmission. In this case, other components for data transmission are installed in the head-form (e.g. radio-transmitter) (see 9.4.1).

9.4.3 Supporting fixture for testing flat test specimens, is shown in Figure 5.

The fixture is composed of two steel frames, with machined edges, 50 mm wide, fitting one over the other and faced with rubber gaskets about 3 mm ± 0,5 mm thick, and 50 mm + 1/-0 mm wide, of hardness 70 IRHD, determined in accordance with ISO 48. The upper frame is pressed against the lower frame by at least eight bolts; the minimum recommended torque for M20 bolts is 30 Nm. Alternatively, other pressing techniques may be used, e.g. hydraulic or pneumatic pressing (see 9.7).

Dimensions in millimetres



Key

1 rubber gasket

2 bolt

NOTE Dashed line indicates centre line of rubber strip, centrally on support edge.

Figure 5 — Support for tests on flat specimens

9.4.4 Supporting fixture for testing complete panes.

The support shall consist of a rigid piece corresponding to the shape of the pane so that the head-form weight faces the internal surface. The pane shall be clamped to the supporting structure by means of appropriate devices, with interposed stripes of rubber of hardness 70 IRHD, determined in accordance with ISO 48, and thickness of about 3 mm, the width of contact over the whole perimeter being about 15 mm.

9.4.5 Equipment to calibrate the head-form.

Drop appliance which shall allow drop heights between 50 mm and 254 mm to be adjusted exactly to within 1 mm. A guide system is not necessary for these small drop heights.

Impact plate made of steel, dimensions 600 mm × 600 mm, minimum thickness 50 mm, flatness tolerance t = 0,05 mm, determined in accordance with ISO 1101.

9.5 Calibration procedure and adjustment of the head-form

Before each test series and no later than each 50 tests within a series, the head-form shall be calibrated and adjusted if necessary.

The impact plate shall be clean and dry and shall lie non-positively on a concrete base during the calibration procedure. Alternatively, the impact plate may be placed in a massive supporting device if this device is connected to a concrete foundation.

The head-form is allowed to hit the impact plate vertically. The drop heights (measured from the lowest point of the head-form to the surface of the impact plate) are 50 mm, 100 mm, 150 mm and 254 mm. The deceleration curves shall be recorded.

The greatest deceleration a_z from the various drop heights on the z-axis shall lie within the limits given in Table 2.

Table 2 — Greatest deceleration a_z on the z-axis which shall be reached for calibration, depending on the drop height

Drop height mm	Greatest deceleration[a] a_z m/s^2
50	(82 ± 8) g
100	(128 ± 8) g
150	(167 ± 10) g
254	(227 ± 14) g

[a] The values of the greatest deceleration a_z are maximum values of the deceleration curves $a_z(t)$, expressed in multiples of g (acceleration due to gravity: g = 9,81 m/s^2).

The deceleration curves shall be based on a uni-modal oscillation. The deceleration curve of the drop height of 254 mm shall run at least 1,5 ms and at most 2 ms over 100 g.

If the requirements given above are not met, the elastic properties of the head-form shall be adjusted by varying the thickness of the intermediate ring (13) of the base plate (24). Corrections can be carried out by adjusting the three self-locking hexagonal nuts (8) on the threaded bolts (16) by which the basin (18) is fixed to the base plate (24). The rubber rings (10) under the hexagonal nuts (8) should not be brittle or cracked.

The cover (19) of the impact surface and the intermediate ring (13) should be replaced if damaged; especially, they should always be replaced simultaneously if the head-form can no longer be adjusted.

9.6 Test pieces

Flat test specimens (1 170 mm + 0/-2 mm × 570 mm + 0/-2 mm) or complete panes shall be subjected to testing.

9.7 Test procedure

In case of flat test specimens, fix the specimen in the supporting frames (see 9.4.3). In case of tests on complete panes, clamp the pane to a support which has a shape corresponding to the pane (see 9.4.4).

The torque on the bolts respectively the amount of hydraulic or pneumatic pressure shall ensure that the movement of an edge of the test piece during the test will not exceed 2 mm.

The plane of the test piece shall be substantially perpendicular to the incident direction of the weight. The head-form weight shall strike the test piece within 40 mm of its geometric centre on that face which represents the inward face of the safety glazing pane when the latter is mounted on the vehicle, and shall be allowed to make only one impact.

In case of data transmission via co-axial cables, the head-form is fixed to the cross arm of the guide system (see Figure 3) and moved to the required drop height[1)] which depends on the desired impact velocity. In case of tests on complete panes, drop heights between 1,5 m and 3 m are used if not specified otherwise. The cross arm which carries the head-form is released. After passing the height-adjustable light barrier the head-form is released from the cross arm, the cross arm's drop is dampened and the head-form drops onto the test piece.

1) The drop height is the distance between the lowest point of the head-form and the upper surface of the test piece.

In case of wireless data transmission, the guide system can be omitted. The head-form is fixed directly to the upper release device of the lifting unit and moved to the required drop height. The head-form is released and drops freely onto the test piece.

No impulse may be given to the head-form by the drop appliance or by the data-transmission cables (if applicable), so that it is accelerated only by gravity and drops freely and vertically.

The deceleration curves occurring on impact on the test piece for a_x, a_y and a_z shall be recorded versus time, t.

After the head-form weight has impacted the test piece, it shall be checked whether a glazing edge has moved more than 2 mm in the support and whether the requirement for the point of impact was met. The acceleration components a_x and a_y shall be smaller than 0,1 a_z for a vertical impact.

9.8 Evaluation

The deceleration curves shall be evaluated as follows:

The resulting deceleration $a_{res}(t)$ in the centre of gravity shall be calculated according to Formula (1) from the measured deceleration curves $a_x(t)$, $a_y(t)$ and $a_z(t)$ as multiple of the acceleration due to gravity, g, expressed in metres per square second (m/s^2).

$$a_{\text{res}}\left(t\right) = \left(a_x^2\left(t\right) + a_y^2\left(t\right) + a_z^2\left(t\right)\right)^{1/2} \tag{1}$$

The period for which the deceleration a_{res} exceeds the value of 80 g continually, and the greatest value of a_{res} shall be determined. The HIC-value[2)] as a measure of the danger of blunt skull-brain-injuries shall be calculated according to Formula (2):

$$\text{HIC} = \max\ f(t) = \max_{t_1,t_2}\left[\left(t_2 - t_1\right)^{-1,5}\left(\int_{t_1}^{t_2} a_{\text{res}}\left(t\right)dt\right)^{2,5}\right] \tag{2}$$

2) The unit of the HIC-value is defined as unit 1.

where

$\max f(t)$ is the maximum value of the function $f(t)$;

t_1 is the point of time selected for the calculation as start point of the deceleration measurement, in seconds;

t_2 is the point of time selected for the calculation as end point of the deceleration measurement, in seconds;

a_{res} is the resulting deceleration according to Formula (1) as multiple of the acceleration due to gravity g, expressed in metres per square second (m/s^2).

The integration limits t_1 and t_2 shall be selected in such a way that the function $f(t)$ gets a maximum value.

9.9 Expression of results

Record the drop height for each impact test.

Evaluate the fracture characteristics of the plastic safety glazing material by recording whether the test piece did not break and the head-form was supported, or the test piece broke and the head-form was supported, or the test piece broke and the head-form was not supported. In the event of fracture, report if or not the piece broke into fully separate large pieces.

Report the following numerical results:

— the period for which the resulting deceleration a_{res} exceeded the value of 80 g continually;

— the greatest value of the resulting deceleration a_{res};

— the HIC value.

10 Ball test

10.1 227 g ball test

10.1.1 Principle

Determination of whether the plastic safety glazing material has a certain minimum strength and cohesion under impact from a small hard object at ambient and low temperatures.

10.1.2 Apparatus

10.1.2.1 Hardened steel ball, with a mass of 227 g ± 2 g and a diameter of approximately 38 mm.

10.1.2.2 Means for dropping the ball freely from a height to be specified, or means for giving the ball a velocity equivalent to that obtained by the free fall.

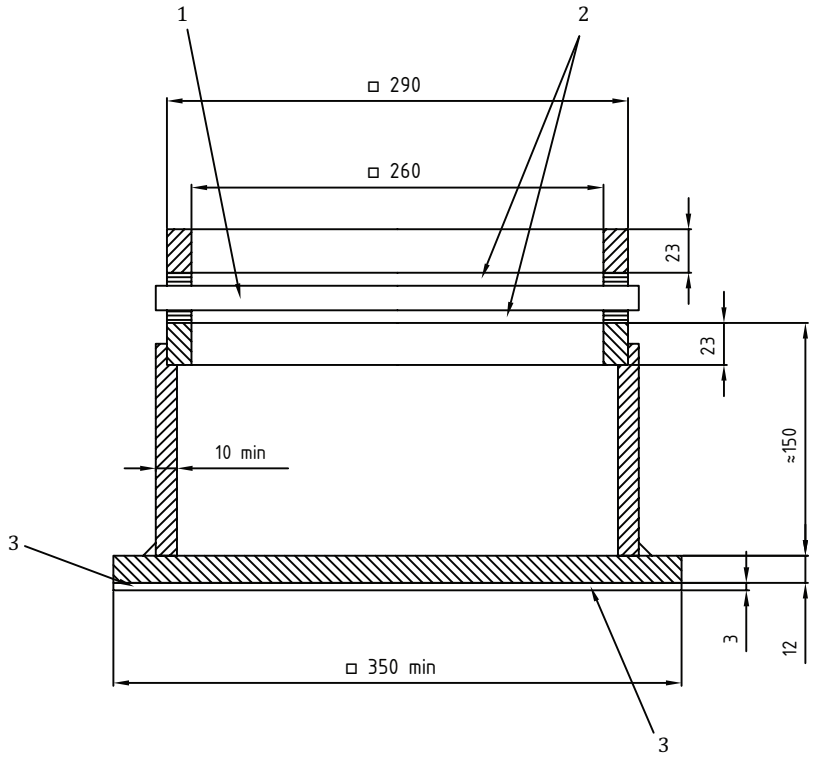
When a device to project the ball is used, the tolerance on velocity shall be ±1 % of the velocity equivalent to that obtained by the free fall.

10.1.2.3 Supporting fixture, such as that shown in Figure 6, composed of two steel frames with 15 mm wide machined borders, fitting one over the other and faced with rubber gaskets about 3 mm thick and 15 mm wide, of hardness 50 IRHD, determined in accordance with ISO 48.

