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Glass in building — Tempered soda lime silicate safety glass

Verre dans la construction — Verre silico-sodo-calcique de sécurité trempé

Reference number
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Foreword

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

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Introduction

Tempered soda lime silicate safety glass has a breakage behaviour that is different to annealed glass. This behaviour is a direct result of the high surface pre-stress.

Tempered soda lime silicate safety glass has a known behaviour under accident human impact together with known mechanical and thermal stress resistance.

NOTE 1 ISO/TC 160/SC 2 produces standards for the determination of the design strength of glass and is preparing a design method.

NOTE 2 In Europe, the term "thermally toughened" is used instead of "tempered".

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Glass in building — Tempered soda lime silicate safety glass

1 Scope

This document covers product definitions, product characteristics, i.e. tolerances, flatness, edgework, etc., fracture characteristics, including fragmentation, and the physical and mechanical characteristics of flat tempered soda lime silicate safety glass for use in buildings.

This document does not cover curved (bent) glass according to ISO 11485.

Other requirements, not specified in this document, can apply to thermally toughened soda lime silicate safety glass which is incorporated into assemblies, e.g. laminated glass or insulating glass units, or undergo an additional treatment, e.g. coating. The additional requirements are specified in the appropriate glass product standard. Thermally toughened soda lime silicate safety glass, in this case, does not lose its mechanical or thermal characteristics.

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 1288-3, *Glass in building — Determination of the bending strength of glass — Part 3: Test with specimen supported at two points (four point bending)*

ISO 11479-1, *Glass in building — Coated glass — Part 1: Physical defects*

ISO 16293-1, *Glass in building — Basic soda lime silicate glass products — Part 1: Definitions and general physical and mechanical properties*

ISO 16293-2:—[1], *Glass in building — Basic soda lime silicate glass products — Part 2: Float glass*

ISO 16293-5:—[1], *Glass in building — Basic soda lime silicate glass products — Part 5: Patterned glass*

ISO 29584, *Glass in building — Pendulum impact testing and classification of safety glass*

3 Terms and definitions

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

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

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

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

3.1
flat tempered safety glass
tempered (thermally toughened) glass which has not been deliberately given a specific profile during manufacture

1) Under preparation.

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3.2
enamelled tempered safety glass
tempered (thermally toughened) glass which has a ceramic frit fired into the surface during the tempering (toughening) process

Note 1 to entry: After tempering, the ceramic frit becomes an integral part of the glass.

Note 2 to entry: The application of the ceramic frit may be by a continuous application or discontinuous, e.g. screen printing.

3.3
horizontal process
process in which the glass is supported on horizontal rollers

3.4
air cushion process
process in which the glass is supported by an air cushion with or without additional rollers

Note 1 to entry: In this process, the glass will be between horizontal and 45° of horizontal.

3.5
vertical process
process in which the glass is suspended by tongs

3.6
edge deformation
deformation of the edge caused by the tong marks

3.7
edge lift
distortion produced in horizontally tempered safety glass, at the leading and trailing edge of the plate, as a result of the glass during the tempering (toughening) process not being supported by a roller

Note 1 to entry: This is a distortion produced by a deviation from surface flatness.

Note 2 to entry: Also referred to as edge dip.

3.8
perimeter deformation
distortion around the edge of tempered safety glass manufactured by air cushion process

3.9
local distortion
local deformation of vertically tempered safety glass underneath the tong marks

3.10
overall bow
deformation of the whole pane of tempered safety glass caused by the heating and cooling process

3.11
roller wave distortion
periodic distortion produced in horizontally tempered safety glass as a result of the glass during tempering process being in contact with the rollers

Note 1 to entry: This is a surface distortion produced by a reduction in surface flatness.

3.12
wave distortion
distortion in tempered safety glass manufactured by the air cushion process as a result of the tempering process

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4 Glass products

Tempered safety glass is made from a monolithic glass generally corresponding to one of the following standards:

— basic soda lime silicate glass products according to ISO 16293-1;

— float glass according to ISO 16293-2;

— patterned glass according to ISO 16293-5;

— coated glass according to ISO 11479-1.

NOTE For drawn sheet glass, an ISO standard is not available. Therefore, see EN 572–4 or national standards.

Other nominal thicknesses of glass than those covered in the above standards are possible.

5 Fracture characteristics

5.1 General

In the event of breakage, tempered safety glass fractures into numerous small pieces, the edges of which are generally blunt.

Fragmentation in service may not correspond exactly to that described in Clause 8, due to restraint from fixing and external actions or due to the cause of fracture.

There can be different fragmentations if heat-strengthened glass is used in laminated glass.

5.2 Accidental human impact

5.2.1 When subjected to an accidental human impact, tempered safety glass will either not break or break in a manner that will reduce the risk of cutting and piercing injuries.

5.2.2 Tempered safety glass can be classified by the use of a pendulum impact test. When tested by this type of test, the safe breakage criteria employed for tempered safety glass is that the 10 largest crack free particles collected within 3 min after impact shall weigh no more than the mass equivalent of 6 500 mm^2 of the original test piece.

5.2.3 The quoted break criteria is taken from the standards given in Annex A. Annex A lists the test methods presently employed to classify this product.

NOTE The safe breakage criteria are different from the fragmentation criteria used to determine that the product complies with its definition.

5.3 Fragmentation

This test method is employed to demonstrate that the tempered safety glass breaks in the manner expected of this product. The fragmentation test (see Clause 8) details the minimum number of crack-free particles that shall be in a set area, i.e. 50 mm × 50 mm, and the dimension of the largest acceptable splinter.

This fragmentation behaviour ignores any influence of support conditions and is a representation of the effect of the surface pre-stress.

These properties are not size dependent.

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6 Dimensions and tolerances

6.1 Nominal thickness and thickness tolerances

The nominal thicknesses and thickness tolerances are those given in the relevant product standards (see Clause 4).

Table 1 — Nominal thicknesses and tolerances

Nominal thickness mm	Float glass tolerances mm	Patterned glass tolerances mm
2	±0,2	Not manufactured
3	±0,3	±0,5
4	±0,3	±0,5
5	±0,3	±0,5
6	±0,3	±0,5
8	±0,6	±0,8
10	±0,6	±1,0
12	±0,8	±1,5
15	±0,8	±1,5
19	±1,2	±1,5
22	±1,2	±2,0
25	±1,2	Not manufactured

The thickness of a pane shall be determined as for the basic product. The measurement shall be taken at the centre of the four sides, and away from the area of any tong marks (see Figure 2), which may be present.

6.2 Width and length (sizes)

6.2.1 General

When tempered safety glass dimensions are quoted for rectangular panes, the first dimension shall be the width, *B*, and the second dimension the length, *H*, as shown in Figure 1. It shall be made clear which dimension is the width, *B*, and which is the length, *H*, when related to its installed position.

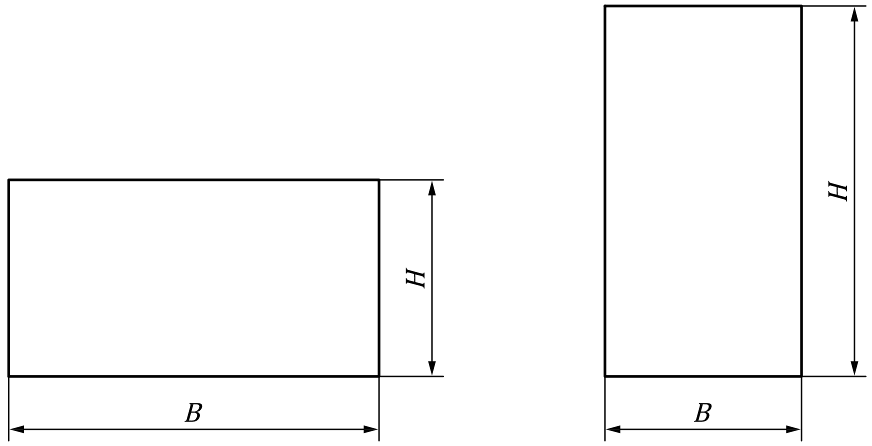

Figure 1 — Examples of width, *B*, and length, *H*, relative to the pane shape

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For tempered safety glass manufactured from patterned glass, the direction of the pattern should be specified relative to one of the dimensions.

6.2.2 Maximum and minimum sizes

For maximum and minimum sizes, the manufacturer should be consulted.

6.2.3 Tolerances and squareness

The nominal dimensions for width and length being given, the finished pane shall not be larger than the nominal dimensions increased by the tolerance, *t*, or smaller than the nominal dimensions reduced by the tolerance, *t*. Limits are given in Table 2.

The squareness of rectangular glass panes is expressed by the difference between its diagonals. The difference between the two diagonal lengths of the pane of glass shall not be larger than the deviation limit, *v*, as specified in Table 3.

