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Glass in building — Heat soaked tempered soda lime silicate safety glass

Verre dans la construction — Verre de sécurité de silicate sodocalcique trempé et traité

Reference number
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Foreword

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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).

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

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

Introduction

Heat soaked tempered soda lime silicate safety glass has a safer breakage behaviour when compared with annealed glass. This behaviour is a direct result of the high surface pre-stress.

It also has a known level of residual risk of spontaneous breakage arising from the possible presence of critical nickel sulfide (NiS) inclusions in the thermally toughened soda lime silicate glass.

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

Other requirements, not specified in this document, can apply to heat soaked tempered 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. Heat soaked tempered soda lime silicate safety glass, in this case, does not lose its mechanical or thermal characteristics.

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

NOTE 2 In Europe, instead of “heat soaked tempered”, the term “heat soaked thermally toughened” is used.

Glass in building — Heat soaked tempered soda lime silicate safety glass

1 Scope

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

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

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)*

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
heat soaked tempered soda lime silicate safety glass
heat soaked tempered safety glass
glass within which a permanent surface compressive stress, additionally to the basic mechanical strength, has been induced by a controlled heating and cooling process in order to give it greatly increased resistance to mechanical and thermal stress and prescribed fragmentation characteristics and which has a known *level of residual risk* (3.2) of spontaneous breakage due to the presence of critical nickel sulphide (NiS) inclusions

3.2
level of residual risk
risk of spontaneous breakage of heat soaked thermally toughened soda lime silicate safety glass, on a statistical basis, due to the presence of critical nickel sulphide inclusions

Note 1 to entry: It is considered that the level of residual risk is no more than one breakage per 400 tonnes of heat soaked thermally toughened soda lime silicate safety glass[6][7][8].

3.3
flat heat soaked tempered safety glass
heat soaked tempered (thermally toughened) glass which has not been deliberately given a specific profile during manufacture

3.4
enamelled heat soaked tempered safety glass
heat soaked 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.

3.5
horizontal tempering process
process in which the glass is supported on horizontal rollers

3.6
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.

3.7
vertical tempering process
process in which the glass is suspended by tongs

3.8
edge deformation
deformation of the edge caused by the tong marks

3.9
edge lift
edge dip
distortion produced in *heat soaked tempered safety glass* (3.1) which was horizontally tempered, 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.

3.10
perimeter deformation
distortion around the edge of *heat soaked tempered safety glass* (3.1) manufactured by *air cushion process* (3.6)

3.11
local distortion
local deformation underneath the tong marks of *heat soaked tempered safety glass* (3.1) which was vertically tempered

3.12
overall bow
deformation of the whole pane of *heat soaked tempered safety glass* (3.1) caused by the heating and cooling process

3.13
roller wave distortion
periodic distortion produced in *heat soaked tempered safety glass* (3.1) which was horizontally tempered 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.

3.14
wave distortion
distortion produced in *heat soaked tempered safety glass* (3.1) manufactured by *air cushion process* (3.6) as a result of the tempering process

3.15
heat soak process
heat treatment after the tempering process during which majority of NiS inclusions is removed resulting in a known level of critical NiS inclusions in the heat soaked tempered soda lime silicate safety glass

3.16
in-line heat soak process
heat soak process (3.15) which follows immediately after the quenching process whereby the glass temperature is directly reduced from quenching to the heat soak temperature in an in-line heat soak oven

3.17
off-line heat soak process
heat soak process (3.15) carried out after the quenching process whereby the glass is cooled down to room temperature and heated up again to the heat soak temperature in an off-line heat soak oven

4 Glass products

Heat soaked 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 Manufacturing processes

5.1 General

Heat soaked tempered safety glass is manufactured as follows.

Basic soda lime silicate glass products (see Clause 4) are cut to size, shaped and edgeworked (see Clause 8).

The prepared glass panes are then tempered (see 5.2).

The tempered panes are then subjected to an off-line or in-line heat soak process cycle (see 5.3.1 and 5.3.2)

After manufacture the heat soaked tempered safety glass shall comply with the fragmentation test (see Clause 9) and mechanical strength requirement (see 10.4).

5.2 Tempering process

The cut, shaped and edgeworked glasses are tempered. The heat soaked tempered glass shall comply with the flatness criteria for horizontal or vertical tempering or the air cushion process (see 7.3).

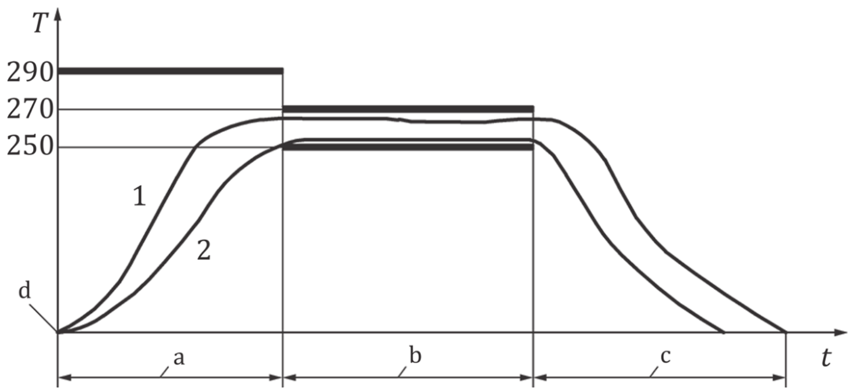
The heat soaked tempered safety glass shall have a level of fragmentation that will ensure that after the glass has been through the heat soak process, and subsequently tested to the fragmentation test (see Clause 9), it shall comply with 9.5.

5.3 Heat soak process cycles

5.3.1 Off-line process

5.3.1.1 General

The heat soak process cycle consists of a heating phase, a holding phase and a cooling phase (see Figure 1).



Key

T glass temperature at any point, °C

t time, h

1 first glass to reach 250 °C

2 last glass to reach 250 °C

a heating phase

b holding phase

c cooling phase

d ambient temperature

Figure 1 — Heat soak process cycle

5.3.1.2 Heating phase

The heating phase commences with all the glasses at ambient temperature and concludes when the surface temperature of the last glass reaches 250 °C. The maximum heating rate is 3 °C per min. The time to reach this temperature is defined in the calibration process. This time will be dependent on the size of the oven, the amount of glass to be treated, the separation between glasses and the heating system capacity.

The glass separation and rate of heating should be controlled to minimize the risk of glass breakage as a result of thermal stress.

To facilitate economic heating, the air temperature within the oven may exceed 290 °C. However, the glass surface temperature shall not be allowed to exceed 290 °C. The period of glass surface temperature in excess of 270 °C shall be minimized.

NOTE Care should be taken to ensure the maximum temperature of the glass does not exceed 270 °C as there is a possibility of the nickel sulphide inclusion reconverting.

5.3.1.3 Holding phase

The holding phase commences when the surface temperature of all the glasses has reached a temperature of 250 °C. The minimum duration of the holding phase is 2 h.

Precise oven control is necessary in order to ensure that the glass surface temperature shall be maintained in the range of 260 °C ± 10 °C during the holding phase.

5.3.1.4 Cooling phase

The cooling phase commences when the last glass to reach 250 °C has completed its holding phase, i.e. been held for two hours at 260 °C ± 10 °C. During this phase, the glass temperature shall be brought down to ambient temperature.

The cooling phase can be concluded when the air temperature in the oven reaches 70 °C.

The rate of cooling should be controlled to minimize the risk of glass breakage as a result of thermal stress.

5.3.1.5 Heat soak process system

5.3.1.5.1 General

The heat soak process system consists of the following:

— oven (see 5.3.1.5.2);

— glass support (see 5.3.1.5.2);

— separation system (see 5.3.1.5.4).

The oven shall be calibrated (see 5.3.1.5.5 and Annex F) and this determines the method of operation of the heat soak process system during manufacture of heat soaked tempered safety glass.

5.3.1.5.2 Oven

The oven shall be heated by convection and shall allow an unhindered air circulation around each glass pane. In the event of glass breakage, the airflow shall not be hindered. The airflow in the oven shall be led parallel to the glass surfaces.

The openings for the air ingress/egress should be designed to ensure that fragments of broken glass do not cause blockages.

5.3.1.5.3 Glass support

Glasses may be supported vertically or horizontally. The glasses shall not be fixed or clamped; they have to be supported to allow free movement.

NOTE Vertically means true vertical or up to 15° either side of true vertical.

The distance between glasses affects the airflow, heat exchange and the heating time. Glass to glass contact shall not be allowed.

5.3.1.5.4 Glass separation

The glasses shall be separated in a manner that does not hinder the airflow. The separators shall also not hinder the airflow, e.g. see Figure 2.

Dimensions in millimetres

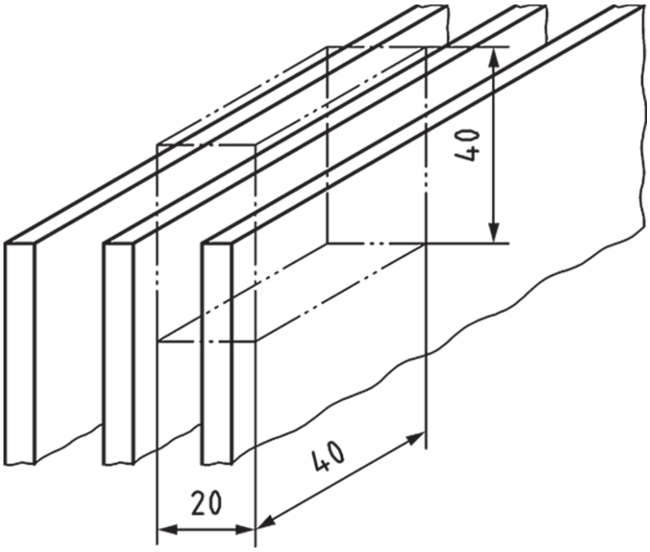


Figure 2 — Example of a vertical glass separator

The minimum separation of the glasses shall be determined during the calibration of the oven, see 5.3.1.5.5 and Annex F.

NOTE 1 Generally, a minimum separation of 20 mm is recommended (see Figure 3).

NOTE 2 If glasses of very different sizes are put on the same stillage, they will require greater separation in order to prevent glass breakage when the furnace is opened after the heat soak process. The same applies to glasses with holes, notches and cut-outs.

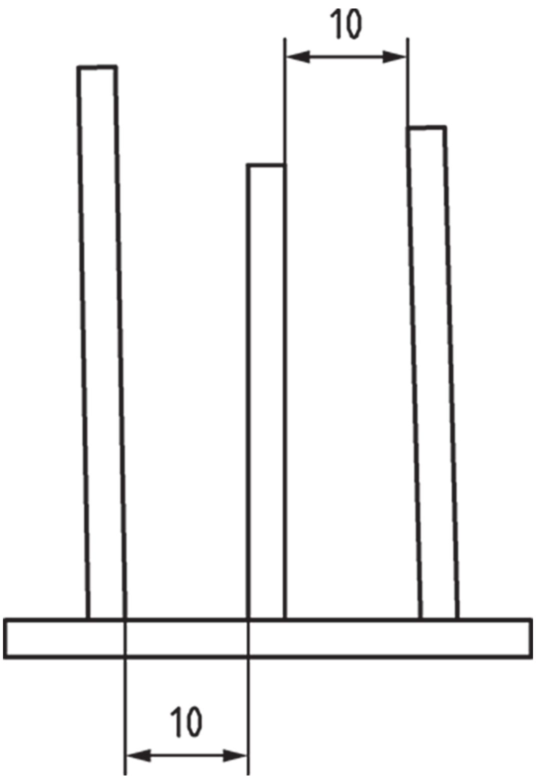


Figure 3 — Recommended separation between glass

The positioning of the separators, material of the manufacture and their shape shall be specified during the calibration test of the oven and shall be reproduced during the manufacturing process.