The lower frame rests on a steel box, about 150 mm high. The test specimen is held in place by the upper frame, the mass of which is about 3 kg. The supporting frame is welded on a sheet of steel about

12 mm thick, resting on the floor, with an interposed sheet of rubber, about 3 mm thick, of hardness 50 IRHD measured in accordance with ISO 48.

Dimensions in millimetres



Key

1 test piece
2 rubber gasket
3 sheet of rubber

Figure 6 — Support for ball tests

10.1.3 Test specimens

Test specimens shall be flat squares with 300 mm $^{+10}_{0}$ mm sides.

10.1.4 Procedure

Place a conditioned test specimen in the supporting fixture and conduct the impact test at once. To minimize the temperature change of the test specimen, the test should take place as quickly as possible (within 30 s of its removal from the conditioning appliance). The plane of the test specimen shall be perpendicular, within 3°, to the incident direction of the ball. When necessary to retain the test specimen in the fixture, it shall be clamped to ensure that the movement of the test specimen during the test will not exceed 2 mm at any point along the inside periphery of the fixture.

The point of impact shall be within 25 mm of the geometric centre of the test specimen for a drop height less than or equal to 6 m, and within 50 mm of the geometric centre of the test specimen for a drop height greater than 6 m.

The ball shall strike the surface of the test specimen which represents the outside face of the plastic safety glazing material when mounted on a vehicle and shall be allowed to make only one impact.

10.1.5 Expression of results

Evaluate the strength, type, and extent of damage to the test specimen. Record the drop height, and temperature for each test specimen and whether the test specimen supported or did not support the 227 g ball.

10.2 2260 g ball test

10.2.1 Principle

Determination of whether the plastic safety glazing material has a certain minimum penetration resistance under impact from a large hard object at ambient and low temperature.

10.2.2 Apparatus

10.2.2.1 Hardened steel ball, with a mass of 2 260 g ± 20 g and a diameter of approximately 82 mm.

10.2.2.2 Means for dropping the ball freely from a height to be specified, or means for giving the ball a velocity equivalent to that obtained by the free fall.

When a device to project the ball is used, the tolerance on velocity shall be ±1 % of the velocity equivalent to that obtained by the free fall.

10.2.2.3 Supporting fixture, such as that shown in Figure 6 and specified in 10.1.2.3.

10.2.3 Test specimens

Test specimens shall be flat squares with 300 mm $^{+10}_{0}$ mm sides or shall be cut out from the flattest part of a plastic safety glazing material.

10.2.4 Procedure

Place a conditioned test specimen in the supporting fixture and conduct the impact test at once. To minimize the temperature change of test specimens conditioned at low temperature, the test should take place as quickly as possible (within 30 s of its removal from the conditioning appliance). The plane of the test specimen shall be perpendicular, within 3°, to the incident direction of the ball. When necessary to retain the test specimen in the fixture, it shall be clamped to ensure that the movement of the test specimen during test will not exceed 2 mm at any point along the inside periphery of the fixture.

The point of impact from a specified drop height shall be within 25 mm of the geometric centre of the test specimen for a drop height less than or equal to 6 m, and within 50 mm of the geometric centre of the test specimen for a drop height greater than 6 m.

The ball shall strike the face of the test specimen which represents the inside face of the plastic safety glazing material when mounted on the vehicle and shall be allowed to make only one impact.

10.2.5 Expression of results

Evaluate the ability of the plastic safety glazing material to support the impacting ball for each velocity and temperature. If the ball passes completely through a test specimen within 5 s after impact, the result shall be recorded as a “non-support”. If the ball remains on top of a test specimen or wedged in a hole, for 5 s or more, the result shall be recorded as a “support”. Record the drop height.

11 Abrasion resistance test

11.1 Principle

Determination of whether the plastic safety glazing material has a certain minimum resistance to abrasion at ambient temperature.

11.2 Abrasion resistance under dry conditions

11.2.1 Apparatus

11.2.1.1 Abrading instrument[3], is shown diagrammatically in Figure 7 a) and Figure 7 b) and consisting of the following:

— a horizontal turntable and centre clamp which revolves counter-clockwise at a fixed speed of 60 ± 2 r/min or 72 ± 2 r/min;

— two weighted parallel arms, each carrying a special abrasive wheel freely rotating on a ball bearing horizontal spindle. Each wheel rests on the test specimen under the pressure exerted by a mass of 500 g. The distance between the internal faces of the wheels shall be 52,4 mm ± 1,0 mm and the horizontal offset of a virtual line, which runs through both wheel axes, from the turntable axis shall be 19,05 mm ± 0,30 mm (see, for example, Figure D.1);

— a vacuum suction system (not depicted in Figure 7) and vacuum pick-up nozzle to remove debris and abrasive particles from the specimen surface during testing. The height of the vacuum pick-up nozzle shall be adjustable, and the nozzle openings shall have a diameter of 11 mm.

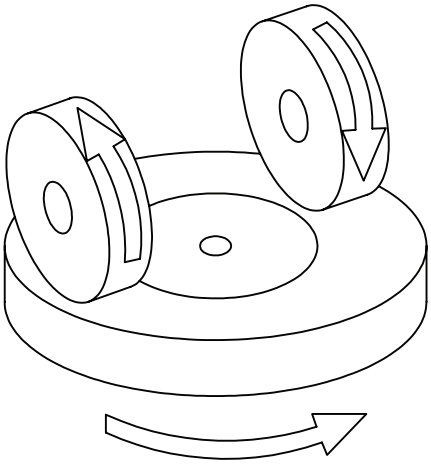
In the case of a nominal nozzle opening equal to 8 mm, the nozzle openings shall be enlarged to 11 mm following the instructions shown in Annex B, or by installation of a replacement nozzle with 11 mm openings.

The turntable of the abrading instrument shall rotate regularly, substantially in one plane (the deviation from this plane shall not be greater than ±0,05 mm at a distance of 1,6 mm from the turntable periphery).

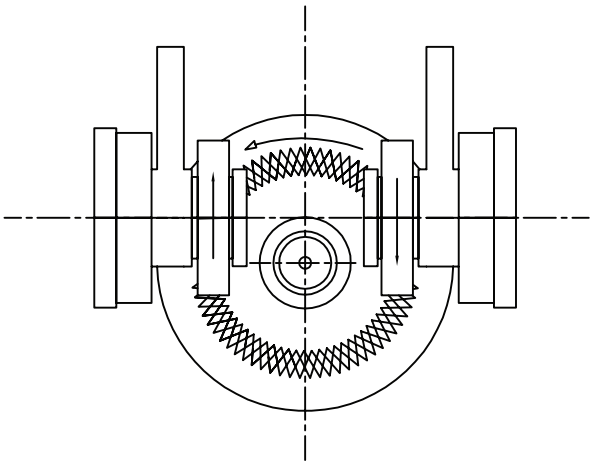
The wheels shall be placed evenly on the specimen in their full width. When they are in contact with the rotating test specimen, they rotate in contrary directions so as to exert a compressive and abrasive action along curved lines over an annular area of about 30 cm^2, twice during each rotation of the test specimen.

Verify calibration of the abrading instrument as directed by the equipment manufacturer. For one Taber abraser, see Annex D.

3) A suitable abrading instrument is supplied by Taber Industries (USA). This information is given for the convenience of users of this International Standard 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.



a) Diagram of abrading instrument



b) Diagrammatical top view of abrading instrument

Figure 7 — Abrading instrument

11.2.1.2 Abrasive wheels[4].

The abrasive wheels have a cylindrical shape and composed of a resilient binder and abrasive particles such as aluminium oxide and silicon carbide particles. The abrasive particles shall have a particle size between 20 and 102 microns and uniform distribution throughout the resilient binder. Each wheel shall be moulded to a hub which includes an axial hole 16,0 mm ± 0,1 mm, allowing the wheels to be mounted to the flange holder on the abraser arms. The sides of the wheel shall be parallel, and each wheel shall be 12,7 mm ± 0,3 mm wide and have an external diameter of less than 52,5 mm and in no case less than 44,4 mm. If a different wheel has been used, which has been documented to produce equivalent results, the description of the wheel shall be included with the results.

The abrasive wheel shall be such that the light scatter resulting from abrading (final haze minus initial haze, see 11.6) of each of three AS 4000S[5] hard-coated polycarbonate samples subjected to abrasion is

4) Such as Calibrase CS-10F wheels available from Taber Industries (USA) This information is given for the convenience of users of this International Standard 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.

5) Hard-coating polysiloxane type AS4000S (AS4000 type coating adjusted to flow coating of large sheets) by Momentive (Germany).

within the qualification range[6] of 0 to 2,6 % after 100 cycles, 0,5 % to 6,3 % after 500 cycles and 1,0 to 7,4 % after 1 000 cycles.

The AS 4000S hard-coated polycarbonate samples shall be free of any inhomogeneity in the surface when examined with a human eye and have a luminous transmittance of at least 70 % and a primer coating thickness of 0,5 µm to 1,5 µm and topcoat coating thickness of 4,5 µm to 8,5 µm after thermal curing for 30 min at 130 °C. The AS-4000S reference hard-coated samples shall be supplied with a certificate of analysis of manufacturing quality for coating thicknesses, cure time and cure temperature. An alternative reference hard-coated polycarbonate sample can be used, provided a correlation has been developed against the standardized AS 4000S hard-coated polycarbonate reference samples. Any proposed alternative hard coated polycarbonate sample shall meet the same qualification requirements as the reference AS 4000S hard-coated polycarbonate sample.

The wheels are qualified if all measured haze values for the three AS 4000S hard-coated polycarbonate reference samples per cycles number, and for each of the three cycles numbers, are within the qualification ranges. Only if this requirement is fulfilled, the test will be proceeded using these wheels. The average of the measured values for the three AS 4000S hard-coated polycarbonate reference samples per cycles number is used to calculate a correction factor per cycles number for exactly this wheel pair (see 11.6). This correction factor is used to correct the measured values obtained when testing a test specimen with this wheel pair.

11.2.1.3 Refacing stone.

The fine side of a Taber ST-11 refacing stone (or equivalent) shall be used for resurfacing the abrasive wheels. It is important that the turntable platform runs true on the abraser and that the refacing stone lies flat on the turntable platform. In case a new refacing stone is used during the "lifetime" of a qualified wheel pair a new qualification as described in 11.2.1.2 shall be performed, and the correction factor (see 11.6) shall be determined for that wheel pair again.

11.2.1.4 Hazemeter[7], consisting of:

— A light source and a photodetector, and the combination shall be filtered to provide an output corresponding to the luminosity response of the 1931 CIE Standard Colourimetric Observer with CIE Standard Illuminant C or, alternatively, Illuminant A. The output shall be proportional to within 1 % to the incident flux over the range of flux used. The photometric stability for source and detector shall be constant throughout the test of each specimen.