Table 2 — Tolerances, *t*, on width, *B*, and length, *H*

Dimensions in millimetres

<table>
<tr><th rowspan="2">Nominal dimension
of side, B or H</th><th colspan="11">Nominal glass thickness</th></tr>
<tr><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>8</th><th>10</th><th>12</th><th>15</th><th>19</th><th>25</th></tr>
<tr><td>≤ 1 000</td><td colspan="6">±2</td><td colspan="2">±3</td><td>±4</td><td colspan="2">±5</td></tr>
<tr><td>1 000 < B or H ≤ 2 000</td><td colspan="8">±3</td><td>±4</td><td colspan="2">±5</td></tr>
<tr><td>2 000 < B or H ≤ 3 000</td><td colspan="9">±4</td><td colspan="2">±6</td></tr>
<tr><td>3 000 < B or H</td><td colspan="6">±4</td><td colspan="3">±5</td><td colspan="2">±6</td></tr>
</table>

Table 3 — Limit deviations, *v*, for the difference between diagonals

Dimensions in millimetres

<table>
<tr><th rowspan="2">Nominal dimension
of side, B or H</th><th colspan="11">Nominal glass thickness</th></tr>
<tr><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>8</th><th>10</th><th>12</th><th>15</th><th>19</th><th>25</th></tr>
<tr><td>≤ 1 000</td><td colspan="6">4</td><td colspan="2">6</td><td>8</td><td colspan="2">10</td></tr>
<tr><td>1 000 < B or H ≤ 2 000</td><td colspan="8">6</td><td>8</td><td colspan="2">10</td></tr>
<tr><td>2 000 < B or H ≤ 3 000</td><td colspan="9">8</td><td colspan="2">12</td></tr>
<tr><td>3 000 < B or H</td><td colspan="6">8</td><td colspan="3">10</td><td colspan="2">12</td></tr>
</table>

6.2.4 Edge deformation produced by vertical tempering

The tongs used to suspend the glass during tempering result in surface depressions, known as "tong marks" (see Figure 2). The centres of the tong marks are situated up to a maximum of 20 mm from the edge. A deformation of the edge less than 2 mm can be produced in the region of the tong mark and there may also be an area of optical distortion.

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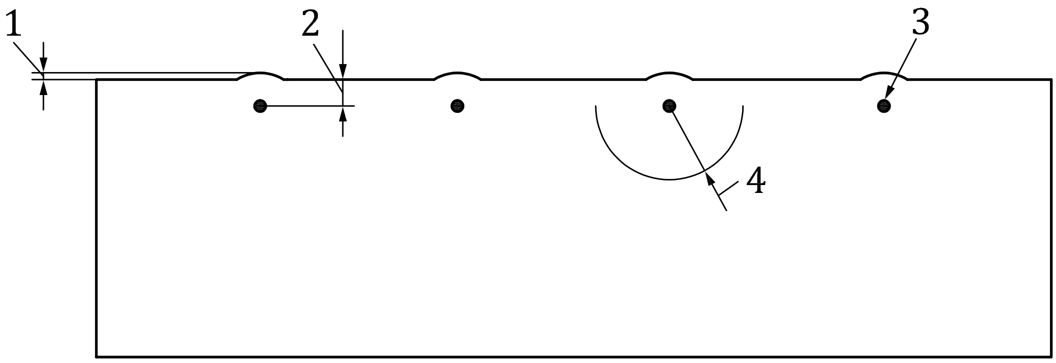

Key

1 deformation in the tolerances of Table 2

2 up to 20 mm

3 tong mark

4 100 mm radius maximum area of optical distortion

Figure 2 — Tong mark deformation

6.3 Flatness

6.3.1 General

By the very nature of the tempering process, it is not possible to obtain a product as flat as annealed glass. This difference in flatness depends on the type of glass, e.g. coated, patterned, etc., glass dimensions, i.e. the nominal thickness, the dimensions, the ratio between the dimensions and the type of the tempering process employed.

There are six kinds of distortion:

a) overall bow (see Figure 3);

b) roller wave distortion (for horizontally tempered safety glass only) (see Figure 4);

c) edge lift (for horizontally tempered safety glass only) (see Figure 5);

d) local distortion (for vertically tempered safety glass only) (see Figure 6).

Local distortion needs to be allowed for within the glazing materials and the weather seals. For special requirements, the manufacturers should be consulted.

e) wave distortion (for air cushion–tempered safety glass only) (see Figure 4);

f) perimeter deformation (for air cushion–tempered safety glass only) (see Figure 10).

NOTE Overall bow, roller wave, edge lift and perimeter deformation can, in general, be accommodated by the framing system.

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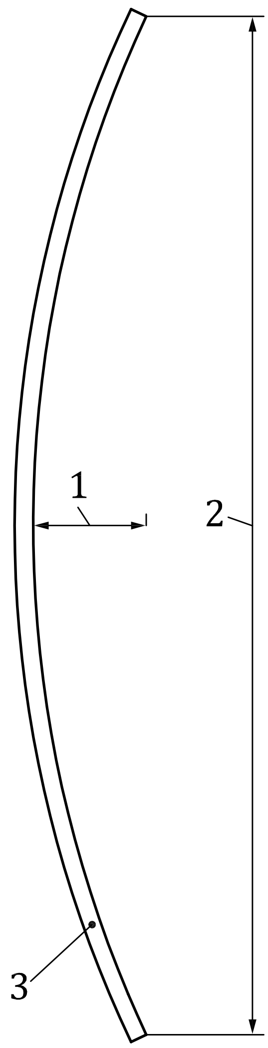


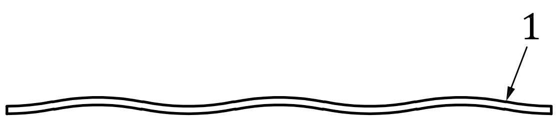
Key

1 deformation for calculating overall bow

2 *B*, or *H*, or diagonal length

3 tempered safety glass

Figure 3 — Representation of overall bow



Key

1 roller wave distortion

Figure 4 — Representation of wave or roller wave distortion

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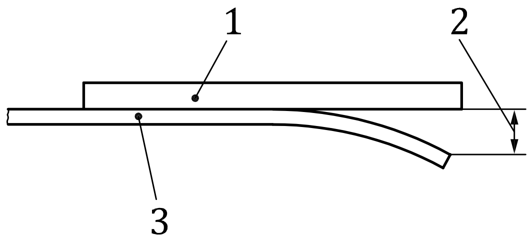


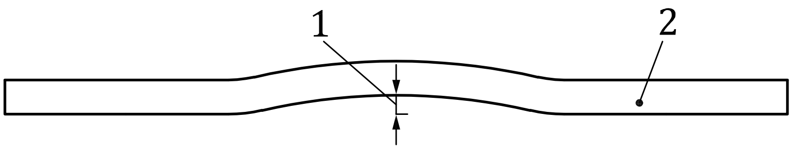
Key

1 straightedge

2 edge lift

3 tempered safety glass

Figure 5 — Representation of edge lift



Key

1 local distortion

2 tempered safety glass

Figure 6 — Representation of local distortion

6.3.2 Measurement of overall bow

The pane of glass shall be placed in a vertical position and supported on its longer side by two load-bearing blocks at the quarter points (see Figure 7).

For glass thinner than 4 mm nominal thickness, a solid back support with an angle between 3° and 7° from the vertical can be used.

The deformation shall be measured along the edges of the glass and along the diagonals, as the maximum distance between a straight metal ruler, or a stretched wire, and the concave surface of the glass (see Figure 3).

The value for the bow is then expressed as the deformation, in millimetres, divided by the measured length of the edge of the glass, or diagonal, in millimetres, as appropriate.

The measurement shall be carried out at room temperature.