5.3.1.5.5 Calibration

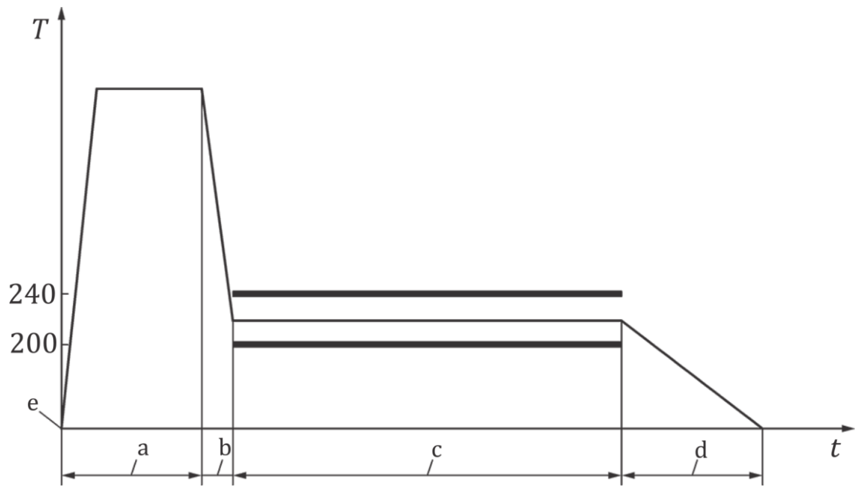
The heat soak system, e.g. oven, glass separation, separators, etc., shall be calibrated. See Annex F.

The calibration shall determine the heating phase of the process, glass separation distance, the positioning, material and shape of separators, the type and positioning of stillage(s) and define the operating conditions for use during manufacture.

5.3.2 In-line process

5.3.2.1 General

The in-line heat soak process cycle consists of only a holding phase subsequent to the quenching (see Figure 4).



Key

T glass temperature at any point, °C

t time, minutes

a heating phase for tempering

b quenching phase for tempering

c holding phase

d cooling phase

Figure 4 — In-line heat soak process cycle

5.3.2.2 Holding phase

The holding phase commences when the glass temperature has reached a temperature of between 200 °C and 240 °C. The duration of the holding phase is 12 min or more.

Precise oven control is necessary in order to ensure that the glass temperature is maintained in the range of 220 °C ± 20 °C during the holding phase.

The glass which has completed its holding phase (has been held at 220 °C ± 20 °C for 12 min or longer) is cooled down by exposure to ambient temperature.

5.3.2.3 In-line heat soak process system

5.3.2.3.1 General

The in-line heat soak process system only consists of the oven subsequent to the quenching furnace.

5.3.2.3.2 Oven

The oven temperature shall be maintained in the range of 220 °C ± 20 °C at all times. The entrance of the oven shall be designed to ensure that the temperature in the oven does not fall rapidly when the glass is moved in and out.

5.3.2.3.3 Glass temperature control

Precise glass temperature control is necessary before the glass enters the in-line heat soak oven in order to ensure that the glass is kept in the range of 220 °C ± 20 °C during the holding phase (see Annex E).

6 Fracture characteristics

6.1 General

In the event of breakage, heat soaked 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 9 due to restraint from fixing and external actions or due to the cause of fracture.

There can be different fragmentations if heat soaked tempered glass is used in laminated glass.

6.2 Accidental human impact

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

6.2.2 Heat soaked 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 heat soaked tempered safety glass is that the 10 largest crack-free particles collected within 3 min after the impact shall weigh no more than 6 500 mm^2 of the original test piece.

6.2.3 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 to the fragmentation criteria used to determine that the product complies with its definition.

6.3 Fragmentation

This test method is employed to demonstrate that the heat soaked tempered safety glass breaks in the manner expected of this product. The fragmentation test (see Clause 9) 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.

7 Dimensions and tolerances

7.1 Nominal thickness and thickness tolerances

The nominal thicknesses and thickness tolerances in Table 1 are those given in the relevant product standards (see Clause 4).

Table 1

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 centres of the 4 sides, and away from the area of any tong marks (see Figure 6), which may be present.

7.2 Width and length (sizes)

7.2.1 General

When heat soaked 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 5. It shall be made clear which dimension is the width, *B*, and which is the length, *H*, when related to its installed position.

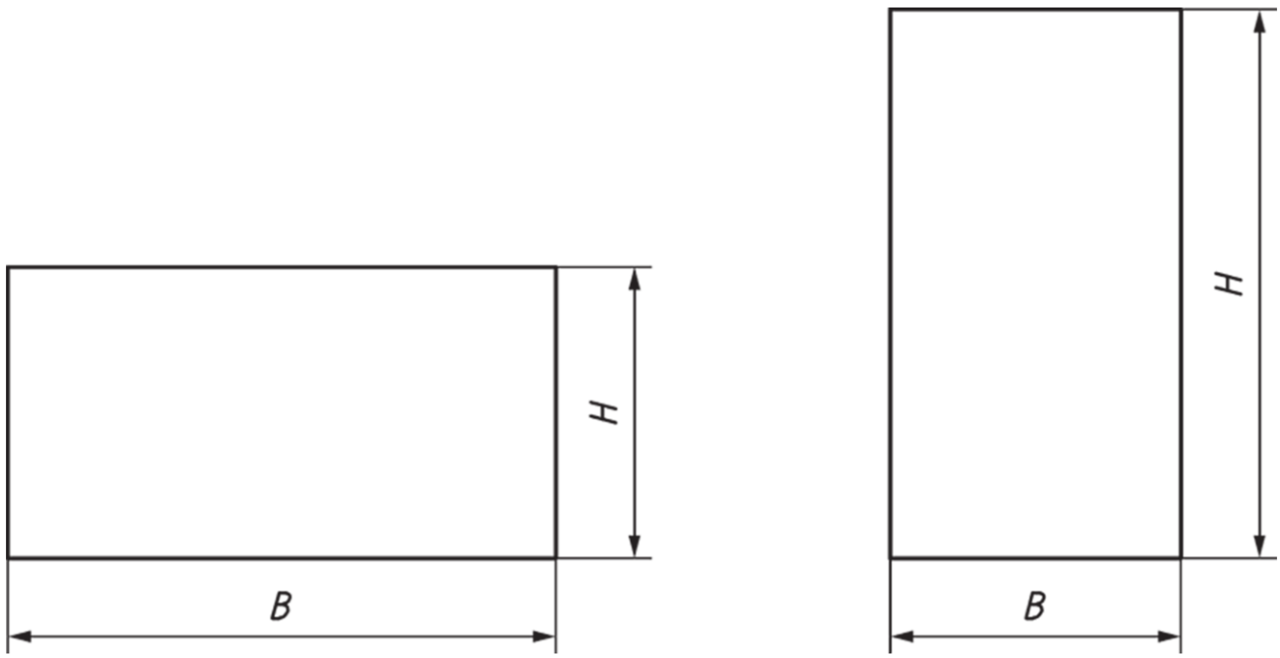


Figure 5 — Examples of width, *B*, and length, *H*, relative to the pane shape

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

7.2.2 Maximum and minimum sizes

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

7.2.3 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>

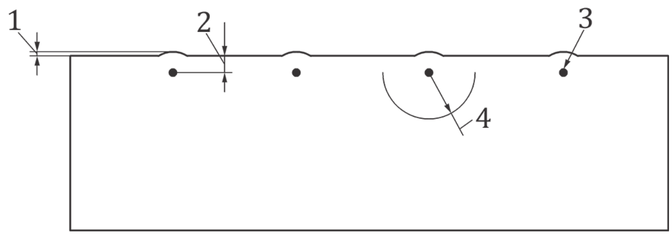
Table 3 — Limit deviations, *v*, for the difference between diagonals

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>

7.2.4 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 6). 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.



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 6 — Tong mark deformation

7.3 Flatness

7.3.1 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:

— overall bow (see Figure 7);

— roller wave distortion (only for heat soaked tempered safety glass which was horizontally tempered) (see Figure 8);

— edge lift (only for heat soaked tempered safety glass which was horizontally tempered) (see Figure 9);

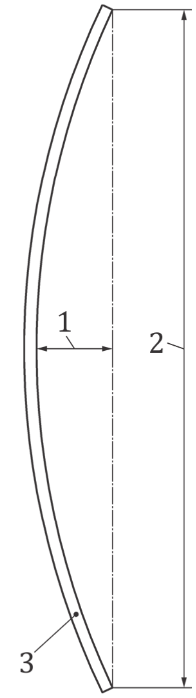
NOTE 1 Overall bow, roller wave and edge lift can, in general, be accommodated by the framing system.

— local distortion (only for heat soaked tempered safety glass which was vertically tempered) (see Figure 10);

NOTE 2 Local distortion needs to be allowed for within the glazing materials and the weather seals. For special requirements, the manufacturers should be consulted.

— wave distortion (for heat soaked air cushion tempered safety glass only) (see Figure 8);

— perimeter deformation (for heat soaked air cushion tempered safety glass only) (see Figure 14).



Key

1 deformation for calculating overall bow

2 *B* or *H* or diagonal length

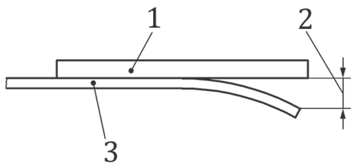
3 heat soaked tempered safety glass

Figure 7 — Representation of overall bow

Key

1 roller wave distortion

Figure 8 — Representation of wave or roller wave distortion



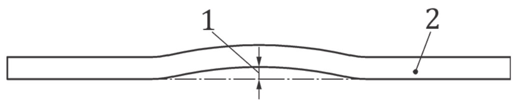
Key

1 straight edge

2 edge lift

3 heat soaked tempered safety glass

Figure 9 — Representation of edge lift



Key

1 local distortion

2 heat soaked tempered safety glass

Figure 10 — Representation of local distortion

7.3.2 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 11).

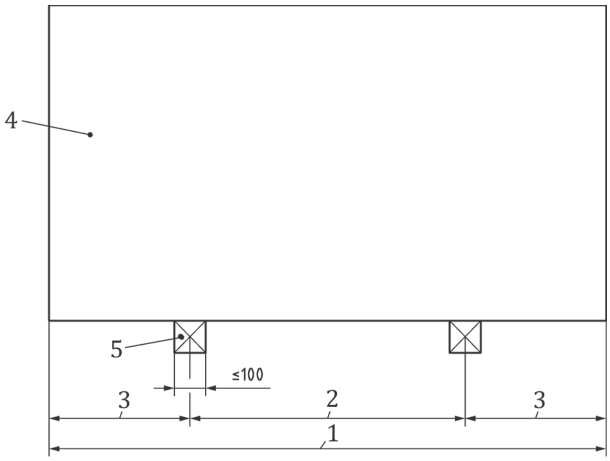
For glass thinner than 4 mm nominal thickness, a solid back support with an angle between 3° and 7° from the vertical can be used.

