PRESSGLASS
LEADING IN EUROPE

COMPANY STANDARD

Edition 6.1

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PART I - GLASS UNITS

1. Preface
1.1 Subject Matter of the Standard

1.1.1 Glass Units
Insulating Glass Unit (IGU)

A unit, consisting of at least two panes of glass separated by one or more spacer bars and hermetically sealed along the periphery, mechanically stable and durable. Selection of, among other things, the dimensions, construction, type of glass used, the properties of the insulating glass unit, etc., shall be based on the design calculations, taking into account the conditions for a specific application.
The main application of insulating glass units is to install them in the windows, doors, curtain walls, roofs and partitions with perimeter protection against direct ultraviolet radiation. In the absence of perimeter protection against direct UV radiation such as silicone in structural glazing systems, windows are made in accordance with Annex A of EN 1279-5. Selection of such a case has to be specified in a specific order.

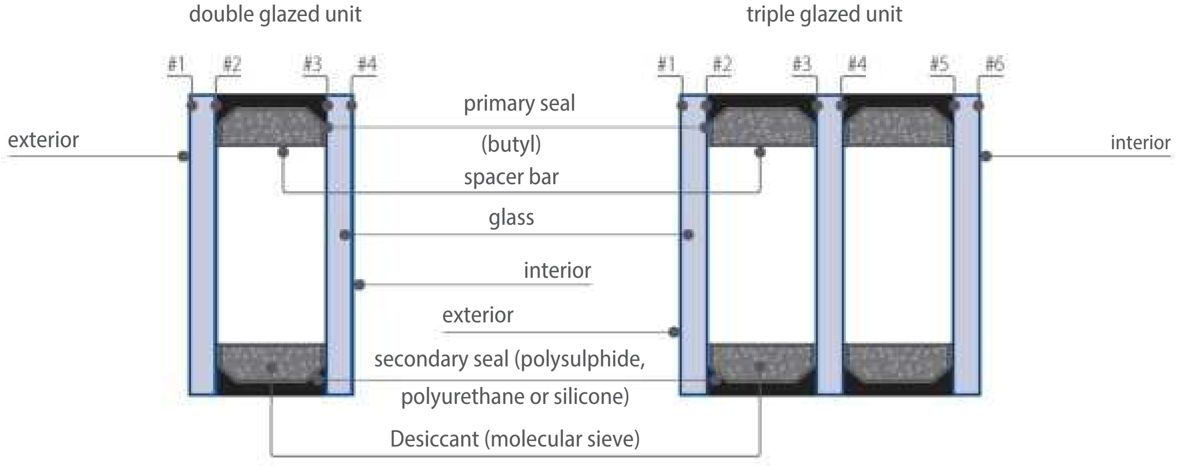


Fig. 1 Diagram of a double and triple glazed unit

1.2 Definitions

1.2.1 Nominal thickness of a double glazed unit
The sum of 2 glass panes plus spacer thickness

1.2.2 Nominal thickness of a triple glazed unit
The sum of 3 glass panes plus 2 spacer thicknesses

(!) NOTE: For tolerance glass unit thicknesses in relation to the nominal thickness, see Table 1 of the Company Standard.

2. Marking

2.1 Method of glass unit identification

All glass units shall be permanently marked on the spacer bar with the following information:

- EN 1279 - European Standard
- PRESS GLASS SA - manufacturers' name
- 2013/09/14 8:15 - date and time of production
- (10114/12) - lauf No. and glass pane position in the lauf (in brackets)
- Z/63034/2013 - PRESS GLASS order No.
- p.3 - order item
- FL 4/16/TH1,1 4 - description of glass type / name and thickness–(generally, the first glass pane in the description of the unit is the outer pane) and spacer bar(s) width(s)
- Ar - type of gas used

NOTE: the description on the spacer bar may optionally include some additional information agreed with the customer. PRESS GLASS maintains records of all orders within the computer archive system. All order information can be retrieved.

2.2 Examples of printed spacer bar information

PN-EN 1279 PRESS GLASS SA 2013/09/14 8:15 (10114/12) Z/63034/2013 p.3 FL 4/16/TH1,1 4 U=1,1 EN673 Ar 704x655

Double glazed unit made in accordance with EN 1279 by PRESS GLASS SA on 14/09/2013 at 8:15, (lauf No.: 10114, pos. 12), PRESS GLASS order No.: Z/63034/2013 item 3, of float (FL) and Thermofloat (TH) glass, of uniform thickness 4mm, with 16mm(/16/) wide spacer bar, U=1.1 acc. to EN673, and filled with argon (Ar), of the following size: 704x655mm.

PN-EN 1279 PRESS GLASS SA 2013/09/14 12:54 (10117/11) Z/63037/2013 p.8 TH1,0 4/16CH.ULT7035/FL4/16CH.ULT7035/TH1,0 4 U=0,5 EN673 Ar

Triple glazed unit made in accordance with EN1279 by PRESS GLASS SA on 14/09/2013 at 12:54, (lauf No.: 10117, pos. 11), PRESS GLASS order No.: Z/63037/2013 item 8 of Thermofloat (TH) and float (FL) glass, of uniform thickness 4mm and spacer bars of equal width of 16mm, U=0.5 acc. to EN673 and filled with argon (Ar).

3. Requirements

3.1 Durability of the glass unit

Durability of the glass unit is ensured by fulfilling the following conditions:

- moisture penetration index (I) shall be in accordance with the requirements of EN 1279-2
- edge seal resistance shall meet requirements of EN 1279-4
- the production process shall take the requirements of EN 1279-6 into account
- the recommendations given in par. 4.4 and Annex B, EN 1279-5 shall be met (see Note 1)
- in the case of gas filled insulating glass units gas leakage rate shall be in accordance with EN 1279-3

NOTE 1: Durability of glazing products depends upon:

- movements of buildings and structures caused by various interactions
- vibration of buildings and structures caused by various interactions
- deformations or damage caused to the frame / glazing system caused by various interactions
- inadequately designed or maintained frame / glazing system (e.g. inadequate / blocked drainage points, protection against direct contact of glass with structural elements, etc.)
- dimensional accuracy of the glass fastening structure and components supporting glass
- quality of installation of glass packing / supporting materials in the framing / glazing system
- quality of the frame / glazing system installation in or on buildings or structures
- expansion / retraction / movement of the frame / glazing system due to moisture or thermal absorption
- installation quality of the glazing product in or on its supporting structure

NOTE 2: When two coated glass panes are used in the construction of a triple glazed unit (including one as the internal pane), due to potential thermal stress, tempering of the glass is advisable. However final construction is the decision of the Purchaser.
When glass with a higher energy absorption index is used within a glass unit, tempering is obligatory.

NOTE 3: Permissible operating temperatures of primary & secondary sealant should also be considered in the glass unit design.

3.2 Shape and dimensions of the glass units

The dimensions of rectangular glass units shall be expressed as width first followed by height. Dimensions shall be given millimetres. The minimum feasible dimension of the glass unit is 250 x 180 mm. Production of shaped glass units other than rectangles is allowed after agreement between the manufacturer and the customer. Shaped glass dimensions must be provided according to the Shaped Glass Catalogue, contained in Part III of this Standard. If/when determination of any shape dimension is not possible, a full sized template (1:1 ratio) made of hardboard/ plywood or a technical drawing of the format must be provided. The outer edges of the template must represent the edges of the glass panes. Shaped glass units manufactured from a template shall be subject to a dimensional tolerance of 2 mm. The templates are stored for a period of 30 days from the date of manufacture. Any complaints concerning the glass dimensions will not be considered after this period.

NOTE 1: In the absence of alternate information from the customer, shapes will be assumed to be viewed from the interior (it applies to companies manufacturing PVC and wooden joinery.)

NOTE 2: Unless specified, the orientation of the glass pattern for orders including patterned glass shall be the glass 'height' dimension

NOTE 3: In the case of reflective glass coatings, location of the coating in the glass unit (position according to Fig.1) must be specified on the customer order. Positions #2 or #3 are recommended, and for triple glazed units positions #4 and #5.
Insulating glass units can be made of monolithic glass and laminated glass of various thicknesses, separated by a spacer bar.

The thickness of the glass unit shall not deviate from the nominal thickness agreed between the manufacturer and the customer of more than the deviations in Table 1 below (Table 3 - according to EN 1279-1.)

Table 1

Thickness deviation of the insulating glass units in relation to the nominal thickness

Glass pane #1	Glass pane #2	Thickness tolerance of IGU
a) Annealed glass [1]	Annealed glass	± 1.0 mm
b) Annealed glass	Tempered or reinforced glass [2]	± 1.5 mm
c) Annealed glass thk. ≤ 6 mm and total thk. ≤12 in other cases	Laminated glass [3]	 ± 1.0 mm ± 1.5 mm
d) Annealed glass	Patterned glass	± 1.5 mm
e) Tempered or reinforced glass	Tempered or reinforced glass	± 1.5 mm
f) Tempered or reinforced glass	Glass/plastic composite [4]	± 1.5 mm
g) Tempered or reinforced glass	Patterned glass	± 1.5 mm
h) Glass/plastic composite	Glass/plastic composite	± 1.5 mm
i) Glass/plastic composite	Patterned glass	± 1.5 mm

[1] The pane thicknesses are specified by their nominal values

[2] Thermally tempered safety glass, heat strengthened glass or chemically strengthened glass

[3] Laminated glass and laminated safety glass consisting of two annealed float glass panes (each having a maximum thickness of 12 mm) and plastic interlayer. In the case of other laminated glass or laminated safety glass units, see EN ISO 12543-5, and then apply the rules for the calculation below (par. 5.3.3 according to EN 1279-1)

Thickness tolerances of insulating glass units with multiple spacer thicknesses can be obtained by applying the following principles:

a) specify tolerances of each component glass/ spacer thickness/glass in accordance with Table 1 (Table 3 acc. to EN 1279-1)
b) square these values
c) sum up the square values
d) calculate the square root of the sums

[4] Glass/plastic composites are laminated glass comprising at least one plastic interlayer material, see EN ISO 12543-1

Table 2

Approximate maximum area of insulating glass units *

Thk. of the glass component [mm]	Max aspect ratio [-]	Max area [m²]	Max length of the side [mm]	Min distance between panes [mm]	Example of the unit description
3	1:6	1,5	1500	9	3-9-3
4	1:6	2,00	2000	6	4-6-4
		2,50	2500	9	4-9-4
		3,35	2500	12	4-12-4
		3,35	2500	16	4-16-4
5	1:10	2,50	2500	6	5-6-5
		3,50	3000	9	5-9-5
		5,00	3300	12	5-12-5
		5,00	3300	16	5-16-5
6	1:10	3,00	3000	6	6-6-6
		4,50	3000	9	6-9-6
		7,00	3500	12	6-12-6
		7,00	3500	16	6-16-6
8	1:10	4,00	3000	6	8-6-8
		6,00	3000	9	8-9-8
		8,75	3500	12	8-12-8
		10,00	5000	16	8-16-8
10	1:10	13,50	5000	16	10-16-10
12	1:10	13,50	6000	16	12-16-12

- for production reasons, the maximum length of the short dimension of the glass unit is limited to 3000 mm and for Toughened (ESG), Heat Strengthened (TVG) and Laminated (VSG) glasses to 2800 mm
- if glass of various thicknesses is used, the area is always limited by the thinnest glass pane
- to determine the appropriate thickness of a laminate glass pane, a conversion factor of 0.63 will be applied to the thickness of the comparable float glass (excluding the thickness of the laminate interlayer / foil)
- Spacer bars with a width >16mm will be assumed to correspond to the data for 16mm spacer bars in the table above

* Maximum dimensions of the manufactured glass units included in the table above only apply to the following conditions:
1 – 90 degree vertical glazing,
2 – height of glazing: 0 - 8 m above ground level,
3 – four edge supported,
4 – not applicable to corner glazing of buildings,
5 – average wind loads for Poland have been assumed.

! The above data is only a suggestion, and does not take into account the loads of the building structure or dynamic loads placed upon the glass, only static loads of glass units themselves. These suggestions are to be approved prior to their use by an appropriately qualified building engineer certified to design in accordance with the prescribed construction regulations.

Table 3

Sealing efficiency of glass units by EN 1279 -1 Glass in building. Insulating glass units. Annex B

Applies to	Sealing efficiency	Valid method	Required acc. to
All IGU systems	Water vapour permeability	EN 1279-2	EN 1279-2
	Sealant adhesion to glass	EN 1279-4	EN 1279-4
Gas filled IGU's	Gas leakage rate	EN 1279-3	EN 1279-3
Gas concentration	—	Factory production control acc. to EN 1279-6	EN 1279-6, Annex A.3

3.3 Material

3.3.1 Glass

The type and quality of glass shall be agreed between the manufacturer and the customer prior to the execution of order. The following glass shall be used in the units:

a) basic glass products acc. to EN 572-1:
- float glass acc. to EN 572-2
- polished wired glass acc. to EN 572-3
- drawn flat glass acc. to EN 572-4
- patterned plate glass acc. to EN 572-5
- wired patterned glass acc. to EN 572-6

b) basic products of special glass:
- borosilicate glass acc. to EN 1748-1-1
- glass ceramics acc. to EN 1748-2-1
- alkaline earth silicate glass acc. to EN 14178-1

c) processed glass:
- heat strengthened soda lime silicate glass acc. to EN 1863-1
- thermally tempered soda lime silicate safety glass acc. EN 12150-1
- heat-soaked, thermally-tempered soda lime silicate safety glass acc. to EN 14179-1
- chemically strengthened soda lime silicate glass acc. to EN 12337-1
- thermally tempered borosilicate safety glass acc. to EN 13024-1
- thermally tempered alkaline earth silicate safety glass acc. to EN 14321-1
- laminated glass and laminated safety glass acc. to EN ISO 12543 -1,-2,-3,-4,-5,-6
- coated glass acc. to EN 1096-1
- surface processed glass (e.g. sand-blasted, acid-etched, etc.)

d) or other processed glasses, such as glass/plastics composite consisting of at least one basic or processed glass product specified above and of at least one plastic interlayer

e) or other glasses covered or not by European specifications

Panes of glass, processed or not, can be:
- transparent, translucent or opaque, and
- colourless or coloured

3.3.2 Other materials

Other materials used in the glass unit construction shall ensure the quality of the product in accordance with the requirements of EN 1279 – 1 - 6.

3.4 Production

Glass production technology shall ensure adequate quality. Dimensional deviations result from tolerances of the machinery and equipment operation.

In double glazed units, permissible offset of glass panes to each other is up to 1 mm.

In triple glazed units, permissible offset of glass panes to each other is up to 1mm, and 2mm for the outermost glass panes. For tempered glass, safety glass or other special glasses, provided that no mutual agreements exist, the dimensional tolerances as specified in Table 4 below shall apply.

Table 4

All glass panes made of float glass and/or drawn flat glass		
Side dimension	Side thickness	Width and height deviations
≤ 3 m	≤ 6 mm	± 2 mm
	> 6 mm	± 3 mm
> 3 m	≤ 6 mm	± 3 mm
	> 6 mm	± 4 mm
With glass/glass sealing, regardless of dimension	regardless of thickness	+ 1 mm - 2 mm
At least one glass pane made of tempered glass		
Side dimension	Side thickness	Width and height deviations
≤ 3 m	regardless of thickness	± 3 mm
> 3 m	regardless of thickness	± 4 mm
At least one glass pane made of plate glass		
	Plate glass thickness	Width and height deviations
	≤ 10 mm	± 4 mm
	> 10 mm	+ 8 mm - 4 mm
At least one glass pane made of laminated glass		
Side dimension	Total thk. of laminated glass	Width and height deviations
≤ 1.5 m	≤ 16 mm	± 3 mm
	> 16 mm	± 4 mm
> 1.5 m and ≤ 2.5 m	≤ 16 mm	± 4 mm
	> 16 mm	± 5 mm
> 2,5 m	≤ 16 mm	± 5 mm
	> 16 mm	± 6 mm

The following components may be permanently installed in the spacer between the panes:

- decorative elements (i.e. Georgian Bars)

In order to ensure a gap between the Georgian Bar and the glass panes (≥ 2 mm on each side), transparent so-called Bumpons™, are used

Due to unfavourable environmental influences, vibration may occur at Georgian Bar from time to time. There are Bumpons that are designed to reduce the vibration and the formation of thermal bridge. They are adhered to the vertical / horizontal Georgian Bar interfaces.

An increase in temperature may cause expansion of Georgian Bar in length and thus a slight shape deviation. Visible raw material, fasteners and slight discolouration within the cut are determined by the manufacturing process.

Number and arrangement of Bumpons depends on the number and length of half Georgian Bar and is determined by the manufacturer.

- elements dividing the glass unit into smaller units through the use of so-called Duplex bar (or Integra bars.

Application of the Duplex bars with widths other than specified in the current offer is to be agreed in each case. Duplex bars are to be used in the interior spacer, leaving a min 2 mm clearance on each side between the bar and glass. When manufacturing arches, the Georgian bar is formed of two spacer bars with a minimum bending radius R ≥ 70 mm. When ordering glass units designed for attaching external Georgian bars, glass deflection subject to climatic factors (i.e. temperature and pressure) should be considered and considered in the design assumptions. The result will be selection of a suitable thickness of the glass, which will be specified in the order and which will ensure correct installation and operation of this type of glass. Moreover, when external bars are to be stuck onto the glass, be sure to use the correct adhesive (preferably weather-resistant soft silicone), which adheres the glass with the outer bar, maintaining a minimum distance of 4 mm.

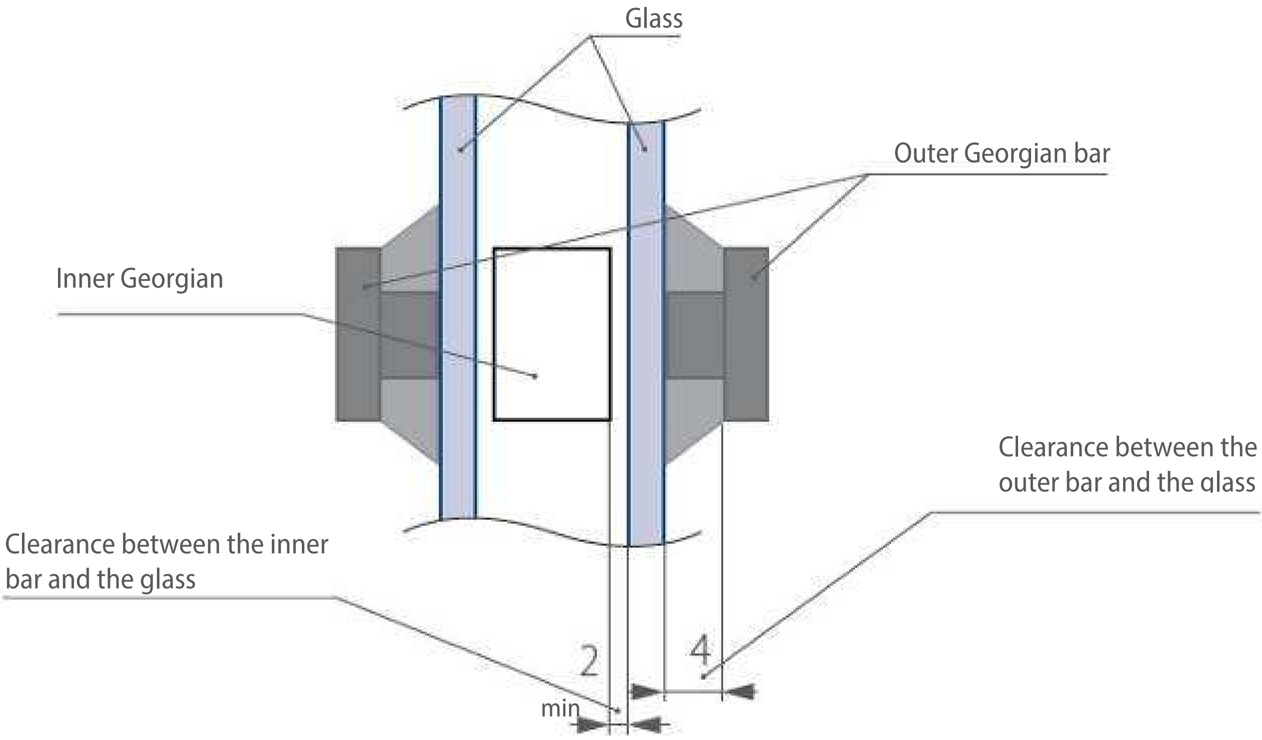


Fig. 2 Installation of inner and outer Georgian bars

When using window dividers, the following is possible:
- manufacturing of arched pane units, where the minimum bending radius is to be considered, equal to, (accordingly):
  - for 8 mm wide Georgian bar - R ≥ 80 mm (only arch)**
  - for 18 mm wide Georgian bar - R ≥ 170 mm
  - for 26 mm wide Georgian bar - R ≥ 200 mm
  - 45 mm wide Georgian bar - may not be bent
- combination of various widths of the Georgian bars
  * no Bumpons may be used for spacer bars wider than 18 mm (use of bars for the distances between the glass panes greater than 18 mm is not recommended)
  ** however, 8mm wide Georgian bars are connected by straps when connecting an arch with straight section, thus the bending radius should be R ≥ 160 mm

- Combination of bars bent at different angles:
- connection of the bars at different angles (for the solution examples, see the Georgian Bar and Duplex bar offer)

Table 5

Examples of combinations of window dividers

Connector \ Basic window divider/bar	8 mm	18 mm	26 mm	45 mm	Max field/box dimensions [mm]
8 mm	+	–	–	–	700 x 700
18 mm	–	+	+	–	1200 x 700
26 mm	–	+	+	–	1200 x 700
45 mm	–	+	+	+	1200 x 1200

Note: For the Duplex Georgian bars, the maximum dimension of the free span may not exceed 1200mm

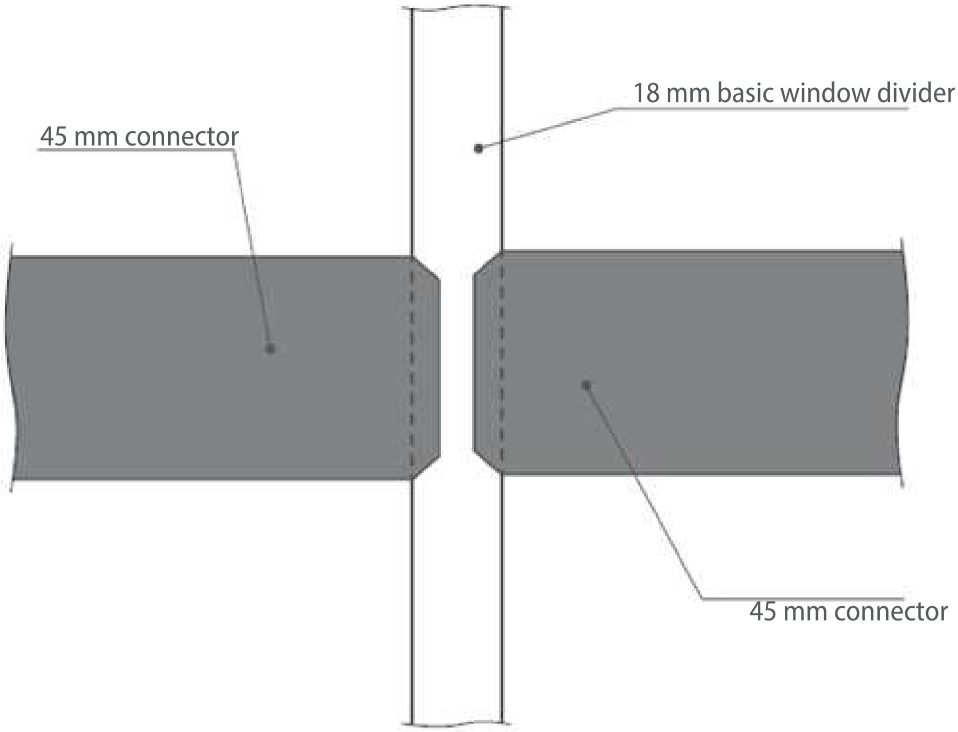


Fig. 3 Example of connection

3.4.1 Positioning of Georgian / Duplex bars

- First, the positioning of Georgian / Duplex bars shall be as specified in the customer order.
- When not specified in the order, their positioning shall be based on pre-exiting agreements with the customer (included in any additional requirements or accepted on ongoing basis.)
- The accuracy of the positioning of Georgian / Duplex bars is +/-2 mm from the nominal dimensions.

3.4.2 Spacer bars

Spacer bars bent in the corners are used, joined along the sides with a maximum of connecting 4 points (for each glass unit chamber). Cut and corner keyed spacer bars are sometimes used when the bending process is unavailable or when making certain shapes. Visible raw material, connecting keys / cleats and slight discolouration, or scratches within the cut area are determined by the production process. Any gap in the spacer bar connection may not be greater than 1 mm.

3.5 CE marking and labelling

The CE marking symbol is printed on the product label (or, if this is not possible, on the packaging or on the accompanying commercial documents, e.g. delivery note). The CE mark shall be accompanied by the web page containing the composition / characteristics of the product in accordance with the requirements of the standard.

4. Packaging, storage, transport and installation

4.1 Packaging

Glass units shall be placed on stillages. For transporting glass units, metal L or A stillages shall be used as standard. The stillage base shall form a right angle with its sides. All metal parts of the stillage in direct contact the glass units shall be lined with rubber, or other cushioning material. Glass units set on racks shall be protected against slipping with straps during transport. Transit pads or interleaving materials made of cork, cardboard, wood or other material agreed with the customer shall be used between the panes. Other packaging requires agreement between the recipient and the supplier.

4.2 Storage

Glass units shall be stored in covered, dry, well-ventilated rooms, protected against rain and direct sunlight, at a temperature not exceeding 40 °C. The supplier shall not be liable for any defects caused by improper storage.

4.3 Transport

In most cases, the units are transported in dedicated vehicles, designed to carry glass. The recipient shall be responsible for unloading of stillages from the truck. The recipient shall be responsible for proper unloading and notification of any defects found during delivery. Receipt by the customer shall take place on the request and at the risk of the recipient (excluding damage during transport.)

4.4 Installation

Insulating glass unit installation considerations are described in Annex B (Information), to EN 1279-5.

5. Testing

5.1 Testing and inspections of insulating glass units include

5.1.1 Periodic testing

- Periodic, not frequently performed tests and inspections are a part of the production control procedures and are performed by a third party as a part of the production control.

- After the inspection of the factory production control by a third party, the starting interval of periodic tests shall be once a year, unless materials important for the production of glass units have to be changed. If a significant material has to be changed (according to EN 1279-1), the tests are to be repeated periodically. When such a re-testing coincides with the next planned periodic tests, repetition of the test is not necessary.

Scope of periodic testing:

- Compliance of the sealing geometry to the system description acc. to EN 1279-6
- Moisture penetration index acc. to EN 1279-2
- Gas leakage rate acc. to EN 1279-3

5.1.2 Factory production control

This consists of:

- delivery control
- manufacturing process monitoring
- final inspection acc. to the Glass Unit Control Plan

5.2 Test methods

5.2.1 Shape and dimension checks

shall be carried out with the appropriate measuring devices or gauges. A checking of width and length is performed with a spring rule and thickness is checked using a slide calliper or micrometre.

5.2.2 Glass check

Checking the quality of the glass and glass unit workmanship is performed by naked eye inspection, conducted in natural light on an opaque black screen background, or in transmitted and/or reflected light depending on the glass used in the unit and the corresponding specifications/standard (see the Company Standard Reference Documents.)

Defects not visible from a distance of 2m (3 m for coated glass) are not classified as defects. Evaluation of the glass units containing float glass shall be made in accordance with Table 6.

NOTE: (in accordance with EN 1279-1 par. 5.2) over time and due to unintentional reasons, the outer surfaces of insulating glass units may weather, which can affect their appearance.