— An integrating sphere to collect transmitted flux; the sphere may be of any diameter as long as the total port areas do not exceed 4,0 % of the internal reflecting area of the sphere. The entrance and exit ports shall be centred on the same great circle of the sphere, and there shall be at least 2,97 rad (170°) of arc between centres. The exit port shall subtend an angle of 0,14 rad (8°) at the centre of the entrance port. With the light trap in position, without the specimen, the axis of the irradiating beam shall pass through the centres of the entrance and exit ports. For a hazemeter, position the photocell or photocells on the sphere 1,57 rad ± 0,17 rad (90° ± 10°) from the entrance port and baffle it from direct exposure to the entrance port. In the pivotable modification where the interior wall adjacent to the exit port is used as the reflectance reference, the angle of rotation of the sphere shall be 0,140 rad ± 0,008 rad (8,0° ± 0,5°).

Illuminate the specimen by a substantially unidirectional beam; the maximum angle that any ray of this beam may make with the beam axis shall not exceed 0,05 rad (3°). This beam shall not be vignette at either port of the sphere.

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6) The qualification ranges have widths of ($4 \times s_R$), where s_R is the reproducibility standard deviation determined in the round robin test (see Annex E) for each cycles number and the above mentioned factor represents the probability of P = 95 %.

7) A suitable instrument for measuring haze is supplied by Byk-Gardner (USA). This information is given for the convenience of users of this International Standard 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.

When the specimen is placed against the entrance port of the integrating sphere, the angle between the perpendicular to the specimen and a line connecting the centres of entrance and exit ports shall not exceed 0,14 rad (8°).

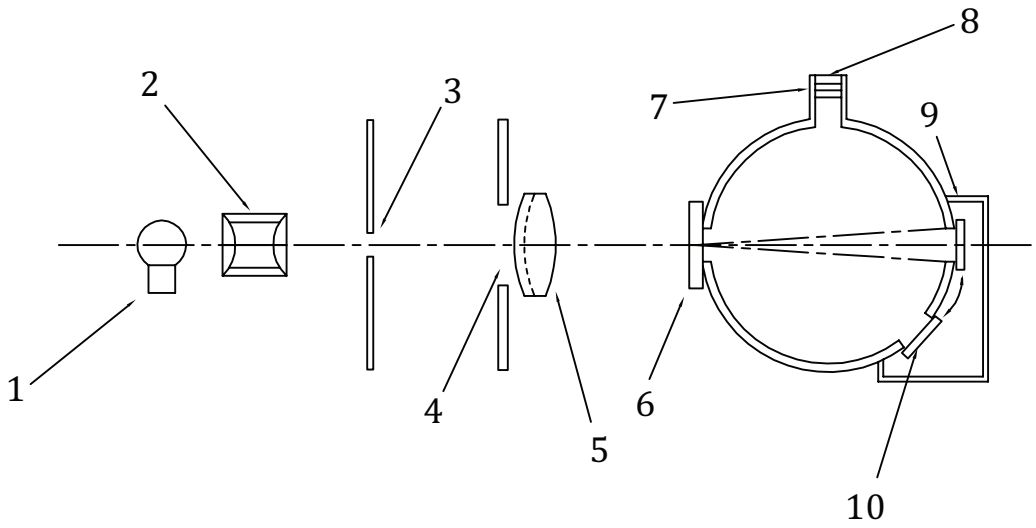
An aperture or diaphragm shall be centrally inserted in the haze measuring apparatus to centre the light beam on the abradant track and limit it to a diameter of 7 mm ± 1 mm at the specimen.

When the reduced light is unobstructed by a specimen, its cross section at the exit port shall be approximately circular, sharply defined, uniformly bright, and concentric within the exit port, leaving an annulus of 0,023 rad ± 0,002 rad (1,3° ± 0,1°) subtended at the entrance port.

The surfaces of the interior of the integrating sphere, baffles, and reflectance standard, if used, shall be of equal reflectance, matte, and highly reflecting throughout the visible spectrum.

A light trap shall be provided that will absorb the beam completely when no specimen is present, or the instrument design shall obviate the need for a light trap.

Forward scattering glass standards can be used to check that the optical system of the hazemeter is properly adjusted.



Key

1 source
2 condenser
3 entrance window
4 aperture
5 lens
6 specimen
7 filter
8 photo detector
9 light trap (if used)
10 reflectance standard

Figure 8 — Hazemeter

11.2.1.1 Specimen holder

A suitable holder shall be used to permit positioning the abraded specimen on the hazemeter so that the light beam is centred in the abraded track and the specimen is flush at the measurement port.

Calibrate the hazemeter with the sample holder before the initial measurement of the haze with no sample present and verify that the reading of the hazemeter is 0.

The whole apparatus shall be checked at regular intervals by means of calibration standards of defined haze.

If haze measurements are made using equipment or methods differing from the above, the results shall be corrected in order to be in agreement with those obtained by the apparatus described above.

11.3 Test specimens

Test specimens shall be flat squares with 100 mm sides having both surfaces substantially plane and parallel, and optionally with a 6,3 mm diameter fixing hole drilled in the centre.

11.4 Standardization of abrading wheels

To ensure that the abrading function of the wheels is maintained at a constant level, prepare the abrading wheels prior to each test. Mount the wheels on their respective flange holders, taking care not to handle them by their abrasive surfaces. Select the load to be used and affix it to the abraser. If no load is specified, use a load of 500 g (per wheel). Visually inspect the fine side of the Taber ST-11 refacing stone and only use it if no contaminations are visible. Mount the visually checked Taber ST-11 refacing stone (or equivalent) on the turntable, fine side up, and secure using the nut.

Lower the vacuum nozzle and adjust the height to 1 mm above the refacing stone with a gage having a thickness equal to 1 mm or a gage pin having a diameter equal to 1 mm. After setting the height of the vacuum nozzle, ensure the rear vacuum nozzle does not contact the refacing stone. Set the vacuum suction force so that a residual pressure of 13,7 kPa (137 millibar) or lower results. Lower the arms so the wheels contact the surface of the ST-11 refacing stone. Reface the wheels for 25 cycles.

After refacing, use a soft bristle, anti-static brush to lightly brush the wheel surfaces to remove any loose particulate matter. A brush found suitable for this purpose is a soft-fibre, static-dissipative brush manufactured from an acrylic fibre (0,04 mm filament diameter) that has been chemically bonded with a layer of copper sulphide to produce an electrical resistance of $3 - 5 \times 10^{-4}$ ohms per centimetre.

New wheels or wheels trued using a diamond tool refacer (such as Taber Diamond Wheel Refacer, or equivalent), shall firstly be broken in with 100 cycles on the fine side of the ST-11 refacing stone followed by a test on the material to be evaluated (results to be discarded).

The fine side of ST-11 refacing stone has a limited life and shall be replaced after 7 500 cycles (approximately 300 refacings).

A thin fin of wheel material is sometimes formed on the left hand edge of the wheel as the main body of the wheel wears down. To remove, gently rub the edge of the wheel using your gloved finger prior to refacing. Avoid touching the running surface of the wheel.

The maximum allowed time between refacing and testing shall not exceed 2 min.

11.5 Procedure

The abrasion test shall be carried out on both inside and outside surfaces of the plastic safety glazing material.

11.5.1 Cleaning

Before testing, remove any protective masking material from the specimen. If required, clean the specimens using a practice recommended by the manufacturer, or if none is recommended, clean the test specimens in the following manner.

a) Using an Isopropyl alcohol (IPA) soaked lint free cloth, gently wipe both surfaces of the specimen in a linear motion to remove any remaining particulate. For those materials where IPA influences the surface characteristics or does not yield a satisfactory result, use a cleaning solution of water with a commercial (e.g. dish-washing) detergent added or a cleaning solution that is compatible with the sample. First wipe the specimen vertically, then wipe the specimen horizontally, and as a final cleaning step wipe the edges.

b) Rinse with distilled, deionized or demineralised water.

c) Dry by pressing lightly between two linen cloths, or blow dry with clean air or nitrogen.

Inspect to confirm that there are no water spots or other residue before haze measurement.

Any treatment with ultra-sonic equipment shall be avoided.

After cleaning, the test specimens shall be handled only by their edges and shall be stored to prevent damage to, or contamination of, their surfaces. It is recommended that latex gloves be worn at all times throughout this test.

11.5.2 Conditioning

Condition the test specimens for a minimum of 48 h at 23 °C ± 2 °C and (50 ± 5) % relative humidity, unless otherwise specified. Begin testing within 5 minutes after removal from conditioning.

When not in use, the abrasive wheels shall be stored in the same conditions of temperature and humidity.

11.5.3 Initial haze measurement

Place the unabraded specimen in the hazemeter sample holder with the side to be abraded facing the entrance port of the integrating sphere. Measure the light scattered (initial haze) at a minimum of four equally spaced points along the track in accordance with Formula (5). Average the results for each test piece. The angle between the normal to the surface of the test specimen and the axis of the beam shall not exceed 8°. In lieu of the four measurements, an average value may be obtained by rotating the piece uniformly at 3 r/s or more. Take the four readings indicated in Table 3.

11.5.4 Abrasion

Mount the specimen on the abraser turntable platform with the side to be abraded facing up. The specimen shall be mounted at a 45° angle from the front of the machine (see Figure 9). Secure using the clamp plate and nut. Select the load to be used and affix it to the abraser. Lower the vacuum pick-up nozzle and adjust the height to 1 mm above the specimen with a gage having a thickness equal to 1 mm or a gage pin having a diameter equal to 1 mm. After setting the height of the vacuum nozzle, ensure the rear vacuum nozzle does not contact the specimen.

Set the vacuum suction force so that a residual pressure of 13,7 kPa (137 mbar) or lower results. Lower the arms so the wheels (qualified with the AS 4000S hard-coated polycarbonate reference samples according to 11.2.1.2) contact the surface of the test specimen. Set the counter to zero and programme the appropriate number of cycles.