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 7).

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.

Dimensions in millimetres



Key

1 *B* or *H*

2 (*B* or *H*)/2

3 (*B* or *H*)/4

4 heat soaked tempered safety glass

5 load bearing block

Figure 11 — Support conditions for the measurement of overall bow

NOTE Special care has 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 may be inaccurate.

7.3.3 Measurement of wave or roller wave distortion

7.3.3.1 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 12).

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

7.3.3.2 Apparatus

A straightedge: length of between 300 mm and 400 mm.

NOTE The actual length of straight edge required will depend upon the wavelength of the wave or roller wave.

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

7.3.3.3 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 straight edge. Record the thickness of feeler gauge(s) to an accuracy of 0,05 mm.

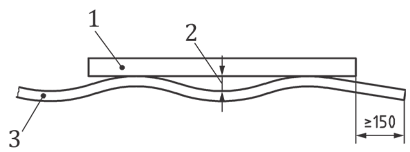
Repeat the measurement at several places over the glass surface.

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

7.3.3.4 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 straight edge

2 wave or roller wave distortion

3 heat soaked tempered safety glass

Figure 12 — Measurement of wave or roller wave distortion

7.3.4 Measurement of edge lift (only for heat soaked tempered safety glass which was horizontally tempered)

7.3.4.1 Apparatus

A straightedge: length of between 300 mm and 400 mm.

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

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

7.3.4.2 Method

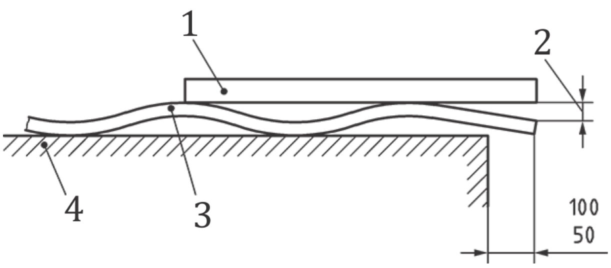
The glass shall be placed on a flat support with the edge lift overhanging the edge of the support. The overhanging distance should be between 5 cm and 10 cm.

The straight edge 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 13).

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

The values in Table 4 only apply to heat soaked tempered safety glass having edgework complying with Figure 16 to Figure 19. For profiled edges or other types of edgework, contact the manufacturer.

Dimensions in millimetres



Key

1 straight edge

2 edge lift

3 heat soaked tempered safety glass

4 flat support

Figure 13 — Measurement of edge lift

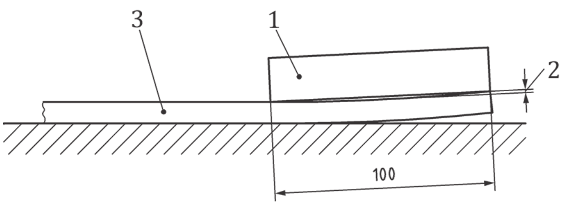
7.3.5 Measurement of perimeter deformation of glass produced by air cushion tempering process

Place the glass on a flat surface with the concave side facing upwards. See Figure 14.

A 100 mm straight edge 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 14). The perimeter deformation is the maximum distance between the surface of the pane and the straight edge.

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

Dimensions in millimetres



Key

1 straight edge

2 perimeter deformation

3 glass

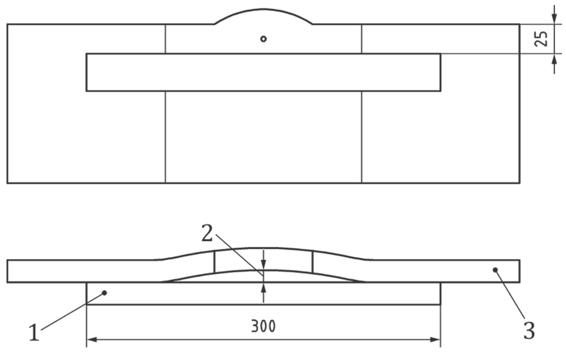
Figure 14 — Measurement of perimeter deformation

7.3.6 Measurement of local distortion (only for heat soaked tempered safety glass which was vertically tempered)

Local distortion can occur over relatively short distances on the edges with tong mark of the heat soaked tempered safety glass which was vertically tempered that contained the tong marks (see Figure 6) 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 15).

Local distortion is expressed as millimetres/300 mm length.

Dimensions in millimetres



Key

1 straight edge

2 local distortion

3 heat soaked tempered safety glass

Figure 15 — 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.

7.3.7 Limitation on overall bow, roller waves and edge lift for heat soaked tempered safety glass which was horizontally tempered

The maximum allowable values for the overall bow, when measured according to 7.3.2, for roller waves, when measured according to 7.3.3 and edge lift, when measured according to 7.3.4 are given in Table 4 and Table 5. These values only apply to thermally heat soaked tempered glass without holes and/or notches and/or cut-outs.

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

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

NOTE Dependant upon the wavelength of the roller wave an appropriate length of straight edge has to be used.

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

Table 5 — Maximum allowable values for edge lift for horizontal tempering

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

NOTE Dependant upon the wavelength of the roller wave an appropriate length of straight edge has to be used.

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

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

The maximum allowable values for the overall bow, when measured according to 7.3.2, for waves, when measured according to 7.3.3 and perimeter deformation, when measured according to 7.3.5 are given in Tables 6 and 7. These values only apply to heat soaked tempered safety glass without holes and/or notches and/or cut-outs.

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

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

7.3.9 Limitation on overall bow and local distortion for heat soaked tempered safety glass which was vertically tempered

The maximum allowable values for the overall bow (see Table 8), when measured according to 7.3.2 and the local distortion, when measured according to 7.3.5 are given in Table 6. These values only apply to heat soaked tempered safety glass without holes and/or notches and/or cut-outs.

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

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.

7.3.10 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 heat soaked tempered safety glass which was horizontally tempered or local distortion in heat soaked tempered safety glass which was vertically tempered.

8 Edge work, holes, notches and cut-outs

8.1 General

Heat soaked 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 shall be made that will affect its structural characteristics or integrity as specified in this document.

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

8.2 Edge working of glass for tempering

The simplest type of edge working is the arrissed edge (see Figure 16). Other common types are shown in Figure 17 to Figure 19. 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 heat soaked tempered without further edge working.

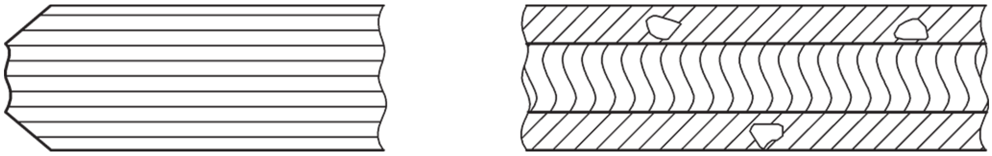


Figure 16 — Arrissed edge (with blank spots)

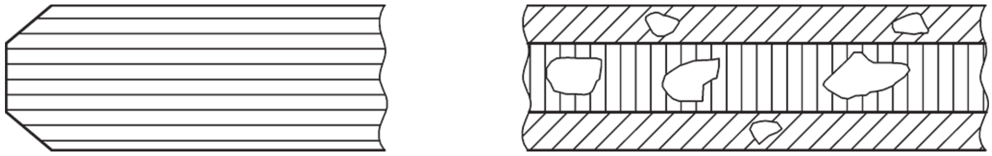


Figure 17 — Ground edge (with blank spots)

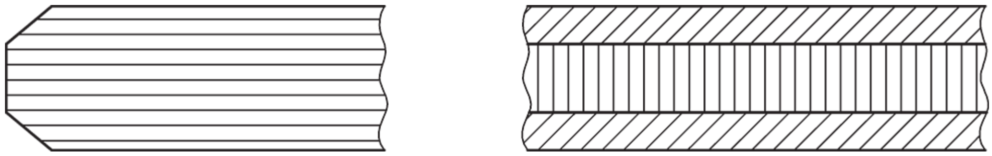


Figure 18 — Smooth ground edge (no blank spots)

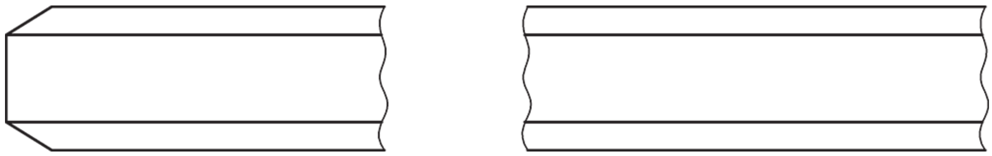


Figure 19 — Polished edge

8.3 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.

8.4 Round holes

8.4.1 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.

8.4.2 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.

8.4.3 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

— the nominal glass thickness (d),

— the dimensions of the pane (B, H),

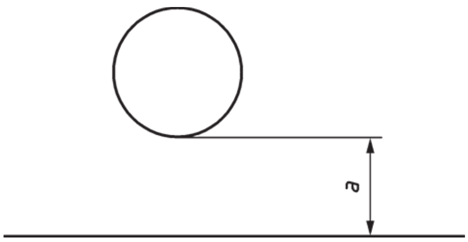
— the hole diameter (Ø),

— the shape of the pane, and

— the number of holes.

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

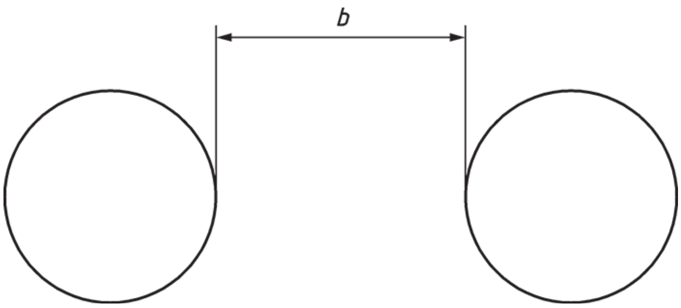
a) The distance, a, of the edge of a hole to the glass edge should be not less than 2d.



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

Figure 20 — Relationship between hole and edge of pane

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



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

Figure 21 — Relationship between two holes

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

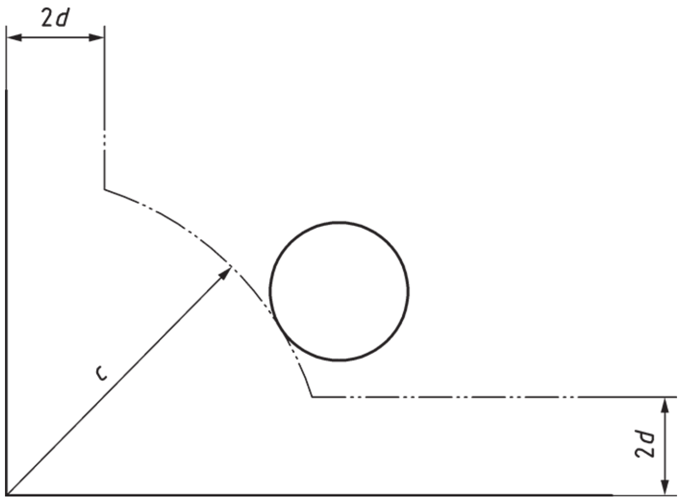


Figure 22 — Relationship between hole and corner of pane

For a distance c less than $6d$, 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.