5.3 Visual assessment

Table 6

Acceptable defects in glass units (float glass)

Item	Defect	The presence of defects in the insulating glass units with an area of		
		up to 1.0 m^2	from 1.0 up to 2.0 m^2	above 2.0 m^2
1	Spot defects in the form of foreign mater inclusions	unacceptable	unacceptable	unacceptable
2	Spot defects in the form of: - burst and broken seeds	unacceptable	unacceptable	unacceptable
	- closed seeds: double glazed unit	acceptable, 2 / unit.; max dim. 2 mm	acceptable, 3 / unit.; max dim. 2 mm	acceptable, 5 / unit.; max dim. 2 mm
	triple glazed unit	acceptable 3 / unit.; max dim. 2 mm in peripheral zone, acceptable up to 3 mm.	acceptable, 4 / unit.; max dim. 2 mm in peripheral zone, acceptable up to 3 mm.	acceptable, 7 / unit.; max dim. 2 mm in peripheral zone, acceptable up to 3 mm.
3	Linear defects:	acceptable	acceptable	acceptable
	double glazed unit	isolated defects up to 15 mm with a total length up to 40 mm	isolated defects up to 15 mm with a total length up to 45 mm	isolated defects up to 15 mm with a total length up to 50 mm
	triple glazed unit	isolated defects up to 15mm with a total length up to 60 mm in peripheral zone, isolated defects with a length up to 20 mm acceptable	isolated defects up to 15mm with a total length up to 70 mm in peripheral zone, isolated defects with a length up to 20 mm acceptable	isolated defects up to 15mm with a total length up to 80 mm in peripheral zone, isolated defects with a length up to 20 mm acceptable
4	Defects in the form of nicks and shells at the edges	Acceptable, Fig.4 $h_1 < (e-1)$ mm $p < (e/4)$ mm $d < (e/4)$ mm	Acceptable, Fig.4 $h_1 < (e-1)$ mm $p < (e/4)$ mm $d < (e/4)$ mm	Acceptable, Fig.4 $h_1 < (e-1)$ mm $p < (e/4)$ mm $d < (e/4)$ mm

- Marginal strip of 20 mm width

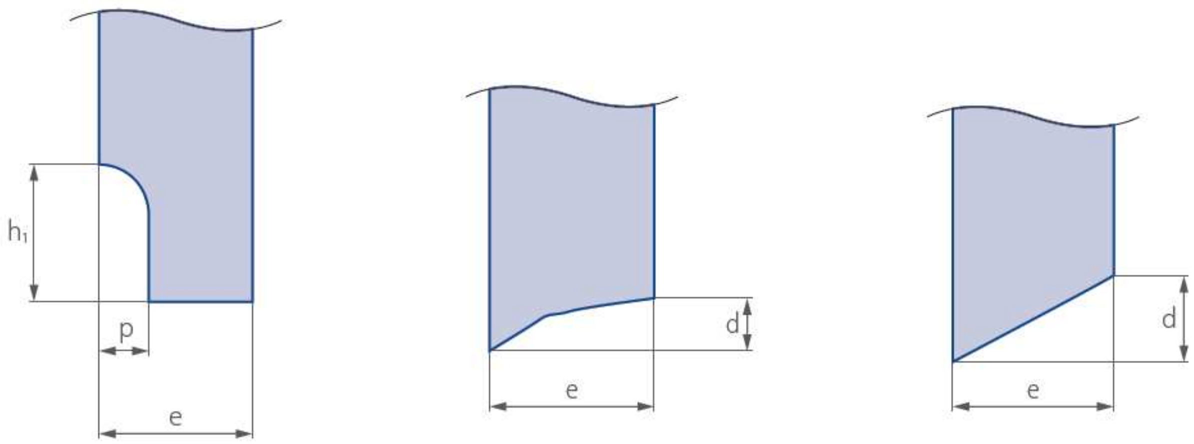


Fig. 4 Edge Defects

5.4 Physical characteristics excluded from the assessment

- colour interference
- glass deflection due to changes in temperature and barometric pressure
- external condensation
- External moisture on the insulating glass due to humidity
- colour variations

Also, glass cracks found later than the date of delivery are to be excluded from the assessment.

Explanation of terms:

5.4.1 Colour interference

The phenomenon of light interference known as Brewster Fringes appear in insulating glass units manufactured with glasses with very small differences in thickness ranging from 400 to 700 nm, i.e. the wave length components of white light.
Float glass used in insulating glass units is characterized by minimal differences in thickness, which is its great advantage. The use of float glass for the construction of a glass unit can lead to this undesirable phenomenon of light interference. In drawn glass manufactured by the Pittsburgh method, thickness variations are considerably greater than in float glass, so when used in insulating glass units, Brewster Fringes practically do not occur where the two sheets are located relative to each other at a slight angle at the same time, i.e. if the difference in parallel panes is in the range from 400 to 700 nm. In practice, this difference is insignificant and does not affect the properties of the insulating glass unit.

(!) Interference of light occurs when the two conditions described above exist, which is visible in the form of wide spots, stripes or rings arranged in different locations on the surface of the unit. This phenomenon is more evident when viewing the glass at an angle. It may not be considered a defect and will not be subject to a complaint or claim.

5.4.2 Glass deflection due to changes in temperature and barometric pressure

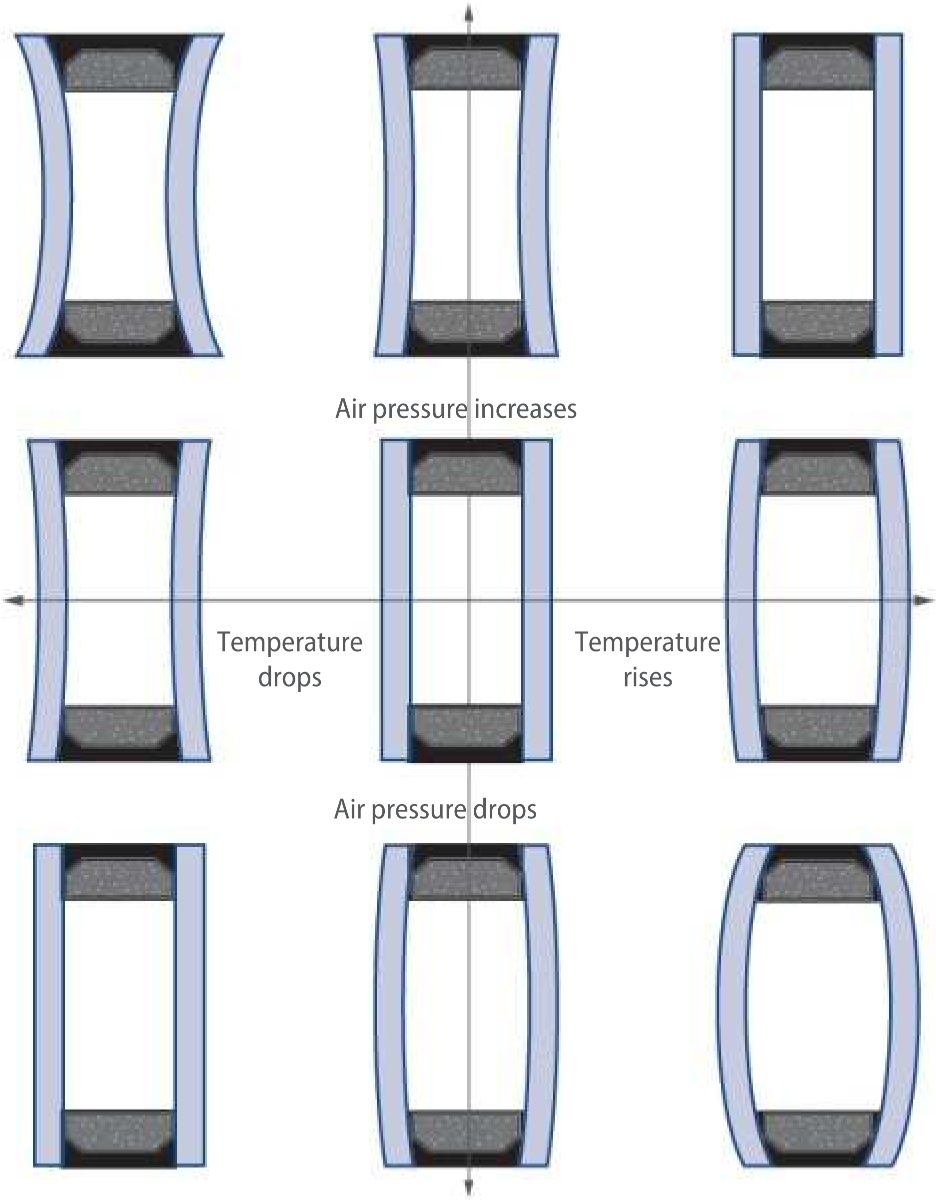


Fig. 5 Glass deflection due to changes in temperature and barometric pressure

Hermetically sealed insulated glass units contain an encapsulated volume of gas / air, the nature of which is defined by the atmospheric pressure, altitude of the production site (above the zero reference level (NN) and air temperature at the time and place of production. Post manufacture, once the hermetically sealed glass unit is exposed to different altitudes, temperatures and barometric pressure (high and low pressure), this can cause concave or convex bending of one or both glass panes leading to optical distortion.
Also, multiple reflections may occur on the surface(s) of the glass units. This effect may be amplified, for example, if the glazing background is dark or if coatings have been applied to the glass. This phenomenon is a physical regularity of all insulating glass units.

5.4.3 External condensation

Condensation forms when moist air is bordered by surfaces of sufficiently low temperature, cooled to saturation, followed by condensation of excess moisture on these surfaces. On the insulating glazing, the

phenomenon of condensation may exhibit on its outer surface (outside the room). The reason for this phenomenon is as follows:
- the outer pane is a cold, atmospherically conditioned plane on which condensation can form at the appropriately high humidity. The cause of the cold, outer surfaces lies precisely in good thermal insulation of insulating glazing (low values of heat transfer coefficient, U). Only a small amount of heat passes from the room to the outside, so that the temperature of the outer pane is low.
The effect of condensation on the outer surfaces of the insulating glass pane is a phenomenon conditioned by the physical properties of the glass and existing atmospheric conditions (low temperature and high humidity). Complete elimination of this phenomenon is not possible due to the fact that the outer pane is exposed to variable conditions. Nowadays, coated glasses are available, which limit the external condensation phenomenon.
To sum up, the effect of condensation in any case does not indicate a defect, but rather confirms the high quality of insulating glass units.
Condensation which forms on the exterior surface of the glass unit glazed to the building interior is usually caused by excessive humidity or inadequate ventilation. The presence of condensation on the exterior surfaces of the glass unit is not a defect, just a physical phenomenon.

5.4.4 Wettability of the insulating glass units due to humidity

Wettability is defined as the ability of a solid surface to reduce the surface tension of a liquid in contact with it such that it spreads over the surface and wets it. The wettability of the glass surface can be affected by contact with a variety of processes or materials e.g. rollers, fingerprints, adhesive labels, paper, vacuum nozzles, residual sealing materials, smoothing or lubrication agents, etc. When the glass surface becomes wet, different wettability may be visible as clear spots, theoretically more transparent.

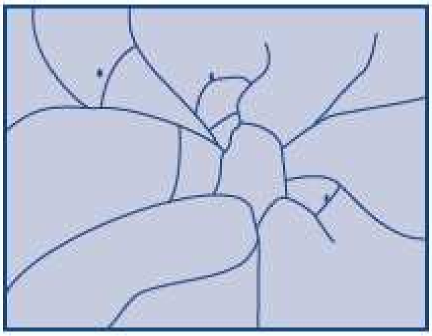
5.4.5 Colour variations

Nominally clear float glass does in fact exhibit a shade of green or blue-green. This is caused by iron ions created in the glass batch raw materials, by dissolving refractories and from other sources.
The shade of the glass depends on the ratio of divalent and trivalent iron ions ($Fe2+$ / $Fe3+$), therefore, the float glasses from various manufacturers may differ. This glass shade is a natural feature of the float glass.
Additionally, glass coatings can affect the appearance or colour of the glass (metal oxide layers deposited on the glass surface giving it special properties, such as low-emissivity coatings). The visible glass shade depends on the type of coating, the thickness of the glass, lighting, viewing angle, etc.

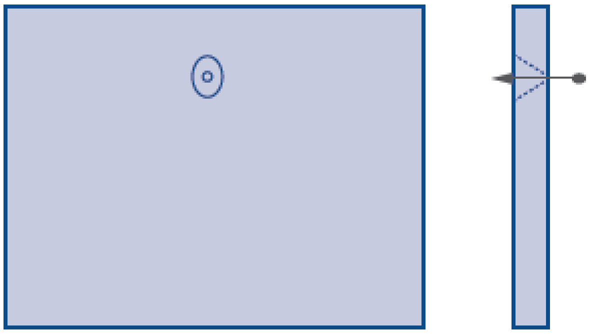
5.4.6 Cracking of the glass

Glass is an homogeneous, amorphous body material, which is, solid, brittle and hard. It has negligible internal stress, so it can be cut and processed. It cracks due to thermal or mechanical external factors. Glass breakage of this nature post-delivery is not covered by the product warranty and will not form the basis of legitimate complaint. In order to increase the resistance of glass to breakage from thermal or mechanical force, the glass must be subjected to the process of tempering or heat strengthening (see part two of this standard). This particularly applies to glasses with higher energy absorption.

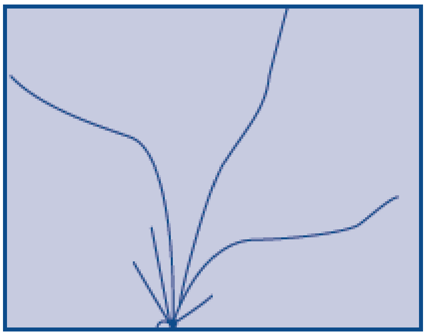
Fig. 6 - Examples of mechanical and thermal fractures



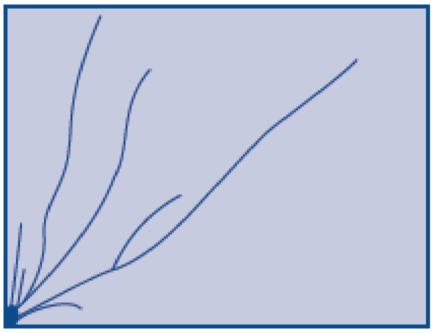
a) A stone throw



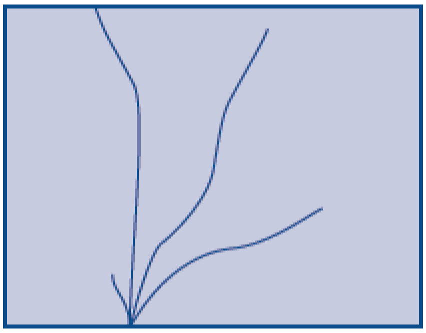
b) Gunshot



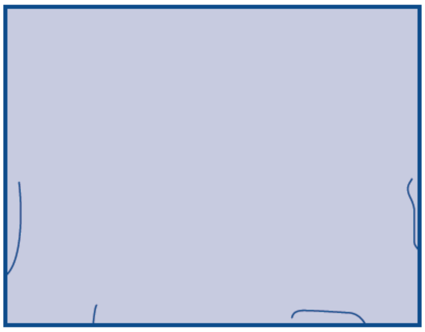
c) A blow to the edge



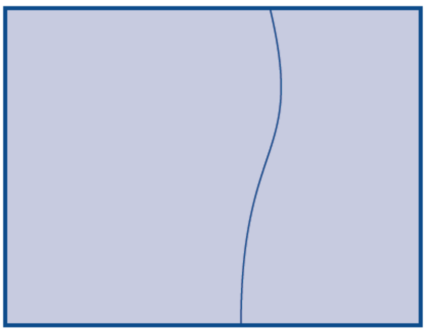
d) A blow to the corner



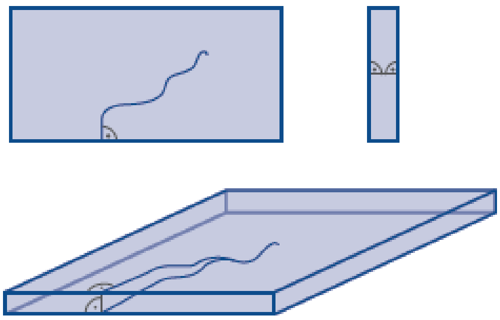
e) Pressure on the edge



f) Clamped pressure on the edge

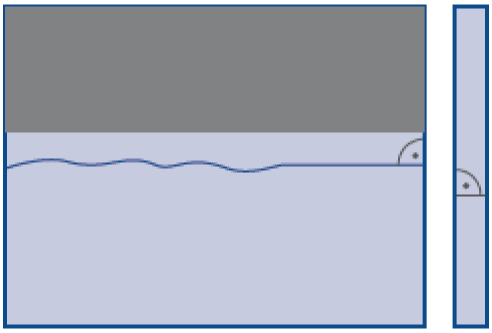


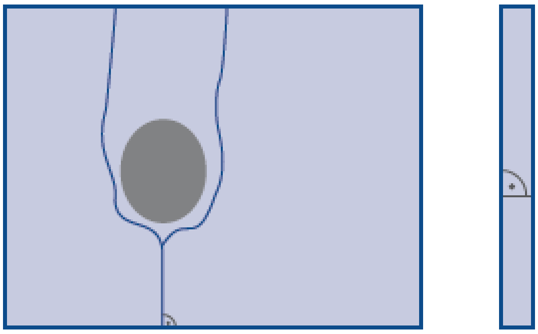
g) Torsional cracking



h) Thermal cracking

i) Thermal cracking caused by the application of manifestation vinyls / stickers etc or by partial shading by e.g. blind, tree, part of a canopy, etc.





5.5 Washing and cleaning of glass

- Clean the glass surface regularly, depending on the degree of soiling.
- Never remove solid contamination, such as dry cement.
- Moisten the glass surface thoroughly with clean water to soak and wash away hard and sharp particles.
- Remove fat and sealant residues with, for example alcohol or isopropyl alcohol, before rinsing the surface thoroughly with water.
- To avoid damage to glass coatings applied to Face 1 (exterior face) never use caustic or alkaline substances (e.g. fluorine, chlorine) or scouring powders to clean

Washing should be done using conventional detergents, to remove dirt in the form of greasy stains, e.g. acetone can be used, respecting the principles of use of these agents. Manufacturers of reflective glass recommend the use of cerium oxide / water mix (50 ÷ 160 g/l of water) for cleaning reflective coatings.

For self-cleaning glass coatings and the like, please observe the special cleaning recommendations issued by the manufacturers of these products. For more detailed information, please contact our Sales Department.

The panes supplier must not be held liable for any glass defects occurring as a result of incorrect washing, using inappropriate cleaning agents, impact of external contamination (atmospheric and other) or using e.g. a steel scraper, where there is high likelihood of damaging the pane.

PART II - SPECIAL GLASS

1. Edge machining

1.1 Glass cutting

Glass cutting is to cut individual pieces from a larger stock sheet. Cutting is performed using specially designed production lines. There is a possibility of cutting monolithic, laminated and fire resistant glass. Table 1 indicates the production capacity of each glass cutting table.

Table 1

Technical capabilities of a production line for glass cutting

Type of glass	Monolithic	Monolithic	Laminated	Fire resistant
Glass thickness [mm]	2	3 – 19	33.1 ÷ 66.4	11-70
Max dimension of raw glass pane (W x H) [mm]	1600 x 2000	3300 x 7000	3210 x 6000	2250 x 3210
Max size possible to cut (W x H) [mm]	–	–	3300 x 4600	–
Min size possible to cut (W x H) [mm]	–	–	–	100 x 500
Max weight [kg]	1000	1000	600	800
Soft coating	+	+	+	–

The possibility of splinters is an important consideration of glass cutting. Fig. 1 is an illustrative diagram of sharp corners, where a splinter may occur. The value of (z) depends on the angle to which you want to cut the corner of the glass pane. Table 2 below summarizes maximum values of the (z) parameter and the corresponding angles. Figure below shows a diagram of an exemplary sharp corner, cut in the glass pane. In order to cut shaped glass accurately we must comply with the following parameters. If we do not follow these parameters there is certain risk of glass breakage or defect.

Table 2

Section length values (z) and the corresponding value of angle of the sharp corner

Type of glass	Angle [°]	Length of cut-out, z [mm]
Float	≤ 12.5	- 30
	≤ 20	- 18
	≤ 35	- 12
	≤ 45	- 8
Laminated	≤ 12.5	- 65
	≤ 20	- 35
	≤ 35	- 12
	≤ 45	- 8

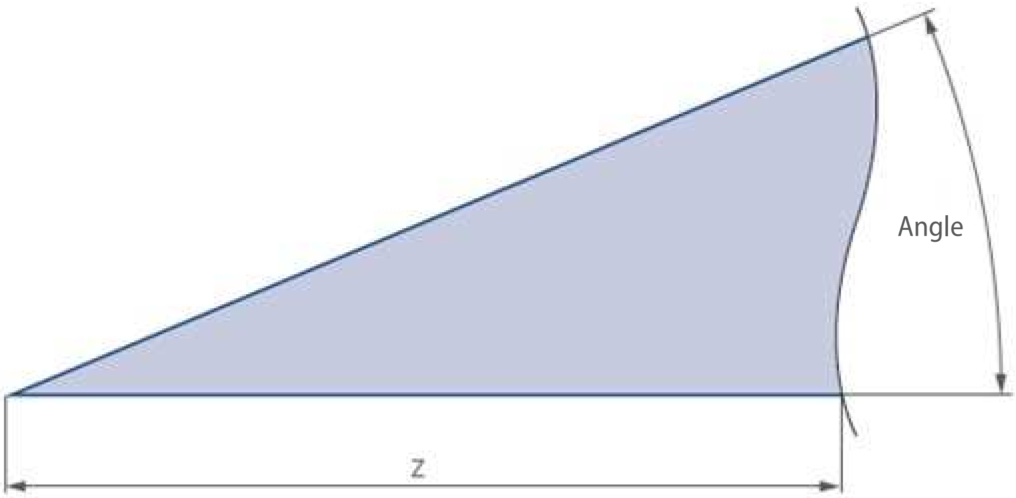


Fig. 1 Sample sharp corner of glass with cut-out area marked, with a length of z

1.2 Arrissing the glass edges

Arrissing the glass edge is to abrasively remove a small layer of the sharp 'as cut' glass edges machine with diamond belts. Optionally, we can trim the face of glass. In addition, a more machined area may occur in the corner of the arrised (blunt) edge compared to the rest of the edge. Fig. 2 below shows a diagram of an arrised edge.
The technical capabilities of arrissing lines are summarized in Table 3.

The Arrissing of shapes included in the shape catalogue in Part III of this Standard is also possible.

Table 3

Arrissed edge production capabilities

Type of glass	Glass thickness [mm]	Max dimension (W x H) [mm]	Min dimension (W x H) [mm]	Max weight [kg/rm]	Soft coating
Monolithic and laminated	2,3 – 19	3000 x 6000	180 x 350	150	+

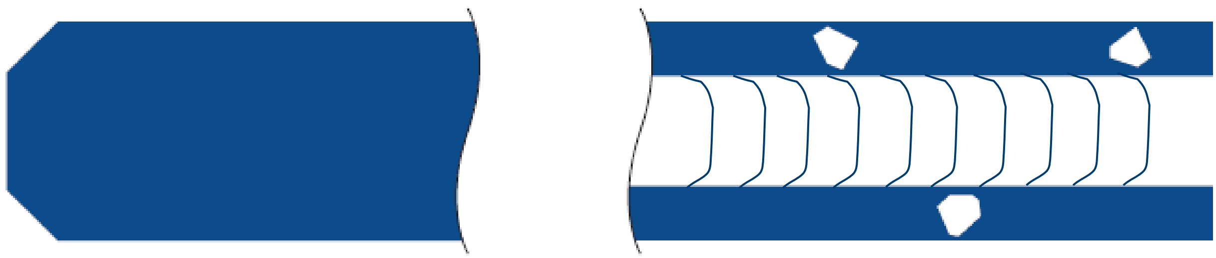


Fig. 2 Arrised edge diagram

1.3 Grinding, polishing and mitring the edge of glass

Grinding and polishing processes are designed to trim the edges and give them a finished look. Diamond wheels are used for grinding, which machine a small amount of material from the edge and leave them dull after processing. The polishing process uses polishing wheels, which practically do not machine the material but cause the edge to become more lustrous than after the grinding process.

Table 4

Technical capabilities of equipment for grinding and polishing rectangular glass

Glass thickness [mm]	Max dimension (W x H) [mm]	Min dimension (W x H) [mm]	Max weight [kg]	Soft coating
2	1300 x 2500	500 x 500	50	–
3 – 19	2800 x 6000	100 x 200	500	–

Table 5

Technical capabilities of equipment for grinding and polishing glass other than rectangles with at least one straight edge

Glass thickness [mm]	Max dimension (W x H) [mm]	Min dimension (W x H) [mm]	Max weight [kg]	Soft coating
3 – 25	2800 x 6000	400 x 800	500	+

Table 6

Technical capabilities of the machining centre (processing of glass other than rectangles – no straight edges)

Glass thickness [mm]	Max dimension (W x H) [mm]	Min dimension (W x H) [mm]	Mitre angle	Max weight [kg]	Soft coating
3 – 80	2250 x 4000 *3600 x 1900	150 x 400	0 – 90°	500	+

* Maximum dimension of mitred glass)

1.3.1 Shapes of ground and polished glass panes

For detailed information, see Tables 4-6.

1.3.2 Glass mitring – grinding or polishing at various angles

Glass can be mitred at various angles. Basic features of this process are shown in Table 6. To change the mitre angle carries additional restrictions. Figure 3 shows an example of the edge with the following parameters indicated:

a) T – the glass thickness below the mitre; min thickness T_{min}=2 mm
b) α – mitre angle; nominal values within α= 0÷90°,
c) S – width of mitre (max 50 mm)

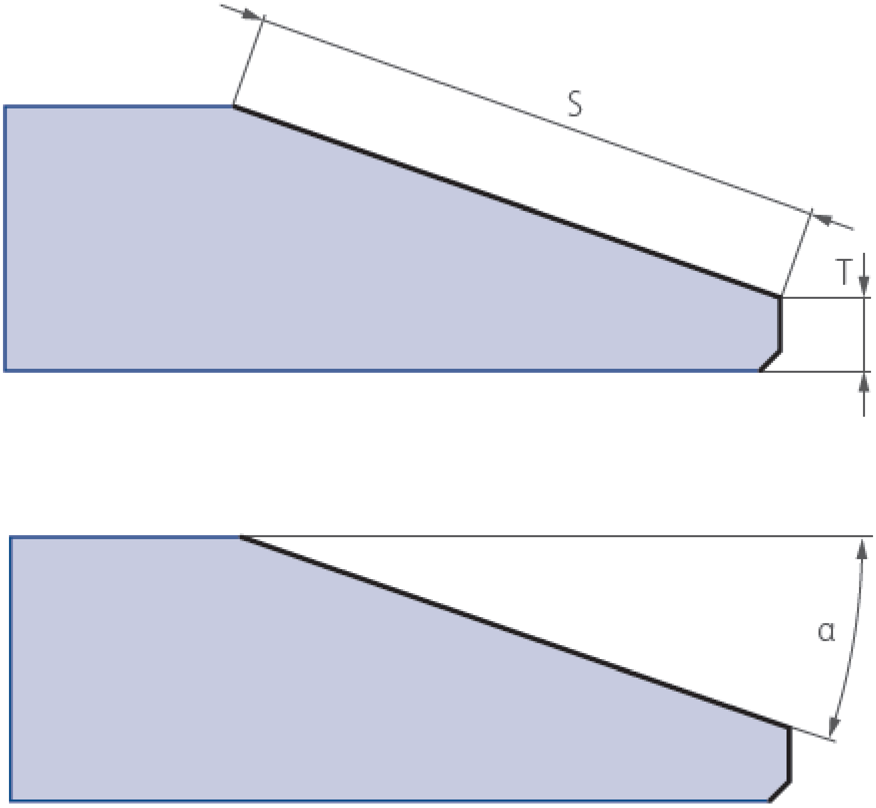


Fig. 3 Diagram of mitred glass edge

1.3.3 Trapezoidal grinding

Trapezoidal grinding appearance is shown schematically in Figure 4. This is done by means of diamond wheels. The process has the following features:

a) The ground edge is dull over the entire length of grinding – possible presence of shiny areas
b) The polished edge is shiny over the entire length
c) Polishing or grinding angles are α=45°

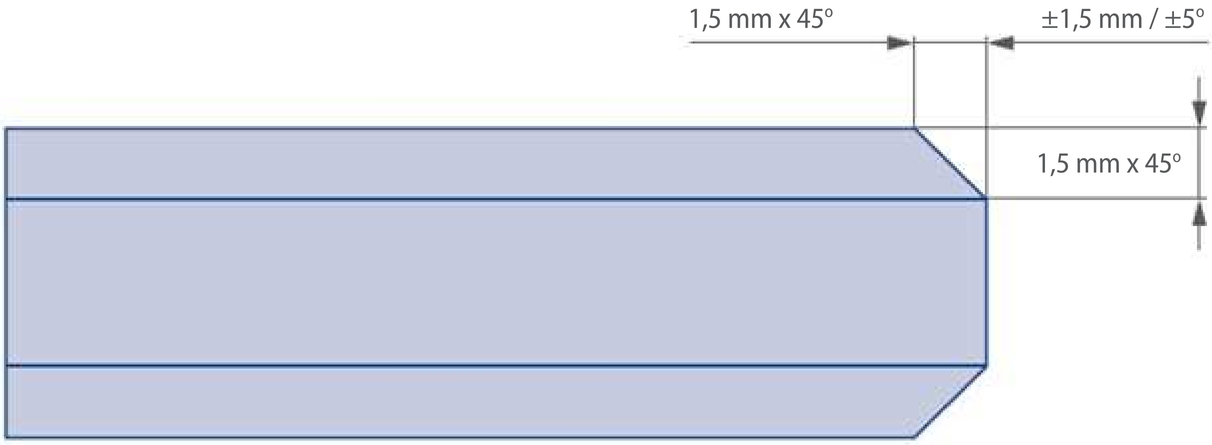


Fig. 4 Diagram of ground or polished glass edge

1.3.4 C-edge grinding

Schematic appearance of C-edge grinding is shown in Figure 5. The minimum radius of the grinding shall be equal to half the nominal glass thickness (d), and be greater than or equal to the (g) value marked on Figure 5:

$$r_{min} = d/2; r \geq g$$

Tolerances for panes with C-edge grinding are identical to those adopted for ground edge glass. If more stringent dimensional tolerances are required, please contact us.