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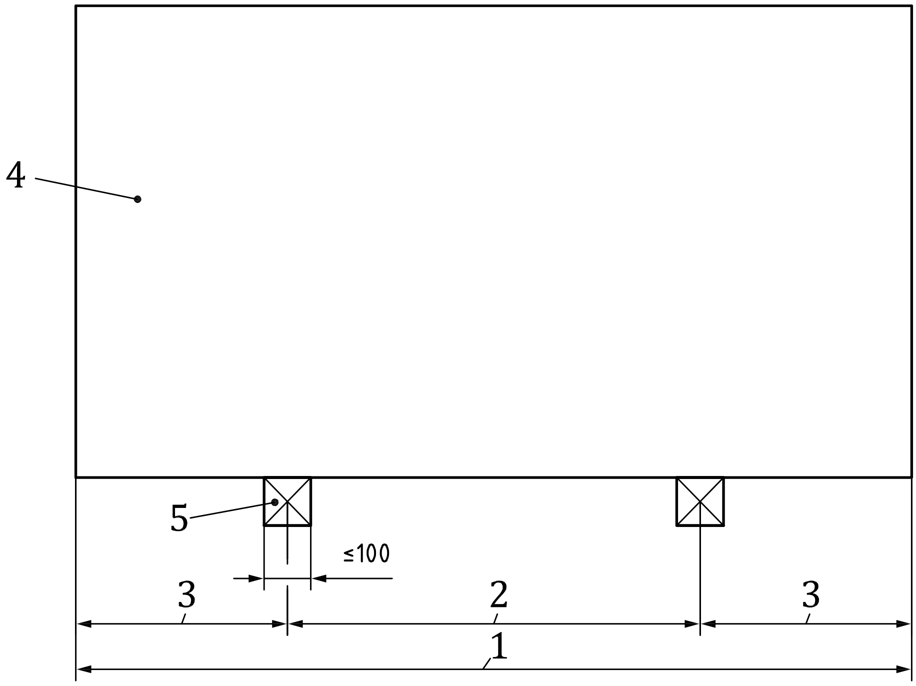
Dimensions in millimetres



Key

1 *B* or *H*
2 (*B* or *H*)/2
3 (*B* or *H*)/4
4 tempered safety glass
5 load-bearing blocks

Figure 7 — Support conditions for the measurement of overall bow

NOTE Special care needs to be taken for large and thin panes because they can show a buckling which is different from an overall bow caused by the tempering process. Results from this test method for glasses thinner than 4 mm can be inaccurate.

6.3.3 Measurement of wave or roller wave distortion

6.3.3.1 General

The wave or roller wave distortion is measured by means of a straightedge, or equivalent, being placed at right angles to the wave or roller wave and bridging from peak to peak of the wave (see Figure 8).

NOTE This subclause deals with measurement using a straightedge and feeler gauges. An alternative method is described in Annex B.

6.3.3.2 Apparatus

6.3.3.2.1 A straightedge, length of between 300 mm and 400 mm.

NOTE The actual length of straightedge required will depend on the wavelength of the wave or roller wave.

6.3.3.2.2 Feeler gauges, various thicknesses in units of 0,05 mm.

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6.3.3.3 Method

Place the straightedge so that it bridges across adjacent peaks. Insert the feeler gauge between the glass surface and the straightedge. Increase the thickness of the feeler gauges until they just fill the gap between glass surface and the straightedge. Record the thickness of feeler gauge(s) to an accuracy of 0,05 mm.

Repeat the measurement at several places over the glass surface.

The measured wave or roller wave distortion is the maximum value measured. The maximum allowable values are given in Table 4 and Table 6.

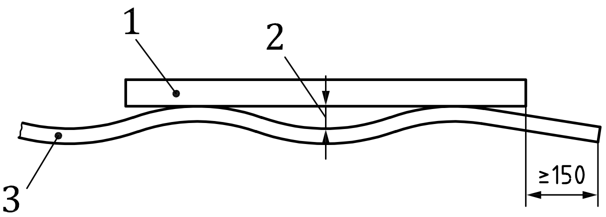
6.3.3.4 Limitations

The following limitations apply.

— The wave or roller wave can only be measured on panes with a dimension greater than 600 mm measured at right angles to the waves or roller waves;

— The wave or roller wave cannot be measured in an exclusion area that is 150 mm from the edges of the pane. The apparatus should not be used in the area of these 150 mm;

— Panes with an overall bow shall be laid on a flat support. This will allow gravity to flatten out the overall bow and hence give a truer result for the wave or roller wave.



Key

1 straightedge

2 wave or roller wave distortion

3 tempered safety glass

Figure 8 — Measurement of wave or roller wave distortion

6.3.4 Measurement of edge lift (for horizontally tempered safety glass only)

6.3.4.1 Apparatus

6.3.4.1.1 A straightedge, length of between 300 mm and 400 mm.

NOTE The actual length of straightedge required will depend on the wavelength of the roller wave.

6.3.4.1.2 Feeler gauges, various thicknesses in units of 0,05 mm.

6.3.4.2 Method

The glass shall be placed on a flat support with the edge lift overhanging the edge of the support. The overhanging distance should be between 5 cm and 10 cm.

The straightedge is placed on the peaks of the roller waves and the gap between the ruler and the glass measured using a feeler gauge (see Figure 9).

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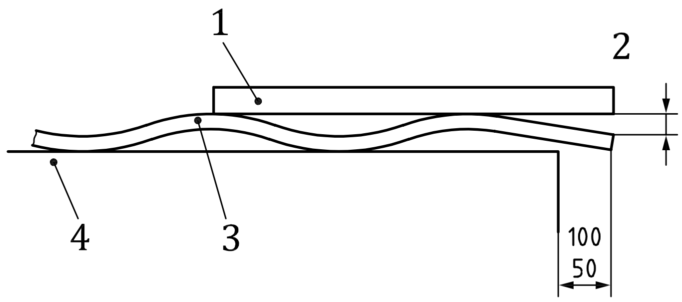
The maximum values for edge lift are given in Table 5.

The values in Table 5 only apply to tempered safety glass having edgework complying with Figures 12 to 15. For profiled edges or other types of edgework, contact the manufacturer.

Dimensions in millimetres



Key

1 straightedge

2 edge lift

3 tempered safety glass

4 flat support

Figure 9 — Measurement of edge lift

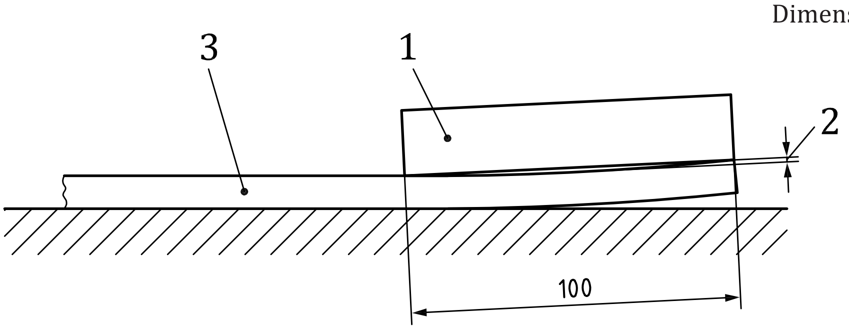
6.3.5 Measurement of perimeter deformation of glass produced by air cushion toughening process

Place the glass on a flat surface with the concave side facing upwards (see Figure 10).

A 100 mm straightedge is laid on the pane at right angles to the edge. The gap between the ruler and the glass is measured using a feeler gauge (see Figure 10). The perimeter deformation is the maximum distance between the surface of the pane and the straightedge.

The maximum allowable values for perimeter deformation are given in Table 7.

Dimensions in millimetres



Key

1 straightedge

2 perimeter deformation

3 tempered safety glass

Figure 10 — Measurement of perimeter deformation

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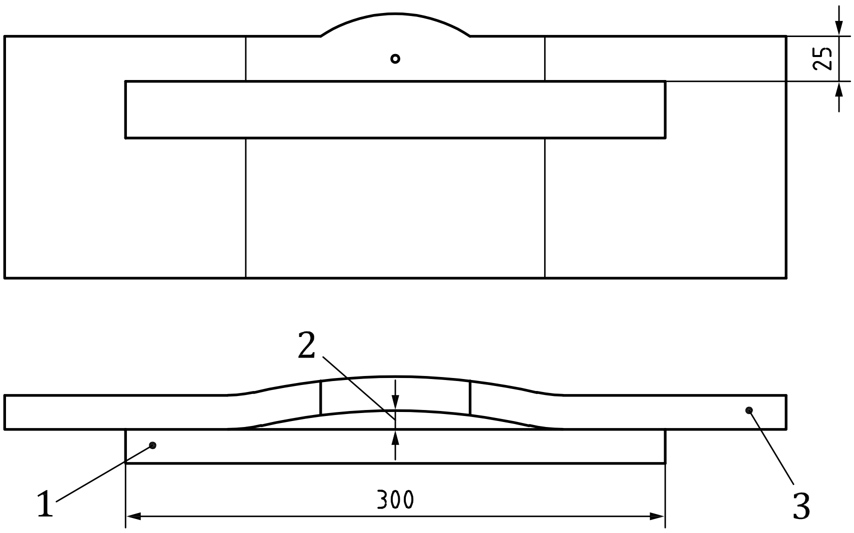
6.3.6 Measurement of local distortion (for vertically tempered safety glass only)

Local distortion can occur over relatively short distances on the edges with tong mark of the vertically tempered safety glass that contained the tong marks (see Figure 2) of the glass. Local distortion shall be measured over a limited length of 300 mm by using a straight ruler, or a stretched wire, parallel to the edge at a distance of 25 mm from the edge of the glass (see Figure 11).

Local distortion is expressed as millimetres/300 mm length.

Dimensions in millimetres



Key

1 straightedge

2 local distortion

3 tempered safety glass

Figure 11 — Measurement of local distortion

For patterned glass, local distortion shall be determined by using a straight ruler resting on the high points of the pattern and measuring to a high point of the pattern.