8.4.4 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 Ø	Tolerances
4 ≤ Ø ≤ 20	±1,0
20 < Ø ≤ 100	±2,0
100 < Ø	consult the manufacturer

8.4.5 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 23, for example).

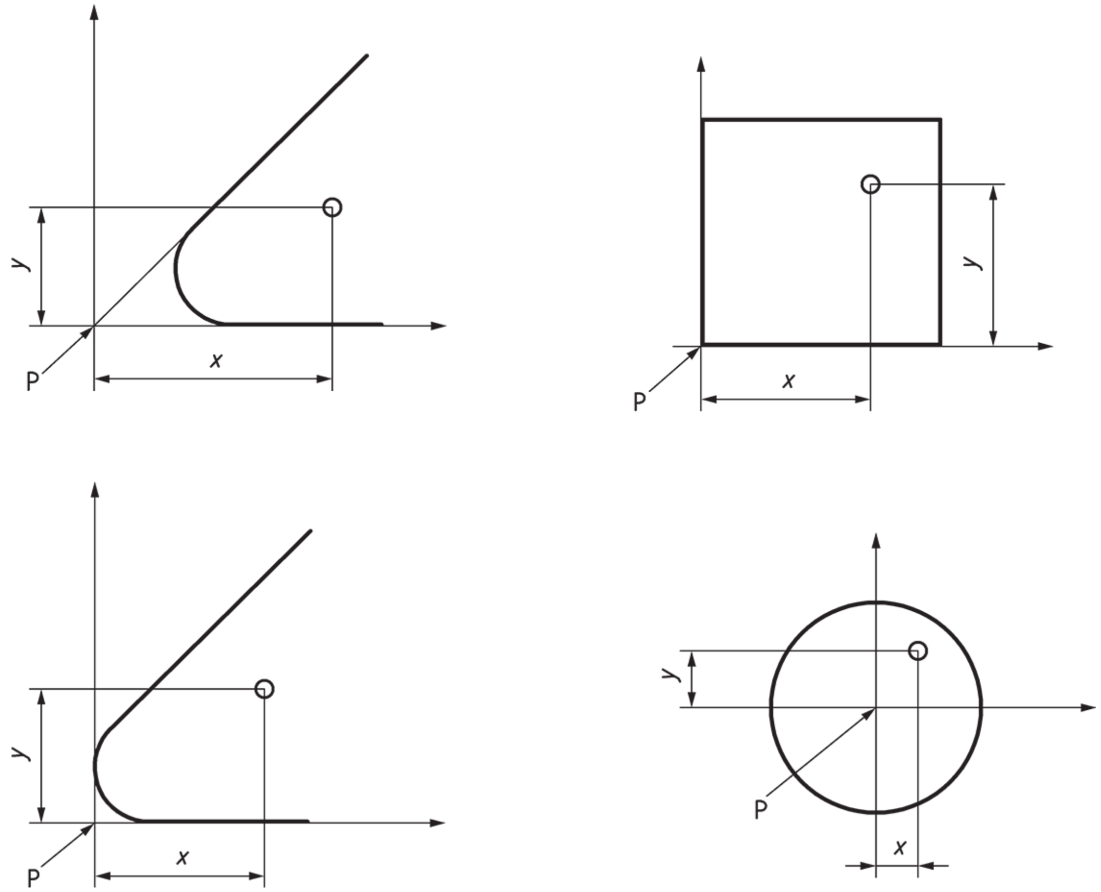
The position of a hole (X, Y) is ($x \pm t$, $y \pm t$), where x and y are the required dimensions and t is the tolerance from Table 10.

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.



Key

P datum point

Figure 23 — Examples of the positioning of holes relative to the reference point

8.5 Holes/others

There are available countersunk holes, see Figure 24. The manufacturer shall be consulted for the tolerances on hole position, hole shape/dimensions and edge work.

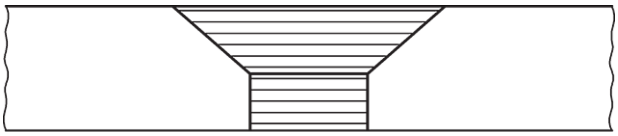


Figure 24 — Countersunk hole

8.6 Notches and cut-outs

Many configurations of notches and cut-outs can be supplied. For examples, see Figure 25.

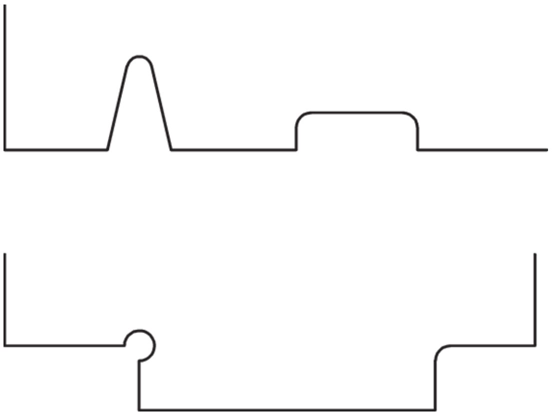


Figure 25 — Examples of notches and cut outs

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

8.7 Shaped panes

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

9 Fragmentation test

9.1 General

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

9.2 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.

9.3 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 26).

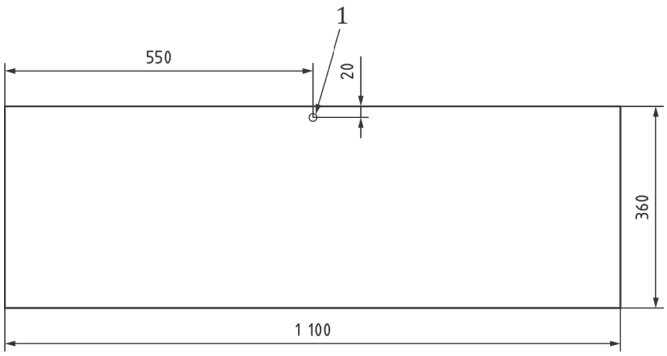
NOTE 1 The fragmentation characteristics of glass are unaffected by temperatures between −50 °C and +100 °C.

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 may constrain the glass when broken.

Dimensions in millimetres



Key

1 impact point

Figure 26 — Position of impact point

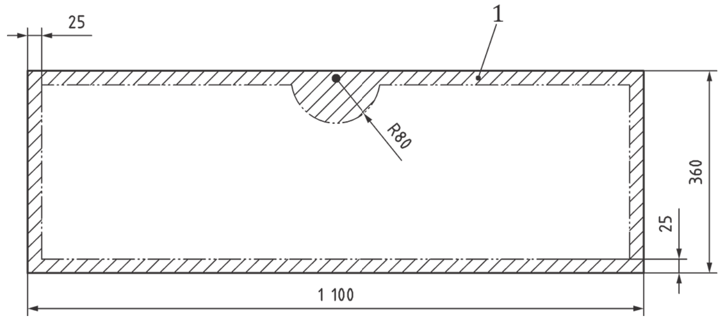
For heat soaked tempered safety glass manufactured by vertical tempering, the impact point shall not be on the tong mark edge.

9.4 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 27), 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 28).

Dimensions in millimetres



1 excluded area

Figure 27 — Area to be excluded from the particle count determination and largest particle measurement

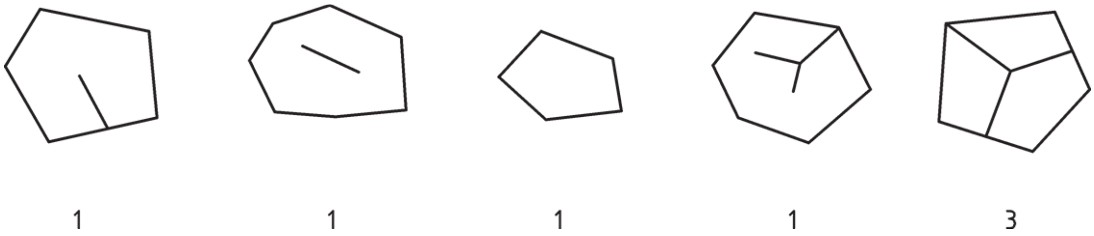


Figure 28 — Examples of crack-free particles and the assessment regarding the number

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).

9.5 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	2 and 3	30
Patterned	2 and 3	15
All glass types	4 to 12	40
All glass types	15 to 25	30

9.6 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.

9.7 Maximum length of longest particle

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

9.8 Test Report

The following information shall be reported:

— identification of the specimen;

— particle count of the fractured test specimen;

— longest particle length;

— date and time of the test;

— names, 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.

10 Other physical characteristics

10.1 Optical distortion

10.1.1 Heat soaked 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 6).

10.1.2 Heat soaked 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 7.3.3.

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

10.2 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 polarized light.

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

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

Anisotropy is a visible physical effect but not a defect.

10.3 Thermal durability

The mechanical properties of heat soaked tempered safety glass are unchanged for continuous service up to 250 °C and are unaffected by sub-zero temperatures. Heat soaked 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.

10.4 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 heat soaked tempered safety glass

Type of glass	Minimum values for characteristic bending strength MPa
Float: clear coated tinted	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 heat soaked tempered safety glass which meets the requirements of 8.5.

At least 10 specimens of heat soaked 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 not be less than the value in Table 12.

10.5 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 N/mm^2 is needed for float glass between 4 mm and 12 mm.

Possibilities for measurement during manufacturing are shown in Table 13.

Table 13 — Possibilities of measurement during manufacturing

Surface pre-stress test MPa	4 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.

11 Marking

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

— name or trademark of manufacturer;

— number of this document.

12 Packaging

Heat soaked tempered safety glasses shall be packaged by using an appropriated buffer material.

Annex A
(informative)

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 heat soaked tempered safety glass against accidental human impact

A.2.1 Japan

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

A.2.2 Australia, New Zealand

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

A.2.3 United States of America

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

A.2.5 Europe

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

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 (see Figure B.1).

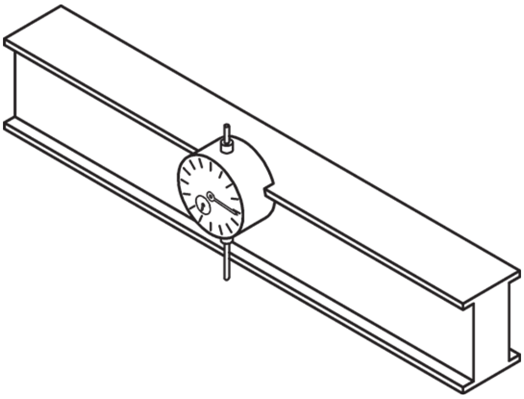


Figure B.1 — Roller wave measurement apparatus

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 (see Figure B.2).

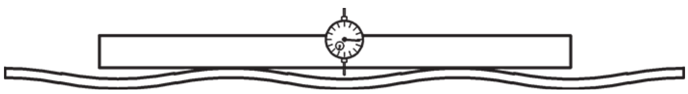


Figure B.2 — Place the apparatus across the roller wave

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

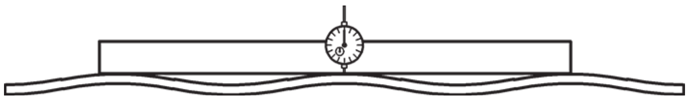


Figure B.3 — Set the zero of the gauge on a peak of the roller wave

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 (see 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.