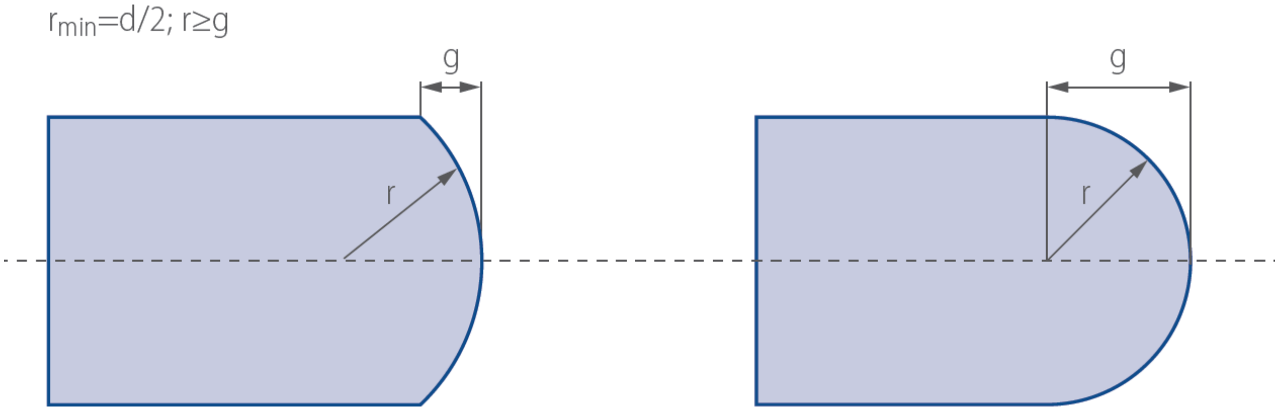


Fig. 5 Diagram of glass edge with C-edge grinding

1.3.5 Finishing of edges

Summarizing the edge machining methods, we can distinguish four basic types of edge finish which are illustrated in Figures 6 – 9, respectively:

a) machined periphery (with shiny areas) – arrised edge,
b) ground periphery (with shiny areas) – arrised edge with trimmed face or ground edge,
c) smoothed ground periphery (no shiny areas) – ground edge,
d) polished periphery – polished edge.

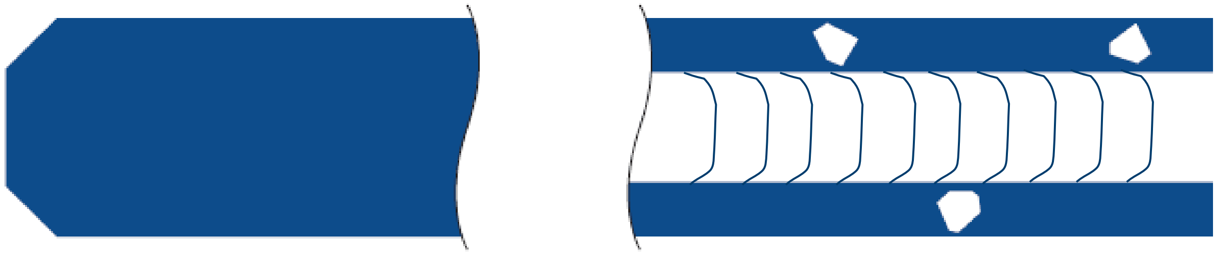


Fig. 6 Machined periphery (with shiny areas) – arrised edge

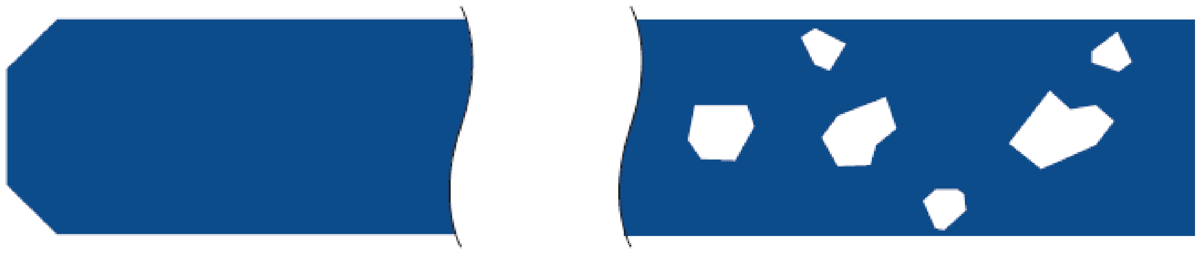


Fig. 7 Ground periphery (with shiny areas) – arrised edge with trimmed face or ground edge

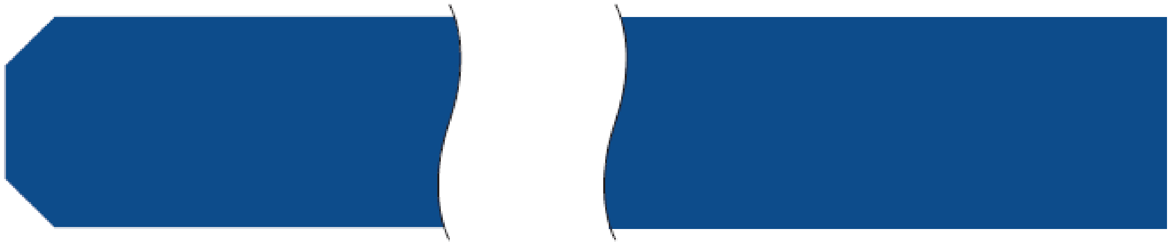


Fig. 8 Smoothed ground periphery (no shiny areas) – ground edge

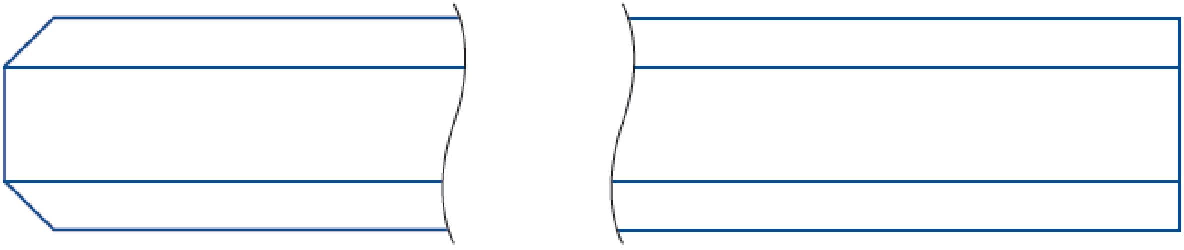


Fig. 9 Polished periphery – polished edge

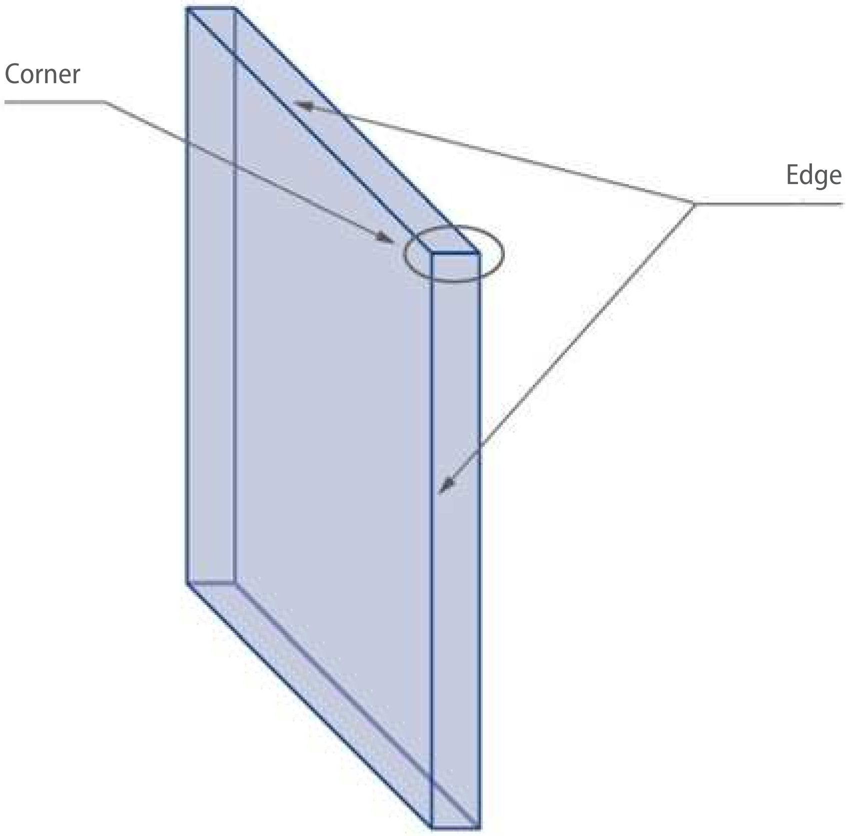


Fig. 10 Definition of edges of a glass piece

2. Drilling, cutting holes and milling

2.1 Drilling

The drilling process is performed using special spindles, within which diamond drill bits for machining the glass are mounted. In order to obtain high quality holes, drilling is carried out simultaneously on both surfaces of the glass.

Basic features of drilling holes in the glass are summarized in Table 7. On the drilling line, holes with 45° countersinks can be made. For an example of a countersunk hole, see Fig. 11.

Table 7

Production capability for drilling, milling and cutting holes

Glass thickness [mm]	Max dimension (W x H) [mm]	Min dimension (W x H) [mm]	Max weight [kg]	Hole dia. φ [mm]	Soft coating
3 – 19	2800 x 6000	250 x 450	500 kg	3÷80 mm	–

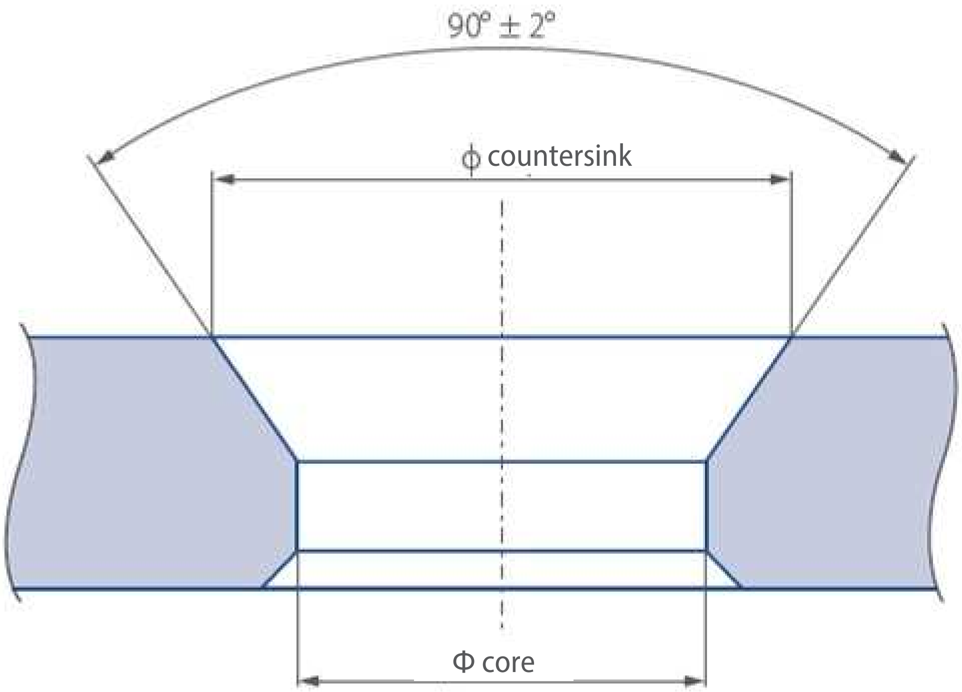


Fig. 11 Example of countersunk hole

2.1.1 Size and location of drill holes

The drilling process imposes certain restrictions on the size and location of holes (i.e. the distance from the edge of the glass, corners, and relative to each other). All restrictions are based on EN 12150-1. In general, the constraints are dependent on:

a) Nominal thickness of the glass – d,
b) Dimensions of the glass sheet – W and L,
c) Hole diameter – φ,
d) Glass shape.

Minimum width of the glass

Minimum width of the glass with round holes (W) shall be at least 8 times greater than the nominal thickness of the glass (d).

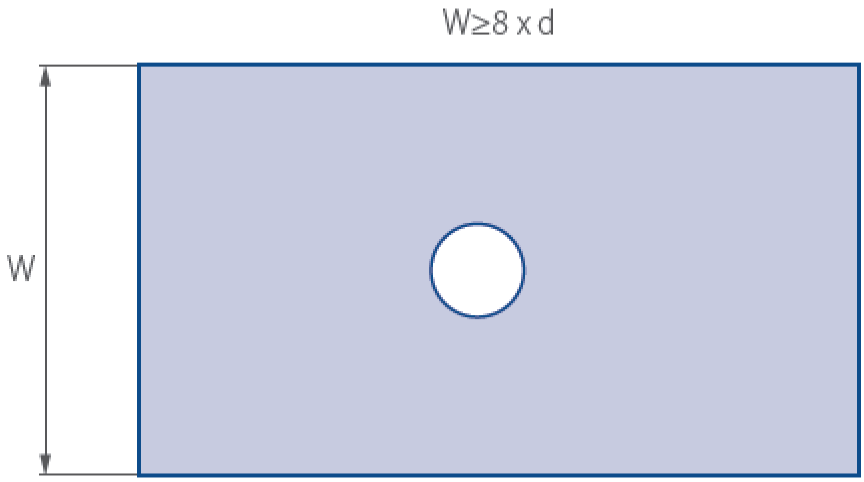


Fig. 12 Minimum width of the glass for a specific hole

Hole diameters

The minimum diameter (D_{min}) of the drill hole may not be less than the nominal thickness of the glass (d). The maximum diameter (D_{max}) of the drill hole may not be greater than one-third of the smallest width of the sheet (W_{min}).

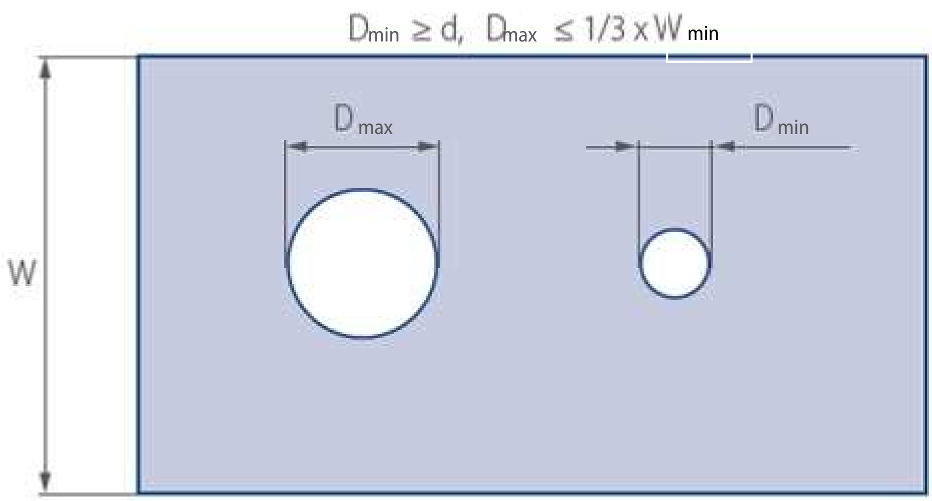


Fig. 13 Maximum and minimum hole diameters

Location of holes

The distance (a) between the glass edge and the edges of the holes and between the edges (b) of each hole may not be less than twice the thickness of the glass (d) (Fig. 14).

$$a \geq 2d, b \geq 2d$$

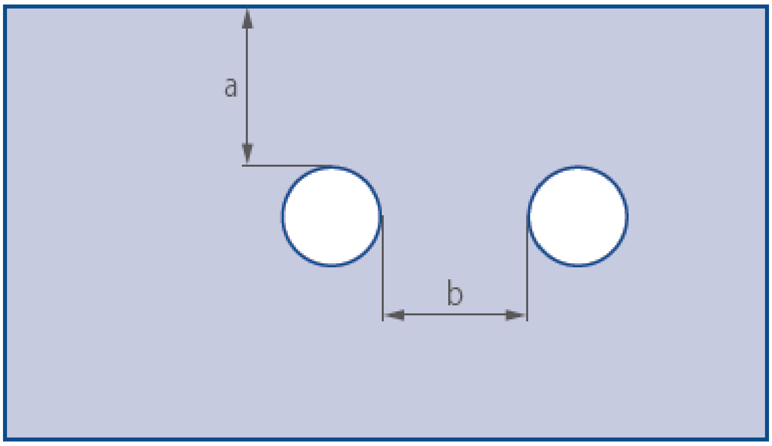


Fig. 14 Example of the location of the holes relative to each other and to the glass edges

Holes in the corners and cut-outs in the holes

For glass with rounded corner angles ≥ 90 °, the distance (a) from the base point of the corner to the edge of the hole shall be at least four times the thickness (d). The distance (c) from the vertex of a corner to the edge of the hole shall be at least six times the thickness of the glass (d). For notches / cut-outs between the glass edge and a drill hole (Fig. 16), the height of the notch / cut-out must be at least 5mm larger than the glass thickness but not more than twice the glass thickness.

$$a \geq 4d, c \geq 6d$$

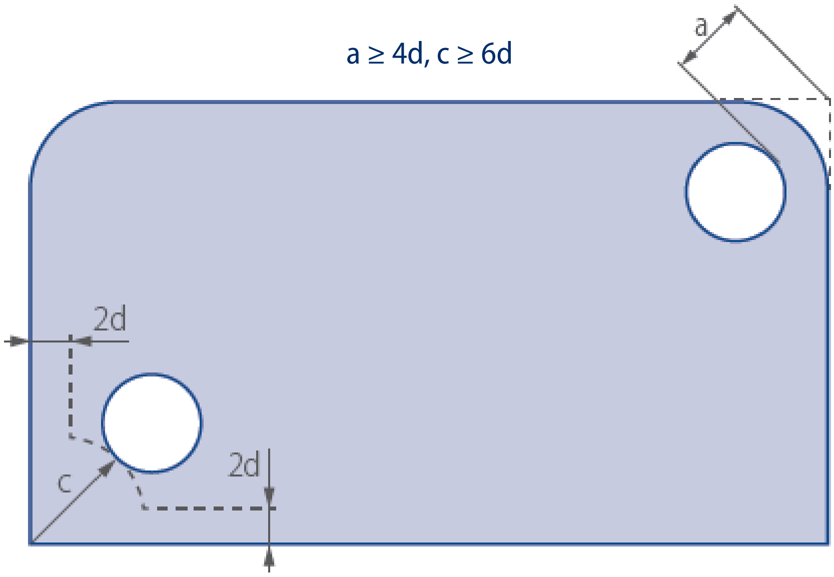


Fig. 15 Location of holes in relation to the corners

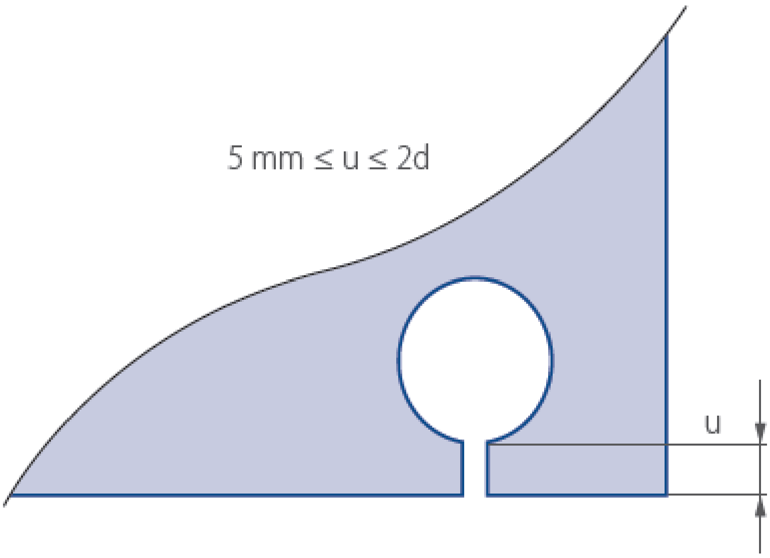


Fig. 16 Example of a notch / cut-out for drill holes close to the glass edge

2.1.2 Tolerances for dimensions and location of the drill holes

For drill hole diameters tolerances, see Table 8.

Table 8

Drilled holes diameter tolerances

Hole nominal dia., φ [mm]	Tolerance [mm]
3 ≤ φ ≤ 20	± 1
20 ≤ φ ≤ 80	± 2

In order to determine the location of a specific hole in the glass pane, a reference / datum point (lower left corner) is to be selected, from which the distance is measured in two axes perpendicular to each other. Fig. 17 shows an example hole location measurements on a glass pane. Drill hole location tolerances are summarized in Table 9, depending on the dimensions of the glass pane, and with regard to its thickness.

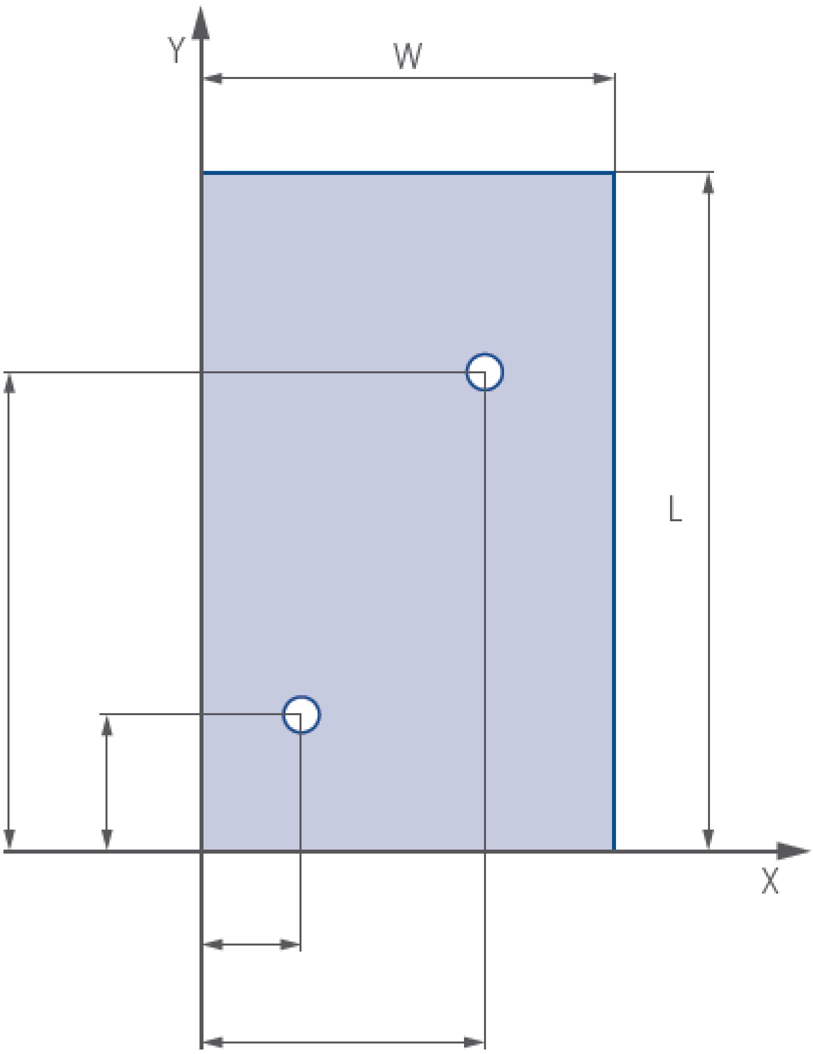


Fig. 17 Measurement of hole locations on the glass

Table 9

Drill hole location tolerances

Glass dimension (W, L) [mm]	Tolerance of hole location [mm]	
	Nominal glass thickness d ≤ 12	Nominal glass thickness d > 12
≤ 2000	± 2,5	± 3,0
2000 < W or L ≤ 3000	± 3,0	± 4,0
> 3000	± 4,0	± 5,0

2.2 Cut-outs and internal edgework of cut-outs

There are some restrictions on the size, corner radii and location of cut-outs

2.2.1 Size and location of cut-outs

The size of cut-outs (width (c) and height (h), respectively) may not be greater than 1/3 of the width and 1/3 of the height of the glass piece. The distance between the shorter edge of the glass and the opening may not be less than half the length of the edge of the opening in that direction. All relations between the dimensions are as follows:

$$h \leq {}^{1}/_{3} \times L, \qquad c \leq {}^{1}/_{3} \times W, \qquad a \geq {}^{1}/_{2} \times c, \qquad b \geq {}^{1}/_{2} \times h, \qquad r \geq 6\ \text{mm}$$

For the respective dimensions, see Fig. 18.

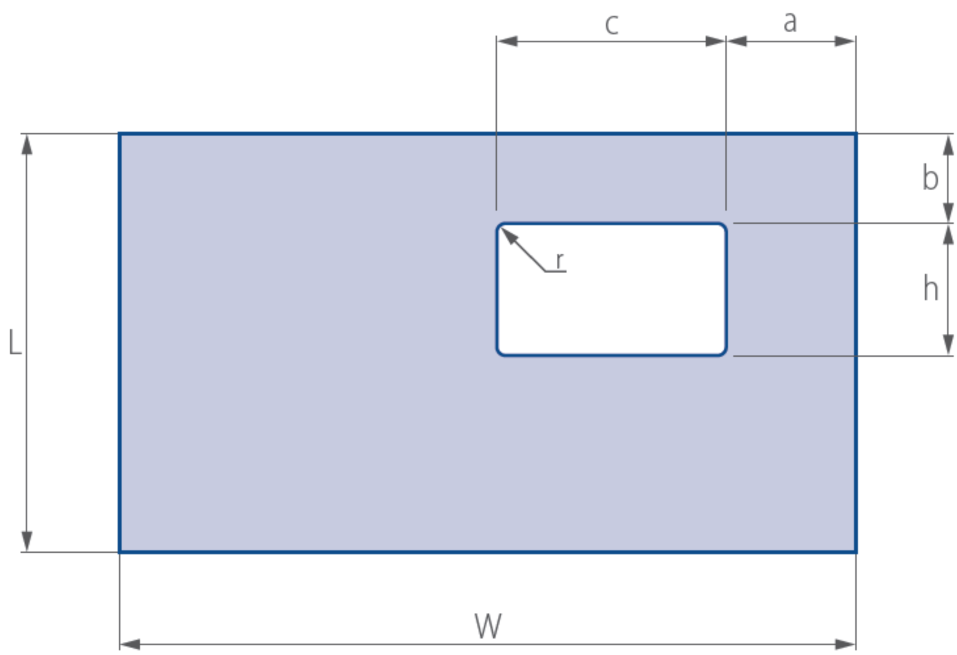


Fig. 18 Example of cut-out location and dimensional restrictions on a glass pane

2.2.2 Cut-out tolerances and their locations

Table 10 summarizes cut-out tolerances.

