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1. Measurements and tolerances of insulated glass units and electrically heated insulated glass units

Measurements of insulated and electrically heated glass units:

Insulated glass units and electrically heated insulated glass units are referred to collectively as insulated glass units later in this document. The tolerances of the length of the side of insulated glass units are presented in the table below. These apply to double as well as triple insulated glass units.

			Measurements	
			Length of side	Tolerance
All panes made of float glass				
Glass thickness max. 6 mm			max. 3.0 m	+/- 2 mm
			over 3.0 m	+/- 3 mm
Glass thickness over 6 mm			max. 3.0 m	+/- 3 mm
			over 3.0 m	+/- 4 mm
At least one pane of heat-tempered glass, depending on thickness				
			max. 2.0 m	+/- 3 mm
			2.0–3.0 m	+/- 4 mm
			over 3.0 m	+/- 5 mm
At least one pane of patterned glass				
Glass thickness max. 8 mm				+/- 4 mm
Glass thickness over 8 mm				+/- 5 mm
At least one pane of laminated glass				
	Length of side	Laminated glass thickness max. 8 mm	Laminated glass thickness over 8 mm	
			All glass under 10 mm	All glass under 10 mm
	Under 1.1 m	+/- 2.0 mm	(+2.5/-2.0) mm	(+3.5/-2.5) mm
	1.1–1.5 m	(+3.0/-2.0) mm	(+3.5/-2.0) mm	(+4.5/-3.0) mm
	1.5–2.0 m	(+3.0/-2.0) mm	(+3.5/-2.0) mm	(+5.0/-3.5) mm
	2.0–2.5 m	(+4.5/-2.5) mm	(+5.0/-3.0) mm	(+6.0/-4.0) mm
	Over 2.5 m	(+5.0/-3.0) mm	(+5.5/-3.5) mm	(+6.5/-4.5) mm

* Thicknesses are presented as nominal values.

Width B and height H of insulated glass and cut glass is measured on each side from the distance of max. 20 mm from the corner. The edges of the pane shall be on the same level as the edge of the insulated glass over which it will be placed during installation.

Thickness of insulated glass:

The thickness of insulated glass is measured on the surface of cleaned glass from the corners of insulated glass and the centre of the edges. The thickness tolerances of double insulated glass are presented in the table.

Pane I	Pane II	Thickness tolerance
Float glass, all thicknesses	Float glass, all thicknesses	+/- 1.0 mm
Float glass, all thicknesses	Tempered glass, all thicknesses	+/- 1.5 mm
Float glass, = < 6 mm	Laminated glass, = <12 mm	+/- 1.0 mm
Float glass, other thicknesses	Laminated glass, other thicknesses	+/- 1.5 mm
Float glass, all thicknesses	Patterned glass, all thicknesses	+/- 1.5 mm
Tempered glass, all thicknesses	Tempered glass, all thicknesses	+/- 1.5 mm
Tempered glass, all thicknesses	Laminated glass, all thicknesses	+/- 1.5 mm
Tempered glass, all thicknesses	Patterned glass, all thicknesses	+/- 1.5 mm
Laminated glass, all thicknesses	Laminated glass, all thicknesses	+/- 1.5 mm
Laminated glass, all thicknesses	Patterned glass, all thicknesses	+/- 1.5 mm

* Thicknesses are presented as nominal values.

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The tolerances of overall thickness for triple insulated glass shall be determined according to the following rules:

- The thickness tolerances of each layer are determined in accordance with the table on thickness of insulated glass above;
- The squares of these values are calculated;
- The values of the squares are added together;
- Square root is taken of this sum.

2. Visual quality of insulated glass

Goal

The goal of this provision concerning the visual evaluation of the quality of insulated glass is to homogenise the criteria for evaluation of quality used by the Supplier and the Client in order to guarantee the satisfaction of the customers and compliance with the quality requirements.