NOTE 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.

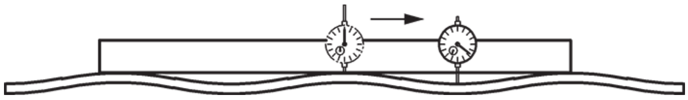


Figure B.4 — Move the gauge to a trough

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 must 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 B.4. 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.

Annex C
(informative)

Example of particle count

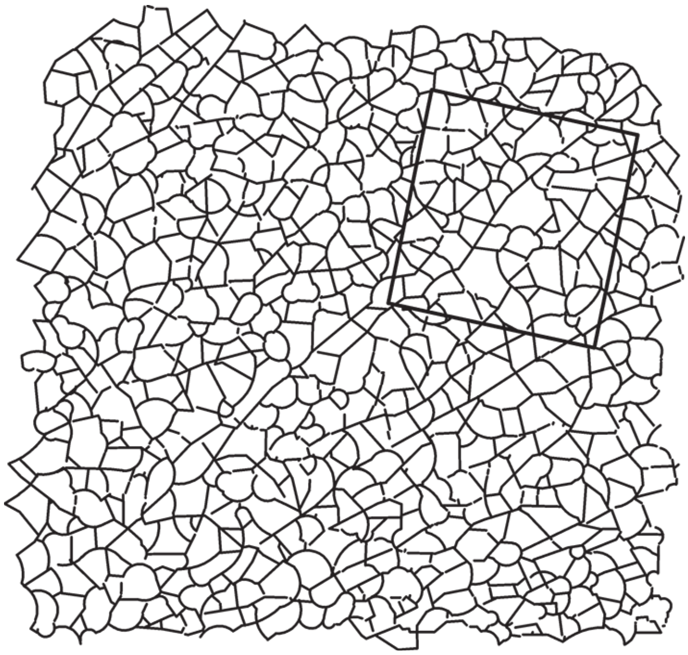
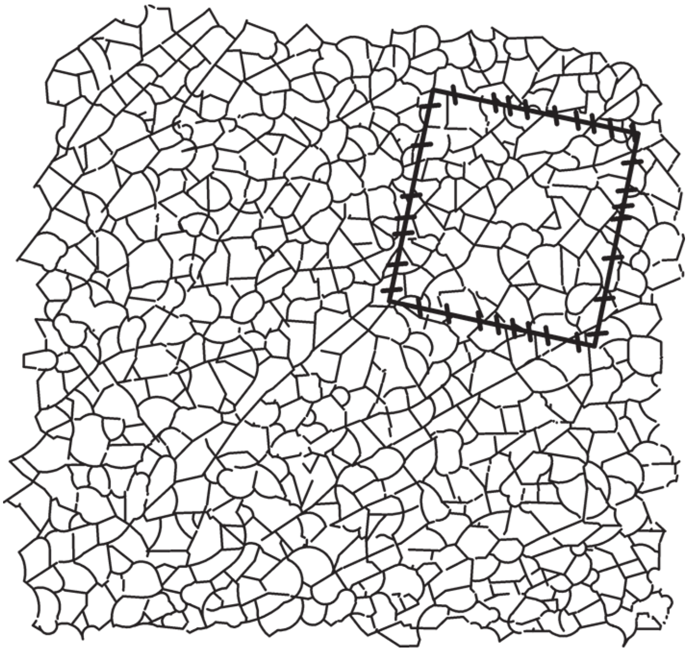


Figure C.1 — Example of selecting the area of coarsest fracture

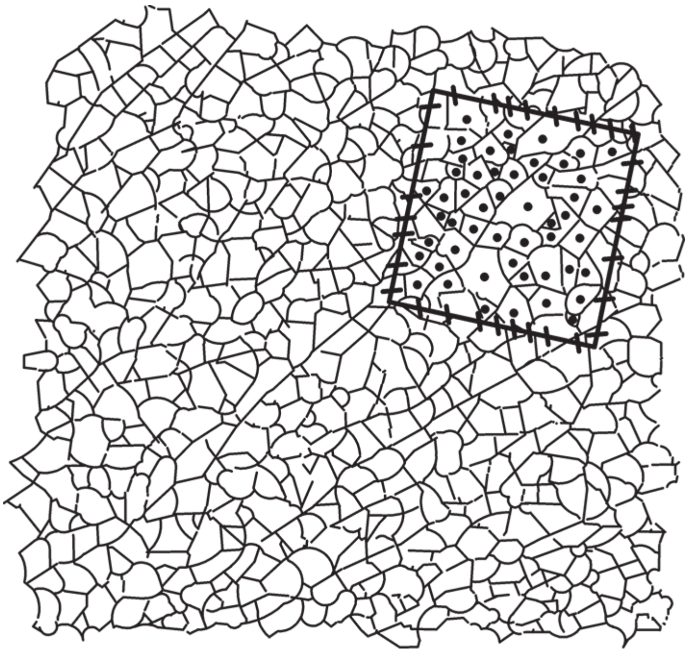
Select the area of coarsest fracture, place the template on the test specimen and draw round the template.



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.



Number of central particles = 53   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.

Annex D
(informative)

Method for the measurement of the surface pre-stress of heat soaked 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® from 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.[1)]

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 be make use of the standard glass provided by the manufacturer or any other standard glass officially certified.

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

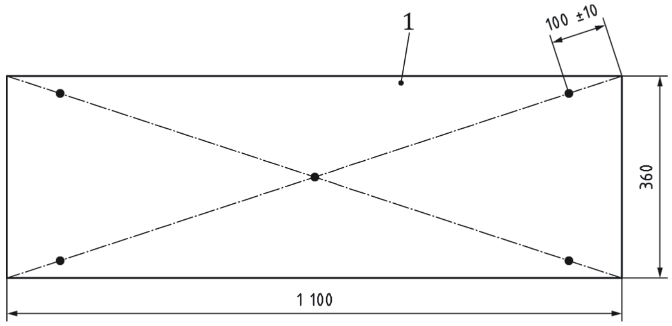
Any correction of the measurement results (see D.2.3) related to calibration shall be applied following the appropriate instruction provided by the manufacturer of the technique used.

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.

1) This information is given for the convenience of users of this document 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.

The sample which is measured should be without holes, notches or cut-outs. Minimum 5 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 heat soaked 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 following:

Mechanical strength (MPa) = surface stress + 40

The mechanical strength should satisfy the requirement of Table 10.

Annex E
(informative)

In-line heat soak process control

E.1 General

An example of a production line for tempered glass with a subsequent in-line heat soak process and a time/temperature diagram are shown in Figure E.1.

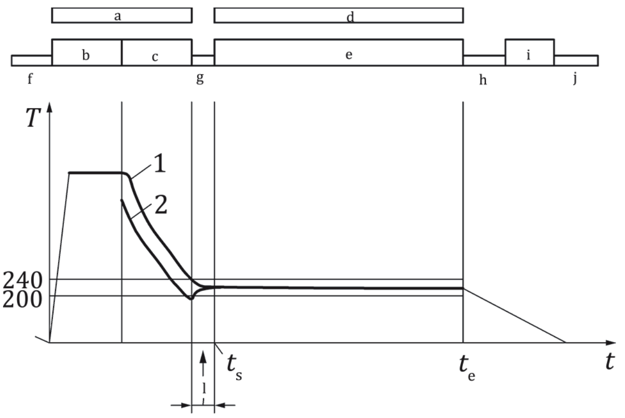
The holding phase commences when the temperature of the whole glass has reached a temperature between 200 °C and 240 °C. When the holding time, $t_e - t_s$, exceeds 12 min, the glass can be cooled down by exposure to the atmospheric temperature.

The temperature of the glass surface just after quenching is lower than the temperature of the glass centre. However, the temperatures equalize within some seconds or tens of seconds.

If the temperature of the glass after quenching is too low or too high, it takes longer to reach a temperature between 200 °C and 240 °C after the glass enters the in-line heat soak oven. Therefore, it is important to measure and manage the temperature of the glass surface before it enters the in-line heat soak oven. The temperature of the glass surface before entering the in-line heat soak oven is measured by using an infrared thermometer or other instruments.

The temperature of the glass may vary while the glass is moving from the quenching furnace to the in-line heat soak oven. This depends on the design of the production line, glass thickness and the measuring point of the temperature. Therefore, it is necessary to determine the appropriate management temperature for the glass surface according to each condition. In general, the measured temperature of glass surface needs to be at least within a range between 180 °C and 220 °C. It is desirable to set the temperature of the glass concretely and manage it by using the relevant calculations.

Generally, situations where the temperature of the glass surface is higher than 240 °C should be avoided since the temperature of the glass centre is equal to or higher than that of the glass surface.



Key

a	tempering furnace	i	washing
b	heating	j	pick up
c	quenching	1	temperature of glass midpane, °C
d	in-line heat soak oven	2	temperature of glass surface, °C
e	heat soak test	T	glass temperature at any point, °C
f	setting	t	time, minutes
g	moving	t_s	starting time of the holding phase
h	cooling	t_e	ending time of the holding phase

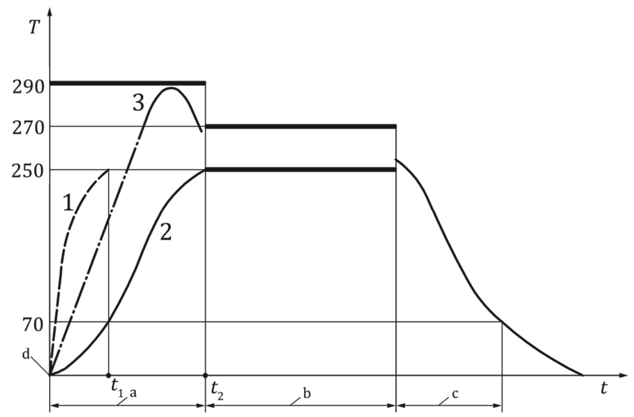
Figure E.1 — Example of the production line of tempered glass with the in-line heat soak process and time/temperature diagram

Annex F
(informative)

Heat soak process system calibration test

F.1 Calibration criteria

The heat soak process system shall comply with the time/temperature regime as shown in Figure F.1. The system shall be capable of meeting in the regime at both 100 % and 10 % load.



Key

- *T* glass temperature at any point, °C
- *t* time, h
- t_1 time for the first glass to reach 250 °C
- t_2 time for the last glass to reach 250 °C
- 1 first glass to reach 250 °C
- 2 last glass to reach 250 °C
- 3 glass temperature
- a heating phase
- b holding phase
- c cooling phase
- d ambient temperature

Figure F.1 — Time/temperature regime as calibration criteria

F.2 Loading of oven and position for glass surface temperature measurement

Figure F.2 to Figure F.9 show the appropriate pattern of stillage(s) loading and thermocouple placements for ovens, which take 1, 2, 6, 8 or 9 stillage(s).

The duration of the heating phase is dependent on the capacity of the oven and the level of load being used.

NOTE 1 Full load will be dependent on glass size, thickness and oven volume. Generally, full load will be defined based on 6 mm or 8 mm thickness.