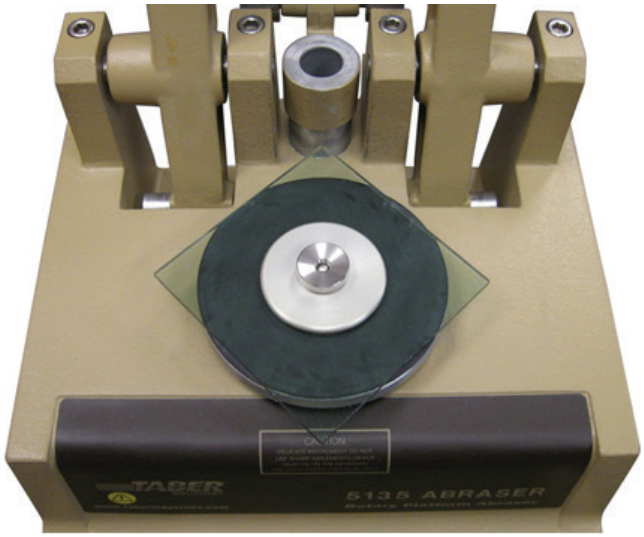


Figure 9 — Sample mounted at 45°

For each safety glazing material, carry out three tests with the same load of 500 g, unless otherwise specified.

Start the abraser and subject the specimen to abrasion for a selected number of cycles. For outside surfaces, subject the test piece to alternatively 100 cycles or 500 cycles or 1 000 cycles (depending on the specification of the material to be tested).

For inside surfaces, subject the test piece to 100 test cycles, using three new test specimens.

The abrasion test of safety glazing material shall be carried out under the same conditions as those which were used to condition the test specimens and abrasive wheels prior to the abrasion test.

11.5.5 After abrasion

After the abrasion test is done, handle test pieces by their edges to prevent contamination of their surfaces. Using a soft bristle, anti-static brush, lightly brush off any debris adhered to the surface of the test specimen or alternatively rinse the test piece with distilled, deionized or demineralised water. Clean the test specimen following the procedure described in 11.5.1.

After each test, inspect the vacuum nozzle for debris and clean as required by using a brush, vacuum cleaner or other suitable means.

11.5.6 Final haze measurement

Place the abraded test piece in the hazemeter sample holder with the abraded side facing the entrance port of the integrating sphere. Measure the light scattered by the abraded track (final haze) at a minimum of four equally spaced points along the track in accordance with Formula (5). If the abrasion track is not homogeneous, up to 16 equally spaced points along the track may be measured. Average the results for each test piece. The angle between the normal to the surface of the test piece and the axis of the beam shall not exceed 8°. In lieu of the four measurements, an average value may be obtained by rotating the piece uniformly at 3 r/s or more.

For all haze measurements, take the four readings indicated in Table 3.

Table 3 — Transmittance readings for abrasion resistance test

Reading	With test specimen	With light-trap	With reflectance standard	Quantity represented
τ_1	No	No	Yes	Incident light
τ_2	Yes	No	Yes	Total light transmitted by test specimen
τ_3	No	Yes	No	Light scattered by instrument
τ_4	Yes	Yes	No	Light scattered by instrument and test specimen

Repeat readings for τ_1, τ_2, τ_3 and τ_4 with additional specified positions of the test specimen to determine uniformity.

Calculate the total transmittance τ_t as follows:

$$\tau_t = \frac{\tau_2}{\tau_1} \tag{3}$$

Calculate the diffuse transmittance τ_d as follows:

$$\tau_d = \frac{\tau_4 - \tau_3\left(\frac{\tau_2}{\tau_1}\right)}{\tau_1 - \tau_3} \tag{4}$$

Calculate the percentage haze as follows:

$$\text{haze} = \frac{\tau_d}{\tau_t} \times 100 \tag{5}$$

11.6 Expression of results

Subtract the average initial haze from the average final haze, the difference representing the light scatter resulting from abrading the test specimen also called Δ haze.

Furthermore, the measured Δ haze value shall be corrected using a correction factor based on the value for the reference material tested with the same wheel pair.

Calculate the corrected delta haze value according to Formula (6):

$$\Delta\text{haze}_c(r) = \Delta\text{haze}_m(r) \times X_c(r) \tag{6}$$

where

Δhaze_c is the corrected delta haze value of a test specimen at a certain cycles number, r;

Δhaze_m is the delta haze value obtained by subtracting measured initial haze from measured final haze of the test specimen at a certain cycles number, r;

$X_c(r)$ is the correction factor of the wheel pair used to test above mentioned test specimen at the same cycles number, r.

The correction factor is determined twice during the life time of its wheel pair, at the beginning (at a wheel diameter of approximately 52 mm) and after half of its life time (at a wheel diameter of 48 mm). At the beginning, no additional measurement is necessary since the data of the wheel qualification can be used to calculate the correction factor.

If a new refacing stone is used during the "lifetime" of that wheel pair, the correction factor should be determined once more, provided that wheel pair has passed a new qualification as described in 11.2.1.2 (see also 11.2.1.3).

Calculate the correction factor for a certain wheel pair according to Formula (7):

$$X_c(r) = \frac{\Delta\text{haze}_{rv}(r)}{\Delta\text{haze}_{av}(r)} \tag{7}$$

where

Δhaze_{rv} is the delta haze reference value of the AS 4000S hard-coated polycarbonate reference sample at a certain cycles number.These fixed Δhaze_{rv} (r) values for the AS 4000S hard-coated polycarbonate reference samples are the mean values per cycles number obtained in the round robin test by those participating test labs which proved to use qualified wheels according to 11.2.1.2 (see Annex E);

Δhaze_{av} is the actual delta haze value of the AS 4000S hard-coated polycarbonate reference samples at a certain cycles number. These values are the mean values per cycles number actually determined for the respective wheel pair by testing three AS 4000S hard-coated polycarbonate samples per cycles number with this wheel pair.

The report shall indicate whether Illuminant A or Illuminant C has been employed. The number of abrasion cycles, the abraser load and the used correction factor shall also be reported.

11.7 Abrasion resistance under wet conditions (car wash test)

11.7.1 Apparatus

The apparatus[8)] shall comprise at least the following individual components.

11.7.1.1 **Washing brush**.

Diameter	(1 000 ± 40) mm
Width	300 mm minimum
Material	polyethylene
Profile	x-shaped, spliced
Bristle thickness	(0,8 ± 0,2) mm
Bristle length	(440 ± 20) mm visible
Penetration depth	(100 ± 20) mm (see Figure 10)

Speed of brush rotation is (127 ± 5) min^{-1}; the rotating direction is opposite to direction of travel of test panel holder.

As a result of their nature, polyethylene brushes are subject to constant change during use. The scratching effect becomes more pronounced after long periods of use, all other conditions remaining constant. Monitor the wear of the polyethylene brushes and replace if they have reached 30 operating hours or earlier if necessary.

8) A suitable apparatus is supplied by Amtec-Kistler GmbH in Germany. This information is given for the convenience of users of this International Standard 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.

11.7.1.2 Spray nozzles, made of stainless steel.

Spread of jet 65°

Water flow rate (2,2 ± 0,1) l/min at (300 ± 50) kPa

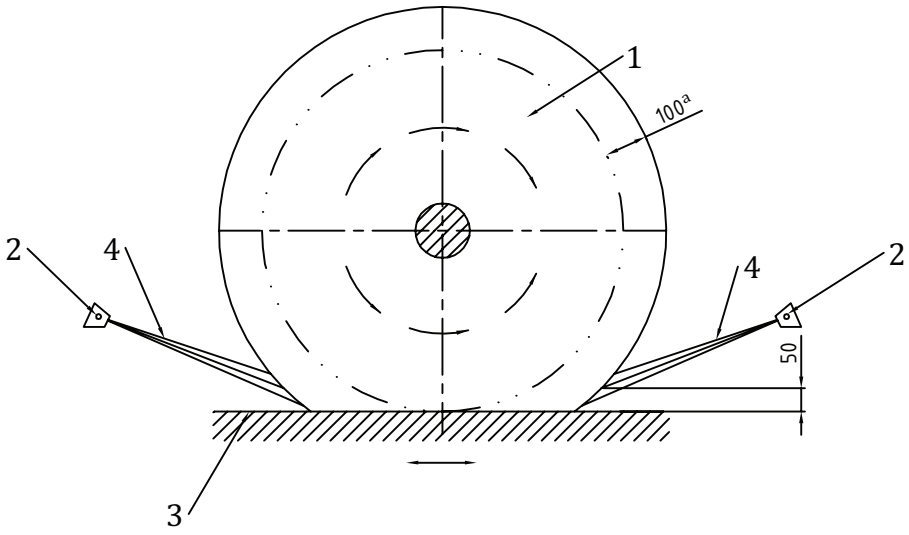
The two nozzles shall spray alternately and against the direction of travel of the test panel holder. They shall produce the specified spray pattern (see Annex C).

11.7.1.3 Test panel holder.

Feed speed (5 ± 0,2) m/min

Pattern of movement If the brush is rotating clockwise, the right nozzle is spraying and the test panel holder travels from the left side to right side (and vice versa), (see Figure 10).

Dimensions in millimetres

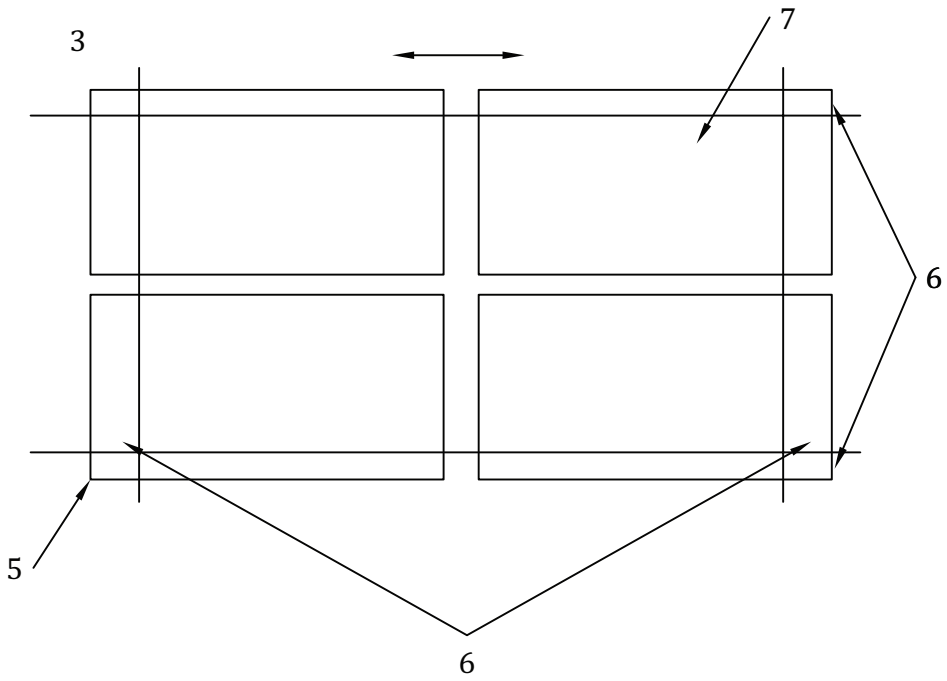


Key

1 brush
2 spray nozzle
3 test panel holder
4 spray jet (horizontal middle of the jet strikes the brush 50 mm above table directly in the brush)
a Penetration depth.