6.3.7 Limitation on overall bow, roller waves and edge lift for horizontally tempered safety glass

The maximum allowable values for the overall bow, when measured according to 6.3.2, for roller waves, when measured according to 6.3.3, and edge lift, when measured according to 6.3.4, are given in Tables 4 and 5. These values only apply to tempered safety glass without holes and/or notches and/or cut-outs.

Table 4 — Maximum allowable values of overall bow and roller wave distortion for horizontally tempered safety glass

Glass type	Maximum allowable value for distortion	
	Overall bow mm/m	Roller wave mm
Uncoated float to ISO 16293-2	3,0	0,4
Others[a]	4,0	0,5
Dependent on the wavelength of the roller wave, an appropriate length of straightedge has to be used.		
[a] For enamelled glass which is not covered over the whole surface, the manufacturer should be consulted.		

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Table 5 — Maximum allowable values of edge lift for horizontally tempered safety glass

Type of glass	Thickness of glass mm	Maximum allowable values mm
Uncoated float to ISO 16293-2	3	0,5
	4 to 5	0,5
	6 to 25	0,3
Others[a]	all	0,5

Dependent upon the wavelength of the roller wave, an appropriate length of straightedge has to be used.

[a] For enamelled glass which is not covered over the whole surface the manufacturer should be consulted.

6.3.8 Limitation on overall bow, wave and perimeter deformation for tempered safety glass manufactured by air cushion process

The maximum allowable values for the overall bow, when measured according to 6.3.2, for waves, when measured according to 6.3.3, and perimeter deformation, when measured according to 6.3.5, are given in Tables 6 and 7. These values only apply to tempered safety glass without holes and/or notches and/or cut-outs.

Table 6 — Maximum allowable values of overall bow and wave distortion for tempered safety glass manufactured by air cushion process

Glass type	Maximum allowable value for distortion	
	Overall bow mm/m	Wave mm
Uncoated float to ISO 16293-2 and coated float glass ISO 11479-1	3,0	0,3
Others[a]	4,0	0,5

For other glass types, the manufacturer should be consulted.

[a] For enamelled glass which is not covered over the whole surface, the manufacturer should be consulted.

Table 7 — Maximum allowable values of perimeter deformation for tempered safety glass manufactured by air cushion process

Type of glass	Thickness of glass mm	Maximum allowable values mm
Uncoated float to ISO/DIS 16293-2 and coated float glass ISO 11479-1	up to12	0,3
Others[a]	up to 12	0,5

For other glass types, the manufacturer should be consulted.

[a] For enamelled glass which is not covered over the whole surface, the manufacturer should be consulted.

6.3.9 Limitation on overall bow and local distortion for vertically tempered safety glass

The maximum allowable values for the overall bow, when measured according to 6.3.2, and the local distortion, when measured according to 6.3.6, are given in Table 8. These values only apply to tempered safety glass without holes and/or notches and/or cut-outs.

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Table 8 — Maximum allowable values of overall bow and local distortion for vertically tempered safety glass

Glass type	Maximum allowable value for distortion	
	Overall bow mm/m	Local distortion mm/300 mm
All[a]	5,0	1,0

[a] For enamelled glass which is not covered over the whole surface, the manufacturer should be consulted.

6.3.10 Other distortions

The incorporation of holes and/or notches in a plate gives the possibility of distortions being produced during the tempering process as a result of the absence of glass and/or an increase in unsupported edges. The magnitude of these distortions will generally be less than edge lift in horizontally tempered safety glass or local distortion in vertically tempered safety glass.

7 Edge work, holes, notches and cut-outs

7.1 General

Tempered safety glass should not be cut, sawed, drilled, edge worked or surface finished (e.g. sandblasting, acid etching) after tempering because the risk of breakage is increased or the glass can be destroyed immediately. Glasses cut, sawed, drilled, edge worked or surface finished (e.g. sandblasting, acid etching) after tempering are not covered by this document.

No modification that will affect its structural characteristics or integrity as specified in the document shall be made.

NOTE Marking, according to Clause 10, in the corner of a product after tempering is allowed.

7.2 Edge working of glass for tempering

The simplest type of edge working is the arrissed edge (see Figure 12). Other common types are shown in Figures 13 to 15. For specialist edge work, such as “water jet cutting,” the manufacturers should be consulted. Corners need not to be treated unless required by the customer.

NOTE Correctly cut edges may be tempered without further edge working.

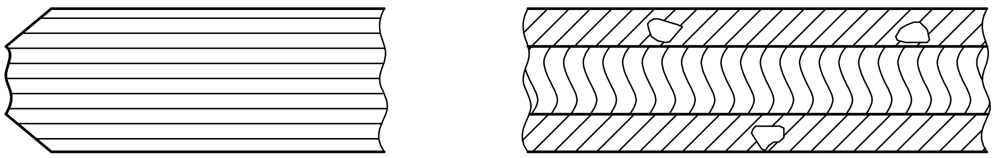

Figure 12 — Arrissed edge (with blank spots)

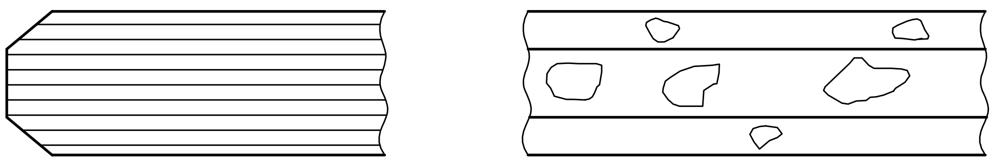

Figure 13 — Ground edge (with blank spots)

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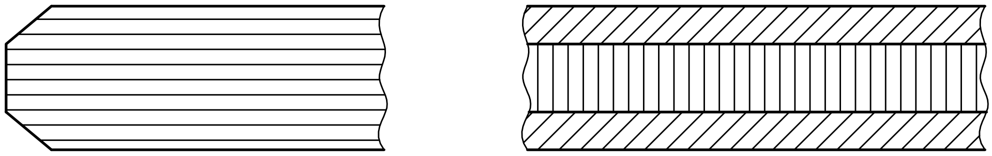

Figure 14 — Smooth ground edge (no blank spots)

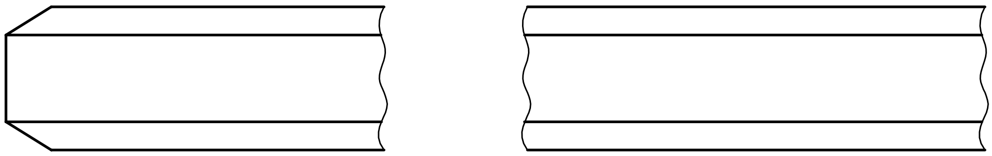

Figure 15 — Polished edge

7.3 Profiled edges

Various other edge profiles can be manufactured with different types of edgework. This kind of product is not covered by Table 5 due to the influence of the profile.

7.4 Round holes

7.4.1 General

This document considers only round holes in glass that is not less than 4 mm nominal thickness. For holes in glasses thinner than 4 mm, the manufacturers should be consulted. The manufacturers should be consulted about edge working of holes.

7.4.2 Diameter of holes

The diameter of holes, Ø, shall not, in general, be less than the nominal thickness of the glass. For smaller holes, the manufacturers should be consulted.

7.4.3 Limitations on position of holes

In general, the limitations on hole positions relative to the edges of the glass pane, the corners of the glass pane and to each other depends on

a) the nominal glass thickness (d),

b) the dimensions of the pane (B, H),

c) the hole diameter (⌀),

d) the shape of the pane, and

e) the number of holes.

Glasses produced following the recommendations given below are assumed to satisfy the requirements of this document.

1) The distance, a, of the edge of a hole to the glass edge should not be less than $2d$.

$a \geq 2d$

NOTE For holes less than $2d$ from the edge, consult the manufacturer.

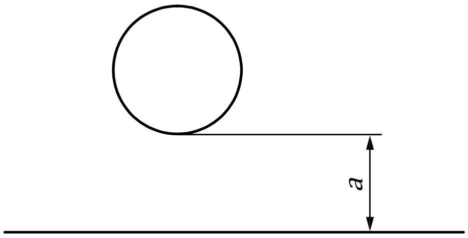

Figure 16 — Relationship between hole and edge of pane

2) The distance, *b*, between the edges of two holes should not be less than 2*d* with a minimum distance of *b* = 10 mm.

$b \geq 2d$

NOTE For hole separation (*b*) less than 2*d* from the edge, consult the manufacturer.