The separation of the glasses shall be specified as shall also the type, position, material and shape of the separators. The separation of the glasses shall be constant on the stillage(s).

The minimum separation used during calibration is the minimum separation that can be employed during the manufacturing process.

NOTE 2 Generally, a minimum separation of 20 mm is recommended.

F.3 Procedure

The measurements of the air temperature in the oven and the glass surface temperatures shall be carried out when the furnace is fully loaded. This maximum load is should be defined by the glass manufacturer and shall not exceed the maximum load as defined by the oven manufacturer.

Depending on the oven construction, the oven air temperature is monitored by one or more control elements, which are located near the air egress. The measurement of the glass surface temperatures is carried out by thermocouples that are stuck, with good thermal contact, to the glass surfaces.

At the beginning of the calibration, the air temperature in the oven shall not exceed 40 °C.

During the heating phase, the oven shall be heated up until the last glass surface temperature reaches 250 °C.

During the heating phase, the glass temperature shall not exceed 290 °C at any place.

During the heating phase, the following parameters shall be recorded:

T_c temperature of the control element (at any time);

t_1 time for the first thermocouple and a glass to reach a temperature of 250 °C;

T_c1 temperature of control element at time t_1;

t_2 time for the last thermocouple and a glass to reach a temperature of 250 °C;

T_{cmax} maximum temperature of the control element during the heating phase;

t_{cmax} time at which T_{cmax} occurs;

T_{glass} temperature of the glass surfaces, measured by the thermocouples (at any time) (see Figure F.2 to Figure F.9).

The holding phase starts at time t_2 and shall last for a minimum period of 2 h. The glass surface temperatures T_{glass} shall remain within the range 260 °C ± 10 °C. The control element temperature T_c shall be recorded.

The cooling phase starts after the holding phase. The control element temperature T_c shall be recorded. The oven can be opened when T_c reaches 70 °C.

F.4 Records

The test parameters:

— t_1, T_c1;

— t_{cmax}, T_{cmax};

— t_2;

— T_c, T_{glass};

— glass separation distance;

— separator position, material, shape;

— stillage(s) configuration;

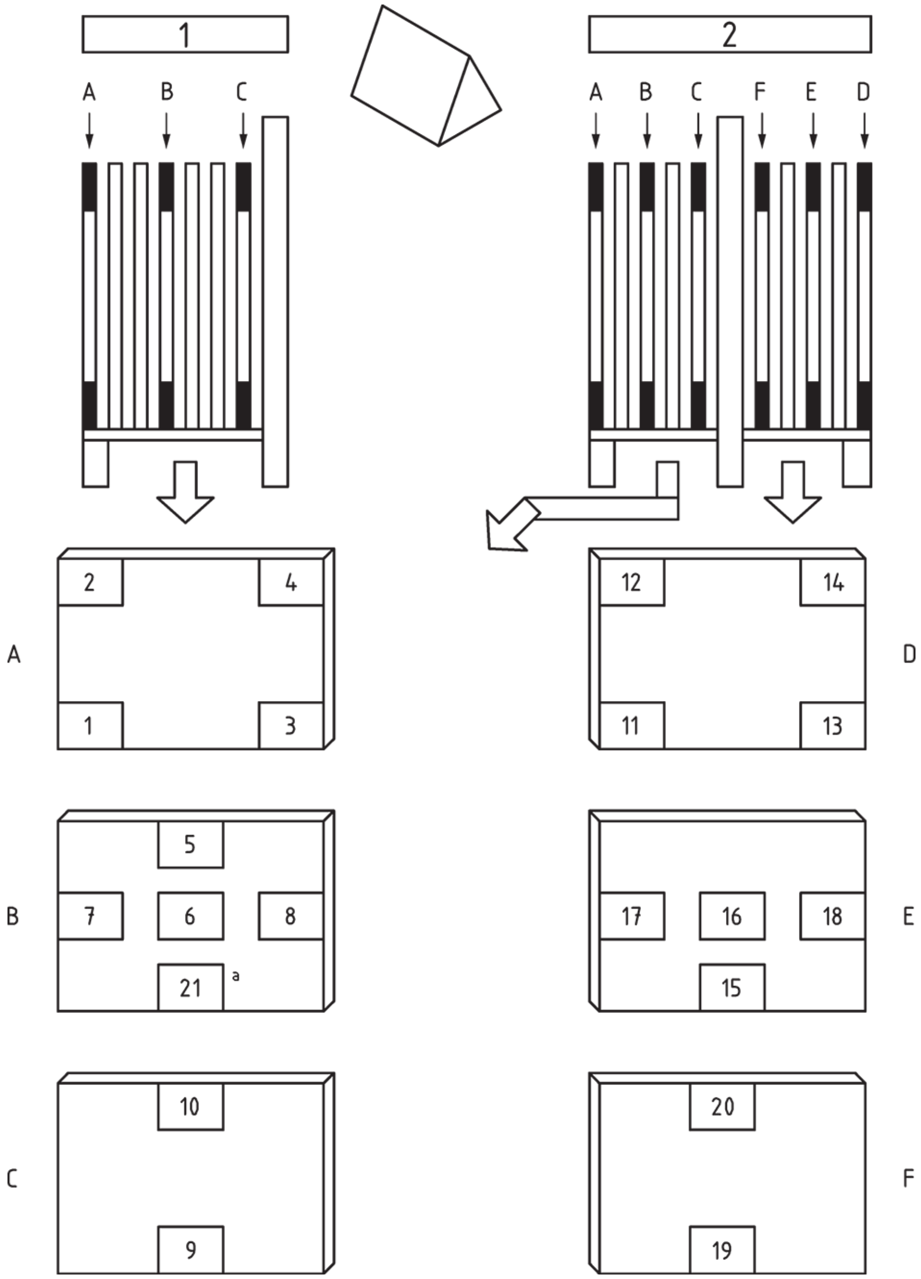
shall be recorded.

F.5 Interpretation of the calibration test

If the conditions for temperatures laid down in F.1 are not met then the oven shall not be regarded as calibrated.

Only ovens, which meet the calibration criteria as laid down in F.1 at full load may be used for the heat soak process cycle during manufacture. The time t_2 shall be used for regular production.

The heat soak process system used for manufacture shall comply with the details of the system as calibrated.



Key

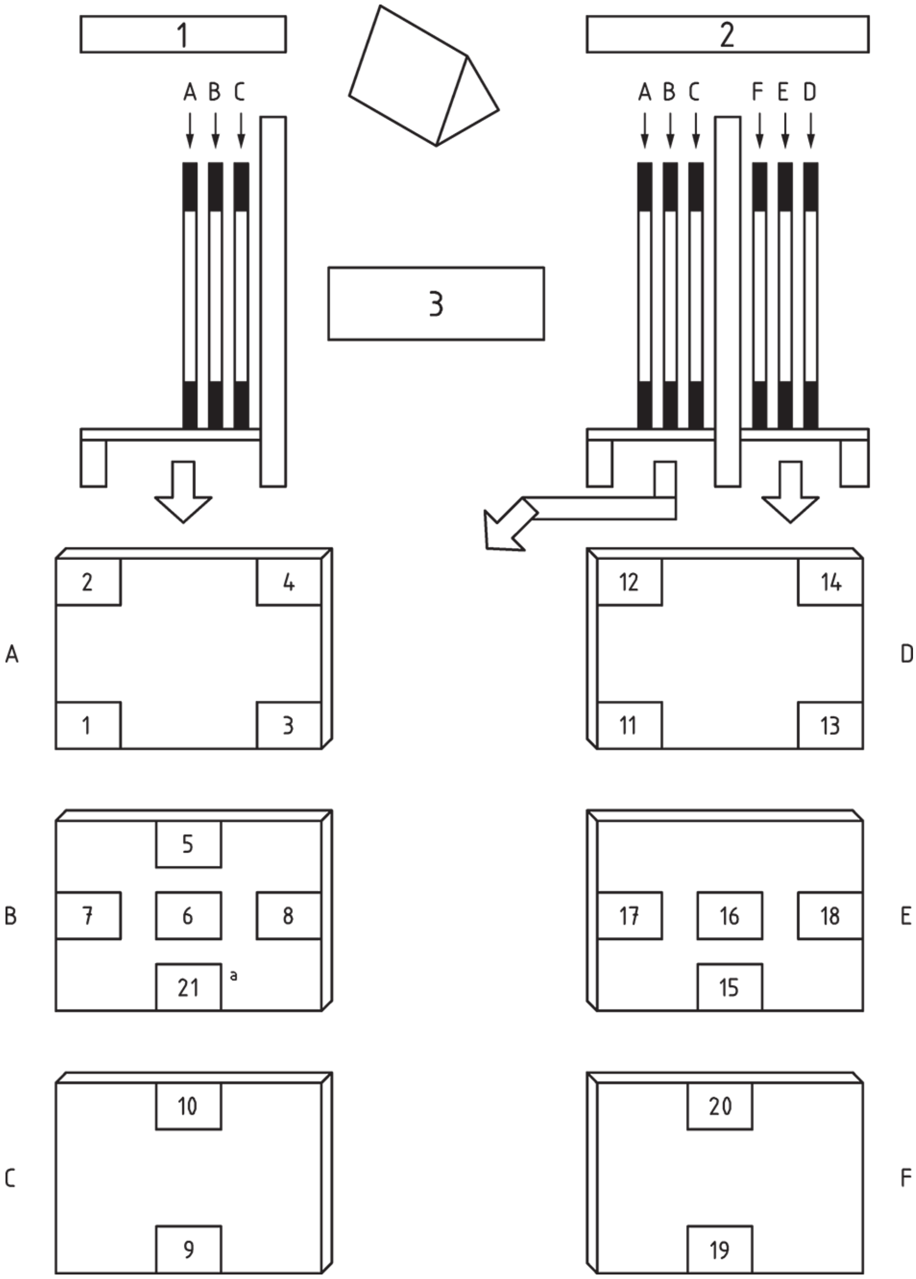
a only used for mono side stillages

1 mono side stillage

2 double sided stillage

Thermocouples should not be fixed nearer to the edge than 25 mm.