Figure 10 — Movement pattern of washing brush and nozzle

The test panel holder can carry four supporting plates each with a size of 150 mm × 300 mm leading to an area of 2 mm × 150 mm in width to 2 mm × 300 mm in length on the test panel holder which will be washed by the brush. Test specimen smaller than 150 mm × 300 mm can be fixed using double-faced adhesive tape onto these supporting plates (see Figure 11).



Key

3 test panel holder

5 supporting plate (150 mm × 300 mm)

6 area not used for testing (*at least* 30 mm edgewise to the direction of travel of the test-panel holder and *at least* 50 mm at the start and finish of the test panel-holder)

7 available position for test specimen to be fixed to one of the supporting plates (test area)

Figure 11 — Bird's eye perspective of the test panel holder including test area

11.7.2 Reagents

11.7.2.1 Washing suspension

Prepare a suspension consisting of (1,5 ± 0,05) g of silica powder (silica micro-powder having a mean particle size of 24 µm)[9] per litre of tap water in a suitable container, mixing it by stirring vigorously. Unless otherwise agreed, the water temperature shall be between 15 °C and 30 °C.

The suspension shall be stirred continuously during the test procedure in such a way that the silica powder does not settle on the bottom of the container as this would result in variations in the concentration.

NOTE The suspension can be reused once the test equipment has come to a standstill. However, it is essential that the suspension is stirred thoroughly again before being reused.

11.7.3 Test specimens

Test specimen shall be flat and free of deformations. An appropriate size for the test specimen is 100 mm × 100 mm with the same thickness as the corresponding safety glazing part.

9) Such as Sikron SH200 from Quarzwerke GmbH in Germany. This information is given for the convenience of users of this International Standard 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.

11.7.4 Procedure

The abrasion test shall be carried out at room temperature and only on the outside surface of the plastic safety glazing material.

Determine the initial haze of the safety glazing material as described in 11.5.4.

Monitor the total amount of operating hours in use for the polyethylene brush and replace the brush as soon as 30 operating hours are reached or earlier if necessary. 30 h equates around 300 test runs since one test takes around 6 min. The amount of operating hours should be reported with the haze increase result of the test specimen.

Do the instrument calibration as described in Annex C on a regular basis. Furthermore, perform a trial run without a test panel, carrying out 10 washing operations (10 double passes) before starting a test sequence, to distribute the suspension evenly in the apparatus.

An area of at least 50 mm at the start and finish of the test panel holder and of at least 30 mm edgewise to the direction of travel of the test panel holder may not be used as testing area for the test specimen. Position the test specimen with the outside surface face up on the test jig (in case of test specimen smaller than 150 mm × 300mm they can be fixed by using a double-faced adhesive tape onto one of the supporting plates which can be positioned on the test jig) and carry out 10 washing operations (10 double passes) unless specified otherwise, using the to-and-fro pattern of movement shown in Figure 10.

Rinse the washed test specimen with cold water, then clean it with a suitable solvent, e.g. Isopropyl alcohol (IPA), using soft, non-scratching paper tissues and wiping in the direction of the scratches. Finally, leave for 10 min to dry off. This process is designed to remove all residues of silica powder, and any fibres from the brush. In case of any inhomogeneous surface appearance of the test specimen repeat this cleaning process to ensure complete removal of any residue.

After drying, take the final readings of haze as described in 11.5.6 of the test specimens across the direction of scratching.

If the test equipment is not to be used for some time (more than 8 h), it is recommended that it be rinsed thoroughly, particularly the brushes, with tap water.

11.7.5 Expression of results

Subtract the average initial haze from the average final haze, the difference representing the light scatter resulting from washing the test specimen also called Δhaze. The report shall indicate whether Illuminant A or Illuminant C has been employed. The number of washing operations (double passes) shall also be reported.

12 Cross-cut test

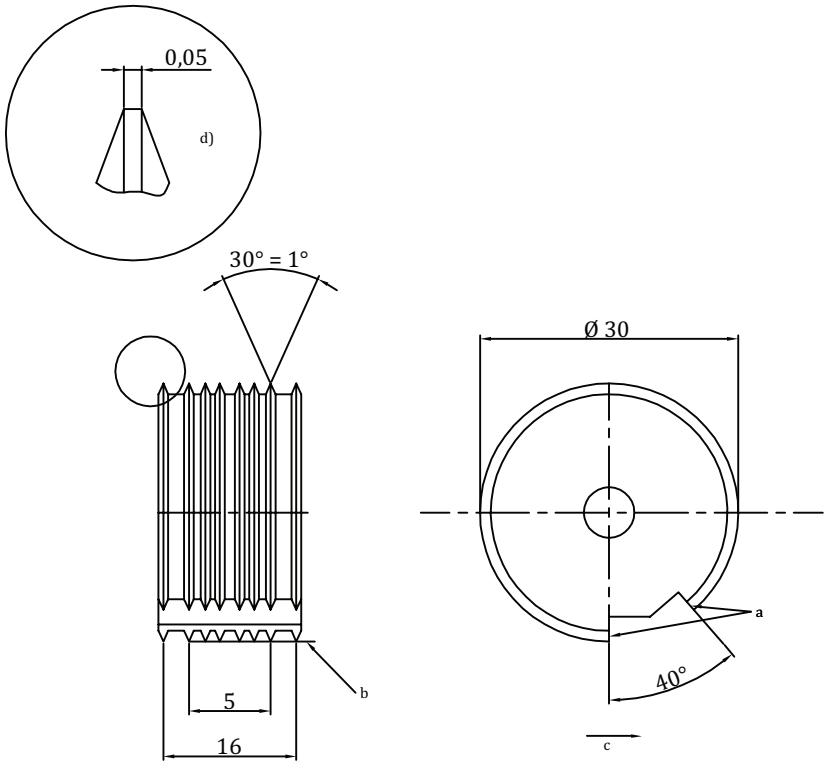
12.1 Principle

Determination of whether the coating of a coated plastic safety glazing material has a certain minimum adhesion to the subsurface at ambient temperature.

12.2 Apparatus

Cutting tool consisting of an array of six cutting edges (blades) at a distance of 1 mm to one another, framed by two guide edges (see Figure 12).

Magnifying glass with a magnification of two times to examine the cross-cut specimen.



Key

a Cutting edges.

b Direction of cut.

c It is essential that the guide edges and the cutting edges lie on the same diameter.

Figure 12 — Cutting tool with eight edges (blades) of identical shape: Six cutting edges and two (outer) guide edges, shown in detail eight times magnified

12.3 Test specimens

The test specimens may be of any given shape, flat or curved, but large enough in order to apply the grid-cut pattern according to 12.4.

The cross-cut test may optionally be carried out on test specimens exposed to simulated weathering conditions according to Clause 14.

12.4 Procedure

Cut through the coating on to the subsurface a pattern of six parallel cuts; then cut another such pattern perpendicularly to the first pattern so that a grid of 25 squares arises (grid cut).

NOTE The cuts produced by the two guide edges are not part of the grid area to be evaluated but only a result of correct tool handling.

The cutting tool shall be drawn steadily with a speed of 2 cm/s to 5 cm/s so that the cuts reach the subsurface but do not penetrate too deeply. The cutting is conducted in such a way that the two guide edges touch the surface of the test specimen uniformly.

After the cuts have been produced they are brushed five times with slight pressure in both diagonal directions using a hand brush with polyamide bristles. The cuts are examined with a magnifying glass in order to check that they reach the subsurface.

The test is carried out at least at two different positions on the specimen.

12.5 Expression of results

The grid cuts are examined by means of the magnifying glass. If the cuts are perfectly smooth and if no part of the coating is detached, the test result is expressed as a cross-cut value of Gt0.

If there are small fragments of the coating detached at the intersections of the cuts and if the exposed area amounts to about 5 % of the total grid area, the cross-cut value is Gt1. Larger areas of detachment are graded in the range Gt2 to Gt5 according to Table4.

Table 4 — Definition of cross-cut values

Cross-cut value	Exposed area (in percent of grid area)
Gt0	none (0 %)
Gt1	between 0 % and 5 %
Gt2	between 5 % and 15 %
Gt3	between 15 % and 35 %
Gt4	between 35 % and 65 %
Gt5	higher than 65 %

13 Chemical resistance test

13.1 Principle

This test method evaluates the resistance of plastic safety glazing materials to various solvents and cleaners at ambient temperature.

13.2 Chemical agents

1 % solution by weight of a non-abrasive soap in deionised water (i.e. potassium oleate or equivalent).

Gasoline or equivalent reference fuel composition, i.e. ASTM Reference Fuel C.

ASTM Reference Fuel C is composed of Isooctane 50 volume percentage and Toluene 50 volume percentage. Isooctane shall conform to A 2.7 in Annex 2 of the Motor Fuels Section of the 1985 Annual Book of ASTM Standards Vol. 05.04 and Toluene shall conform to ASTM specification D362–84, Standard Specification for Industrial Grade Toluene.

Kerosene, No. K-1 or K-2 (as defined by ASTM D3699-92 Standard Definitions for Kerosene, JIS K-2203) or equivalent.

Denatured alcohol, one part 100 % methyl alcohol to 10 parts 95 % ethyl alcohol by volume.

Commercial windshield cleaner, An aqueous solution of isopropanol and glycol ether solvents in concentration no greater than 10 % or less than 5 % by weight each and ammonium hydroxide no greater than 5 % or less than 1 % by weight each, simulating typical commercial windshield cleaner.

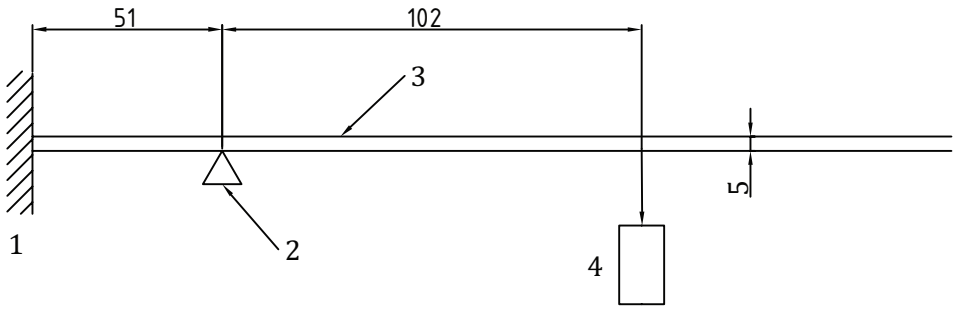
13.3 Test specimens

Test specimens shall be flat, 25 mm wide × 180 mm long.