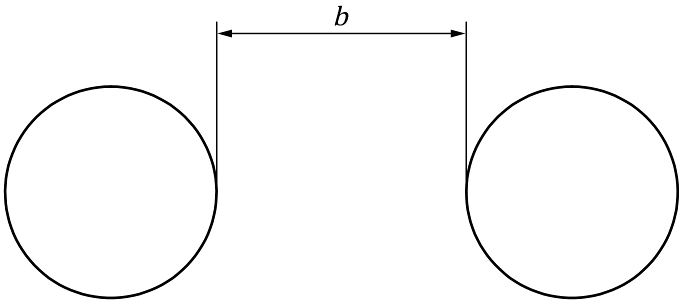

Figure 17 — Relationship between two holes

3) The distance, *c*, of the edge of a hole to the corner of the glass should be not less than 6*d*.

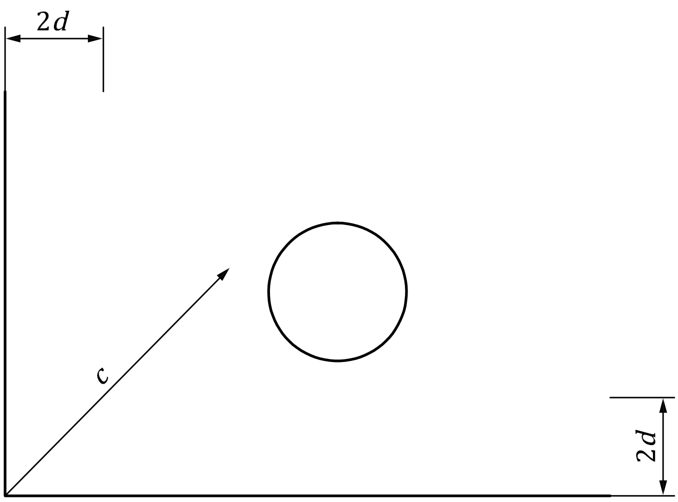

Figure 18 — Relationship between hole and corner of pane

For a distance *c* less than 6*d,* the manufacturer should be consulted.

If one of the distances from the edge of the hole to the edge of the glass is less than 35 mm, it may be necessary to position the hole asymmetrically with respect to the corner. The manufacturers should be consulted.

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7.4.4 Tolerances on hole diameters

The tolerances on hole diameters are given in Table 9.

Table 9 — Tolerances on hole diameters

Dimensions in millimetres

Nominal hole diameter ⌀	Tolerances
4 ≤ ⌀ ≤ 20	±1,0
20 < ⌀ ≤ 100	±2,0
100 < ⌀	consult the manufacturer

7.4.5 Tolerances on position of holes

The tolerances on positions of holes are given in Table 10. The positions of holes are measured in two directions at right angles (*x*- and *y*-axes) from a reference point to the centre of the holes. The datum point is generally chosen as a real or virtual corner of the pane (see Figure 19 for examples).

The position of a hole (X, Y) is ($x \pm t$, $y \pm t$), where x and y are the required dimensions and t is the tolerance from Table 10.

Table 10 — Tolerances on positions of holes

Dimensions in millimetres

Nominal dimension of side, *B* or *H*	Tolerance *t*	
	Nominal glass thickness $d \leq 12$	Nominal glass thickness $d > 12$
<2 000	±2,5 (horizontal and air cushion tempering) ±3,0 (vertical tempering)	±3,0
2 000 < *H* or *B* < 3 000	±3,0	±4,0
<3 000	±4,0	±5,0

The manufacturers should be consulted if tighter tolerances on hole positions are required.

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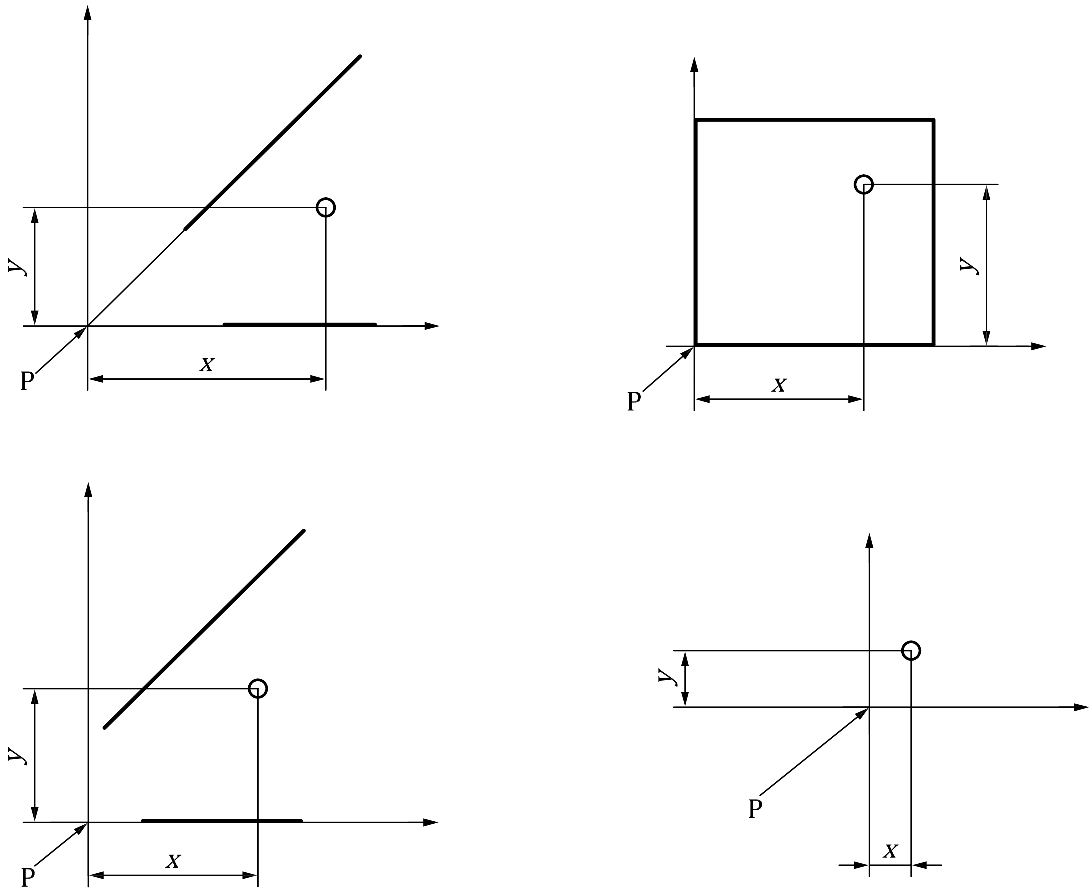

Key

P datum point

Figure 19 — Examples of the positioning of holes relative to the reference point

7.5 Holes/others

There are available countersunk holes (see Figure 20). The manufacturer shall be consulted for the tolerances on hole position, hole shape/dimensions and edge work.

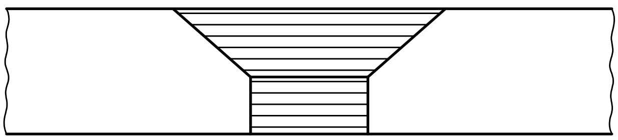

Figure 20 — Countersunk hole

7.6 Notches and cut-outs

Many configurations of notches and cut-outs can be supplied. See Figure 21 for examples.

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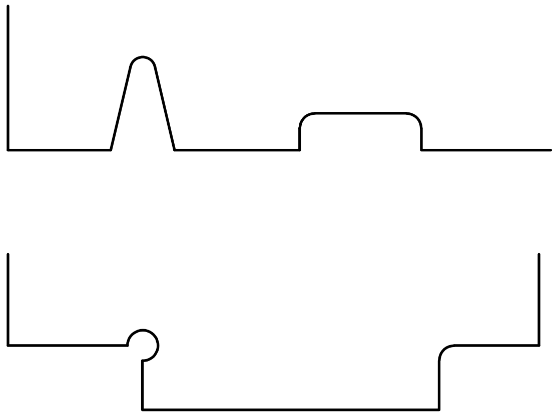

Figure 21 — Examples of notches and cut outs

The manufacturer should be consulted about edge working of notches and cut-outs.

7.7 Shaped panes

Many non-rectangular shapes can be manufactured and manufacturers should be consulted.

8 Fragmentation test

8.1 General

The fragmentation test determines whether the glass breaks in the manner prescribed for a tempered safety glass. This fragmentation test shows the behaviour of breakage of a tempered safety glass without any stress of external action only by the pre-stress. In service, the real breakage behaviour can be different.

8.2 Dimensions and number of test specimens

The dimensions of the test specimens shall be 360 mm × 1 100 mm, without holes, notches or cut-outs.

Five specimens shall be tested.

8.3 Test procedure

Each test specimen shall be impacted, using a pointed steel tool, at a position 20 mm in from the longest edge of the test specimen at the mid-point of that edge, until breakage occurs (see Figure 22).

NOTE 1 The fragmentation characteristics of glass are unaffected by temperatures between −50 °C and +100 °C.

Examples of steel tools are a hammer of about 75 g mass, a spring-loaded centre punch or other similar appliance with a hardened point. The radius of curvature of the point should be approximately 0,2 mm.