Table 10

Cut-out dimensional tolerances

Side of opening [mm]	Tolerance (h, c) [mm]
h or c	± 3.0

In order to determine the location of a specific cut-out, a reference / datum point (lower left corner) is used, from which the distance is measured in two axes perpendicular to each other. Cut-out location tolerances are summarized in Table 11, depending on the dimension and thickness of the glass pane.

Table 11

Cut-out location tolerances

Glass dimension [mm]	Cut-out location tolerances (for a and b values in Fig. 13) [mm]	
	Nominal glass thickness d ≤ 12	Nominal glass thickness d > 12
≤ 2000	± 2,5	± 3,0
2000< W or L ≤ 3000	± 3,0	± 4,0
> 3000	± 4,0	± 5,0

2.3 Cut-outs / notches in corners and edges

Cuts and notches can be made in many different configurations depending on the size and shape of the glass pane. The following are general principles that should be followed when designing cut-outs / notches on the glass edge or corners. Additionally, size and location tolerances are presented.

2.3.1 Size of cut-outs / notches and their location on the glass edge

Sizes of any cut-outs on the edge (h x c) may not be greater than 1/3 of the width (W) and the height (L), respectively:

$$h \leq {}^{1}/_{3} \times L, \quad c \leq {}^{1}/_{3} \times W$$

For example cut-out locations together with necessary dimensions and method of measurement, see Fig. 19.

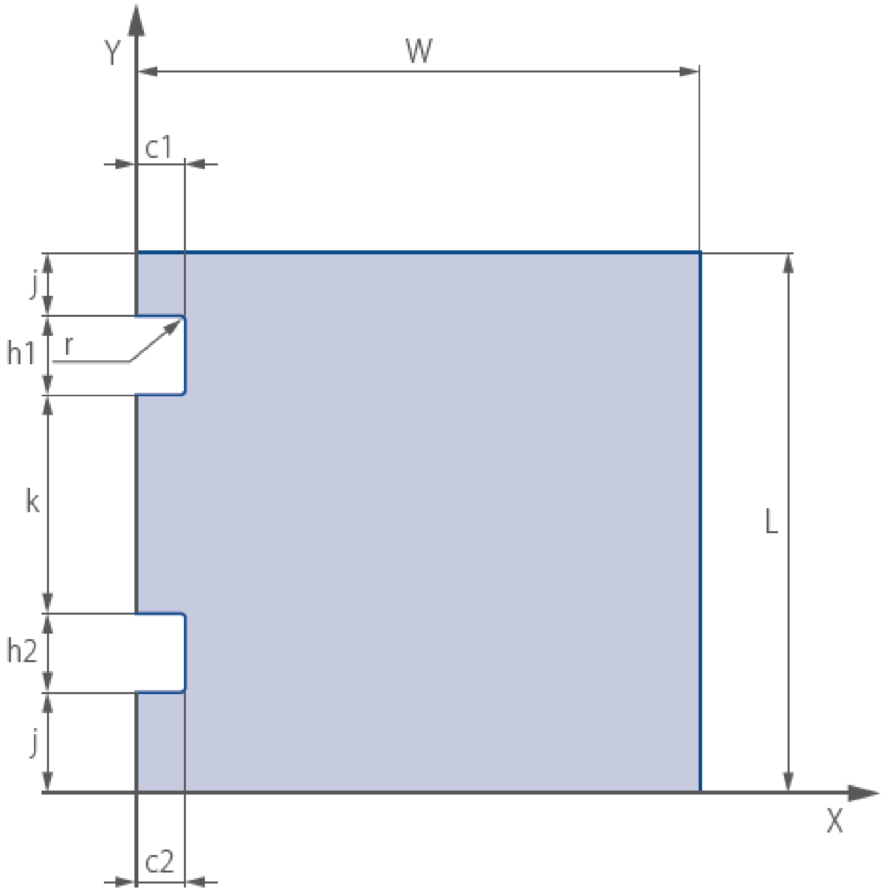


Fig. 19 Parameters of cut-outs

The distance between two cut-outs / notches (k) shall be greater than or equal to half the width of the larger cut-out. The width of a cut-out / notch on the edge means the dimension measured parallel to the edge on which the cut-out is made.

$$k \geq ½ \times h$$

The distance between a cut-out on the edge and the edge of the glass pane (j) shall be greater than or equal to half the width of the cut-out and not less than 100mm. Please note that the corner inside the cut-out / notch must be rounded (internal radius). The minimum radius of this rounding is r ≥ 6 mm.

$$j \geq ½ \times h$$

2.3.2 Tolerances of cut-outs and their location on the glass edge

Dimensional and location tolerances for cut-outs / notches on the edge of the glass can be found in Tables 12-13. The parameters in Fig. 20 indicate an example glass pane. In order to determine the position of cut-outs on the pane, a reference point (lower left corner) is to be selected, from which the distance is measured in two axes perpendicular to each other.

Table 12

Tolerances of cut-outs / notches on the glass edge

Side of cut-out [mm]	Tolerance (h1, h2, c1, c2) [mm]
h or c	± 3,0

Table 13

Tolerances of cut-out / notch locations on the glass edge

Glass size [mm]	Tolerance of cut-out / notch location on the glass edge (a_1, a_2, a_3, a_4, b_1, b_2, b_3, b_4) [mm]	
	Nominal glass thickness d ≤ 12	Nominal glass thickness d> 12
≤ 2000	± 2,5	± 3,0
2000< W or L ≤ 3000	± 3,0	± 4,0
> 3000	± 4,0	± 5,0

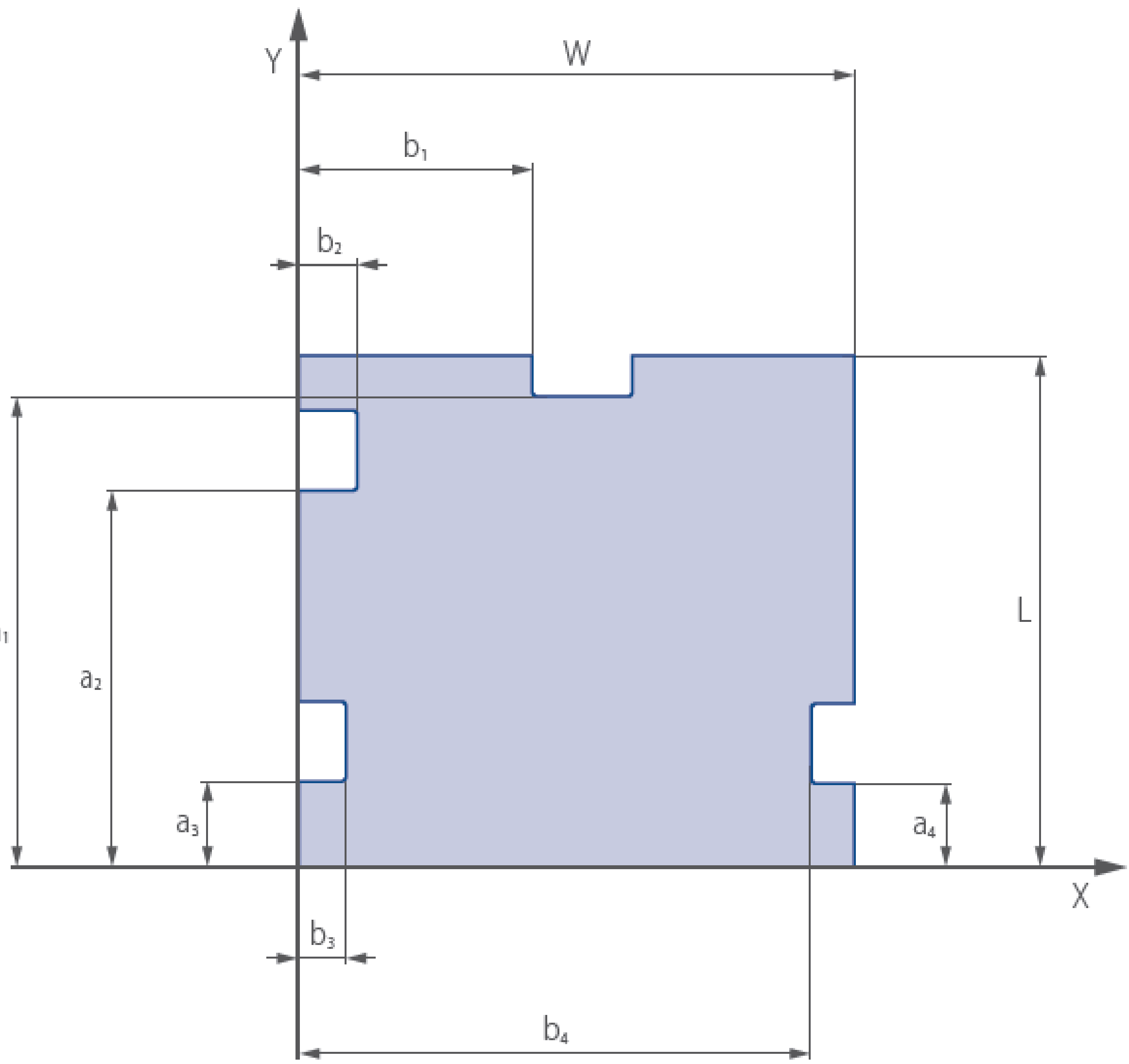


Fig. 20 Parameters of cut-out / notch location on the edges of a specific glass pane

2.3.3 Size of cut-outs / notches in corners

The size of the cut-outs /notches in corners (dimensions: c x h) may not be greater than 1/3 of the width (W) and height (L), respectively:

$$h \leq {}^{1}/_{3} \times L, \qquad c \leq {}^{1}/_{3} \times W$$

Figure 21 illustrates an exemplary arrangement of cut-outs along with the most relevant dimensions. Please note that the corner inside the cut-out (internal radius) must be rounded. The corner radius must be at least 6 mm.

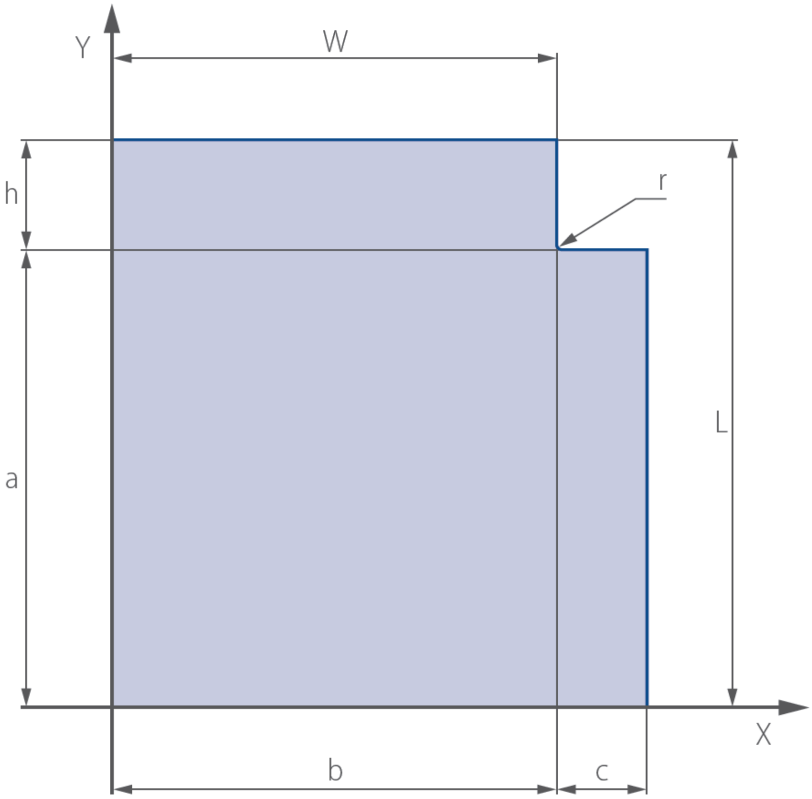


Fig. 21 Example of a corner cut-out / notch plus relevant dimensions

2.3.4 Corner cut-out / notch tolerances and locations

Corner cut-out / notch dimension and location tolerance date can be found in Tables 14-15. The parameters in Fig. 21 are for an illustrative pane. To determine the position of cut-outs / notches, a reference / datum point (lower left corner) is to used, from which the distance is measured in two axes perpendicular to each other.

Table 14

Corner cut-out / notch tolerances

Side of cut-out [mm]	Tolerance (h, c) [mm]
h or c	± 3,0

Table 15

Corner cut-out / notch location tolerance

Glass dimension [mm]	Corner cut-out / notch location tolerance (a, b) [mm]	
	Nominal glass thickness d ≤ 12	Nominal glass thickness d > 12
≤ 2000	± 2,5	± 3,0
2000< W or L ≤ 3000	± 3,0	± 4,0
> 3000	± 4,0	± 5,0

2.3.5 Size of corner cut-offs / cant corners

Cutting of corners may only be performed when cutting a shape is not possible on the glass cutting table for a given thickness of glass. Parameters for corner cutting are summarized in Table 16. Figure 22 is a diagram of a glass pane with a corner cut off.

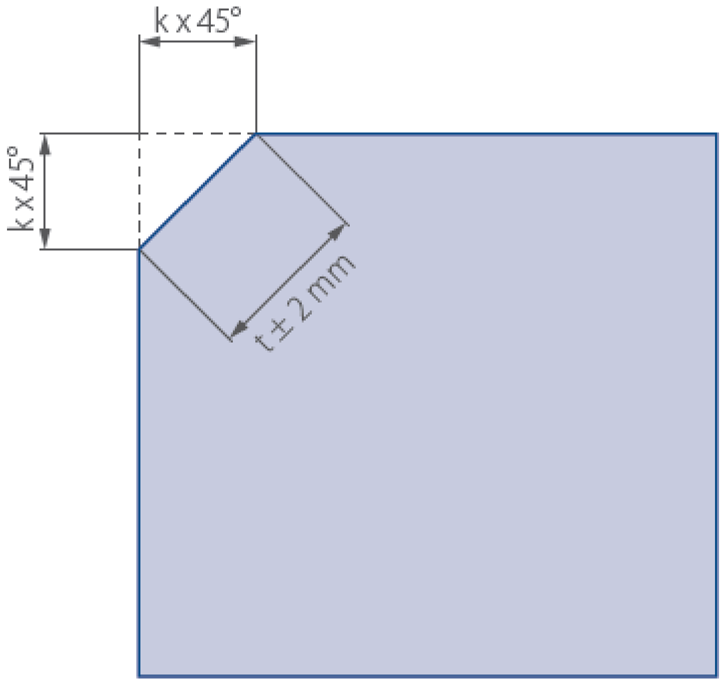


Fig. 22 Diagram of a glass pane with corner cut-off

Table 16

Corner cut-off parameters

Type of processing / glass	Glass thk. [mm]	Max length of corner cut-off; t [mm]	Tolerance [mm]
Cut-off / monolithic	4	21	± 2
	5	28	
	6	35	
	8	57	
	10	113	
	12 – 15	141	
	19	170	
Cut-off / laminate	No limitation	85	
Breaking	No limitation	4	-3 /+2

3. Application of ceramic paints

PRESS GLASS SA production sites use 3 methods of applying ceramic paints: roller method, silk-screen printing and digital printing. These guidelines are used to assess the visual quality of glass partially or completely covered with ceramic enamel. In each method, ceramic enamel is used, which is fired after application by means of tempering or heat strengthening the glass.

The main parameters affecting the quality and correct assessment of ceramic painted products are as follows:

- internal or external use
- glass visible from both sides (e.g. partition walls, curtain walls, etc.)
- direct illumination or a combination with direct lighting
- Glass edgework and any exposed edges
- a reference point on the surface of the glass

3.1 Explanations

3.1.1 Complete coverage of glass with ceramic coating

For complete coverage of the glass with enamel, one of the possible methods can be used. Evaluation of enamel is performed through the glass (looking at the uncoated side of the glass) so that the glass shade should affect the colour impression. Enamelled surface may not be exposed to weather conditions (position 2 or higher in the unit). The enamel may be applied to the position 1 for indoor applications after consultation with the supplier. Applications where the enamelled glass is visible from both sides must always be consulted with the supplier. Depending on the method of production, there are differences in the process, which are described below.

Roller method

Ceramic enamel is applied to the glass using a grooved rubber roller (with circumferentially arranged grooves). This method provides a uniform and as homogeneous as possible distribution of the ceramic enamel, provided that the glass surface is completely flat. A characteristic feature of this method is that the roll grooves are visible in close proximity (from the enamel side). It is difficult to see the grooves from the glass side under normal conditions (enamel viewed through the glass). In the case of bright enamel, keep in mind that the objects placed directly on the enamelled surface (such as sealing, glued panels, insulation, fixtures, etc.) can be seen through the glass. Glass with enamel applied with the roller is generally used for applications in which it is visible from both sides. For this reason, the use of this type of coating must be consulted with the supplier. Due to the manufacturing process, more enamel is applied on all edges and it may be slightly corrugated in particular along the edges parallel to the rollers.

Silk-screen printing

The enamel is applied to the surface of the glass on a horizontal table using a printing screen. The thickness of the applied layer is dependent on the used screen and is relatively thinner than in the roller method. Please note that objects placed directly on the enamel surface (such as sealing, glued panels, insulation, fixtures, etc.) can be seen through the glass. The use of this method must be consulted with the supplier for the applications where the glass can be seen from both sides. Characteristic features of this method of production include (depending on the selected enamel): fine stripes in both the longitudinal and transverse directions, and isolated ‘slightly blurred spots’. In the silk-screen printing method, the edges tend to remain clean. There may be a small ‘bulge’ on the edge of the enamel layer, so the exposed edges shall be specified in the order to satisfy the relevant requirements of the application.

3.1.2 Partial glass covering with ceramic coating

Glass may be partially covered with enamel using the above three methods. The information contained in par. 3.1.1 are applicable to this section. Due to the size tolerances of the glass and screen, unprinted rim can remain at the edges.

3.1.3 Digital printing

Digital printing permits multi-colour printing on the glass surface. High print resolution (up to 360 DPI) allows very accurate representation of artwork or photography. Very small droplets of enamel are deposited on the glass surface from print heads until the desired image is reproduced at the desired quality. All colours are applied simultaneously. Materials placed directly on the enamel, for example sealants, adhesives, panels, insulation, fixtures, etc. are visible through the glass. The appropriateness of this method should be discussed with the manufacturer where the glass can be seen from both sides. Dependent on the colour, printing intensity and application, it is possible to observe the following: small lines in the direction of print, occasional 'pinholes', shadows and isolated 'slightly blurred spots'.

3.2 Assessment of glass with ceramic coating applied

Glass with enamel applied to it shall be assessed from a distance of at least 3 m perpendicular to the surface. During the assessment, generating angle with the line perpendicular to the surface of the glass being evaluated may not be greater than 30 °. The assessment must be carried out in normal daylight conditions without direct sunlight or artificial lighting, in front of the glass pane, with an opaque background. The assessment is always performed looking through the glass, viewing the surface without the enamel layer. Glass seen from both sides shall be subject to the same criteria. If the printed glass is to be used on a bright background, or will be illuminated on the side opposite to the observer, spots, stains, streaks, or a 'starry sky' impression may be visible all of which are production process-dependent. This is because enamel is not impervious to light. Guidelines for the visual assessment of tempered or heat strengthened glass are to be applied to glass with enamel applied. Defects, visible from a distance of less than the specified viewing distance in the relevant standard for the type of glass, are not classified as defects.

Table 17

Tolerances for complete/partial coating of glass with ceramic enamel, glass with overprints or patterns

Specification	Major zone		Edge zone, 15 mm along the circumference (a
Enamel defects per piece	Max 3 ea. of an area not larger than 25 mm^2/ 1m^2 Sum of all defects: max area 25 mm^2/ 1m^2		Width: 3 mm Length: no limitation
Excess enamel on the edge	N/A		Acceptable
Tolerance of partial enamel coating (b	Dependent on length:		N/A
	Length of enamel: ≤ 2000 mm > 2000 mm	Tolerance: ± 3.0 mm ± 5.0 mm	
Tolerance on location of partial enamel coating	± 3.0 mm(c		
Tolerance of overprints and patterns	Depending on the length of the printed edge:		
	Length of enamel: ≤ 100 mm ≤ 1000 mm ≤ 2000 mm ≤ 3000 mm ≤ 4000 mm	Tolerance: ± 1.0 mm ± 2.0 mm ± 2.5 mm ± 3.0 mm ± 4.0 mm	

Defects ≤ 0.5 mm (very small imperfections in the glaze – pinholes known as starry sky effect) are acceptable and are usually not taken into account. Repair of defects by means of ceramic materials prior to tempering is

acceptable. Repaired nonconformities may not be seen from a distance of 3 meters.
[a] If the edge zone is smaller or does not exist, it requires prior consultation with the supplier
[b] Tolerance of the glaze location shall be measured from a reference point
[c] For the glass with an arrised edge, measurement is to be carried from the face of the glass. For ground / polished or mitred edge glass, measurement is to be carried out from the chamfered edge on the glass surface (see Fig. 23)

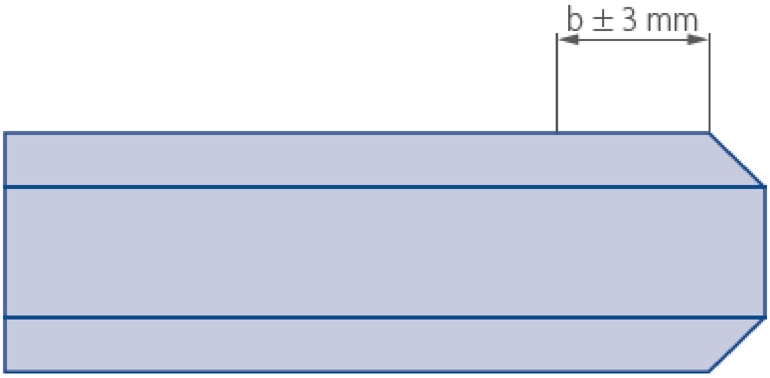


Fig. 23 Location of silk-screen and digital (b) printing from a chamfered edge

3.3 Colour assessment

Colour variations are caused by many factors and it is not possible to eliminate them. The factors set out below (for the actual lighting conditions) affect the assessment of recognizable colour variations between the two panes of glass coated with ceramic enamel. The real colour of the enamel can only be determined by viewing the fired specimen through the glass. Possibility of variations of colours selected basing on standard systems, e.g.: RAL, is possible.

3.3.1 Influence of glass type (substrate) on the colour

Generally, float glass is used as a substrate – its surface is very flat and reflects light intensely. In addition, the glass may be coated with various types of coatings. Furthermore, the same type of glass can have a different colour depending on the manufacturer, the glass thickness, the glass batch (e.g. the tinted glass, glass with a reduced iron content, etc.), all affect the final colour of the enamel-coated glass. The colour impression is also dependent on the method of application. Due to the relatively thinner enamel layer obtained by screen printing or digital printing, coated surfaces are more permeable to light than those produced with the roller method, wherein the layer is relatively thick. Assessment of the enamel-coated glass is always performed after tempering or heat strengthening.

3.3.2 Influence of the type of enamel

Ceramic enamel is made of inorganic materials, which are responsible for a specific colour. The enamel itself may have a slight output colour variation; therefore, the colour of enamel can be compared in one batch.

3.3.3 Type of lighting for the enamel assessment

Light constantly changes depending on time of year, time of day and weather conditions. This means that the various components in the visible range of the visible light spectrum (i.e. wavelengths of 400 - 700 nm) passing through a number of objects (air, glass), hit the fired ceramic enamel at varying degrees. Depending on the angle of incidence, the surface of the glass reflects part of the light beam to a lesser or greater extent. Light of different lengths, which reaches the fired enamel is partly reflected and/or absorbed. This explains why the impression of colour varies depending on lighting conditions.

3.3.4 Evaluation / assessment method

The human eye reacts very differently to different colours. It is very sensitive to even very slight changes in blue, while the same changes in green are not seen as distinctly. Other factors influencing the colour

assessment are as follows: the viewing angle, the viewing area size and the distance between two items being compared.
To assess the feasibility of producing an enamel printed order, the following steps must be followed in order:

a) Assessment against production capabilities and published tolerances – on the basis of data provided by the customer (order size, pane sizes, availability of glass and enamel, etc.)
b) Production of a 1:1 mock-up and its approval by the customer
c) Order-based production in accordance with the arrangements and/or the mock-up approved by both parties

Comparison and evaluation may only take place when the glass and applied enamel is from a single supplier. Enamel colour comparison may only take place on one customer order, using the same glass type and ceramic enamel. When comparing two pieces of glass covered with enamel of the same colour, the colour difference equal to ΔE* = 3 (CIE L * a * b), is allowed – the measurement is to be made on the glass surface.

3.4 Additional information

All comments and information not described above relating to tempered or heat strengthened glass are included in the standards appropriate for those glass. The manufacturer reserves the right to amend this information in the event of changes to the manufacturing technology.
Enamelled glass, due to firing process, may only be tempered or heat strengthened glass. Treatment of such glass after tempering is not possible. The mechanical strength of enamelled tempered or enamelled heat strengthened glass is lower than that of tempered or heat strengthened glass without enamel.
The production capability for enamel printing on glass is summarized in Tables 18-20.

Table 18

Production capability for roller applied enamelled glass

Glass thickness [mm]	Max format size [mm]	Min format size [mm]	Max weight [kg]
3	1700 x 3500	200 x 550	350
4	1700 x 2500	200 x 550	
5	2000 x 3000	200 x 550	
6 – 19	2500 x 4500	200 x 550	

Table 19

Production capability for silk screen printed enamelled glass

Glass thickness [mm]	Max format size [mm]	Min format size [mm]	Max weight [kg]
3	1700 x 3500	180 x 500	350
4	1700 x 2500	200 x 300	
5	2000 x 3000	200 x 300	
6 – 19	2500 x 4500	200 x 300	

Table 20

Production capability for digitally printed enamelled glass

Glass thickness [mm]	Max format size [mm]	Min format size [mm]	Max weight [kg]
3	1700 x 3500	180 x 500	350
4	1700 x 2500	200 x 300	
5	2000 x 3000	200 x 300	
6 – 19	2600 x 3700	200 x 300	

4. Heat treatment

4.1 Properties of the tempered glass

Tempered glass is characterized by increased mechanical and thermal strength and the specific way cracks into small usually blunt edge fragments when broken, considered safe. The increased mechanical and thermal strength of the tempered glass results from the specific distribution of thermal stress within the glass. By symmetrically and uniformally cooling (quenching) the glass stress patterns are achieved, where the outer layers are compressive stress zones and the inner layer is a tensile stress zone.

Compressive stresses in the surface layers of the glass allow the application of bending loads much greater than the equivalent annealed glass by the compensation of tensile stresses and thus reduction of the resultant local stresses. Average breaking stress for tempered glass is several times higher than that of annealed glass. Thereby, the phenomenon of static glass fatigue is also reduced. By superposition of the stress the dangerous bursting stress of the glass – which limits the glass strength - is reduced. In the tempered state, surface defects cannot spread through the outer zone as they are under compressive stress. Once the mechanical strength is undermined, tempered glass fractures into tiny and usually blunt edged pieces creating an appropriate fracture (fragmentation) pattern.

Thermally tempered glass is widely used in construction, furniture, household appliances (in microwaves with high thermal resistance), automotive, railway, aviation, shipbuilding and shipping and many other industries.

The following types of float glass may be thermally tempered: clear, tinted, glass with ‘hard’ (pyrolytic) coatings and some types of ‘soft’ coated glass (magnetron ‘sputtered’ coatings - it is the glass manufacturer who always decides this option), drawn flat glass and plate glass.

Note that some additional phenomena resulting from thermal treatment may occur in the tempered glass. These phenomena do not mean that the tempered glass is defective.

They include the following:

a) The phenomenon anisotropy or rainbow formation: arising from the directional irregular stress fields introduced into the glass during the tempering process (see Fig. 24). It produces a double refraction of light in the glass, which becomes visible in polarized light – the stress field is visible in the form of coloured areas known as ‘polarizing fields’ or ‘leopard spots’. ‘Polarizing fields’ are visible on the glass when observed at a slight angle and also in daylight (this phenomenon can be seen well on tempered car windscreens especially when viewed with polarized sunglasses)

b) ‘Roller waves' or local bow – formed when tempering glass in a horizontal furnace. These are surface distortions caused by hot glass (temperature near to the melting point) being in direct contact with the furnace rollers. Distortions in the flatness of the glass are thus created. These distortions are usually visible in reflected light. When ordering glass for building façades, the customer should take ‘Roller waves' into account and define the directional orientation of loading the glass into the tempering furnace (horizontal or vertical directional tempering).

c) 'Roller imprints' – for glass thicker than 8 mm and for thinner glasses with large dimensions, small imprint marks can enhance ('roller imprints').