13.4 Test procedure

The test specimen shall be simply supported as a horizontal lever arm between a fixed supporting edge at one end in such a way that the entire width will rest on a cutting edge (fulcrum) which is 51 mm from the fixed end support. A load shall be suspended from the free end of the test specimen at a distance of 102 mm from the fulcrum as shown in Figure 13.

Dimensions in millimetres



Key

1 fixed end
2 fulcrum point
3 specimen
4 load
5 plate thickness

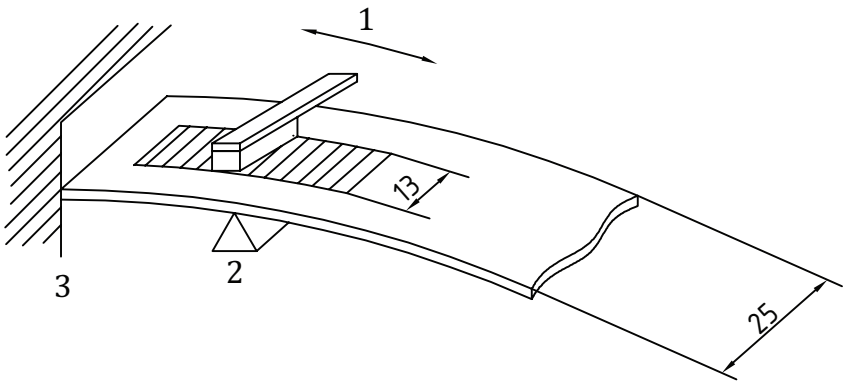
Figure 13 — Method of setting up the test specimen

The load mass shall be 28,7 t2 g where t is the thickness in millimetres of the test specimen. The resulting stress on the outer fibre of the test specimen is approximately 6,9 MPa.

EXAMPLE For a 3 mm thick test specimen placed horizontally between a downward fixed edge and an upward fulcrum edge separated by 51 mm, the applied downward load at 102 mm from the fulcrum is to be 258 g.

While the test specimen is stressed, one of the prescribed chemicals shall be applied to the top surface of the test specimen above the fulcrum point. The chemical shall be applied with a soft, 13 mm wide brush, wetted before each stroke. Ten individual strokes at 1 s intervals across the width of the test specimen, avoiding the end and edges, shall be required (see Figure 14).

Dimensions in millimetres



Key

1 direction of application
2 fulcrum point
3 fixed end

Figure 14 — Method of applying chemicals to the test specimen

One minute after the last stroke, the test specimen shall be wiped dry with clean absorbent cotton and immediately examined visually for any change in physical appearance while in the stressed state.

13.5 Expression of results

Identify each of the chemical agents used by recording the actual composition or standard reference material. Examine each of the test specimens tested and note any evidence of surface defects, tackiness, crazing, cracks or loss of transparency. For each of the chemical agents used, record the number of test specimens tested.

14 Resistance to simulated weathering test

14.1 Principle

Determination of whether plastic safety glazing materials will successfully withstand exposure to simulated weathering conditions.

14.2 Exposure apparatus

14.2.1 Long arc xenon lamp

The exposure apparatus[10)] shall use a long arc xenon lamp as the source of irradiation, which shall comply with relative spectral irradiance in ISO 4892-2:2013, 4.1.2, method A (artificial weathering).

The long arc xenon lamp is advantageous in that it can, when correctly filtered and maintained, yield a spectrum closely approximating that of natural sunlight. To this end, the quartz xenon burner tube shall be fitted with suitable borosilicate glass optical filter(s)[11)]. The xenon lamps employed shall be

10) Such as Atlas Ci Series and Xenotest Series Alpha or Beta, or Suga X Series. These are tradenames. This information is given for the convenience of users of this International Standard 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.

11) Borosilicate glass filters such as Atlas Xenochrome 300 and Suga Quartz #275/#295 have been found satisfactory. These are tradenames. This information is given for the convenience of users of this International Standard 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.

operated, from a suitable 50 Hz or 60 Hz power supply, through suitable reactance transformers and electrical equipment.

14.2.2 Measurements

The exposure apparatus shall include equipment necessary for measuring and/or controlling the following:

a) irradiance;

b) black standard temperature;

c) water spray;

d) operating schedule or cycle.

The exposure apparatus shall be made from inert materials, which do not contaminate the water employed in the test.

Irradiance shall be measured at the test specimen surface and shall be controlled according to the recommendation of the exposure apparatus manufacturer.

Total ultraviolet radiant exposure, in joules per square metre, shall be measured or computed and shall be considered the primary measure of test specimen exposure.

NOTE Total ultraviolet is considered to be all radiation of wavelength less than 400 nm.

14.3 Test specimens

The dimensions of the test specimens shall normally be those specified in the appropriate test method for the property or properties to be measured after exposure.

The number of control and test specimens for each test condition or exposure stage shall be determined, in addition to those required for visual evaluations specified in 14.5, by the number required by the test methods.

It is recommended that visual evaluations be conducted on the largest test specimens tested.

14.4 Procedure

Measure in accordance with the ISO 3538, the luminous transmission of the test specimens to be exposed. Measure, in accordance with the abrasion resistance test specified in Clause 11, the resistance to abrasion of both faces of the control specimens.

That face of each test specimen which would represent the surface mounted to the outside of the vehicle shall face the lamp.

NOTE It is not necessary to condition test specimens prior to exposure in this test as the test itself includes special conditions.

Other exposure conditions shall be as follows.

In accordance with ISO 4892-2, the irradiance shall not vary more than +10 % over the whole test specimen area.

At appropriate intervals, clean lamp filters by washing with detergent and water. Xenon arc filters shall be replaced according to the recommendations of the equipment manufacturer.

14.4.1 Temperature

Within the exposure apparatus during the dry portion of the cycle, the temperature shall be controlled by circulation of sufficient air to maintain a constant black standard temperature.

This temperature shall be 70 °C ± 3 °C [as indicated by a Black Standard Thermometer[12)] or equivalent]. The thermometer is preferably mounted on a support for a test panel in such a way that it receives the same radiation and cooling conditions as a flat test panel surface on the same support. It may also be located at a fixed distance position different from the test specimen distance and calibrated for temperature at the test specimen distance.

14.4.2 Relative humidity

Within the exposure apparatus, the relative humidity shall be controlled at (50 ± 5) % during the dry portions of the cycle.

The deionized water used in the spray cycle shall contain less than 1 µg/ml silicon dioxide solids and shall leave no permanent deposit or residue on the test specimens which would interfere with subsequent measurements.

12) The Black Standard Thermometer (BST) is defined in ISO 4892-1.

14.4.3 Water

a) The pH of the water shall be between 6,0 and 8,0 and the conductivity shall be less than 5 µS.

b) The temperature of the water in the line where it enters the exposure apparatus shall be the ambient water temperature.

The water shall strike the test specimens in the form of a fine spray in sufficient volume to wet the test specimens uniformly, immediately upon impact.

Water spray will be directed only against the test specimen surfaces facing the light source. No recirculation of the spray water or immersion of the test specimens in the water shall be permitted.

The test specimens shall be rotated about the arc in order to provide uniform distribution of the light. All positions in the exposure apparatus shall be filled with test specimens or surrogates to ensure that a uniform temperature distribution is maintained. Test specimens shall be held in frames with backs exposed to the cabinet environment. However, reflections from cabinet walls shall not be permitted to strike the back surface of test specimens. If necessary, test specimens may be backed to block such reflections; the backing shall not be in direct contact with the test specimen and shall not impede the free circulation of air at the test specimen surface.

The exposure apparatus shall be operated to provide continuous light and intermittent water spray in 2 h cycles. Each 2 h cycle, in accordance with ISO 4892-2, shall be divided into periods during which the test specimens are exposed to light without water spray for 102 min and to light with water spray for 18 min.

14.5 Evaluation

After exposure, the test specimens may be cleaned, if necessary, by a practice recommended by their manufacturer to remove any residues present.

Evaluate the exposed test specimens visually with respect to the following properties:

a) bubbles;

b) colour[13)];

c) haze;

d) noticeable decomposition.

Measure on separate test specimens, in accordance with the abrasion resistance test, specified in Clause 11, the resistance to abrasion of the exposed test specimens on both sides, and in accordance with ISO 3538 the luminous transmission of one of the test specimens.

14.6 Expression of results

Report visual evaluations of exposed test specimens, comparing the appearance of each with that of the unexposed control specimens. If colour is measured instrumentally, compute the colour change.

Report the changes in luminous transmittance and the changes in resistance to abrasion, comparing results of tests on exposed test specimens with results of tests on unexposed control specimens. Note whether the side tested was facing toward or away from the lamp.

14.7 Report of test parameters

Report the following:

a) apparatus manufacturer;

13) Colour change can be evaluated optionally by a method given in CIE 15.2.

b) radiation intensity in watts per square metre at 340 nm;

c) exposure time, in hours; or no. of 2 h-cycles;

d) total ultraviolet radiant exposure, in joules per square metre.

15 Fire resistance test

Alternatively, the apparatus and method described in ISO 3795 may be used.

15.1 Principle

The purpose of this test is to determine the horizontal burning rate of safety glazing materials, of which at least one surface is plastic, after exposure to a small flame.

15.2 Apparatus

15.2.1 The test shall be conducted in a **laboratory hood or draft-free enclosure** greater than 0,5 m^3 in size and provided with a means for venting the fumes from burning test specimens samples.

If a hood is used, its exhaust fan will be turned off during the test but allowed to run periodically to clear out the fumes between tests.

15.2.2 The test specimen shall be clamped in **a suitable holder support**, at the end farthest from the 25 mm mark, with its longitudinal axis horizontal and its transverse axis inclined at 45° to the horizontal.

The specimen is held with the plastic surface downward, facing the flame.

15.2.3 Under the test specimen, there shall be clamped a 20 mesh per 25,4 mm **Bunsen burner gauze**, about 125 mm square, in a horizontal position 6 mm below the edge of the test specimen and with about 13 mm of the test specimen extending beyond the edge of the gauze as illustrated in Figure 15.

15.2.4 The flame is provided by a **Bunsen burner**.

The gas supplied to the burner shall have a caloric value of about 38 MJ/m^3 (for example, natural gas).