The test specimen shall be laid flat on a table without any mechanical constraint. In order to prevent scattering of the fragments, the specimen shall be simply held at the edges, e.g. by a small frame, adhesive tape, etc., so that the fragments remain interlocked after breakage yet extension of the specimen is not hindered.

NOTE 2 The use of adhesive backed polymeric films is not recommended as it could constrain the glass when broken.

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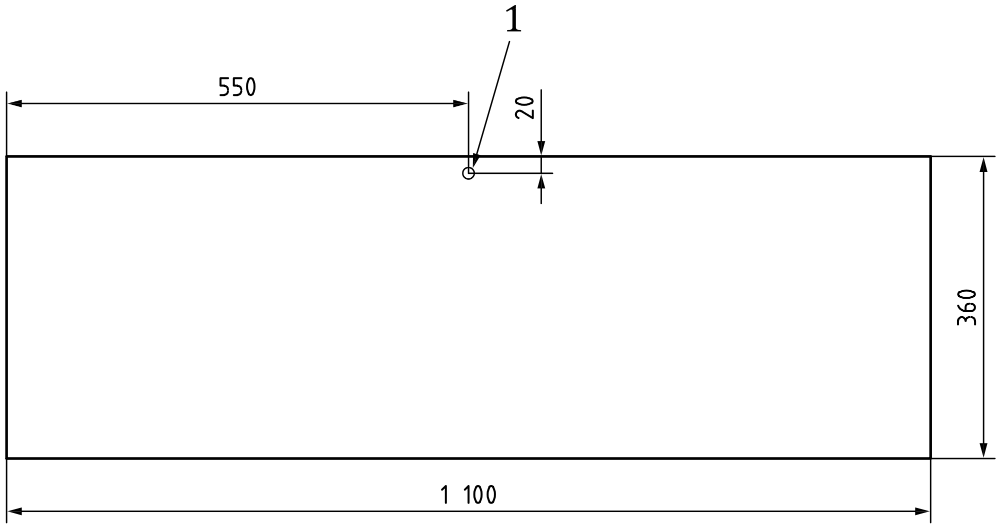
Dimensions in millimetres



Key

1 impact point

Figure 22 — Position of impact point

For tempered safety glass manufactured by vertical tempering, the impact point shall not be on the tong mark edge.

8.4 Assessment of fragmentation

Counting starts 3 min after fracture and should be finished 5 min after fracture. An area of radius 80 mm, centred on the impact point, and a border of 25 mm, round the edge of the test specimen (see Figure 23), shall be excluded from the assessment.

The particle count shall be made in the region of coarsest fracture (the aim being to obtain the minimum value). The particle count shall be made by placing a mask of (50 ± 1) mm × (50 ± 1) mm on the test piece (see Annex C). The number of crack-free particles within the mask shall be counted. A particle is “crack-free” if it does not contain any cracks which run from one edge to another (see Figure 24).

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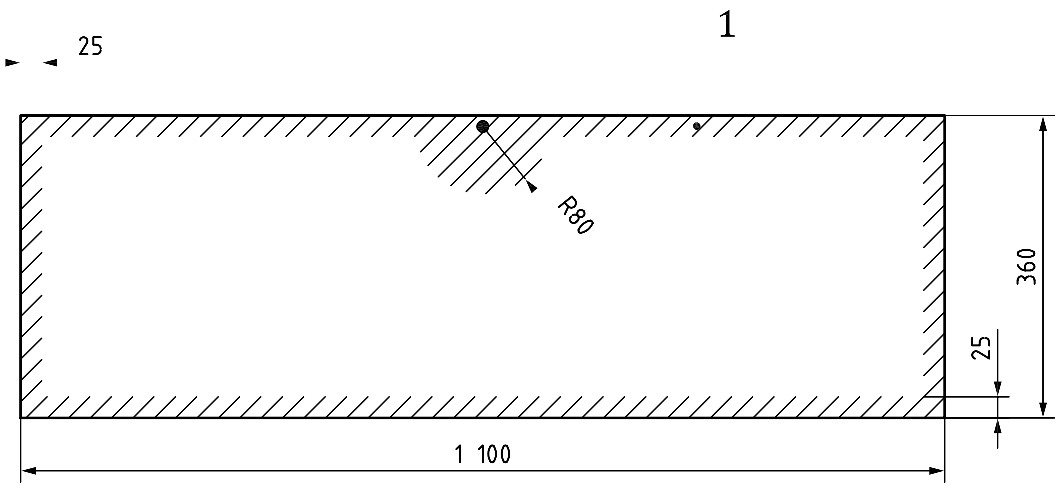
Dimensions in millimetres



Key

1 excluded area

Figure 23 — Area to be excluded from the particle count determination and largest particle measurement

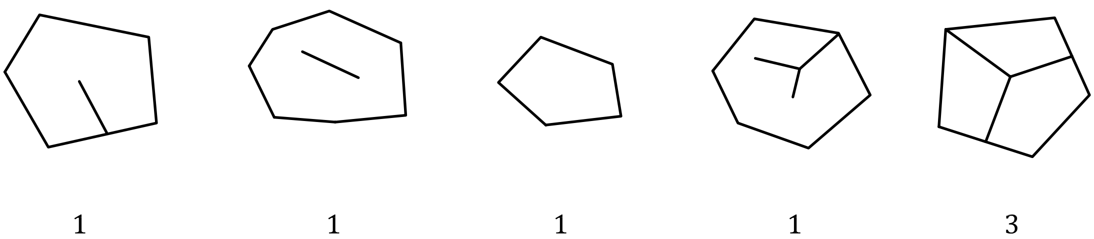


Figure 24 — Examples of crack free particles and the assessment regarding the number

In the particle count, all particles wholly contained within the area of the mask shall be counted as one particle each and all the particles which are partially within the mask shall be counted as 1/2 particle each (see Annex C).

8.5 Minimum values from the particle count

The particle count of each test specimen shall not be less than the values given in Table 11.

Table 11 — Minimum particle count values

Glass type	Nominal thickness *d* mm	Minimum particle count
Float	less than 2	15
Float	2 and 3	30
Patterned	2 and 3	15
All glass types	4 to 12	40
All glass types	15 to 25	30

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8.6 Selection of the longest particle

The longest particle shall be chosen from the body of the test specimen.

It shall not be measured in the excluded area (see 8.4). If the splinter is in both areas, the length of the splinter in the counting area is measured.

8.7 Maximum length of the longest particle

The length of the longest particle shall not exceed 100 mm.

8.8 Test report

The following information shall be reported:

a) identification of the specimen;

b) particle count of the fractured test specimen;

c) the longest particle length;

d) date and time of the test;

e) names and positions of personnel carrying out or supervising the test.

Each page of the report shall be signed and dated by the person responsible for the test.

9 Other physical characteristics

9.1 Optical distortion

9.1.1 Tempered safety glass produced by vertical tempering

The tong marks can produce additional optical distortion which is generally in an area of radius 100 mm centred on the tong mark (see Figure 2).

9.1.2 Tempered safety glass produced by horizontal tempering

While the hot glass is in contact with the rollers during the tempering process, a surface distortion is produced by a deviation from surface flatness, known as “roller wave”. Roller wave is generally noticed in reflection. See also 6.3.3.

Small imprints may be shown in the surface of the glass (“roller pick-up”).

9.2 Anisotropy (iridescence)

The tempering process produces areas of different stress in the cross section of the glass. These areas of stress produce a birefringent effect in the glass, which is visible in polarised light.

When tempered safety glass is viewed in polarised light, the areas of stress show up as coloured zones, sometimes known as “leopard spots”.

Polarised light occurs in normal daylight. The amount of polarised light depends on the weather and the angle of the sun. The birefringent effect is more noticeable when the tempered safety glass is examined either at a glancing angle or through polarised spectacles.

Anisotropy is a visible physical effect but not a defect.

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9.3 Thermal durability

The mechanical properties of tempered safety glass are unchanged for continuous service up to 250 °C and are unaffected by sub-zero temperatures. Tempered safety glass is capable of resisting both sudden temperature changes and temperature differentials up to 200 K.

NOTE The resistance against temperature difference is sufficient to withstand the temperature differential which occurs in glazing exposed to solar radiation, usually below 100 K.

9.4 Mechanical strength

The value of mechanical strength can only be given as a statistical value associated with a particular probability of breakage and with a particular type of loading, i.e. four-point bending test according to ISO 1288-3.

NOTE These values are determined in accordance with ISO 1288-3.

Table 12 — Minimum values for the characteristic bending strength of tempered safety glass

Type of glass	**Minimum values for characteristic bending strength** MPa
Float: clear tinted coated	120
Enamelled float (based on the enamelled surface under tensile stress)	75
Patterned glass and drawn sheet	90

NOTE The values in Table 12 represent the strength of tempered safety glass which meets the requirements of 8.5.