Requirements for cleanliness and quality

Glass is a product that consists of lime, quartz and sodium carbonate. Even if these raw materials are cleaned very carefully, it is not possible to avoid some impurities in the final product. Although insulated glass is manufactured in a very careful production process, small scratches and impurities may still occur inside the glass and on its surface.

Complaints about the impurities of the glass shall be inspected in the way described below. The principle is whether the impurity of the glass is irrelevant, to what extent it is caused by the natural qualities of the material – and is therefore not covered by warranty – or is it significant enough to give the right to a replacement glass.

Evaluation criteria

The glass being evaluated shall be looked at from a distance of look 2.0 m from the inside and perpendicularly to the surface of the glass surface being evaluated. The evaluation shall be done in diffused light (e.g. in cloudy weather) without direct sunlight or artificial light. Irregularities that are not visible from a distance of 2 m shall not be regarded as defects. For the inspection of external reflection, the distance for observing shall be 5 m from the glass.

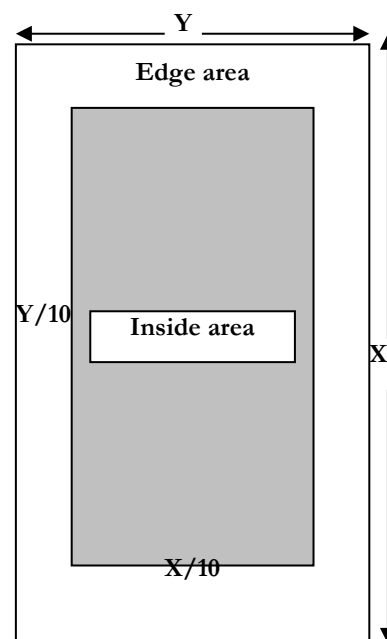


Table 2.1 may only be used with certain reservations, because glass products come in many different variations. Hence the evaluation shall be carried out on a concrete product. For example, the special qualities of safety glass shall only be evaluated after the product has been installed and taken into use. In evaluating certain qualities, the special characteristics of the glass in question need to be taken into consideration.

Table 2.1: Criteria for visual evaluation of insulated glass made of float glass

	Permitted visible irregularities
Seal area 18 mm from the edge	External flat damages to the edge that do not affect the strength of the glass or exceed the closing width of the edge. Inner damages to the edge without open fragments that are filled with sealant. Point-form or flat product residue and scratches shall not be considered defects. The following damages to the edge are permitted: Max. width ½ of the thickness of glass, length 10 mm and width 2 mm. If the width of the fragment is less than 1/5 of the thickness of glass, the maximum permitted depth is 6 mm.
Edge area 10% of the length of the side of glass measured from the edge of glass	Bubbles, dots, spots etc. inside the glass Surface area of glass < 1 m ² : max. 4 items à Ø 3.0 mm Surface area of glass > 1 m ² : max. 1 item à Ø 3.0 mm per running meter of the edge of glass Product residue (point-form) between panes: Surface area of glass < 1 m ² : max. 4 items à Ø 3.0 mm