Figure F.2 — First category — 1 stillage — Full load



Key

1 mono side stillage

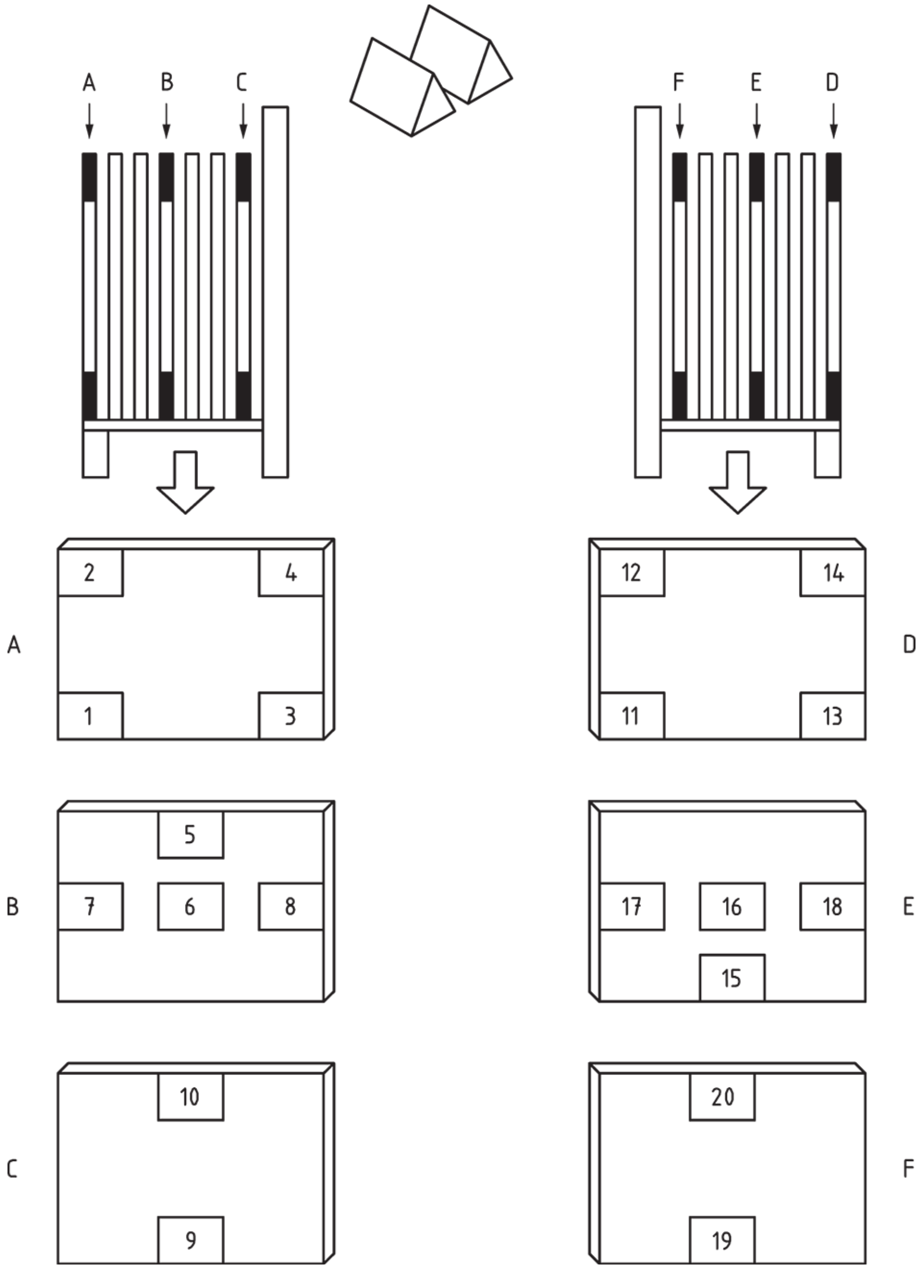
2 double sided stillage

3 on the stillage: minimum 3 glasses in parallel side by side

a only used for mono side stillages

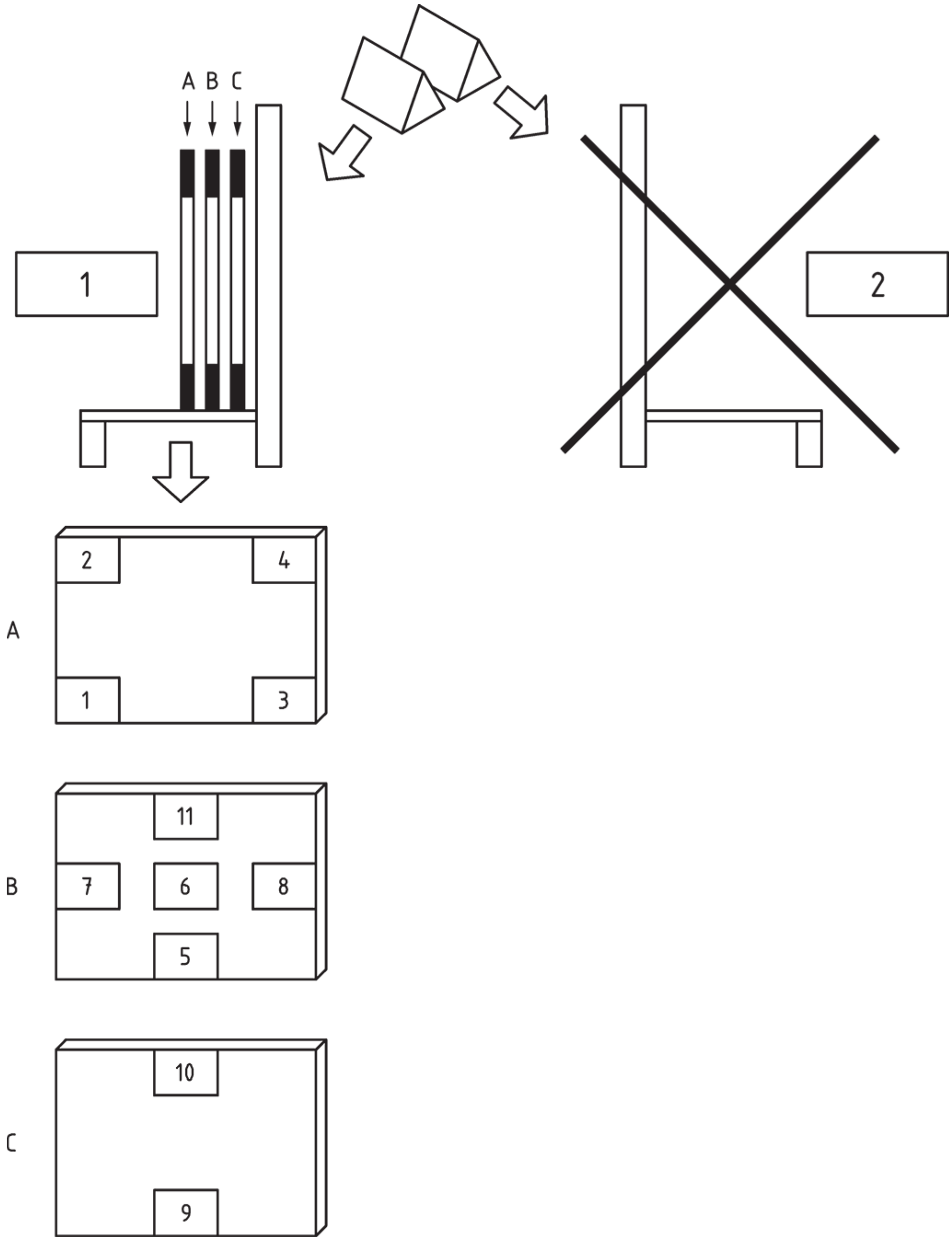
Thermocouples should not be fixed nearer to the edge than 25 mm.

Figure F.3 — First category — 1 stillage — 10 % load



Thermocouples should not be fixed nearer to the edge than 25 mm.