At least 10 specimens of tempered safety glass shall be tested according to ISO 1288-3. The 5 % breakage probability, statistically evaluated at the lower limit of the 95 % confidence interval, shall be not less than the value in Table 12.

9.5 Surface pre-stress

To achieve a bending strength of 120 MPa, as determined according to ISO 1288-3, for a single float glass pane between 4 mm and 12 mm, a minimum value for surface pre-stress of 80 MPa is needed.

Additionally, to achieve 40 particles in the fragmentation test the minimum value for surface pre-stress (see Annex D) of 90 MPa is needed for float glass between 4 mm and 12 mm.

Table 13 — Possibilities of measurement during manufacturing

Surface pre-stress test MPa	**Four-point bending test is necessary** MPa	**Fragmentation test is necessary**
90	no	no[a]
80	no	yes
no	120	yes

[a] Only applicable for glass of nominal thickness 4 mm to 12 mm.

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10 Marking

Tempered safety glass conforming to this document shall be permanently marked. The marking shall give the following information:

a) name or trademark of manufacturer;

b) the number of this document, i.e. ISO 12540.

11 Packaging

Tempered safety glasses shall be packaged by using an appropriated buffer material.

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Annex A
(normative)

Pendulum impact test methods

A.1 General

ISO 29584 classifies pendulum impact test methods.

A.2 Pendulum test methods employed around the world for the classification of thermally tempered safety glass against accidental human impact

A.2.1 Japan

Lead shot filled leather shot bag, weight (45 ± 0,1) kg as per JIS R 3206.

A.2.2 Australia, New Zealand

Lead shot filled leather shot bag, weight (46 ± 0,1) kg as per AS/NZS 2208.

A.2.3 United States of America

Lead shot filled leather shot bag, weight (45,4 + 0,2) kg as per ANSI Z97.1.

NOTE Federal regulation CPSC 16 CFR 1201 also details a pendulum test method similar to ANSI Z97.1.

A.2.4 Canada

Lead shot filled leather shot bag, weight (45,4 + 0,2) kg as per CAN/CGSB 12.1-M 90.

A.2.5 Europe

Twin tyre impactor, weight (50 ± 0,1) kg as per EN 12600.

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Annex B
(informative)

Alternative method for the measurement of roller wave distortion

B.1 Apparatus

This is a 350 mm long aluminium channel with a centrally mounted deflection gauge/dial gauge (Figure B.1).

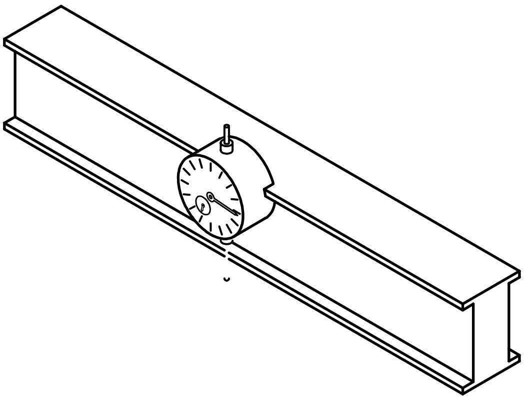

Figure B.1 — Roller wave measurement apparatus

B.2 Method

The apparatus is placed on the glass at right angles to the roller wave, so that it can bridge from peak to peak of the wave (Figure B.2).

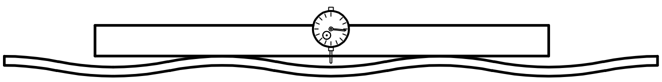

Figure B.2 — Place the apparatus across the roller wave

The apparatus is then moved along its axis until the dial gauge reads the highest value (Figure B.3).

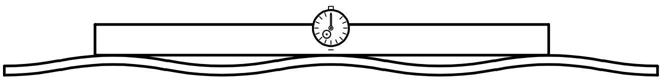

Figure B.3 — Set the zero of the gauge on a peak of the roller wave

At this point, the dial gauge is resting on a peak of the roller wave. The scale of the gauge is positioned (rotated) so that the needle points to 0 (zero) on the scale. The apparatus is then moved again along its axis until the gauge reads the lowest value (Figure B.4). At this point, the dial gauge is resting in the lowest point of the trough. The reading is then taken, and the depth of the roller wave is the difference between the zero point and the reading.

The dial gauge scale is usually arranged so that a positive value is obtained by raising the post. Care should be taken to not misread the depth of the roller wave.

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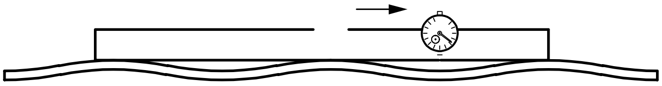

Figure B.4 — Move the gauge to a trough

The roller wave depth is recorded to the nearest 0,05 mm.

The above procedure can be performed several times on the same pane, giving a variety of answers, since the roller waves are unlikely to be consistent. The worst roller wave of those recorded is the value of the pane.

B.3 Limitations

The apparatus should only be used on panes with a dimension larger than 600 mm at right angles to the roller wave. There is an exclusion area, 150 mm from the edge of the pane, where the apparatus should not be used.

The deformation of the edges (up to 150 mm from the edge of the pane) can be different from the deformation of the rollers the surface out of this area of the glass.

A true measurement of roller wave can only be obtained on an otherwise flat pane of glass. If the pane has an overall bow, this will contribute to the value measured by the roller wave and shall be taken into account. This can be reduced by laying the pane of glass flat on a table, which will reduce the overall bow in the pane due to the self-weight of the pane, particularly with larger panes.

B.4 Alternative use of apparatus

If the dial gauge is mounted on the end of the aluminium channel rather than at the centre, then it may be used for the measurement of edge lift.

Lay the test sample over the end of a table so that the edge lift is as shown in Figure 9. Move the apparatus towards the edge of the sample. Measure the maximum deflection of the gauge from when sitting on a peak to touching the edge of the sample.

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Annex C
(informative)

Example of particle count

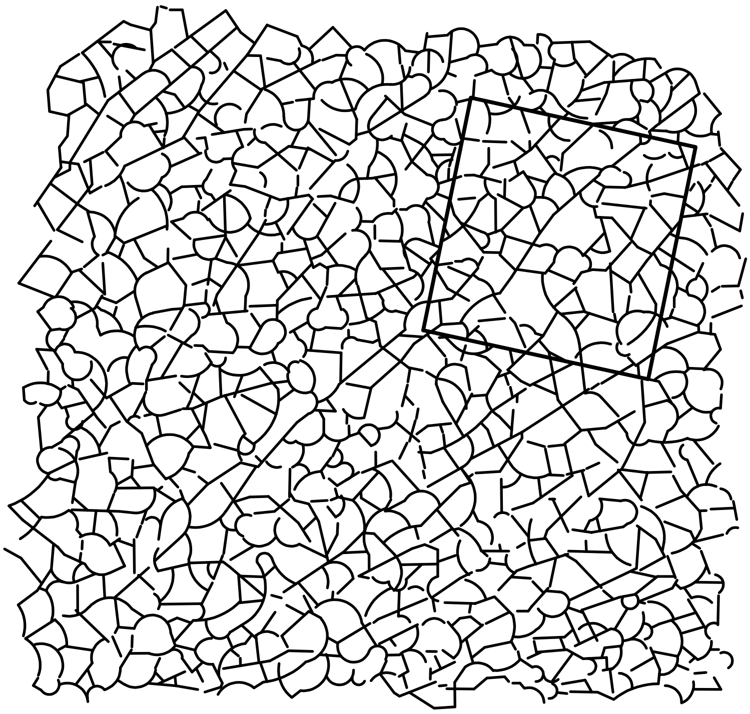

Figure C.1 — Example of selecting the area of coarsest fracture

Select the area of coarsest fracture, place the template on the test specimen and draw round the template.

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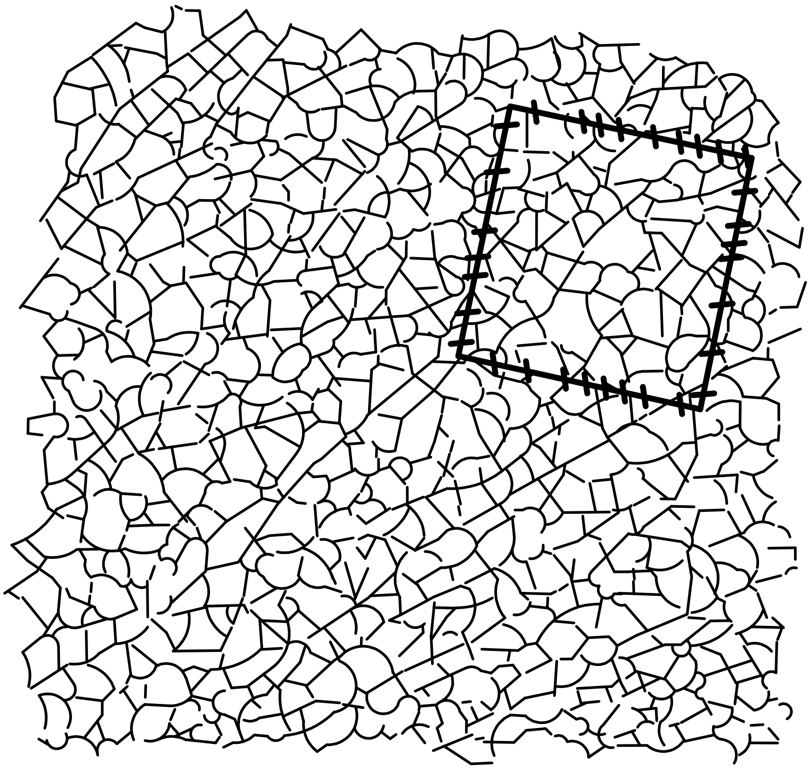

NOTE Number of perimeter particles = 32/2 = 16.