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	<p>Surface area of glass > 1 m²: max. 1 item à Ø 3.0 mm per running metre of the edge of glass</p> <p>Product residue (flat) between panes: Light grey or transparent permitted max. 1 item < 3 cm²</p> <p>Scratches: Max. 30 mm x 2 mm per one length, visible from distance of 2 m Sum of lengths of single scratches max. 90 mm.</p> <p>Filamentous scratches: Permitted, but not in bulk.</p>
Inside area	<p>Bubbles, dots, spots etc. inside the glass Surface area of glass < 1 m²: max. 2 items à Ø 2 mm Surface area of glass > 1 m² and ≤ 2 m²: max. 3 items à < Ø 2 mm Surface area of glass > 2 m²: max. 5 items à < Ø 2 mm</p> <p>Scratches: Max. 30 mm x 2 mm per one scratch. Sum of lengths of single scratches max. 90 mm.</p> <p>Filamentous scratches: Permitted, but not in bulk.</p>
Edge and inside area	<p>Internal residues, bubbles, dots and spots inside the glass with size 0.5 < 1.0 mm are permitted whatever the surface area of glass, except in large quantities. A large quantity means at least 4 internal residues, bubbles, dots, spots etc. on an area with a diameter of < 20 cm. Defects with diameter of under 0.5 mm are permitted. Their maximum size of permitted irregularities related to said defects is 3 mm.</p>
	<p>Laminated glass: The permitted frequency of visible defects on the edge and inside area is 50% higher per glass layer. Waves caused by production may occur in laminated glass.</p> <p>Tempered glass: Maximum permitted local bow is 0.5 mm per 300 mm. Maximum permitted overall bow is 3 mm per 1000 mm of the length of the side of glass (applies to 4–15 mm tempered, cast safety glass).</p> <p>Cast glass and ornaments: Casting defects and defects of pattern consistency shall be considered permitted irregularities.</p> <p>Decorative spacers and Georgian bars: Surface area of glass < 1 m²: irregularities of location +/- 1 mm to the parting strip of insulated glass. Surface area of glass < 1 m²: irregularities of location +/- 2 mm to the parting strip of insulated glass.</p>

Properties of glass products

The criteria applied to properties of glass products, such as sound and heat insulation and transmission of sound, are linked to test standards. Concrete measuring results are taken from the test reports. The properties of glass products may vary due to the measurements and structure of glass, installation and external influences.

Coated glass

“Pinholes” may occur on coated insulated glass which is a permitted manufacturing defect. The general criteria for the evaluation of pinholes are shown in table 2.2.

The criteria concerning reflections from glass: shadowing, double image, slight colour differences, deformation and distortion of image are permitted in glazed free glass surface. Waves may occur in tempered glass.

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Table 2.2: Coated glass

Edge area	Pinholes in coated glass: Ø 1 mm – 1.5 mm, 5 items / 200 mm Ø over 1.5 mm is not permitted	Inside area	Ø 1 mm–1.5 mm, 2 items/m ² . Ø over 1.5 mm is not permitted
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Cast glass and ornaments

Casting defects or defects of pattern consistency shall be considered permitted irregularities. Defects of parallelism of the wire may occur in wired glass. The wire must not be oxidised.

Individual colour

Glass products have their own individual colour that depends on the raw material and the thickness of glass. Glass with surface coating has its own colour which is different when looking through the glass or observing the reflections. Individual colour and impression of colour may vary e.g. due to the thickness of glass, content of ferric oxide, type of coating, and the process of applying the coating.

Insulated glass with decorative bars

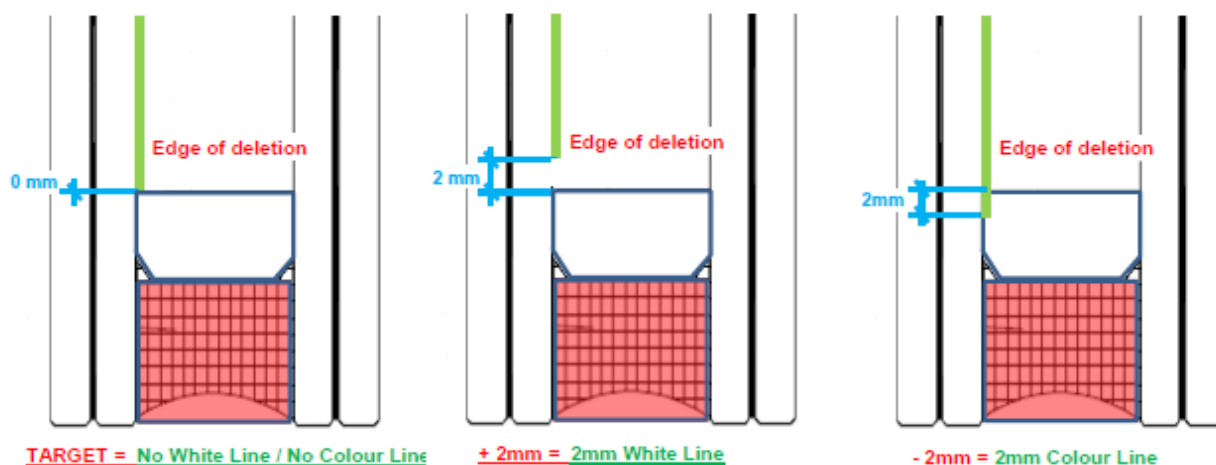
Due to the environment (e.g. double glass effect) and shaking or vibration caused by hand the decorative bars may make a chattering noise. Visible sawing cracks and smaller areas where paint has come off result from production. The insufficiently right-angled decorative bars shall also be evaluated, taking into account the tolerances of production and installation, and the overall impression. The differences in length of the decorative bars between panes due to temperature fluctuations cannot be avoided.