Figure F.4 — Second category — 2 mono side stillages — Full load



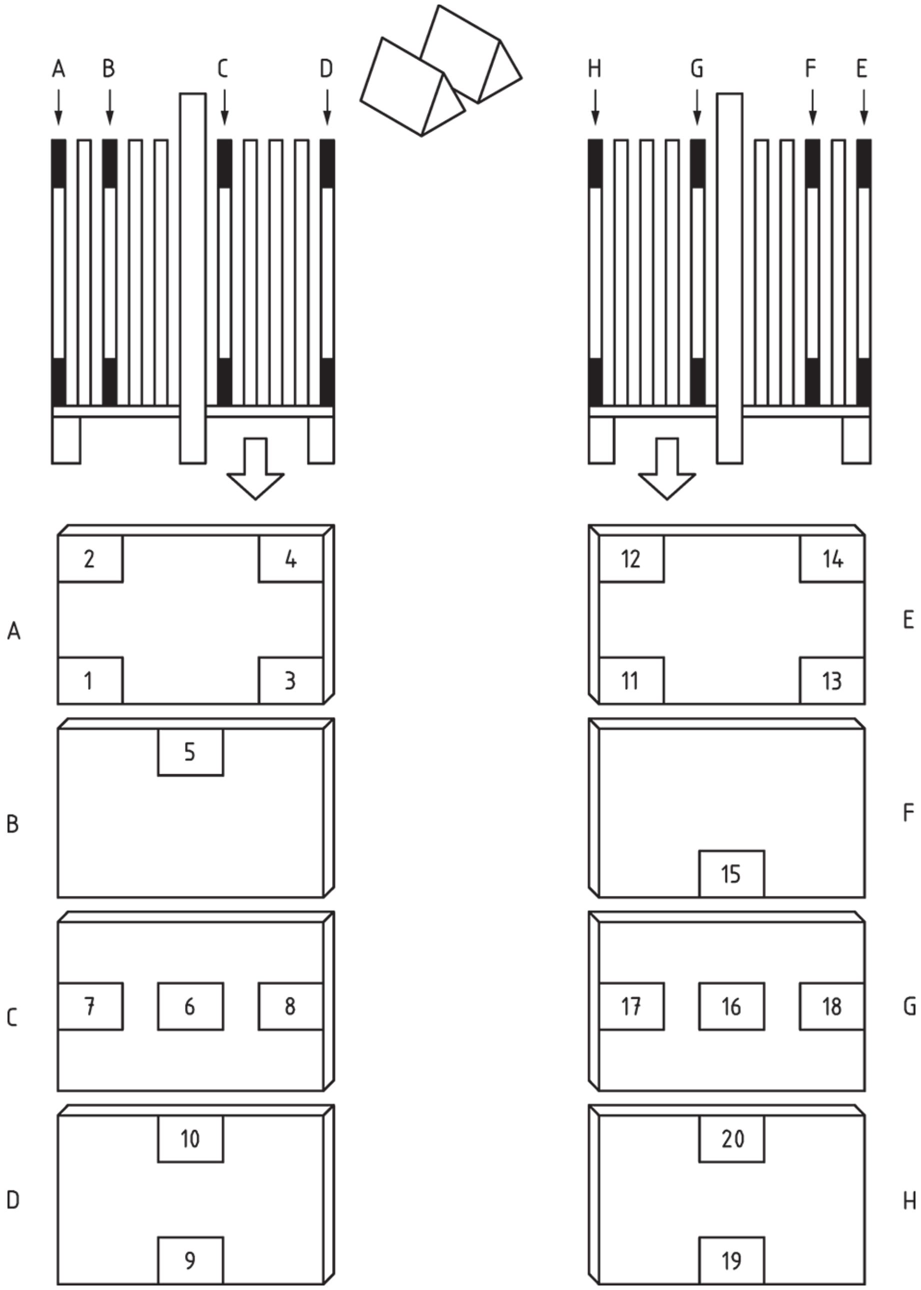
Key

1 first stillage: minimum 3 glasses in parallel

2 do not use the second stillage

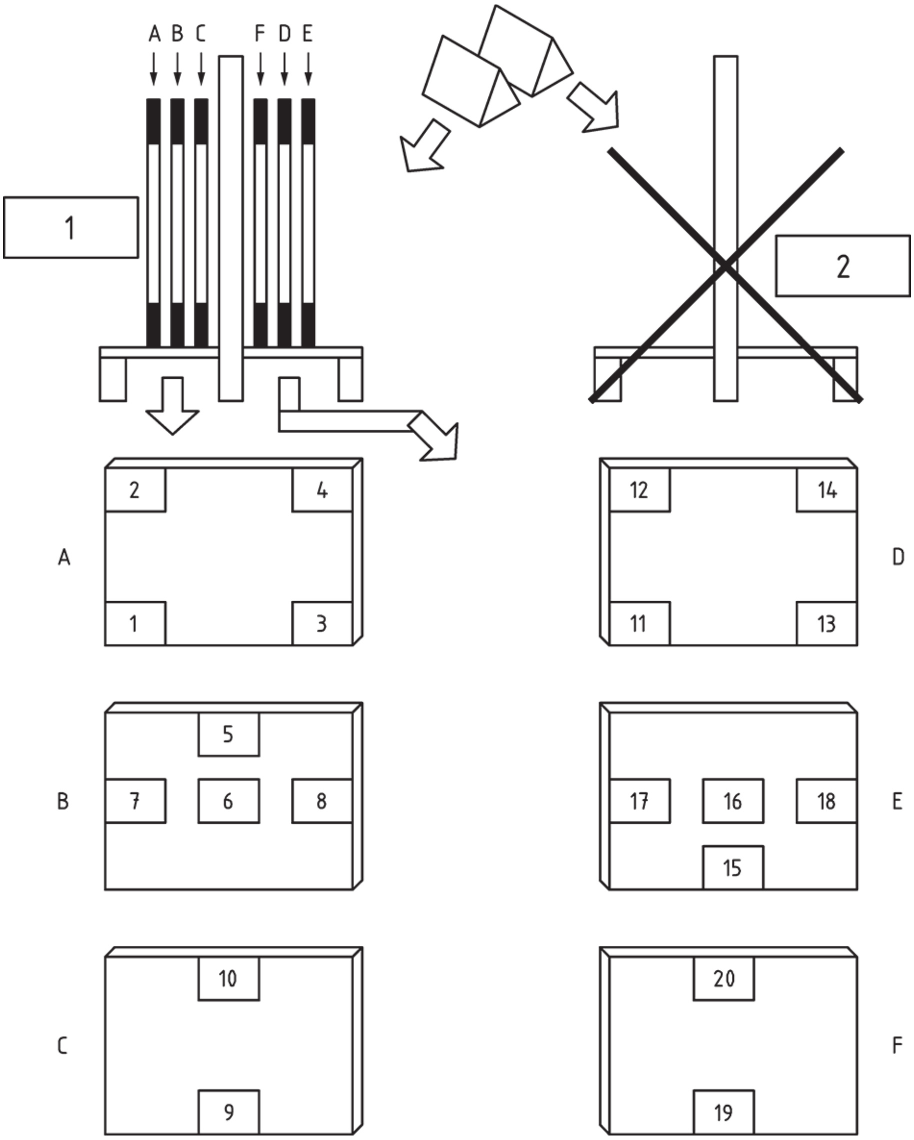
Thermocouples should not be fixed nearer to the edge than 25 mm.

Figure F.5 — Second category — 2 mono side stillages — 10 % load



Thermocouples should not be fixed nearer to the edge than 25 mm.

Figure F.6 — Second category — 2 double sided stillages — Full load



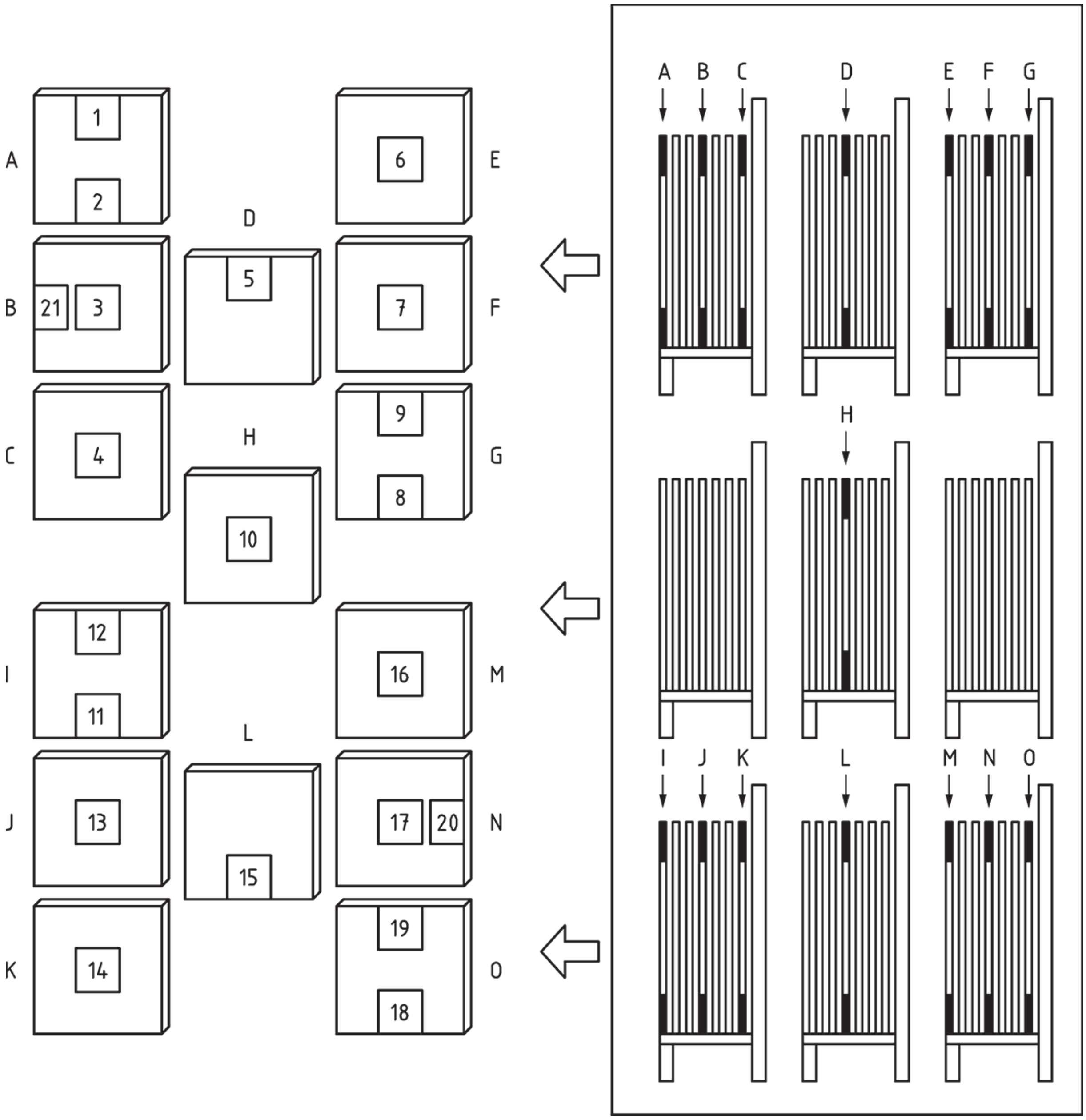
Key

1 first stillage: minimum 3 glasses in parallel side by side

2 do not use the second stillage

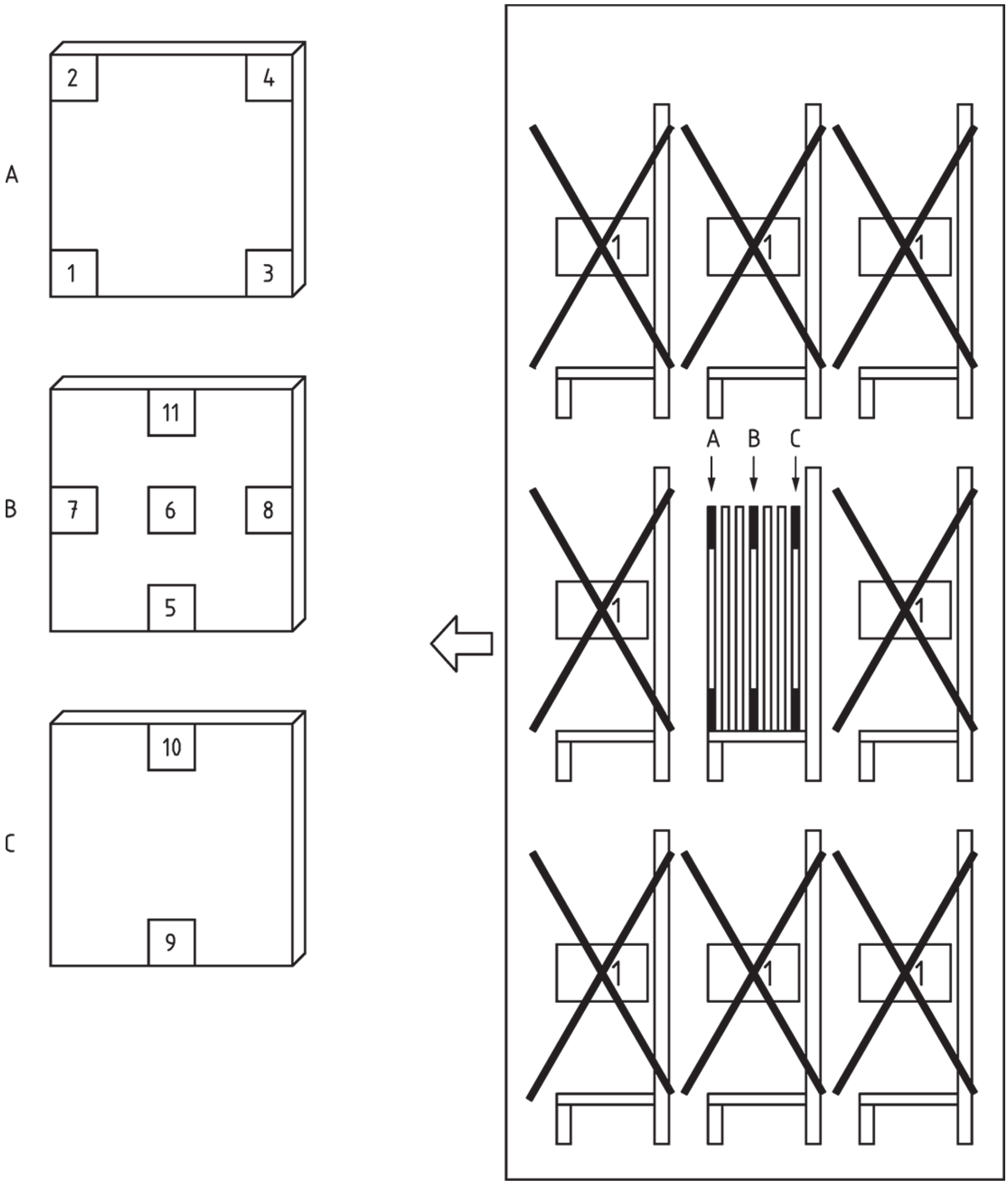
Thermocouples should not be fixed nearer to the edge than 25 mm.

Figure F.7 — Second category — 2 double sided stillages — 10 % load



Thermocouples should not be fixed nearer to the edge than 25 mm.

Figure F.8 — Third category — 6 or 8 or 9 ... stillages — Full load



Key

1 do not use

Thermocouples should not be fixed nearer to the edge than 25 mm.

Figure F.9 — Third category — 6 or 8 or 9 ... stillages — 10 % load

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