Figure C.2 — Example of marking and counting

Mark and count the perimeter fragments as 1/2 particle each.

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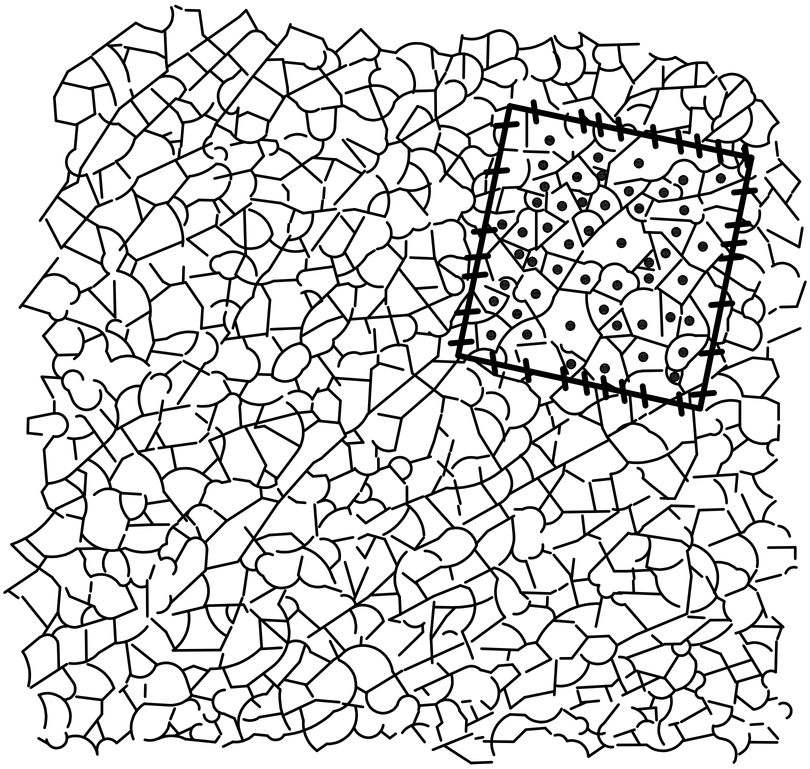

NOTE 1 Number of central particles = 53.

NOTE 2 Total number of particles = 16 + 53 = 69.

Figure C.3 — Example for marking and counting of overall particle count for the specimen

Mark and count the central fragments and add these to the perimeter count to obtain the particle count for the specimen.

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Annex D
(informative)

Method for the measurement of the surface pre-stress of tempered safety glass

D.1 Measurement of surface pre-stress

The manufacturer may also use surface pre-stress measurement as a means of product control. If this is done then the appropriate procedure given below shall be applied. This procedure shows the relationship between surface pre-stress and mechanical strength/fragmentation.

Manufacturers with more than one production line may perform the test on specimens from one line. The outcome value of surface pre-stress measurement may then be used as reference for the other production lines and shall be confirmed by factory production control. This may also be applied to new production lines.

D.2 Method

D.2.1 Principle of the method

The method covers the measurement of residual surface stress. It is a non-destructive method based on surface total reflexion. Several techniques are currently available. As the different techniques vary slightly in detail of principle and operation, it shall refer to the technique particular instructions.

NOTE LDSR from Gaertner Scientific, GASP® of Strainoptics Inc., BTP of Orihara Ind., LSM-902 from Rukeo, FSM-30 from Toshiba, Epibiascope from Saint-Gobain, Scalp from GlasStress Ltd. were shown satisfying the requirements of this document. ASTM C 1279–13, making use of the GASP® of Strainoptics, is a measurement method satisfying the requirements to this document.[2)]

This method is only applicable on the tin side of the flat float glass. It is not applicable to enamelled glass side or on drawn sheet or patterned glass.

D.2.2 Calibration of the method

Each technique shall be calibrated following the particular instruction of the technique manufacturer. It shall make use of the standard glass provided by the manufacturer or any other standard glass officially certified.

NOTE Strainoptics Cal-Plate GS900[2)] was shown satisfying the requirements of this document. ASTM C 1279–13 is a calibration method satisfying the requirements to caliber techniques.

Any correction of the measurement results (see D.2.3) related to calibration shall be applied following the appropriate instruction provided by the manufacturer of the technique used.

D.2.3 Procedure of measurement

Measurement shall be performed following the particular instruction of the device manufacturer. In order to avoid additional thermal stress, the glass shall be allowed to reach the room temperature before to perform the measurement procedure and shall be placed horizontally on a table.

2) This information is given for the convenience of users of this standard and does not constitute an endorsement by ISO of the product/equipment named. Equivalent products/equipment may be used if they can be shown to lead to the same results.

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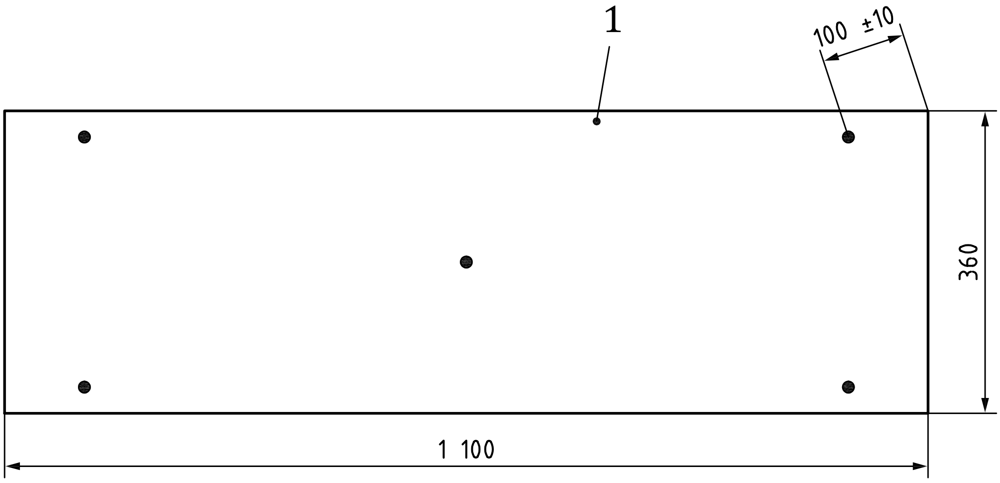
The sample which is measured should be without holes, notches or cut-outs. Minimum of five measurements on one specimen should be tested. The surface stress measurements should have place on five points as indicated in Figure D.1.



Key

1 tempered safety glass

Figure D.1 — Location of the five measurements

D.2.4 Results

Any correction of the measurement result (see D.2.3) related to calibration should be applied following the appropriate instruction provided by the manufacturer of the technique used.

The lowest value of the five measurements is taken. The mechanical strength should be calculated from the surface stress measurement using Formula (D.1):

$$\text{Mechanical strength (MPa)} = \text{surface stress} + 40 \tag{D.1}$$

The mechanical strength should satisfy the requirement of Table 12.

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Bibliography

[1] ISO 11485-1, *Glass in building — Curved glass — Part 1: Terminology and definitions*

[2] ANSI Z97.1,*American National Standard for safety glazing materials used in buildings safety Performance specifications and methods of test*

[3] AS/NZS 2208, *Safety glazing materials in buildings*

[4] CAN/CGSB 12.1-M 90,*Tempered or laminated safety glass*

[5] CPSC 16 CFR 1201, *Safety standard for architectural glazing materials*

[6] EN 572–4, *Glass in building — Basic soda lime silicate glass products — Drawn sheet glass*

[7] EN 12600*, Glass in building — Pendulum test — Impact test method and classification for flat glass*

[8] JIS R 3206, *Japanese language — Tempered glass*

[9] DUBRU M.. NUGUE J.C., VAN MARCKE DE LUMMEN G., "Toughened glass: Mechanical properties and EN 12600 behaviour", Glass Processing Days. Proceedings, 2005, pp. 66–70

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