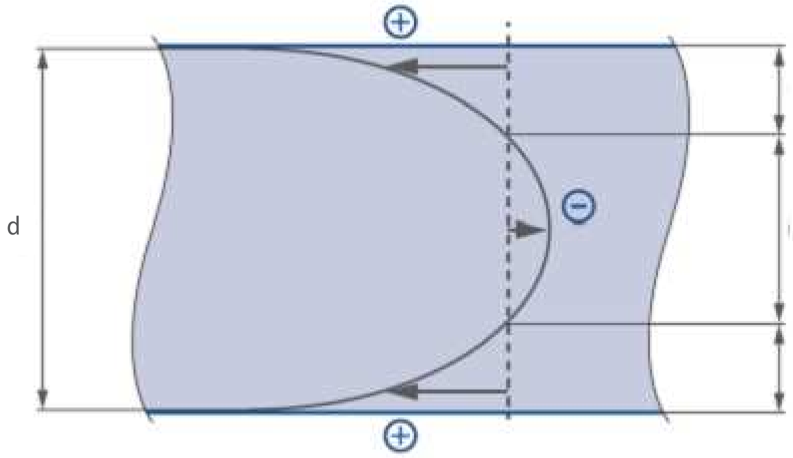


Fig. 24. Stress distribution in tempered glass (d – nominal glass thickness)

4.1.1 Requirements for heat treatment processes

Glass which is to be heat treated through the furnace must be subjected to a minimum level of edgework i.e.:

1. Arrissing for glass up to 8 mm thick
2. edge grinding for glass ≥ 10 mm thick

During the tempering process, there are significant stresses in the glass that concentrate on the edges of each pane. Inadequately prepared edges may cause the glass to fracture inside the furnace.

All edgework, drill holes, cut-outs, notches and mitring must take place before tempering. Please also note that the presence of holes and cut-outs increases the risk of glass fracture during the tempering process. For heat treated glass processing requirements and limitations, in terms of opening dimensions and their location, see par. 2.1.1 of Part II of this Standard. Minimum internal radii of cut-outs shall be greater than or equal to the thickness of the glass, but not less than 6 mm.

4.2 Tempering

4.2.1 Premium toughened (PREMIUM ESG)

In the PREMIUM TOUGHENED furnace, rollers have been replaced by abed of air on which the glass sheet is moved at a certain angle. Rollers contact the glass sheet only on one edge. Therefore, at least one glass edge of each pane must be straight.

Table 21

Production capability of the PREMIUM TOUGHENED furnace

Glass thickness [mm]	Max format size [mm]	Min format size [mm]	Max weight [kg]
2 – 3	1700 x 3500	180 x 500	200
4 – 8	1700 x 5000	180 x 500	200

In the PREMIUM TOUGHENED tempering process (see Fig. 25), no effect specified in par 4.1.c can be observed. It is a glass characterized by the absence of local distortions (except for a small strip just at the edges). The flatness of the PREMIUM TOUGHENED glass is practically the same as of annealed float glass (see Fig. 26.)

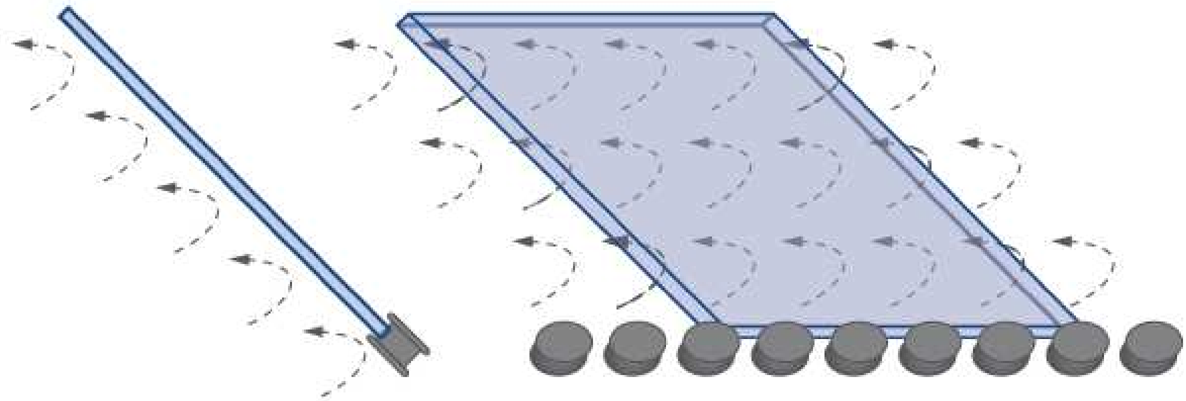


Fig. 25 Diagram of the PREMIUM TOUGHENED tempering process

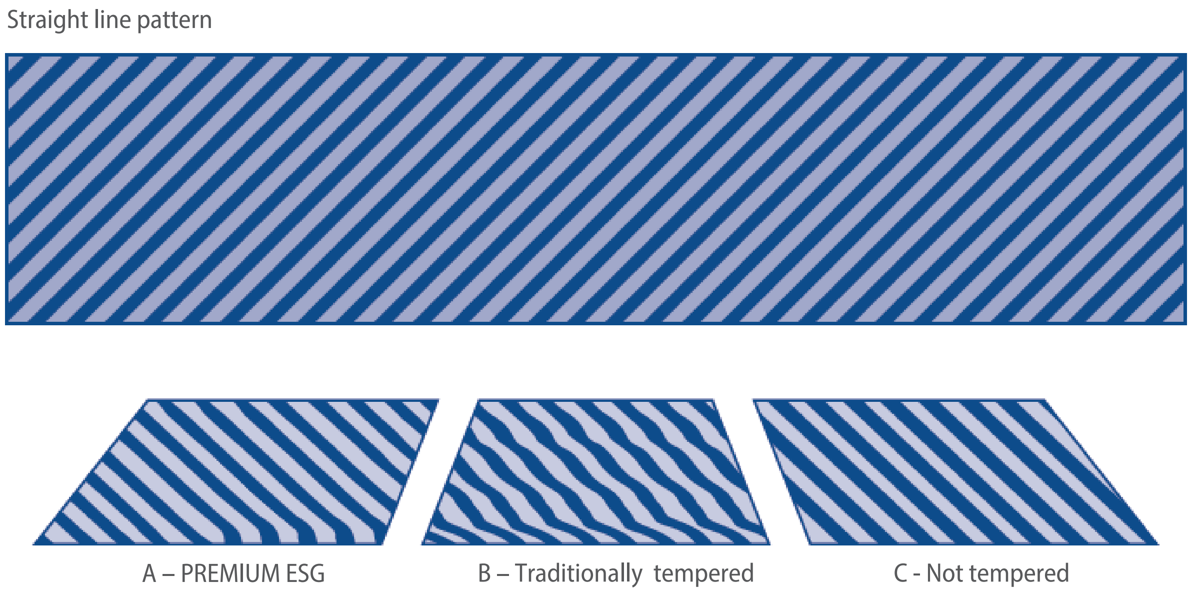


Fig. 26 Comparison of traditionally tempered and PREMIUM TOUGHENED glass

4.2.2 Toughened (ESG)

The traditional tempering process according to EN12150 is performed in oscillating horizontal furnaces. Glass is heated close to its melting point to the appropriate temperature and viscosity. After heating, the glass is directed to the quenching chamber where it is rapidly cooled with cold air. This causes stresses as illustrated in Fig. 24. By selecting this type of heat treatment, the phenomena listed in par. 4.1.a - 4.1.c become possible. It is necessary to select the right tempering direction – with the length of the sheet parallel or perpendicular to the rollers in the tempering furnace.

Figure 27 shows the example orientations of glass panes within the furnace. Orientating a glass pane in a direction which would mean the W or L dimensions exceeding the furnace width is impossible. Such limitations should be considered for individual panes exceeding the furnace width as well as all remaining pieces on the order which are not subject to this limitation. In order to perform directional tempering, the direction of tempering should be specified by the customer on each order. Failure to specify the tempering direction authorizes the manufacturer to process the glass without considering tempering direction.

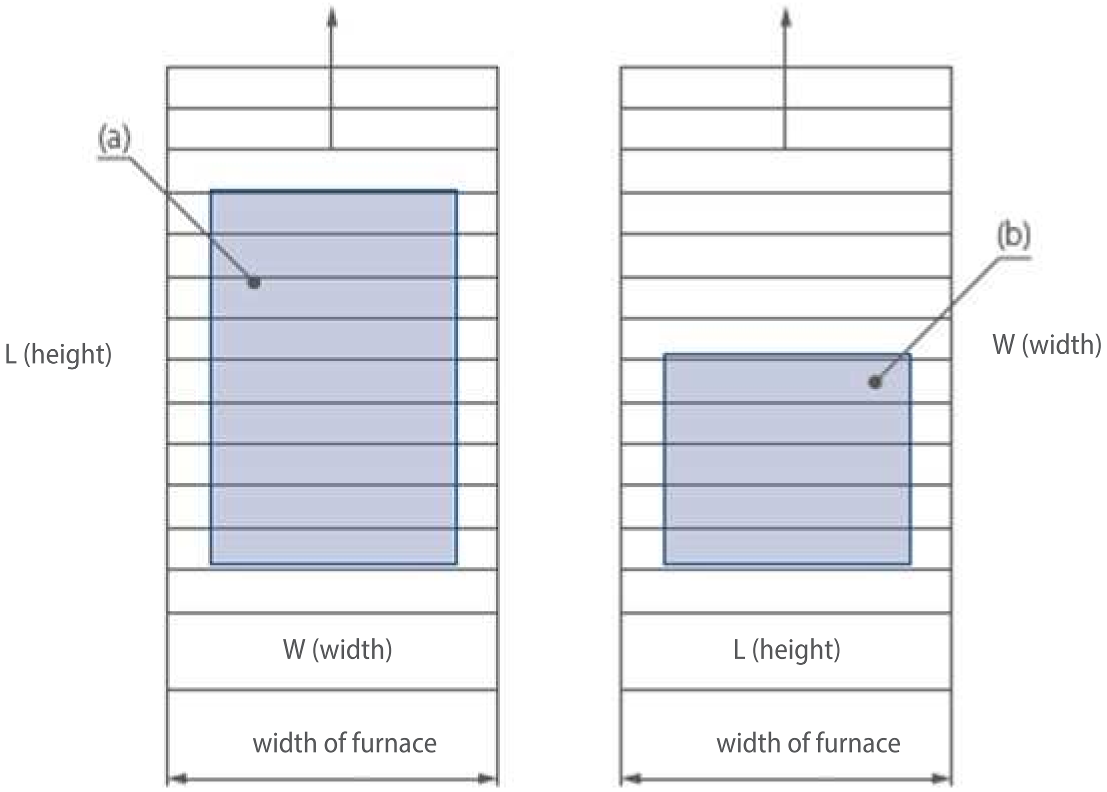


Fig. 27 Arrangement of a sample glass pane on the bed of the tempering furnace

For the tempering line production capability, see Table 22. Tempering of shapes is possible.

Table 22

Production capability of the tempering line

Type of glass	Glass thickness [mm]	Max format size [mm]	Min format size [mm]	Max weight [kg]
Float	3	1700 x 3500	180x500	500
	4	1700 x 2500	100 x 250	
	5	2000 x 3000	100 x 250	
	6-19	2800 x 6000	100 x 250	
Float with soft coating	3	1700 x 3500	180x500	500
	4	1500 x 2500	100 x 250	
	5	1700 x 2500	100 x 250	
	6-19	2800 x 6000	100 x 250	

4.2.3 Heat Strengthened (TVG)

Semi-tempered or heat-strengthened glass (TVG) according to EN 1863 is obtained by thermal treatment. It aims to increase the mechanical and thermal strength of the glass. Differences between heat strengthened and toughened glass lie mainly in the different fracture pattern and lower mechanical strength of the TVG glass in relation to the toughened (ESG) glass (see Table 24). It is worth remembering that TVG glass is not a safety glass. In the event of fracture, TVG soda lime silicate glass cracks in a manner similar to that of annealed glass.

The nature of the heat strengthening process prevents the attainment of a product as flat as annealed glass. The difference in flatness depends on the type of glass, (e.g. coated, patterned, etc.), the dimensions of the glass, its nominal thickness, the aspect ratio of the pane as well as the process employed, i.e. horizontal or vertical.

The following types of distortions can be found in the horizontal process:

- total convexity
- roller waves
- raised periphery

All glass processing must be carried out before the heat treatment. For the production capability of the heat strengthened glass, see Table 23.

Table 23

Production capability of heat strengthened glass

Line / type of glass	Glass thickness [mm]	Max format size [mm]	Min format size [mm]	Max weight
Line 1 / float / float with soft coating	2 – 3 4 – 8	1700 x 3500 1700 x 5000	180 x 500 180 x 500	200 kg/m
Line 2 / float	4 5 6 – 12	1700 x 2500 2000 x 3000 2800 x 6000	200 x 450	500 kg
Line 2 / float with soft coating	4 5 6 – 10	1500 x 2500 1700 x 2500 2800 x 6000	200 x 450	500 kg

Table 24

Mechanical strength values for glass acc. to EN 12150-1; EN 14179-1; EN 1863-1

Type of heat treatment	Mechanical strength [N/mm^2]	
Type of glass	Tempered, thermally annealed	Heat strengthened
Monolithic: colourless, colour, coated	120	70
Enamelled	75	45
Patterned and drawn flat glass	90	55

4.3 Requirements and testing of heat-treated glass

4.3.1 Dimensions and tolerances for tempered flat glass

Dimensions of tempered glasses are imposed by the pre-tempering processing equipment capabilities and the capacity of the tempering furnace. The values of the nominal thickness of the glass as well as tolerance for each thickness are given in accordance with EN 12150-1 and are summarized in Table 25.

Table 25 Glass thicknesses and thickness tolerances for toughened panes

Table 25

Nominal thickness and thickness tolerances

Nominal thickness *d*	Thickness tolerances for glass type			
	Float	Patterned	Drawn sheet	New antique drawn sheet
2	± 0,2	Not manufactured	± 0,2	Not manufactured
3	± 0,2	± 0,5	± 0,2	Not manufactured
4	± 0,2	± 0,5	± 0,2	± 0,3
5	± 0,2	± 0,5	± 0,3	Not manufactured
6	± 0,2	± 0,5	± 0,3	± 0,3
8	± 0,3	± 0,8	± 0,4	Not manufactured
10	± 0,3	± 1,0	± 0,5	Not manufactured
12	± 0,3	± 1,5	± 0,6	Not manufactured
14	Not manufactured	± 1,5	Not manufactured	Not manufactured
15	± 0,5	± 1,5	Not manufactured	Not manufactured
19	± 1,0	± 2,0	Not manufactured	Not manufactured
25	± 1,0	Not manufactured	Not manufactured	Not manufactured

NOTE: Dimension in mm

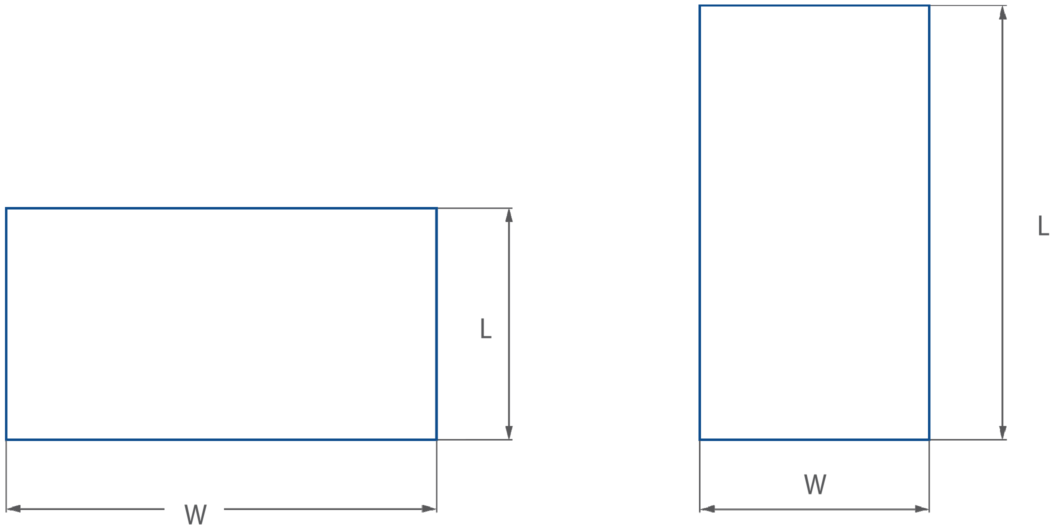


Fig. 28 Examples of width W, and length L, relative to the pane shape

Glass dimensional tolerances are given in accordance with EN 12150-1 for tempered flat glass.
If you wish to achieve more stringent tolerances, please contact our Sales Department.

Table 26 – Tolerances of width, height and diagonal for flat toughened panes according to EN 12150-1

Table 26a

Tolerances of width W, and length L

Nominal dimensions of side, *W* or *L*	Tolerance, *r*	
	Nominal glass thickness, $d \leq 8$	Nominal glass thickness, $d > 8$
≤ 2 000	± 2,0	± 3,0
2 000 < W or L ≤ 3000	± 3,0	± 4,0
> 3000	± 4,0	± 5,0

NOTE: Dimension in mm

Table 26b

Limit deviations for the difference between diagonals

Nominal dimensions, W or L	Nominal glass thickness, $d \leq 8$	Nominal glass thickness, $d > 8$
≤ 2 000	≤ 4	≤ 6
2 000 < W lub L ≤ 3000	≤ 6	≤ 8
> 3000	≤ 8	≤ 10

NOTE: Dimension in mm

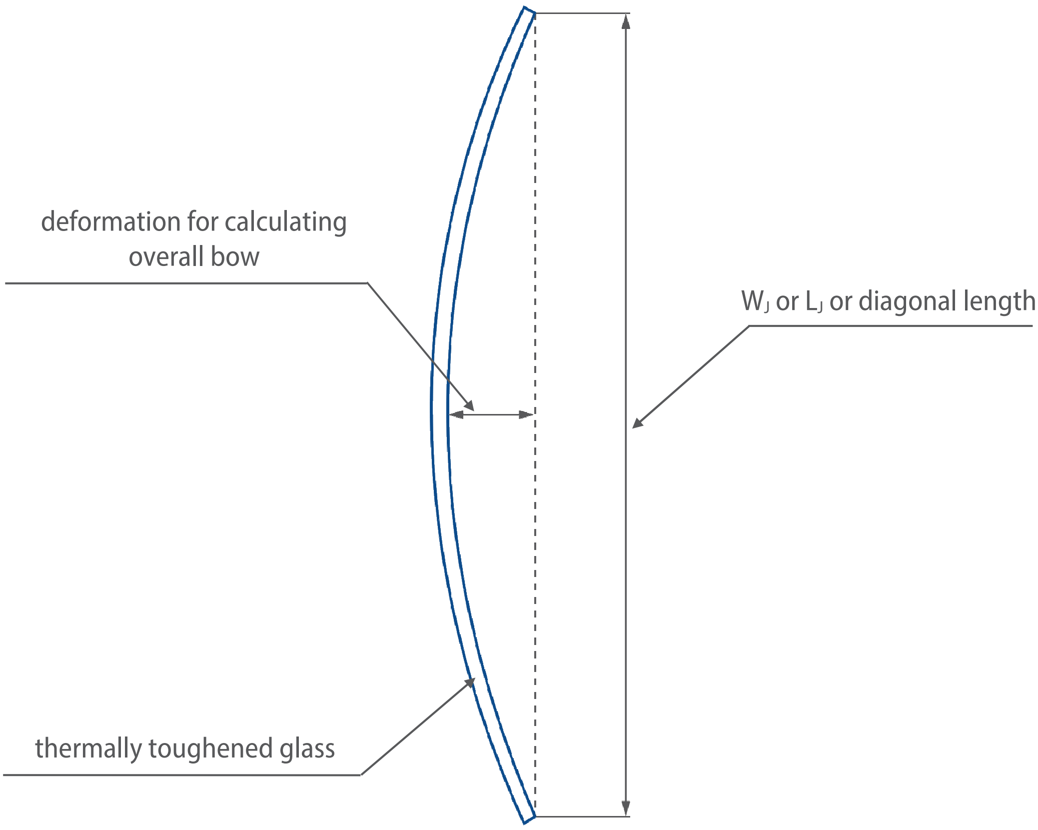
4.3.2 Straightness for tempered flat glass

In the tempering process, it is not possible to produce glass of a flatness equal to the equivalent annealed (i.e. not tempered) glass. The deviation from flatness depends on the thickness, size and aspect ratio of the glass pane. Within certain tolerances, some distortions of glass surface are allowed. Measurement according to EN 12150 is to be carried out in order to investigate distortions. There are five kinds of distortions:

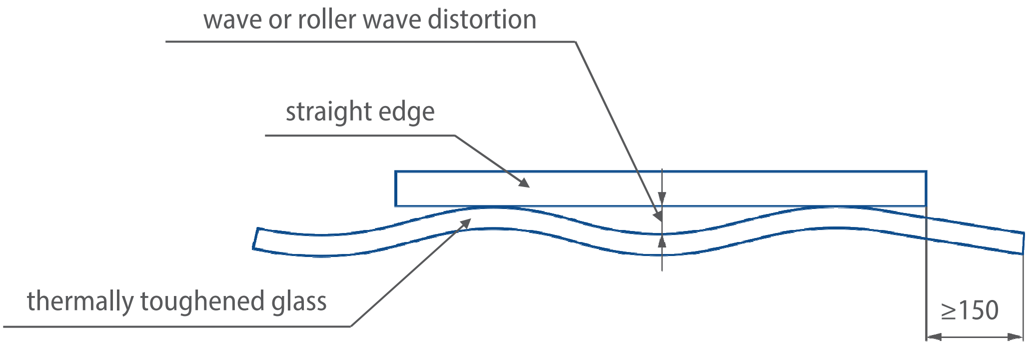
a) Overall bow;
b) Roller wave distortions (for horizontally toughened glass only);
c) Edge lift (for horizontally toughened glass only);
d) Air cushion wave distortion (for air cushion toughened glass only);
e) Edge deformation (for air cushion toughened glass only).

In the case of the overall bow, roller waves, edge lift, aircushion waves, edge deformation the total size may be compensated by frames and glazing beads.

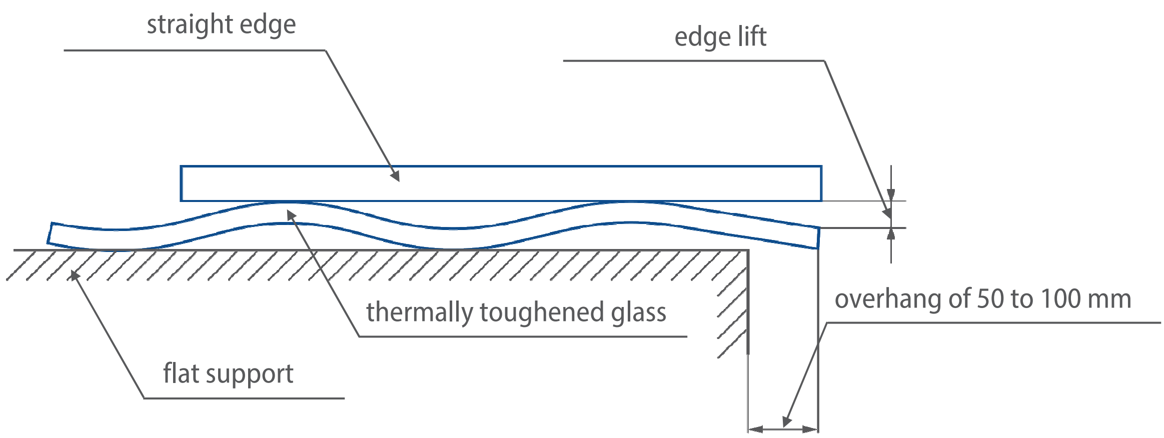
NOTE: Use of a more stringent tolerance requires additional consultation and agreement with the supplier.



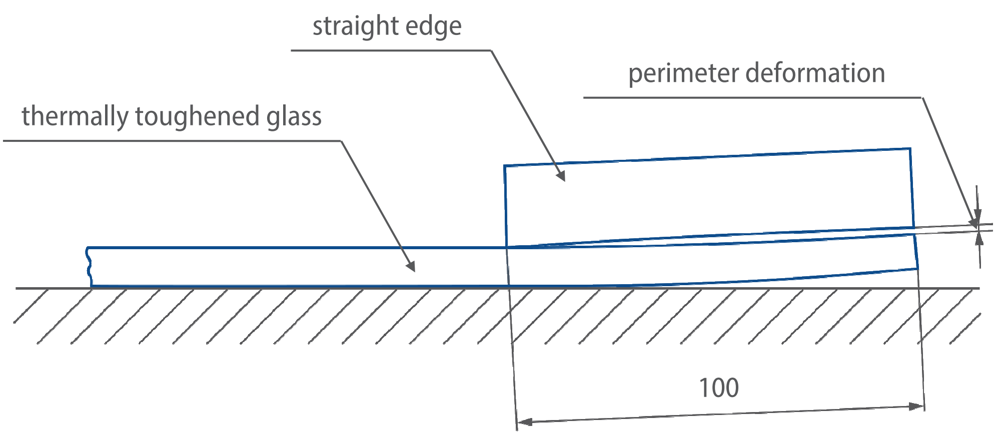
a) Representation of overall bow



b) Measurement of wave or roller wave distortion



c) Measurement of edge lift



d) Measurement of perimeter deformation

Fig. 29) a) overall bow; b) wave and roller wave; c) edge lift; d) perimeter deformation.

Table 27 (a, b, c and d).

Table 27a:

Maximum allowable values of overall bow and roller wave distortion for horizontally toughened glass

Glass Type	Maximum allowable value for distortion	
	Overall bow [mm / m]	Roller wave [mm]
Uncoated float glass in accordance with EN 572-1 and EN 572-2	3,0	0,3
Others [a)]	4,0	0,5

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

NOTE: Dependent upon the wavelength of the roller wave an appropriate length of gauge needs to be used.

Table 27b

Maximum allowable values for edge lift for horizontal toughening

Type of glass	Thickness of glass [mm]	Maximum allowable values [mm]
Uncoated float glass in accordance with EN 572-1 and EN 572-2	3	0,5
	4 to 5	0,4
	6 to 25	0,3
Others[a)]	3 to 19	0,5

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

NOTE 1: Dependent upon the wavelength of the roller wave an appropriate length of gauge needs to be used.

NOTE 2: For uncoated float glass with a thickness of 2 mm it is advised to consult the manufacturer.

Table 27c

Maximum allowable values of overall bow and wave distortion for toughened glass manufactured by air cushion process

Glass Type	Maximum allowable value for distortion	
	Overall bow [mm / m]	Wave [mm]
Float glass in accordance with EN 572-1 and EN 572-2 and coated float glass in accordance with EN 1096-1	3,0	0,3
Others [a)]	4,0	0,5

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

NOTE: For other glass types it is advised to consult the manufacturer.

Table 27d

Maximum allowable values for perimeter deformation for toughened glass manufactured by air cushion process

Type of glass	Thickness of glass [mm]	Maximum allowable values [mm]
Float glass in accordance with EN 572-1 and EN 572-2 and coated float glass in accordance with EN 1096-1	2 to 12	0,3
Others[a)]	2 to 12	0,5

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

NOTE: For other glass types it is advised to consult the manufacturer.

4.3.3 Heat soaking of thermally-tempered glass in accordance with EN 14179-1 (Heat Soak Test – HST)

Heat soak testing of thermally-tempered glass (HST) is a test for nickel sulphide (NiS) inclusion within the glass pane. The method itself involves heating the toughened to a temperature of approx.. 290 °C and maintaining it for a time predetermined by the standard. Within this time, the glass sheets with inclusions shall fracture with a probability close to 99%.