15.3 Test specimens

At least three 150 mm × 13 mm flat test samples specimens shall be tested. The test specimens shall be marked by inscribing two lines, 25 mm and 100 mm from one end of each specimen.

The specimens shall be conditioned for at least 48 h, at a temperature of 23 °C ± 2 °C and a relative humidity of 50 % ± 5 %, and shall be maintained under these conditions until immediately prior to the test.

15.4 Test procedure

A Bunsen burner with a stable, blue, gas flame 12 mm to 20 mm in height shall be placed under the free end of the test specimen and adjusted so that the flame tip is just in contact with the test specimen.

At the end of 30 s, the flame shall be removed and the test specimen allowed to burn.

A stop watch shall be started when the flame reaches the first mark, 25 mm from the free end, and the time recorded when the flame reaches the 100 mm mark. In case the test specimen does not continue to burn after the first ignition, the burner shall be placed under the free end for a second period of 30 s immediately following extinction of the flame burning.

15.5 Expression of results

The horizontal burning rate of each test specimen, as well as the average of all specimens tested, shall be recorded in millimetres per minute according to the Formula (8):

$$B = \frac{s}{t} \times 60 \tag{8}$$

where

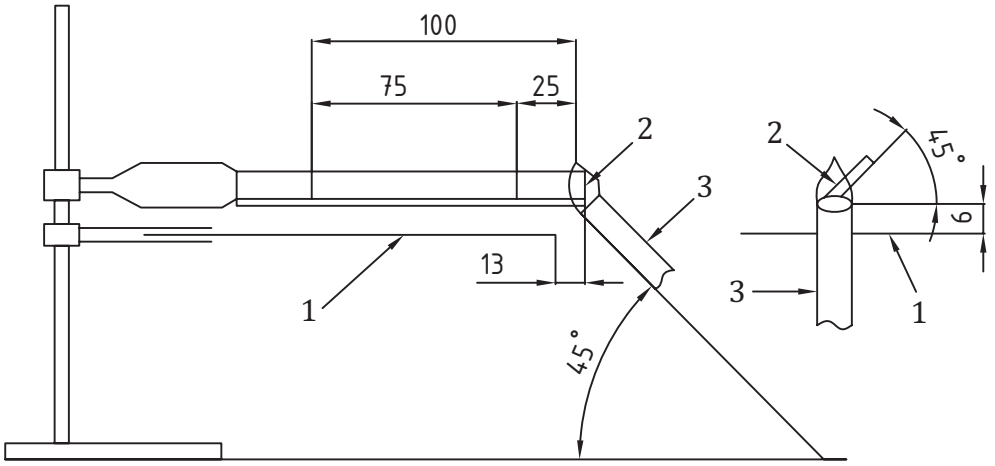
s is the burnt distance in millimetres;

t is the time in seconds, taken to burn the distance s.

If the specimen does not ignite or does not continue to burn, reaching the first mark, after the gas flame has been removed, a burning rate of 0 mm/min shall be reported.

If a test specimen does not continue burning to the 100 mm mark after a second ignition with the gas flame, it shall be reported as non-sustaining.

Dimensions in millimetres



Key

1 wire gauze
2 test specimen
3 burner

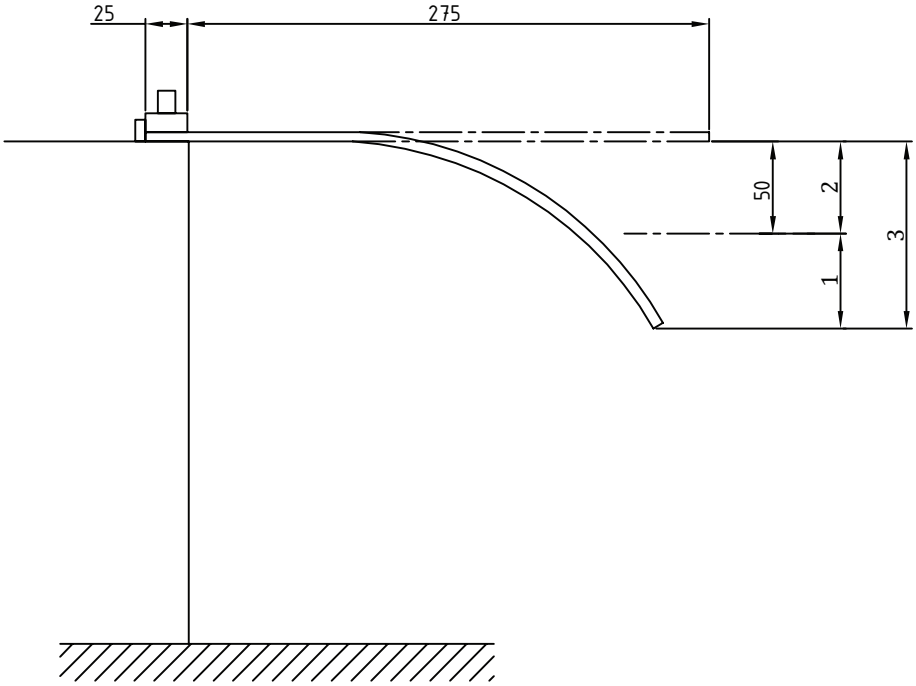
Figure 15 — Horizontal burning test

Annex A
(informative)

Flexibility/rigidity categorization test for plastic safety glazing material

Condition a 300 mm × 25 mm test specimen of the material to be categorized in accordance with Clause 5. Horizontally clamp the test specimen at one end, and allow it to bend freely under its own weight (see Figure A.1) at the test conditions in accordance with Clause 4.

Dimensions in millimetres



Key

1 flexible
2 rigid
3 displacement

Figure A.1 — Arrangement of flexibility/rigidity test

If the deflection from horizontal is less than or equal to 50 mm after 60 s, the material shall be categorized as rigid. If the deflection is greater than 50 mm after 60s, the material shall be categorized as flexible.

Annex B
(informative)

Vacuum pick-up nozzle modification

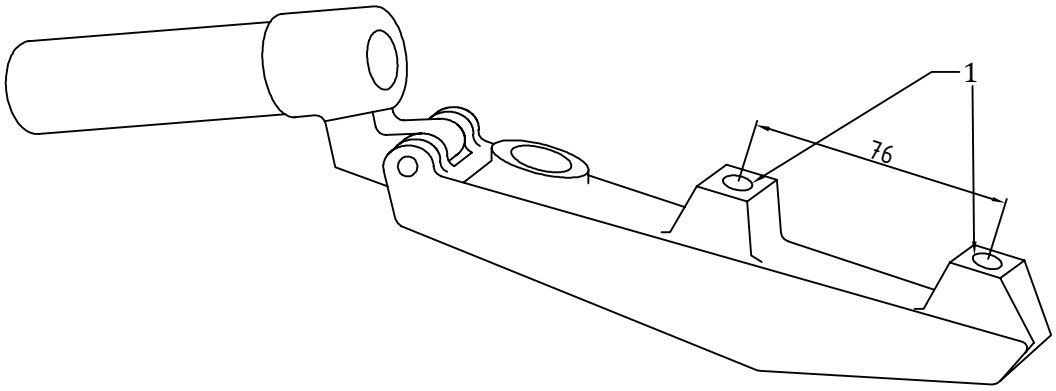
The vacuum pick-up nozzle referenced in this test method has a larger diameter hole bore than the standard nozzle, 11 mm versus 8 mm. A replacement nozzle is available, or the user can modify the vacuum nozzle according to the following instructions.

1) Secure the nozzle with the opening aligned under the drill bit so that the drilled hole is perpendicular to the hole axis.

2) Use an 11 mm drill bit, enlarge the hole taking care not to drill completely through the vacuum pick-up nozzle.

3) Repeat for the second hole so that the distance between the axes of the two openings is 76,0 mm ± 1,0 mm (see Figure B.1).

4) Remove any burrs prior to use.



Key

1 enlarge (2) holes from 8 mm diameter to 11 mm diameter

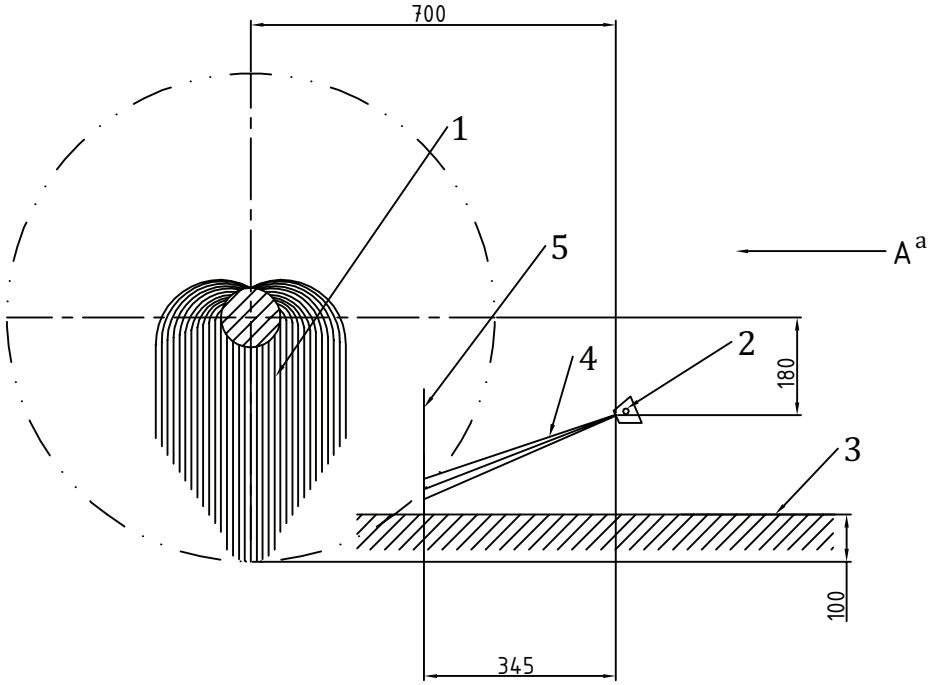
Figure B.1 — Schematic of modified vacuum pick-up nozzle

Annex C
(normative)

Calibration of the washing equipment

Set up the equipment as shown in Figure C.1. Fill with washing suspension (11.7.2.1) and wet the brush sufficiently. Confirm the flow rate of the water, (2,2 ± 0,1) l/min, by measurement and adjust by altering the pressure, (300 ± 50) kPa. Check the spray pattern of the nozzles (see Figure C.2). If the spray pattern cannot be achieved or if the pressure regulation exceeds the tolerances, check, and if necessary replace, the nozzles.