The presence of very small particles of nickel sulphide (NiS) is associated with their occasional entry into the molten glass of a float glass production process. During the tempering process, nickel sulphide particles contained in the glass change their volume (undergo polymorphic transformation). The rapid quenching of the heated glass, which causes it to toughen, makes that the nickel sulphide particle, which needs a certain amount of time to return to its original volume, no such possibility (i.e. it remains in the meta-durable state). It becomes ‘frozen’ in this state, which may produce additional stress in the glass pane in the future.

This mechanism works like a time bomb. Fixed, tempered glass panes containing nickel sulphide inclusions which become heated e.g. under the influence of solar radiation, increase in volume slowly, which results in an additional increase of internal stress. If such a particle is located in the zone of tensile stress, there is a very high probability that the stress level shall exceed the acceptable level and the glass sheet will fracture spontaneously.

Table 28 summarizes the capacity of the HST line. It is worth emphasizing that during the heating process, safety class and strength parameters are not compromised. The advantage of the HST is to obtain a very high likelihood that the glass installed will not fracture spontaneously due to the presence of NiS. Example glass broken as a result of nickel sulphide inclusion is shown in Figure 30. The test can be performed on soft coated glass, and on various shapes.

Table 28

Process capabilities for HST

Glass thickness [mm]	Max pane size (W x L) [mm]	Min pane size (W x L) [mm]	Max weight [kg]
4 - 19	3300 x 8000	1 side ≥ 400 mm	900

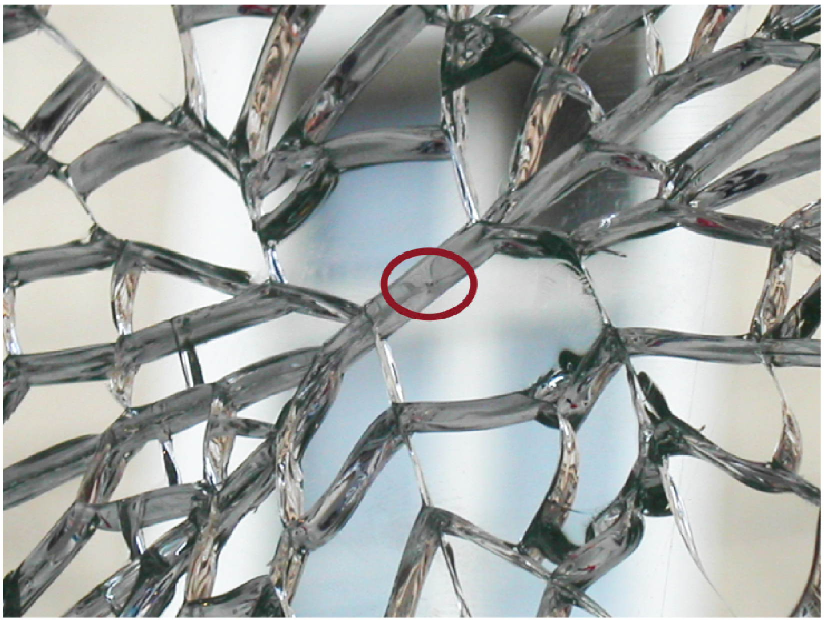


Fig. 30. Example of spontaneous cracked glass due to the presence of nickel sulphide

4.3.4 Marking of tempered glass (ESG), heat-soaked thermally-tempered glass (ESG-H) and heat strengthened glass (TVG)

In accordance with EN 12150-1 toughened glass, EN 14179-1 heat-soaked thermally-tempered glass, and EN 1863 heat strengthened glass shall be marked in a legible and permanent way. The marking shall include information on the name of the manufacturer together with its trademark and the number of EN 12150-1, EN 14179-1 or EN 1863, respectively.

4.3.5 Testing of tempered glass critical characteristics

All testing of tempered glass shall be performed in accordance with EN 12150-1 and related standards.

Fracture (fragmentation) pattern

Within a specimen sample of broken tempered glass, the largest fragments shall be counted within a selected square size 50 x 50 mm. In order to consider the result positive, the number of fragments in each specimen may not be less than that given in Table 29. An additional requirement is that the length of a single fragment in the test specimen may not exceed 100mm. The glass shall be broken by hitting it at a point in the middle of the longer side of the glass pane, at a distance of 13mm from its edge. For a pictorial diagram of the test specimen, see Figure 32. The shaded area is excluded from the assessment, and it includes: the peripheral strip with a width of 25mm and within 100mm radius from the point of impact.

Table 29. The list of crack pattern requirements depending on the glass type and thickness

Table 29

Minimum particle count values

Glass type	Nominal thickness, *d* mm	Minimum particle count number	Shower enclosures (see. EN 14428)
All glass types	2	15	Not applicable
All glass types	3	15	40
All glass types	4 to 12	40	40
All glass types	15 to 25	30	30

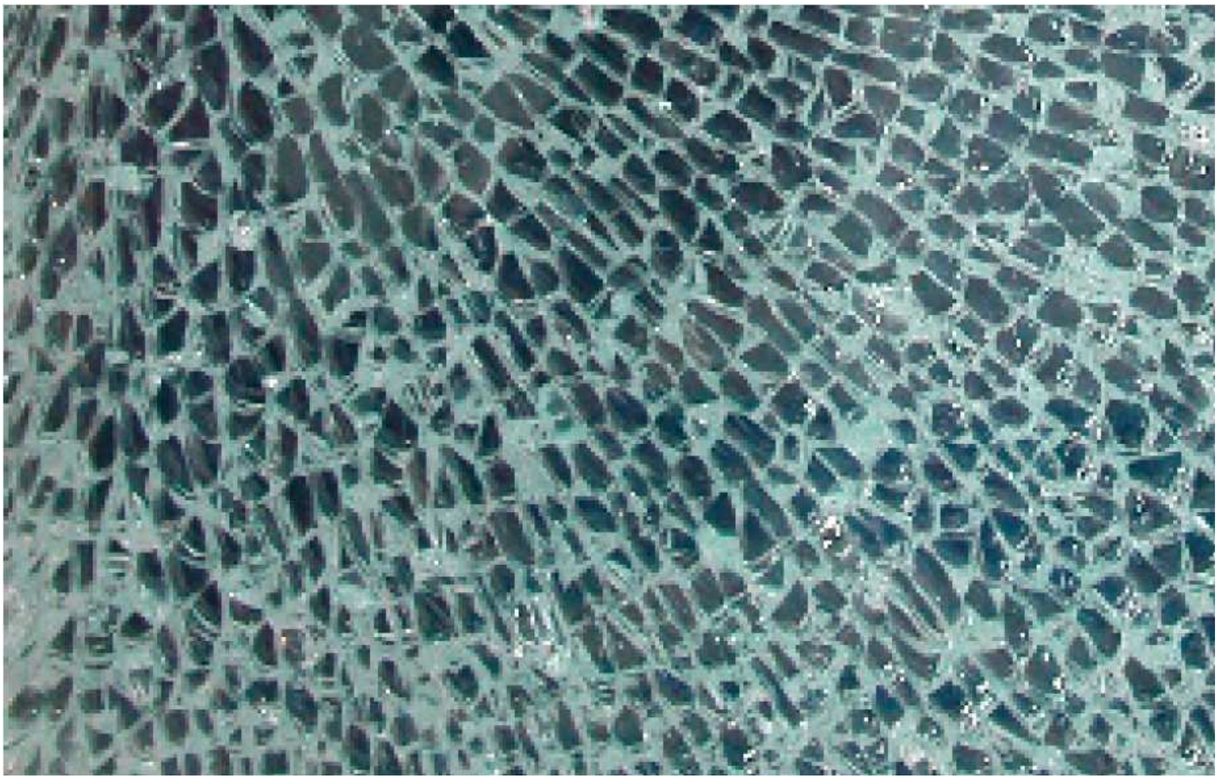


Fig. 31 Sample image of fracture (fragmentation) pattern of tempered glass with a thickness of 10mm. The structure of the cracks meets the standard requirements

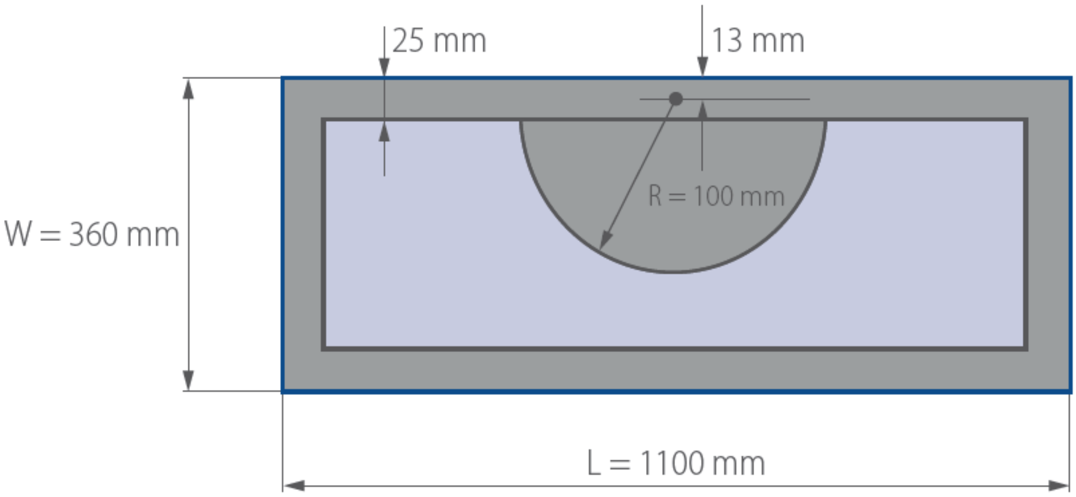


Fig. 32 An example of a specimen tested for the nature of the fracture pattern. The specified area is excluded from the assessment. The dimensions of the normative specimen shall be 360 mm x 1100 mm (W x L). Due to the manufacturing process, testing for the nature of the fracture pattern is also allowed on a sample of a different size

Pendulum test (component with tyres)

Tempered and enamelled tempered glass shall be pendulum tested. The pendulum test represents accidental collision of a human with glass. It is required that glass, hit by the pendulum from different heights (acc. to EN 12600), withstands the impact or cracks in a safe manner.

Testing of the bending strength of glass

The test is carried out for tempered glass and enamelled heat-soaked thermally-tempered glass and heat strengthened glass. The glass is subjected to bending pressure supported at four points according to EN 1288-3. The tested glass shall withstand a load with the value given in Table 24, depending on the type of glass.

4.3.6 Furniture glass

Toughened panes for furniture applications are thermally toughened safety panes. They have an improved mechanical strength as compared to standard non-toughened panes and when cracking, they crack into fine particles with blunt edges.

An order for such panes should contain a clause informing about their application in furniture. Otherwise, an order for toughened panes will be treated as an order for construction glass (e.g. the panes will be marked permanently).

Panes for furniture applications are tested for the nature of the crack pattern and the following tests:

- overall bow;
- roller wave (only for horizontally toughened glass);
- edge lift (only for horizontally toughened glass);
- wave (only for toughened glass manufactured by air cushion process);
- edge distortion (only for toughened glass manufactured by air cushion process).

The crack pattern test and interpretation of the results will be carried out according to item 4.3.5 part II of the Standard. The Ordering Party shall always inform about their request not to mark the glass permanently on a case-to-case basis. A different kind of marking, e.g. using labels, is then used.

On request, a Test Certificate can be issued, containing the results of the crack pattern tests. In case of any deviations from the assumptions given above, please contact the Sales Department.

4.3.7 Acceptable defects in tempered, tempered heat soaked and heat strengthened glass

Checking the quality and workmanship of tempered, tempered heat soaked and heat strengthened glass consists of visual inspection with the naked eye under natural light on the background of a mat black screen or in transmitted and/or reflected light, depending on the glass used and the corresponding specifications/standards (see the Reference Documents to this Company Standard). Defects not visible from a distance of 2m (3m for coated glass), shall not be classified as defects. Assessment of tempered, tempered heat soaked and heat strengthened glass shall be performed in accordance with Table 30.

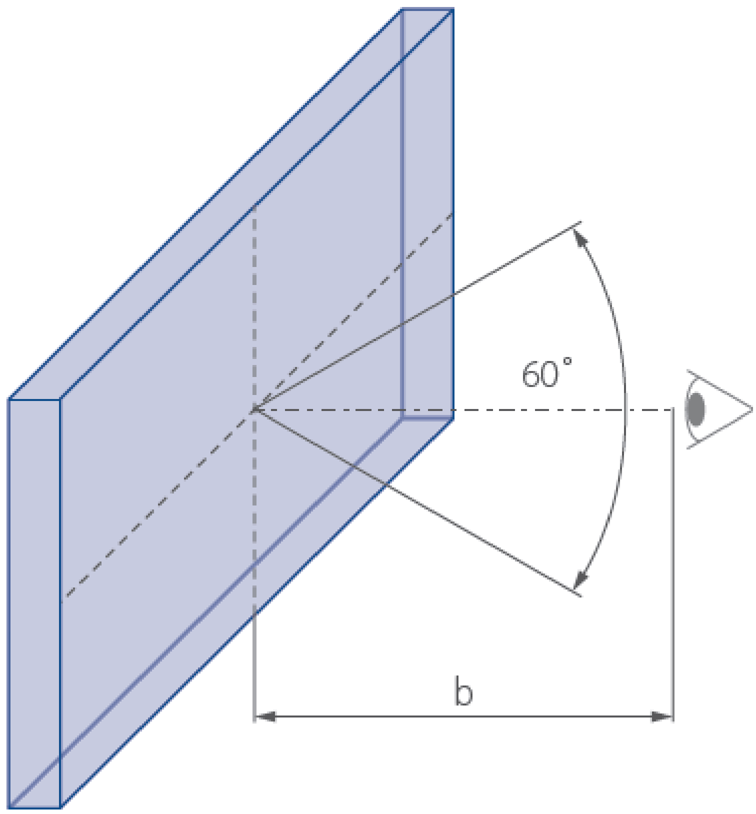


Fig. 33 Pictorial diagram: visual assessment of a glass pane. Approximate distance b of the observer is 3 m for coated glass and 2 m for uncoated glass.

Table 30

Specification of acceptable defects in tempered, tempered heat soaked and heat strengthened glass

Item	Defect	Glass surface		
		< 1 m²	1 ÷ 2 m²	>2 m²
1	Spot - inclusions of foreign matter	unacceptable	unacceptable	unacceptable
2	Broken seeds (bursting)	unacceptable	unacceptable	unacceptable
3	Closed seeds (incl. spot defects up to 0.5 mm shall not be considered)	acceptable, 2 ea. of max dim. 2 mm	acceptable, 3 ea. of max dim. 2 mm	acceptable, 5 ea. of max dim. 2 mm
4	Linear defects	Acceptable with a total length of 40 mm and of a single length up to 15 mm. In the peripheral zone, acceptable isolated up to 20 mm	Acceptable with a total length of 45 mm and of a single length up to 15 mm. In the peripheral zone, acceptable isolated up to 20 mm	Acceptable with a total length of 50 mm and of a single length up to 15 mm. In the peripheral zone, acceptable isolated up to 20 mm
5	Edge defects	Blunt edge (machined periphery) – small splinters acceptable, provided they will be blunt; shiny areas – acceptable Ground edge (with shiny areas) – bunt edge with trimmed face or ground – insufficiently ground shiny areas) – acceptable Smoothed ground edge (no shiny areas) – ground edge – splinters, some insufficiently ground areas (shiny spots) – unacceptable Polished periphery – polished edge – dull spots, splinters – unacceptable		
6	Spots, streaks	Acceptable, if not visible from the distance specified in the standard relevant for a specific type of glass, in daylight.		
7	Defects of enamel applied:	According to point 3.2 – II part of Company Standard		

5. Laminated glass

Laminated glass has virtually unlimited application possibilities. To customize their design to different needs, the standard market offer for laminated glass of symmetric construction made from annealed float glass is insufficient, which is why PRESS GLASS SA has expanded its own production range of laminated products. The production capability of the glass laminating line is summarized in Table 31.

Table 31

Production capability of the laminated glass line

Glass thickness [mm]	Max weight [kg]	Max dim. [mm]	Min dim. [mm]	Soft coating
2 – 19 for a single pane	500 kg	2800 x 6000	250 x 500	+
6 – 100 for laminated glass	1000 kg			

5.1 Definitions acc. to EN ISO 12543–1 & EN 357

Laminated glass: is a unit manufactured by permanently bonding two or more panes of glass with a plastic layer of one or more interlayers.

Fire resistant glazing: Is a structural unit which consists of one or more clear or translucent glass panes mounted in a frame, sealed and fixed, together with any special structural materials, tested and assigned a classification symbol.
For detailed information regarding fire resistant glazing manufactured as single panes or used in glazing units, please see the fire resistant glass manufacturer's instruction manual.

Fire resistance - Fire resistance is defined by the following:
R – Capacity of a load-bearing surface to resist heat transfer: the ability of one or more exposed surfaces of a structural member to resist fire for a prescribed period of time without losing structural functionality

E - Heat resistance: the ability of a structural member exposed surface to resist fire and prevent spread of flames to the unexposed surface as a result of flames or hot gases passing from the exposed side to the unexposed side and to prevent ignition of the unexposed surface or any fire load attached thereto

W - Heat radiation reduction: the ability of a structural member to resist fire on only one exposed side for a prescribed period of time while the heat radiation measured before glazing is lower than the required level

I - Insulation: the ability of a structural member to resist fire on only one exposed surface and to prevent spread of flames resulting from a considerable amount of heat passing to the unexposed surface and causing ignition of the unexposed surface or any fire load attached thereto; and the ability to provide a sufficient heat barrier to protect people who are close to such a member for a period of time specified in a relevant rating

S - Smoke resistance: the ability of a structural member to limit the passage of hot / cold gases or smoke from one side to the other

Fire resistance ratings should apply to a complete glazing system with panes, and specify all dimensions and tolerances.

Fire resistance ratings are represented by specific letter(s) which define(s) functional requirement(s), followed by the time period expressed in minutes:

R(minutes)/E(minutes)/EW(minutes)/EI(minutes)/S(minutes)

5.2 Acceptable dimensional tolerances of single bonded laminated panes (according to EN ISO 12543-5)

Nominal width and length shall be neither larger nor lower than the deviation (t), as specified in Table 32 below.

For the method of measurement of the width/length and squareness tolerances, see Fig. 28.

Table 32

Dimensional tolerances of laminated glass depending on the glass pane thickness

Acceptable deviations of L and H. (Table 3: PN-EN ISO 12543-5)

Deviation limits for L or H [mm]

Nominal L & H (mm)	Nominal thickness ≤ 8 mm	Nominal thickness > 8 mm	
		Each glass pane of nominal thk. < 10 mm	At least one glass pane of nominal thk. ≥ 10 mm
≤ 2000	+3,0 -2,0	+3,5 -2,0	+5,0 -3,5
≤ 3000	+4,5 -2,5	+5,0 -3,0	+6,0 -4,0
> 3000	+5,0 -3,0	+6,0 -4,0	+7,0 -5,0

Acceptable deviations of diagonals as specified in Table 4: PN-EN ISO 12543-5

Nominal L & H (mm)	Nominal thickness ≤ 8 mm	Nominal thickness > 8 mm	
		Each glass pane of nominal thk.< 10 mm	At least one glass pane of nominal thk. ≥ 10 mm
< 2000	6	7	9
< 3000	8	9	11
> 3000	10	11	13

NOTE: If the laminated glass consists of tempered glass panes, the dimensional tolerances shall be referenced to tempered glass.

5.2.1 Offset

Offset is a misalignment of any periphery of the glass pane or plastic glazing material components forming a laminated glass.

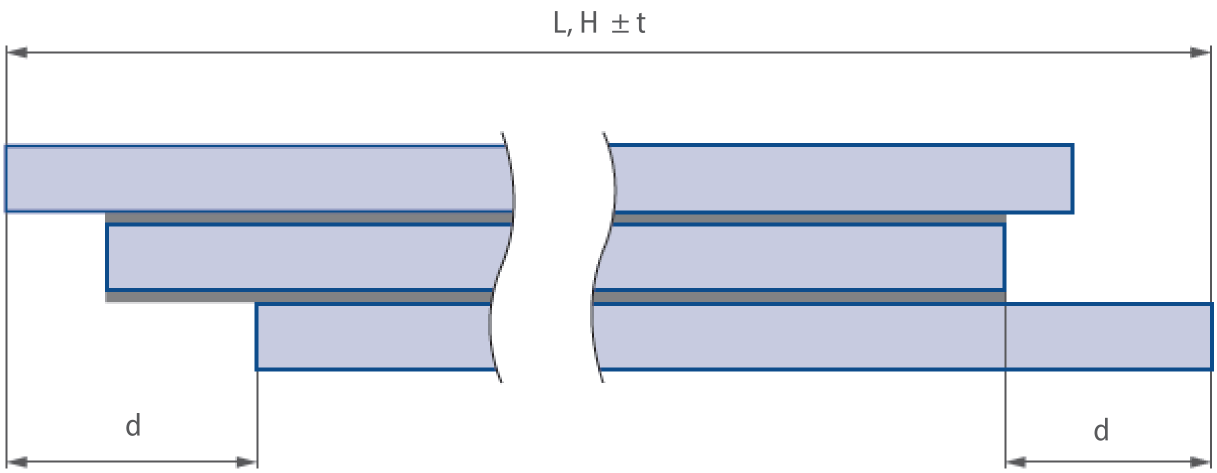


Fig. 34 Offset in cross-section of a sample laminated glass

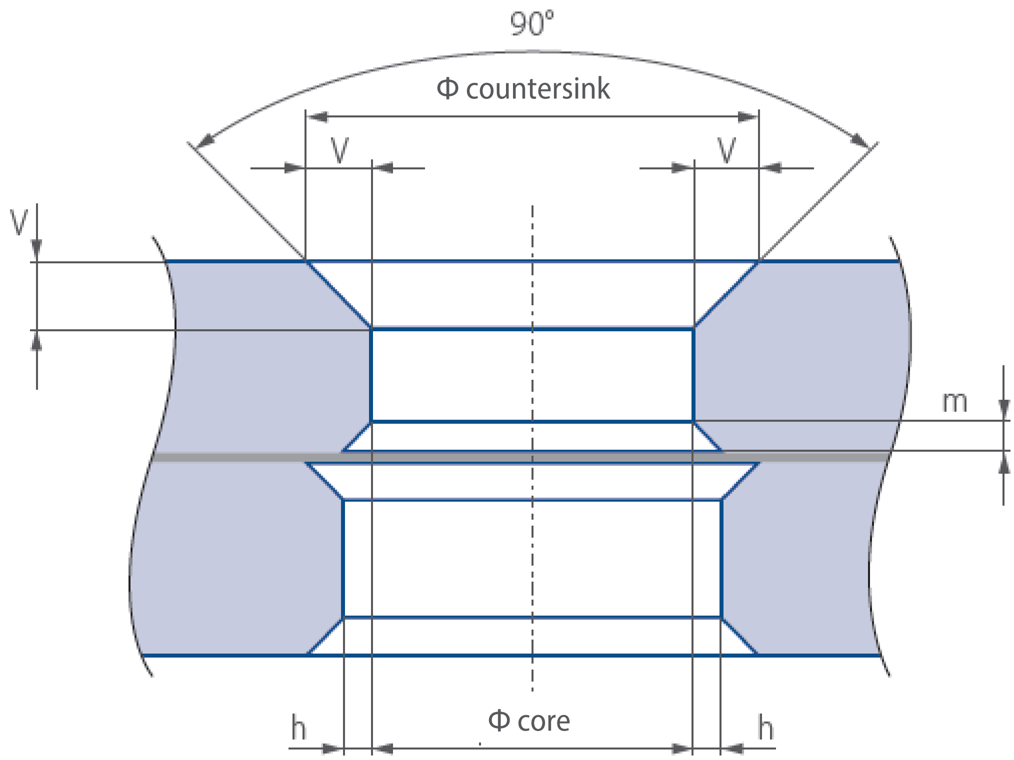


Fig. 35 Diagram of holes in laminated glass, h = 2 mm, m ≥ 1.5 mm, $v=(\varphi_{chamf} - \varphi_{core})/2$

For laminated glass, due to its layered structure, it is necessary to specify some additional parameters and their tolerance. Table 34 shows the maximum offset between layers of glass to be measured as shown in Fig. 34. Table 35 indicates the thickness tolerance of the layer between the panes. In addition, when drilling in laminated glass (see Fig. 35), it is possible that the offset between the holes can occur, as well as small nicks on the perimeter inside the hole (Table 32). The occurrence of this type of imperfection is due to the specificity of the process and is not subject to complaint.

Table 33

Limitation for drilling holes in laminated glass

Parameter	Value of parameter in Fig. 35 [mm]
h	2
m	1.5
v	$(\varphi_{chamf} - \varphi_{core})/2$

Table 34

Max offset d for laminated glass

Nominal L or H [mm]	Max acceptable offset, d [mm]
L,H ≤1000	2
1000 < L,H ≤ 2000	3
2000 <L,H ≤ 4000	4
L,H > 4000	6

Table 35

Interlayer thickness deviation limits for fire resistant glass

Interlayer thickness	Deviation limits
< 1 mm	± 0,4 mm
≥ 1 mm do < 2 mm	± 0,5 mm
≥ 2 mm do < 5 mm	± 0,6 mm
≥ 5 mm	± 1,0 mm

5.3 Permissible laminated glass defects

When visually inspecting the laminated glass, the glass pane shall be placed vertically. Observations shall be carried out in parallel to a mat grey screen lit by a bright diffused daylight or equivalent. The observer shall be at a distance of not less than 2 m from the glass, looking at it in a perpendicular direction, and the mat screen shall be placed behind the glass.
Defects of less than 0.5 mm shall be omitted. On the other hand, defects larger than 3 mm are unacceptable. After the lamination process, slight dirt may appear at the edges of the glass panes.

5.3.1 Acceptable spot defects

Table 36 summarizes acceptable spot defects in the observer's field of view.

Table 36

Acceptable spot defects of size d

Size of defect, d [mm]		0.5 < d < 1.0	1.0 < d < 3.0			
No. of panes	Pane area, A [m²]	No limitation	A ≤ 1	1 < A ≤ 2	2 < A ≤ 8 [/m²]	A > 8 [/m²]
2	No. of acceptable defects [-]	No limitation (however, no clusters)	1	2	1	1,2
3			2	3	1,5	1,8
4			3	4	2	2,4
≥ 5			4	5	2,5	3

A cluster of defects occurs when four or more defects occur at a distance <200 mm. This distance is reduced to 180 mm for laminated glass consisting of three panes, to 150 mm for laminated glass consisting of four panes, and to 100 mm for laminated glass consisting of five or more panes.

5.3.2 Number of acceptable linear defects

Table 37 specifies the limits for glazing depending on its area. In the case of linear defects, one should distinguish between defects on the glass surface and defects in the peripheral zone (a strip along the edge of the glass). The dimensions of this strip are dependent on the size of the window – for glass panes ≤ 5 m^2, width of this strip is 15 mm, and for glass
> 5 m^2, width of this strip is 20 mm.

Table 37

Linear defects in the field of view

Pane area [m²]	No. of acceptable defects of < 30 mm in length	No. of acceptable defects of ≥ 30 mm in length	Fractures	Wrinkles and streaks
≤ 5	acceptable	unacceptable	unacceptable	Unacceptable in the field of view
5 up to 8		1		
> 8		2		

In addition, bubbles in the peripheral zone are acceptable, if the area of their incidence shall not exceed 5% of the area of the strip. In the peripheral zone not planned to be framed, only those defects that are not noticeable during the test are permitted.

5.4 Marking of safety glass according to EN 356

According to EN 356 Section 12, products that meet the requirements of this standard shall be provided with a supply note, containing a code mark e.g. EN 356 P1A, according to Table 4 of the above standard. The same marking may be attached to the product (e.g. 'On request'), or may be omitted.

5.5 Marking of fire resistant glass according to EN 357

In accordance with EN 357, fire resistant safety panes are identified with a letter(s) which define(s) their functional requirement(s), followed by the operating time in minutes:

R(minutes)/E(minutes)/EW(minutes)/EI(minutes)/S(minutes)

5.5.1 Marking of fire resistant glass

In accordance with EN 357, marking with the permanent mark at the bottom right corner of approximately 30mm from the edge of the glass is required. Figure 36 shows how to affix the mark appropriate for glass for indoor use, glass for outdoor applications and double glazing with fire resistant glass.

NOTE: Installation of double glazing with fire resistant glass in the building must be carried out in accordance with the instructions for glazing fire resistant glass.

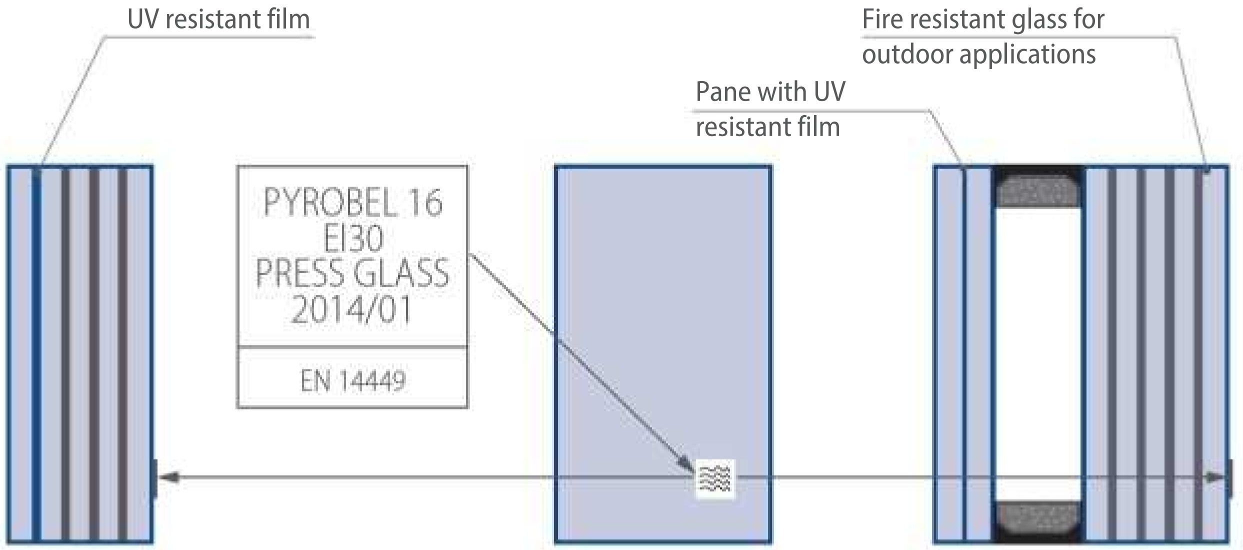


Fig. 36 Location of marking on glass for indoor and outdoor use and on glass units

5.6 Marking of flat glass according to EN 12600

Pendulum impact resistance (component with tyres) is the test for flat glass used in buildings as described in par. 4.3.5. Classification of impact resistance of flat glass is conditioned upon the following parameters:

a) type of glass
b) way of cracking due to impact (A-cracking of annealed glass, B-cracking of laminated glass and C-cracking of tempered safety glass)
c) the height from which the pendulum (component with tyres) drops (Class 3 - 190 mm, Class 2 - 450 mm, Class 1 - 1200 mm)

Classification example for flat glass panes:

2(B)2 – Laminated glass of pendulum impact resistance Class 2
1(C)1– Tempered safety glass of pendulum impact resistance Class 1

After passing the test and assigning the appropriate class for impact resistance and after consultation with the customer and obtaining the relevant test certificates, glass may be marked accordingly.

6. Factory production control

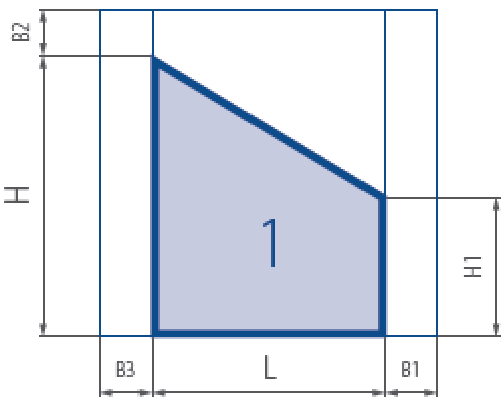
Production control includes supply of raw materials for the production, and monitoring of process parameters is carried out continuously, which allows for an early response to any nonconformity in the process.

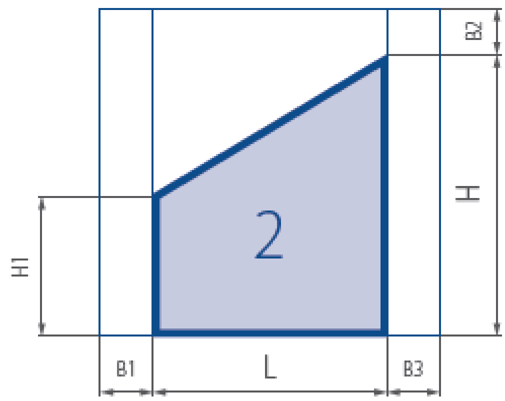
Product quality control is carried out in accordance with the Control Plan, which includes:

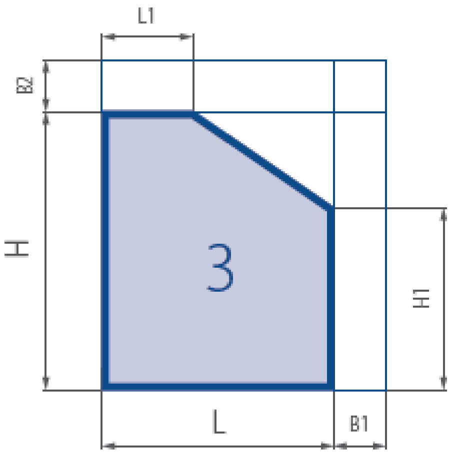
a) self-control - checking the quality of products at every stage of production by production workers
b) inspections - carried out by Inspectors at the various stages of production. In addition, a check of shipments is made assessing the methods of packing and protecting the glass on the racks
c) final inspection and testing – testing of randomly selected samples taken from the series of continuous production of a given quantity of the product in question creating a whole unit

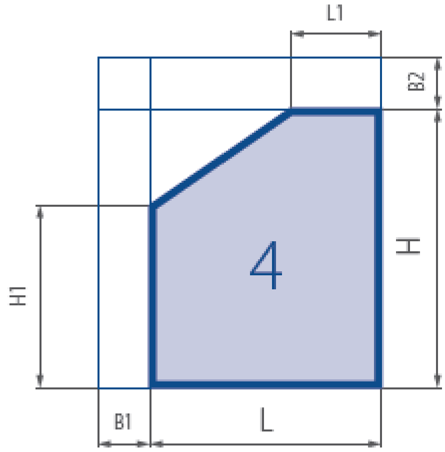
Product assessment is carried out on the basis of the requirements of the standards laid down for the type of product.

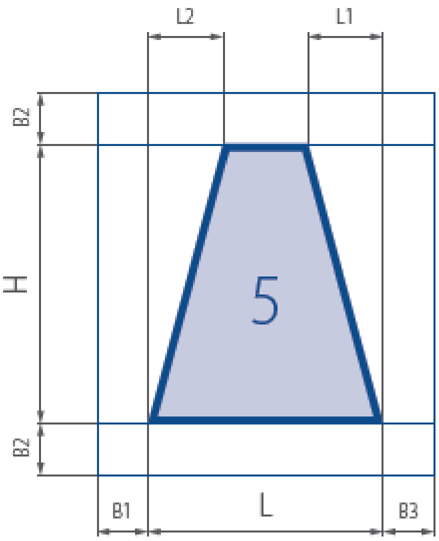
PART III – SHAPED GLASS CATALOGUE

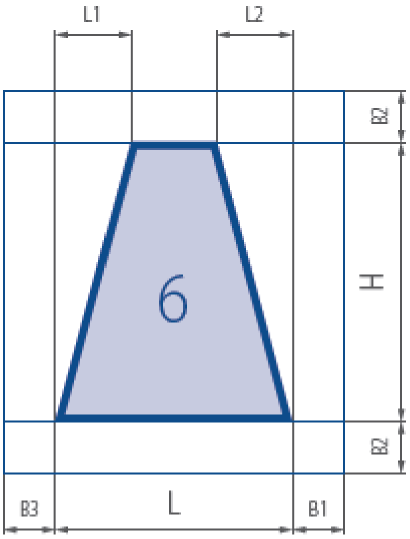


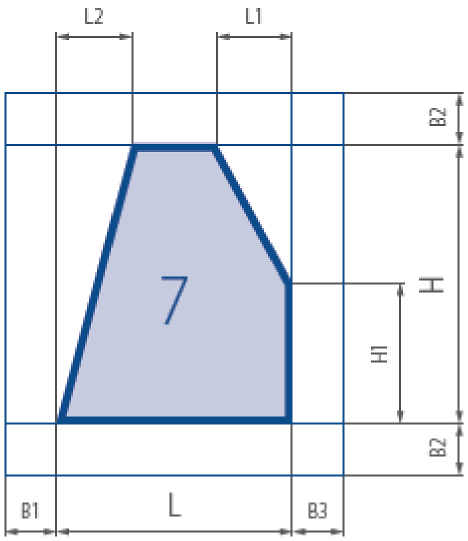








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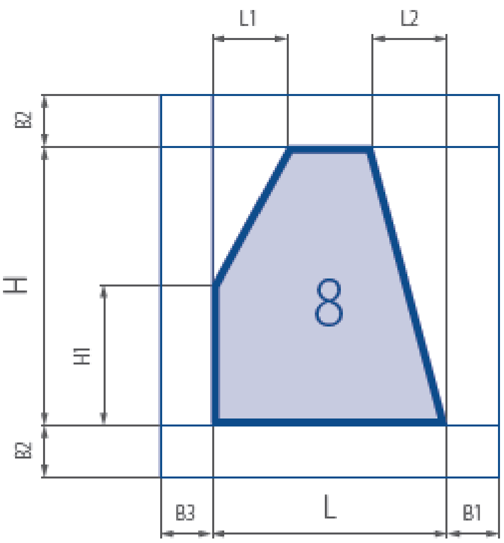
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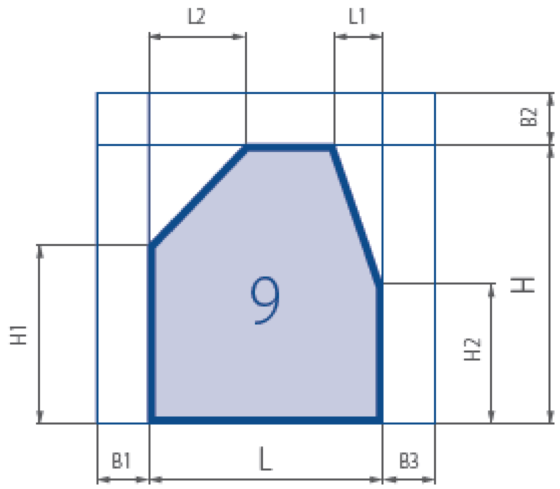
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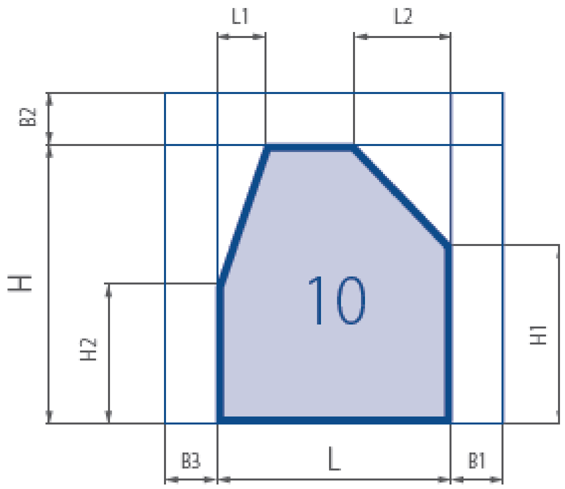
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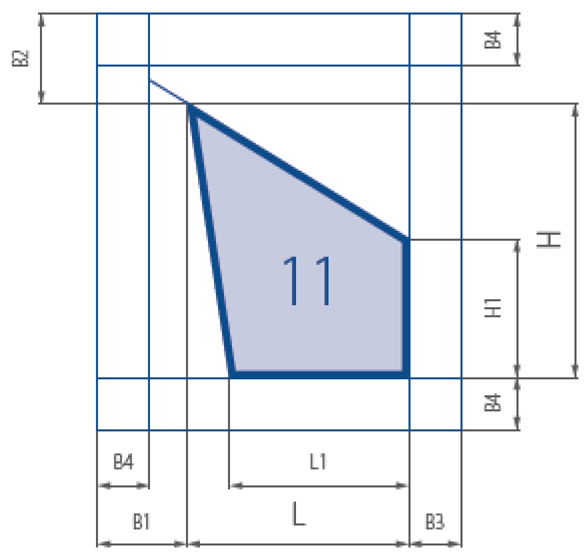
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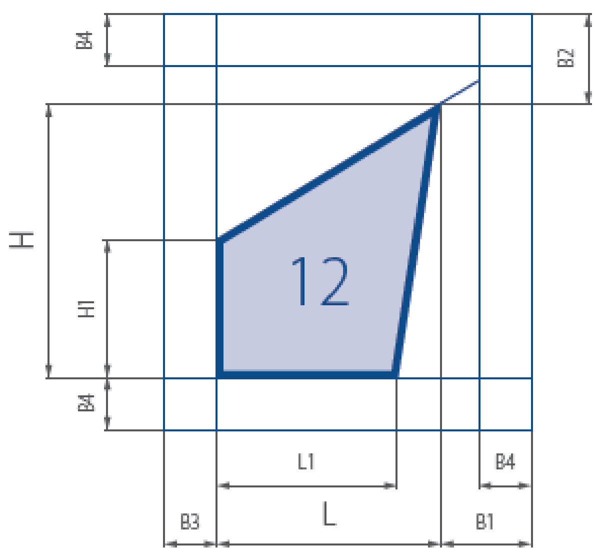
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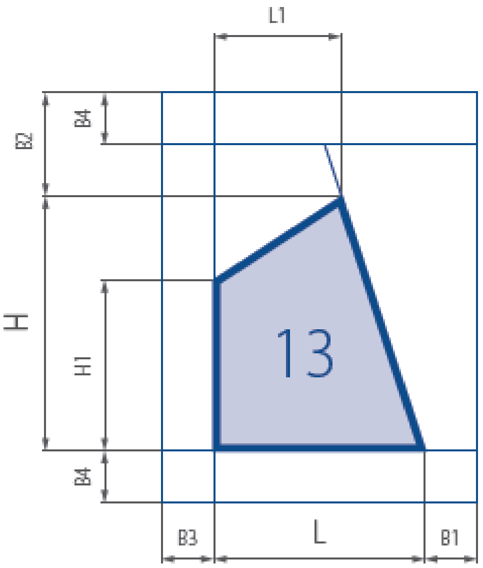
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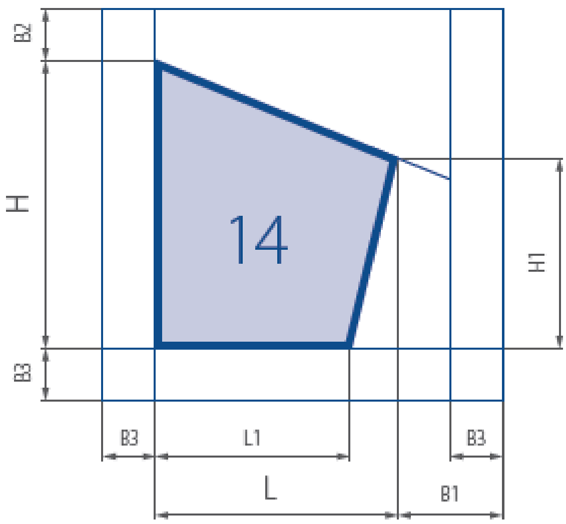
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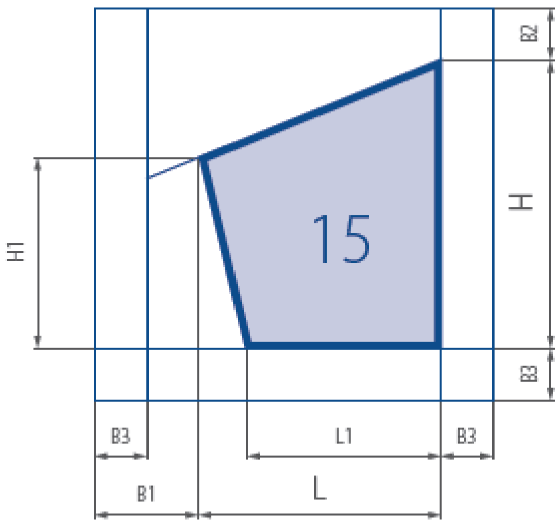
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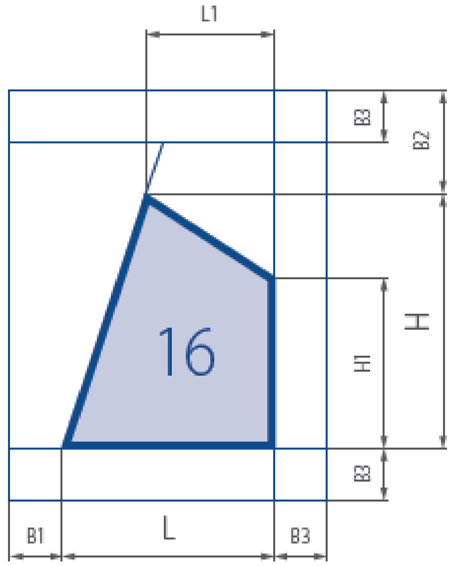
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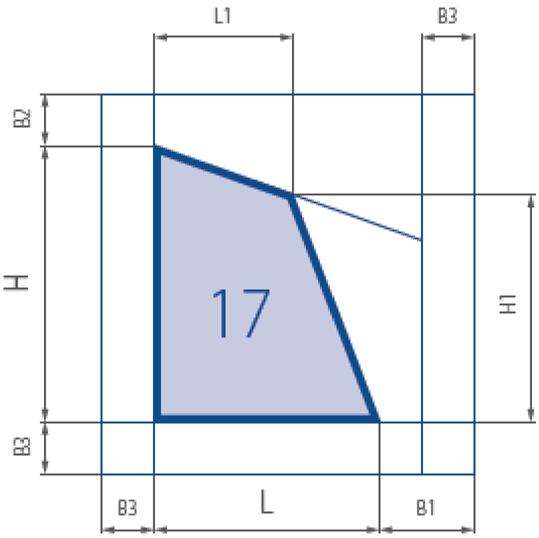
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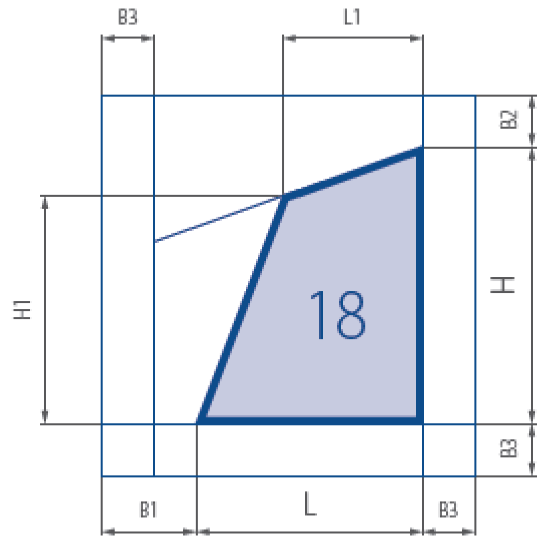
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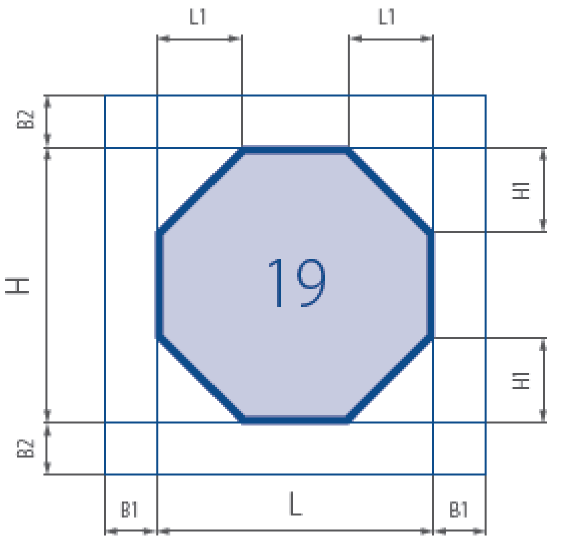
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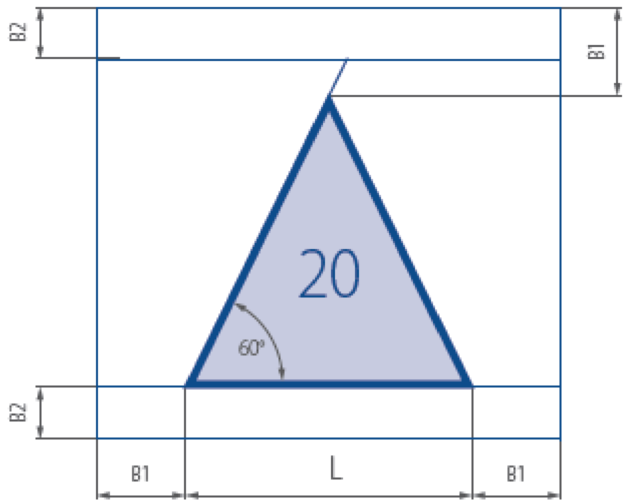
L
B1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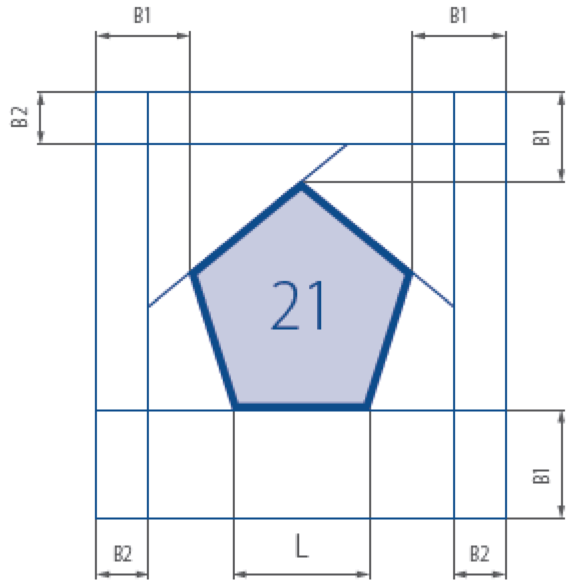
B1
20
60°
B2
B1
L
B1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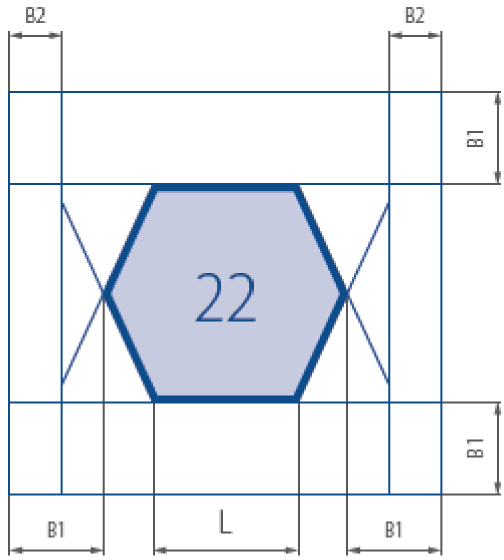
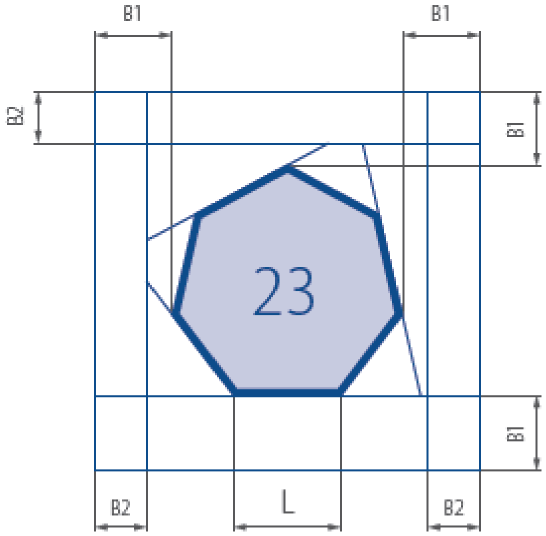
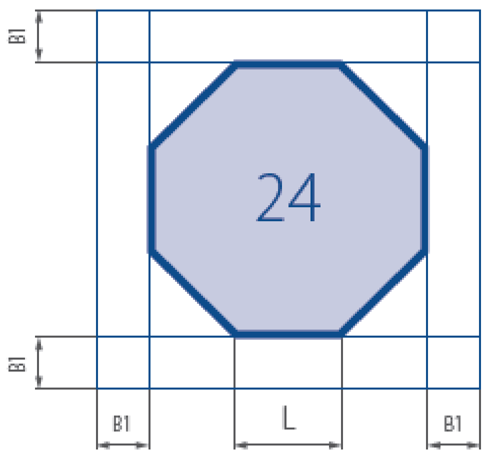
B1
B2
B1
21
B1
B2
L
B2


B2
B2
B1
22
B1
B1
L
B1


B1
B1
B2
B1
23
B1
B2
L
B2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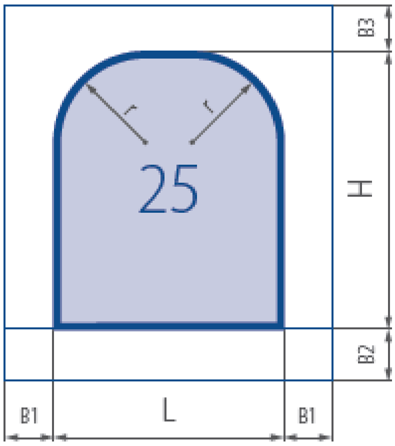
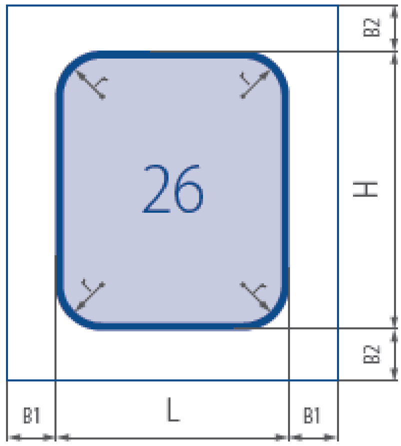
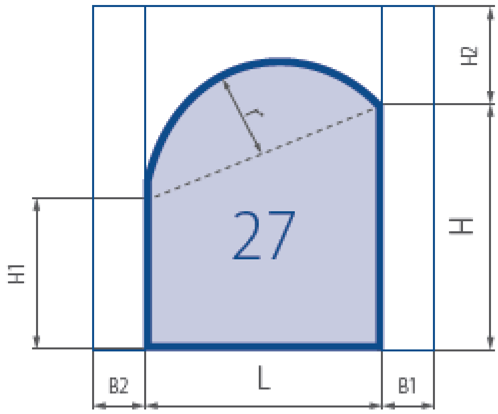
24
B1
B1
L
B1







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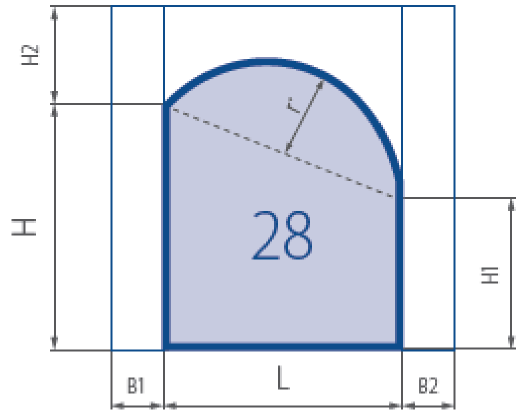