Dimensions in millimetres

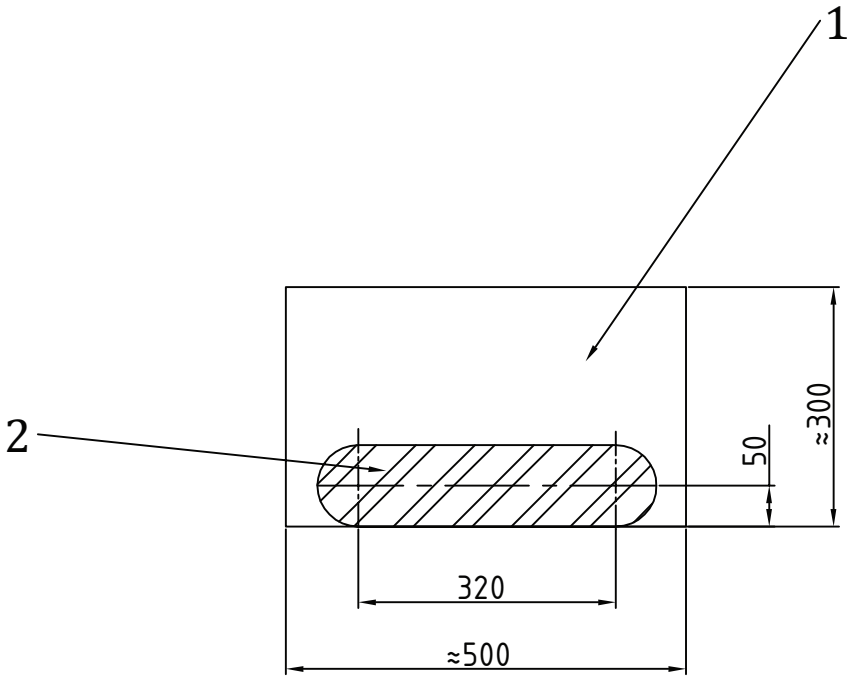


Key

1 brush
2 spray nozzle
3 test panel holder
4 spray jet
5 sheet of cardboard
a View A (see Figure C.2).

Figure C.1 — Calibration arrangement

Dimensions in millimetres



Key

1 sheet of cardboard

2 spray pattern

Figure C.2 — View A of spray pattern

Annex D
(informative)

Calibration verification of Taber abraser

D.1 Verification of calibration of the Taber abraser

To facilitate the verification of calibration of the Taber abraser, a kit is available from the manufacturer that provides a fast reliable system check. This kit is not meant as a substitute for regular instrument calibration. Procedures in the kit allow the user to verify the following.

D.1.1 Wheel alignment and tracking

The wheels should be spaced equally on both sides from the wheel-mounting flange to the centre of the specimen holder. When resting on the specimen, the wheels will have a peripheral engagement with the surface of the specimen, the direction of travel of the periphery of the wheels and of the specimen at the contacting portions being at acute angles, and the angles of travel of one wheel periphery being opposite to that of the other. Wheel internal faces shall be 52,4 mm ± 1,0 mm apart and the hypothetical line through the two spindles shall be 19,05 mm ± 0,3 mm away from the central axis of the turntable (see Figure D.1).

D.1.2 Wheel bearings condition

The Taber abraser wheel bearings should be able to rotate freely about their horizontal spindles and not stick when the wheels are caused to spin rapidly by a quick driving motion of the forefinger.

D.1.3 Vacuum suction force

Air pressure in the suction device shall have a residual pressure of 13,7 kPa (137 millibar) or lower, as measured by a suction gauge.

Vacuum suction force may be influenced by the condition of the collection bag, which shall be emptied or replaced on a regular basis. Clean any debris that collects on the inside of the vacuum pick-up nozzle on a frequent basis. Any connection or seal leaks will also influence suction force.

D.1.4 Turntable platform position

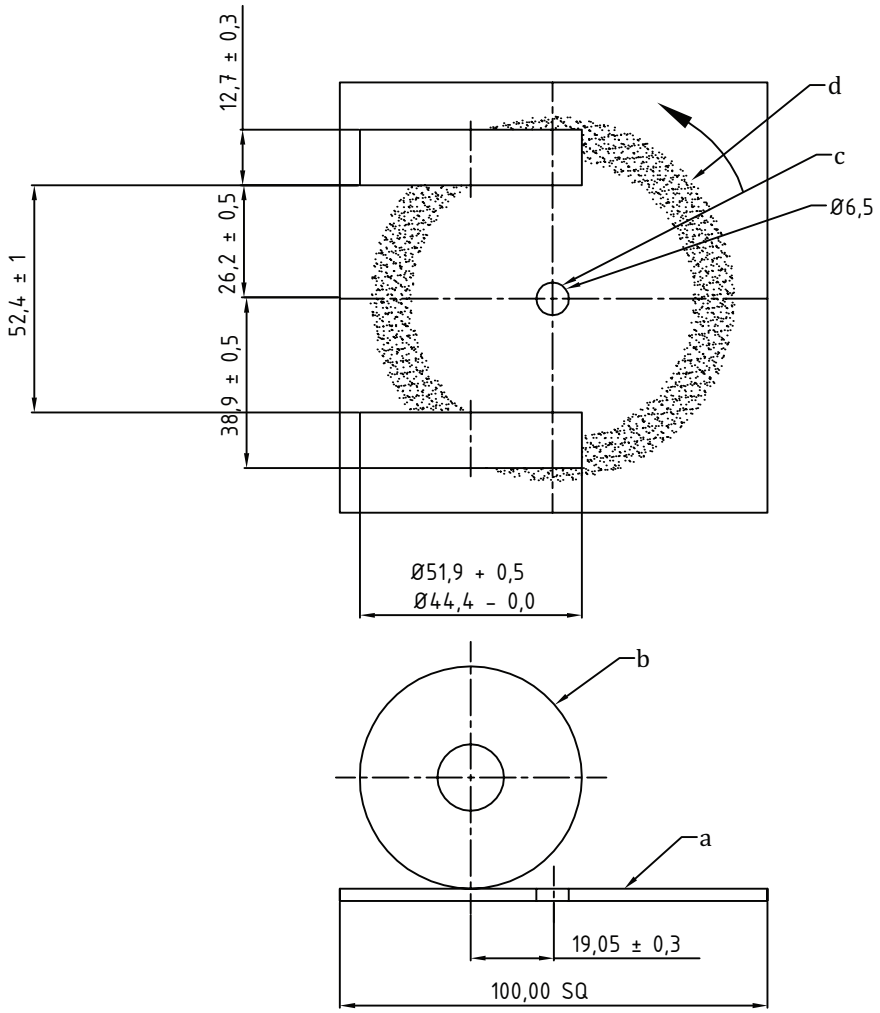
The vertical distance from the centre of the pivot point of the Taber abraser arms to the top of the turntable platform should be approximately 25 mm. The turntable platform shall rotate substantially in a plane with a deviation at a distance of 1,6 mm from its periphery of not greater than ±0,051 mm.

D.1.5 Turntable speed

The turntable should rotate at the speed 60 r/min ± 2 r/min or 72 r/min ± 2 r/min.

D.1.6 Load

The accessory mass marked 500 g shall weigh 250 g ± 1 g and the accessory mass marked 1 000 g shall weigh 750 g ± 1 g.



Key

a test specimen
b abrasive wheel
c center hole
d wear zone

Figure D.1 — Diagrammatic arrangement of Taber Abraser test set-up

Annex E
(informative)

Round robin test results to determine values for AS 4000S hard-coated polycarbonate reference samples in the Taber abrasion test

In 2013 the Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 11, *Safety glazing materials* conducted a round robin test using AS 4000S hard-coated polycarbonate reference samples (see 11.2.1.2) involving nine test laboratories. Each laboratory used six replicates (half of these replicates have been abraded using the same Taber CS-10F wheel lot in all laboratories, while the others have been abraded with different CS-10F wheel lots among the laboratories) for each cycle condition.

Each laboratory used the test conditions described in this document (see Clause 11).

The statistical evaluation was done according to ISO 5725-2. The results are summarized in Table E.1.

Table E.1 — Statistical results of the round robin test used to determine the qualification ranges for the wheels

Cycles no.	Mean Δ haze	Standard deviation	Repeatability standard deviation, s_r	Reproducibility standard deviation, s_R	Repeatability $r = (2{,}8\ s_r)$	Reproducibility $R = (2{,}8\ s_R)$
100	1,270 5	0,540 3	0,424 8	0,665 0	1,19	1,86
500	3,352 1	1,298 6	0,769 0	1,476 2	2,15	4,13
1 000	4,173 8	1,411 9	0,876 4	1,622 8	2,45	4,54
Note All statistical values refer to Δ haze in % (see 11.6).						

All data from wheel pairs used by test laboratories which were not able to yield results for the AS 4000S hard-coated polycarbonate reference samples with their wheels in between the ranges given by the 95 % confidence intervals (total range width 4 S_R) for the different cycles numbers (i.e. the wheel qualification requirement was not met, see 11.2.1.2) were discarded. A re-evaluation of the round robin test results then leads to the following results.

Table E.2 — Statistical results of the round robin test used to determine the correction factors Xc(r) according to Formula (7) required to correct the measured values of test specimens according to Formula (6), (see 11.6)

Cycles no.	Qualification range for the wheels in Δ haze in %	No. of test laboratories with qualified wheels	Mean Δ haze of all data from laboratories with qualified wheels in %	Δ haze reference value for AS 4000S hard-coated polycarbonate reference samples in %	Correction factor X_c
100	0 – 2,6	7	1,061 2	1,1	$1{,}1/\Delta haze_{av}(100)$
500	0,5 – 6,3	7	2,827 3	2,8	$2{,}8/\Delta haze_{av}(500)$
1 000	1,0 – 7,4	7	3,655 8	3,7	$3{,}7/\Delta haze_{av}(1000)$

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[2] ISO 4892-1:1999, *Plastics — Methods of exposure to laboratory light sources — Part 1: General guidance*

[3] CIE 15.2, *Colorimetry*

[4] ISO 3536, *Road vehicles — Safety glazing materials — Vocabulary*

[5] ISO 3795, *Road vehicles, and tractors and machinery for agriculture and forestry — Determination of burning behaviour of interior materials*

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[7] ISO 3917, *Road vehicles — Safety glazing materials — Test methods for resistance to radiation, high temperature, humidity, fire and simulated weathering*

[8] ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method (ISO 5725-2:1994 including Technical Corrigendum 1:2002)*

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