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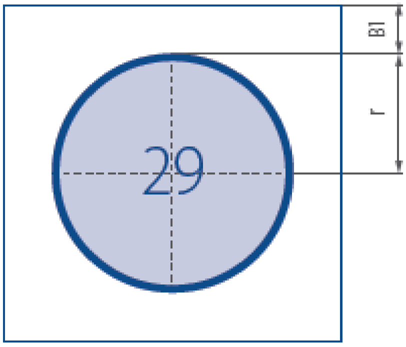
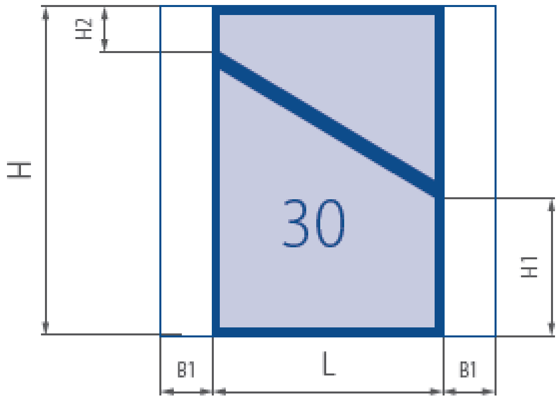
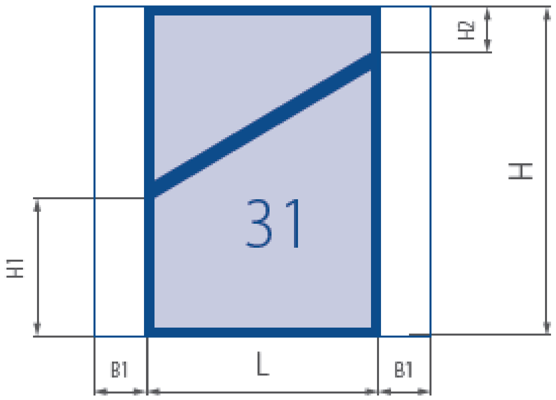
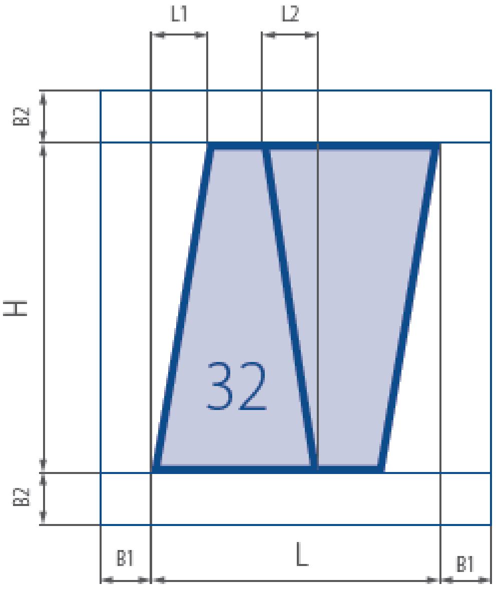
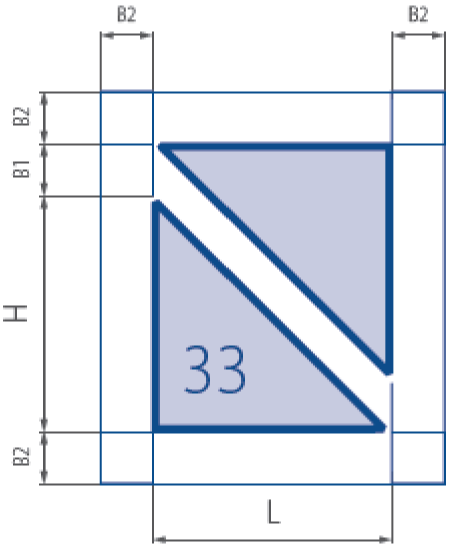
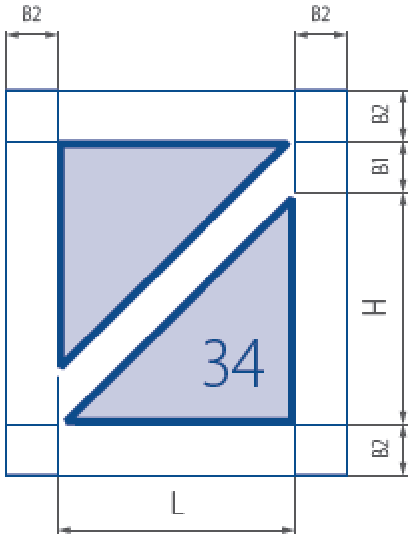


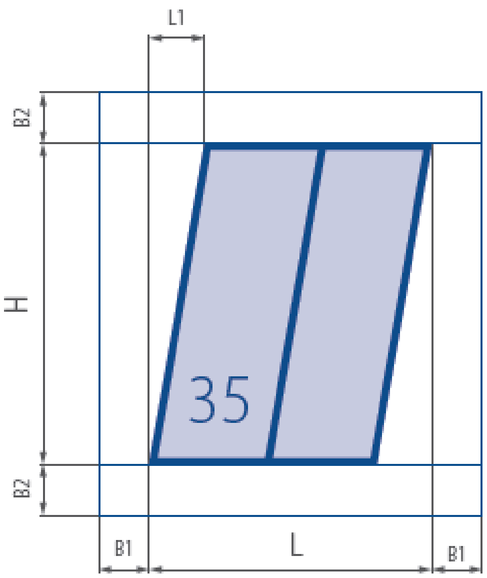


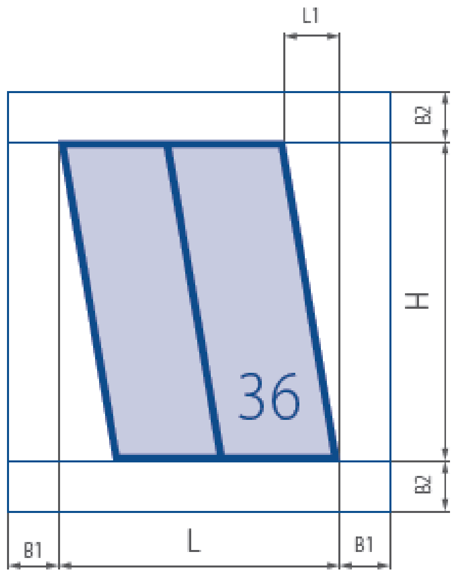

H2
H
H1
31
B1
L
B1

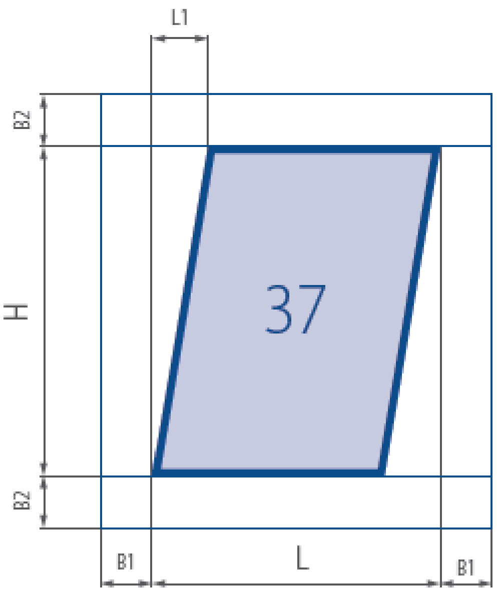

L1
L2
B2
H
32
B2
B1
L
B1

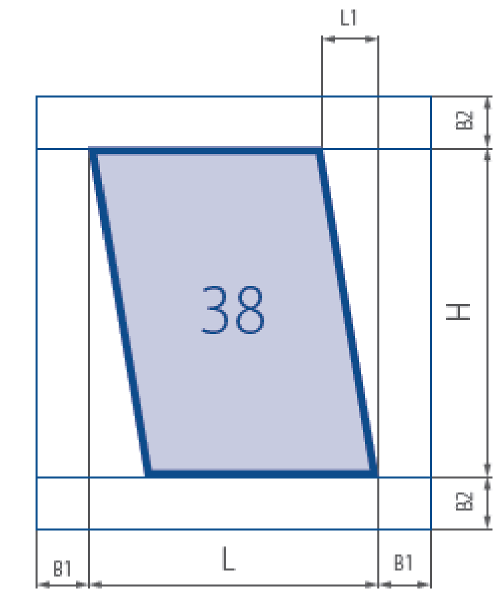

B2
B2
B2
B1
H
33
B2
L

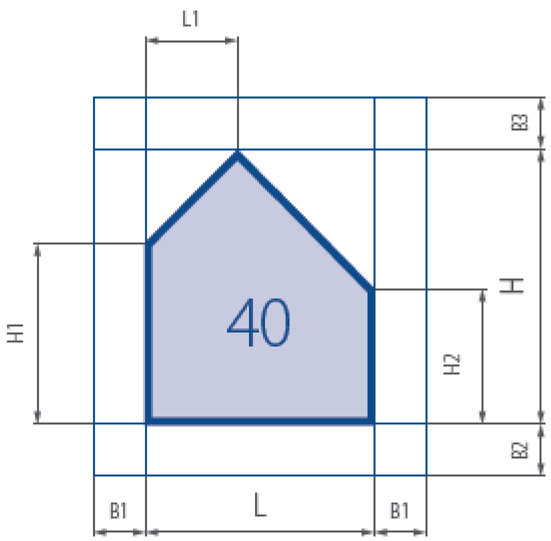

B2
B2
B2
B1
H
34
B2
L

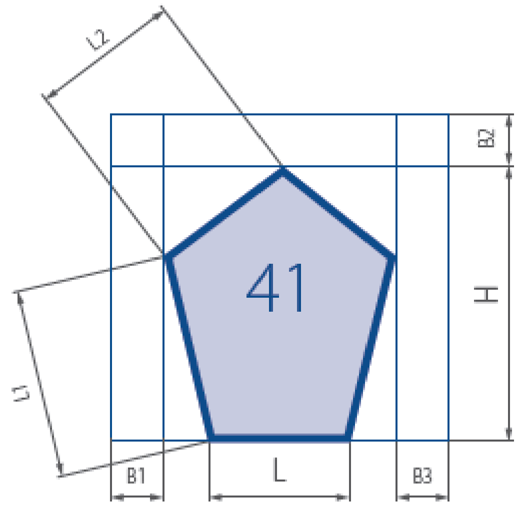

L1
B2
H
35
B2
B1
L
B1

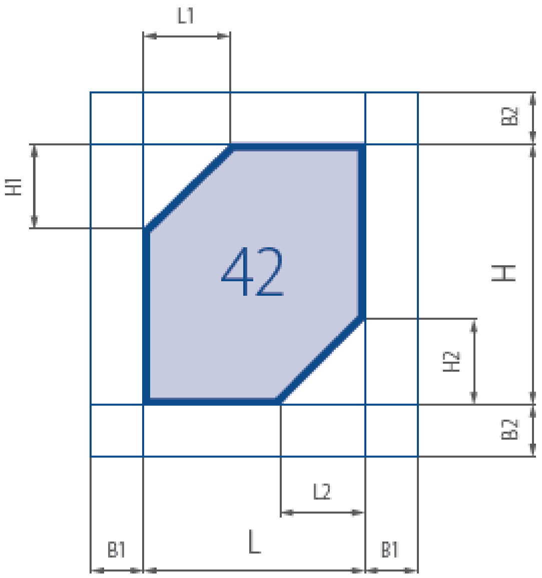

L1
B2
H
36
B2
B1
L
B1

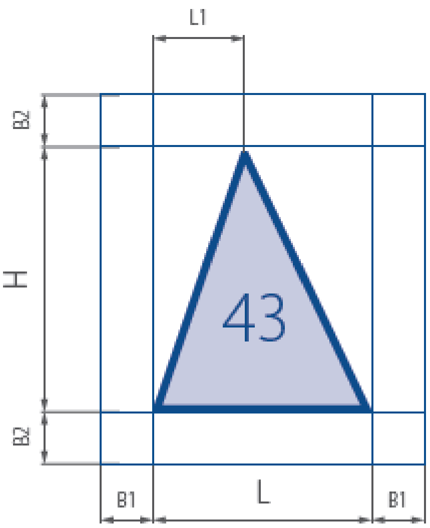

L1
B2
H
B2
37
B1
L
B1

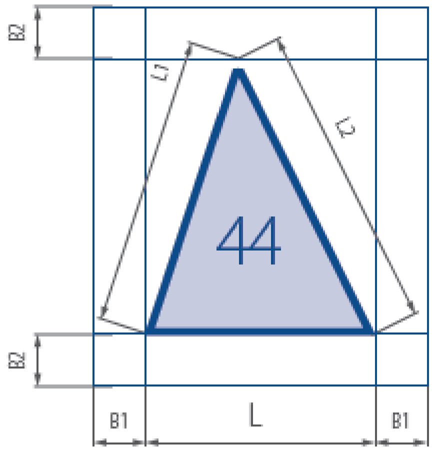

L1
B2
38
H
B2
B1
L
B1


L1
B3
H1
40
H
H2
B2
B1
L
B1


L2
B2
41
H
L1
B1
L
B3


L1
B2
H1
42
H
H2
B2
L2
B1
L
B1


L1
B2
H
43
B2
B1
L
B1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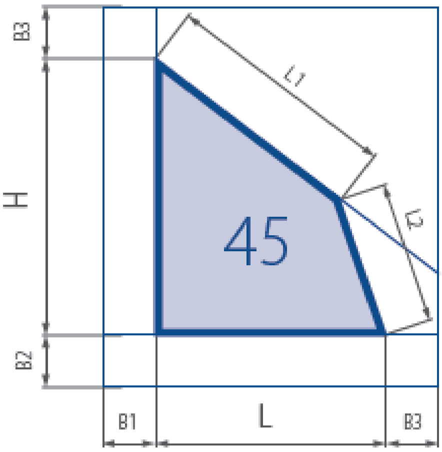
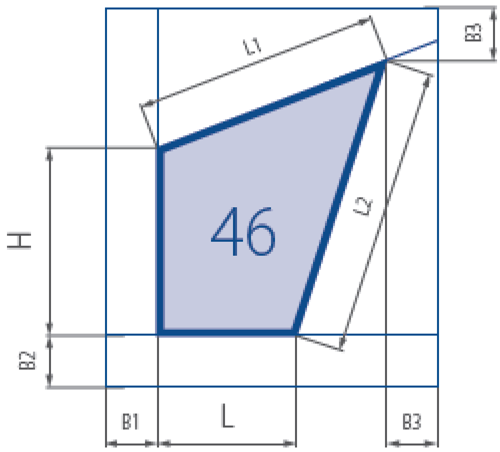
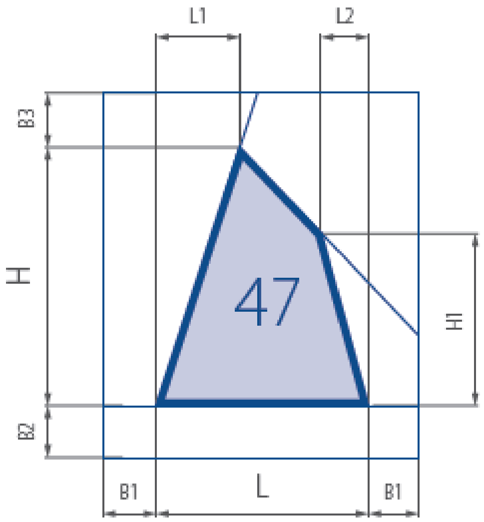
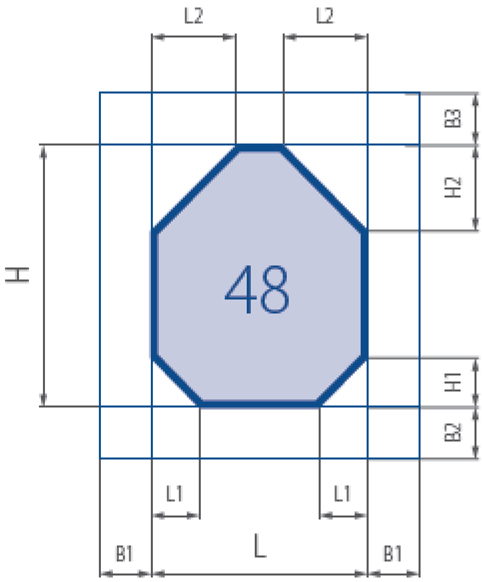
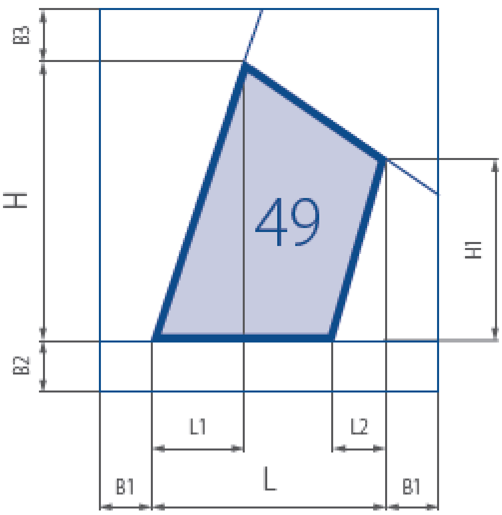
B2
B2
L1
L2
B1
L
B1

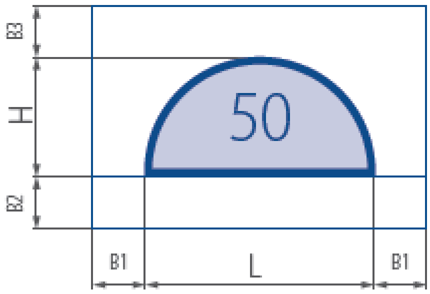

45
B3
H
B2
L1
L2
B1
L
B3


46
L1
L2
B3
H
B2
B1
L
B3


47
L1
L2
B3
H
B2
H1
B1
L
B1


48
L2
L2
B3
H2
H
H1
B2
L1
L1
B1
L
B1


49
B3
H
B2
H1
L1
L2
B1
L
B1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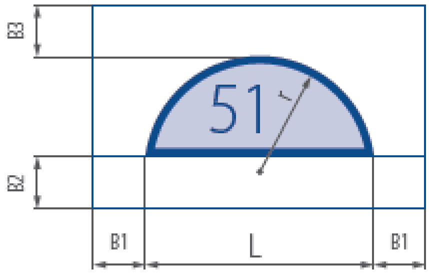
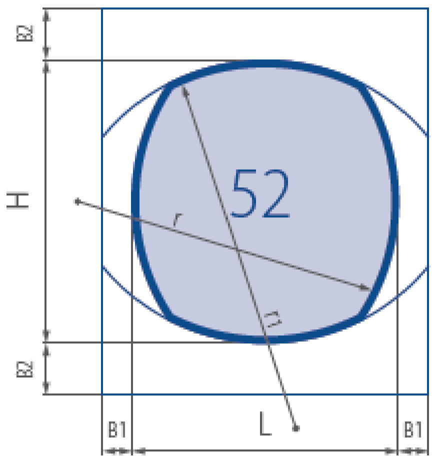
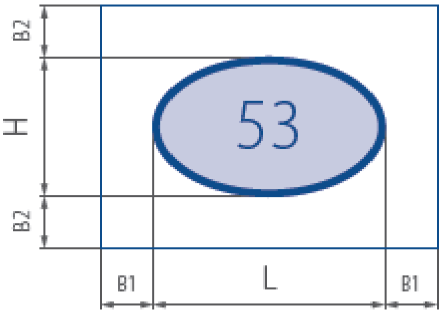
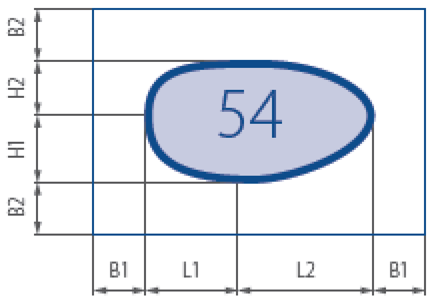
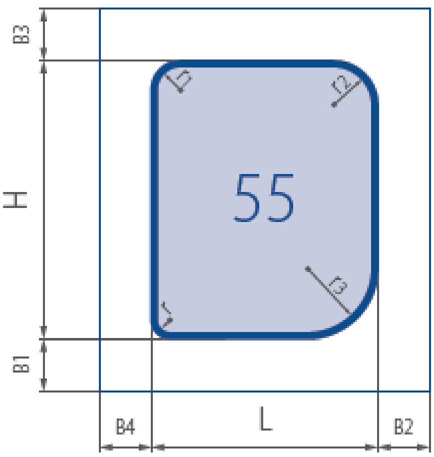
H
50
B2
B1
L
B1

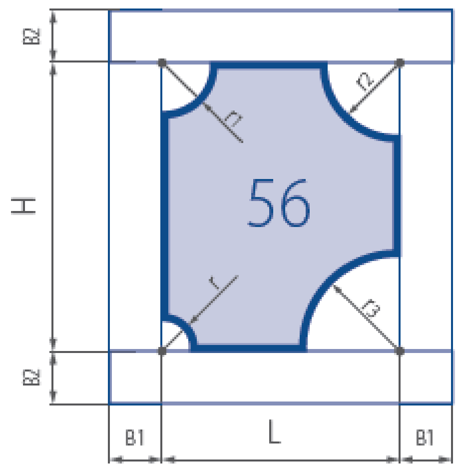

B3
51
r
B2
B1
L
B1

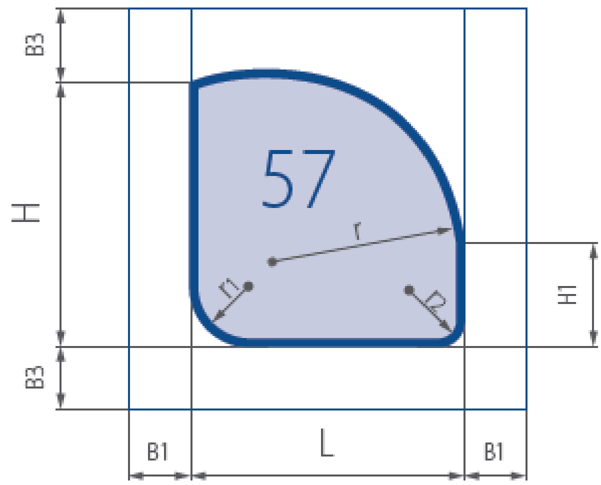

B2
H
52
r
r1
B2
B1
L
B1

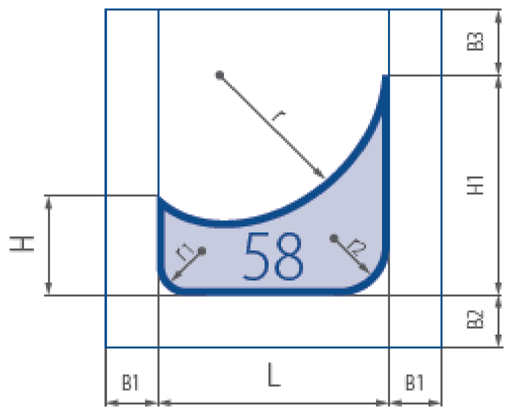

B2
H
53
B2
B1
L
B1

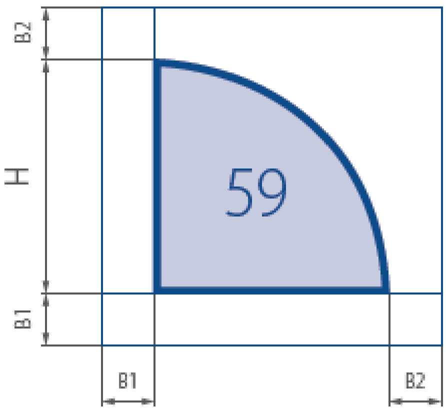

B2
H2
54
H1
B2
B1
L1
L2
B1

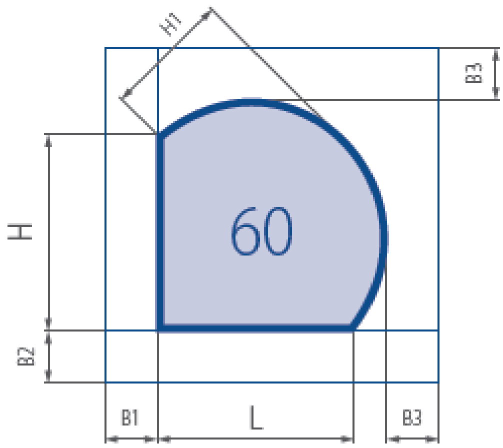

B3
r1
r2
H
55
r3
r
B1
B4
L
B2

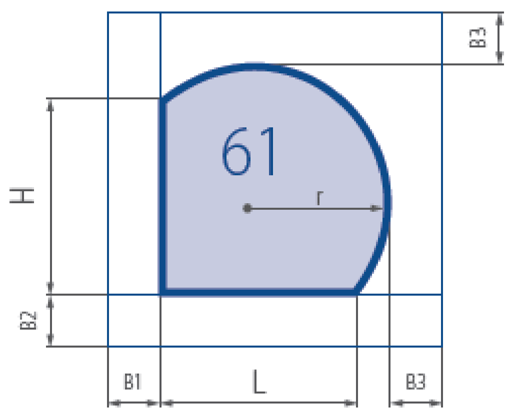

56
B2
H
B2
B1
L
B1
r1
r2
r
r3

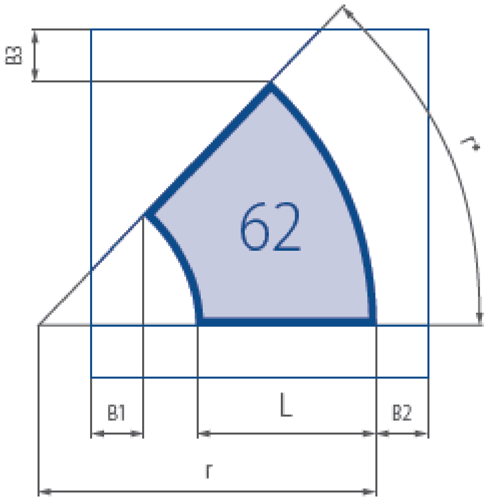

57
B3
H
B3
H1
B1
L
B1
r
r1
r2


58
H
B3
H1
B2
B1
L
B1
r
r1
r2


59
B2
H
B1
B1
B2


60
H1
B3
H
B2
B1
L
B3


61
B3
H
B2
r
B1
L
B3


B3
r*
62
B1
L
B2
r

PART IV – REFERENCE DOCUMENTS

- PN–EN 1279 -1÷6 Szkło w budownictwie. Szyby zespolone izolacyjne (Glass in building. Insulating glass units)
- PN–EN 12150 -1 Szkło w budownictwie. Termicznie hartowane bezpieczne szkło sodowo-wapniowo-krzemianowe (Glass in building. Thermally tempered soda lime silicate safety glass)
- PN-EN 14179 -1 Szkło w budownictwie. Termicznie wygrzewane hartowane bezpieczne szkło sodowo-wapniowo-krzemianowe (Glass in building. Heat-soaked thermally-tempered soda lime silicate safety glass)
- PN-EN 572 -1÷9 Szkło w budownictwie. Podstawowe wyroby ze szkła sodowo-wapniowo-krzemianowego (Glass in building. Basic soda lime silicate glass products)
- PN-EN 1096 -1 Szkło w budownictwie. Szkło powlekane (Glass in building. Coated glass)
- PN-EN ISO 12543 -1÷6 Szkło w budownictwie. Szkło warstwowe i bezpieczne szkło warstwowe (Glass in building. Laminated glass and laminated safety glass)
- PN-EN 356 Szkło w budownictwie. Szyby ochronne. Badania i klasyfikacja odporności na ręczny atak (Glass in building. Security glazing. Testing and classification of resistance against manual attack)
- PN-EN 12600 Szkło w budownictwie. Badanie wahadłem. Udarowa metoda badania i klasyfikacja szkła płaskiego (Glass in building. Pendulum test. Impact test method and classification for flat glass)
- PN-EN 357 Szkło w budownictwie -Ognioodporne elementy oszkleniowe z przezroczystych lub przejrzystych wyrobów szklanych -Klasyfikacja ognioodporności (Glass in building. Fire resistant glazed elements with transparent or translucent glass products. Classification of fire resistance)
- PN-EN 1863-1 Szkło w budownictwie. Termicznie wzmocnione szkło sodowo-wapniowo-krzemianowe (Glass in building. Heat strengthened soda lime silicate glass)
- PN-EN 1288-3 Szkło w budownictwie. Określanie wytrzymałości szkła na zginanie (Glass in building. Determination of the bending strength of glass)
- Technologia szkła – collectiva work
- Glasschaeden – Ekkehard Wagner
- GlassTime; Glass Manual, Guardian
- Insulating Glazing Guide, Dow Corning
- A Guide to Glass, Saint Gobain Glass
- Glazing Guidelines Guideline for Visual Assessment of the Visible Quality of Enamelled and Screen-Printed Glass, Interpane
- Concept of nonlinear analysis and design of glass panels - Andrew K.W. So, Benny Lai, S.L. Chan

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