Defects on the outer surface

The reasons for the mechanical or chemical damage of the outer surface that come visible after the installation need to be investigated. The Supplier shall not be liable for mechanical or chemical damage of the outer surface.

Removal of coating in the edge area of insulated glass

Off-line low-e and solar control coatings shall be removed from the edge areas of insulated glass in order to achieve long-term durability. The coating shall be removed from under the sealant of the insulated glass (edge deletion) and partially from under the butyl. Unless specifically otherwise agreed with the customer regarding the width of edge deletion, tolerance of ± 2.0 mm shall be used. Then the removal of coating may be visible in the daylight opening for a maximum of ± 2.0 mm (white line) and correspondingly it may extend max. ± 2.0 mm under the butyl (red line).



These tolerances are not applicable in corner areas. The area that extends to 150 mm from the corner of a glass unit is included in the corner area.

Note: Sometimes these described tolerances on the removal of coating in the edge area may be exceeded, but it may only occur partially in insulated glass after production.

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After installation the width of the butyl area is affected by the following:

- temperature
- weather stress on the insulated glass unit
- wind loads
- compression pressure of surface strips in the edge areas of glass units

In certain cases (structural glazing, glasses with overlaps) the edge of insulated glass will remain visible. As the coatings of coated glass has been removed from the edges by grinding, uneven surfaces may occur (especially is the grinding area is wider than 10 mm). Insulated glass sealants may highlight a coloured stripe on the unground surface.

Dirt between insulated glass panes

Production technology may result in a small amount of desiccant residue in the cavity between the insulated glass panes. This does not constitute a reason for a complaint.

The following items/irregularities are not deviations from the Quality Criteria:

- heat soak – spontaneous breakage of untested thermally tempered glass due to nickel sulphide precipitate;
- interference phenomena;
- double glazing effect;
- anisotropies;
- occurrence of condensed water on the outer surfaces (sweating of glass);
- humidity patterns on the surfaces of glass;
- built-in elements and their effect (leaden glass, alarm systems, blinds etc.);
- breakages as a result of technical tension.

Interference phenomena

These phenomena occur in unequal rainbow-coloured stripes. They are usually visible when looking through the glass at a certain angle. In addition, it is characteristic of these stripes to move around if you press on the window lightly. The phenomenon occurs in case of windows made of float glass due to extreme smoothness and parallelism of the panes.

Light is wave movement and the wavelength of daylight is 0.00035–0.00078 mm. Daylight consists of many different colours that can be seen if the light is directed through a prism in which the light is divided into spectral colours. When rays of light pass through the glass, some light waves may travel a shorter or longer distance due to inner reflections. When the waves meet again their phase may not necessarily be the same anymore, and if unevenness corresponds e.g. to the wavelength of red light, the red colour will intensify (interference) and therefore it will occur on the glass as a stripe. The same applies to all other spectral colours.

Double glazing effect

Due to the airtight sealing of the edges, insulated glass is filled with a mixture of air and gas, the pressure of which depends on barometric pressure and ambient temperature at the production site. When insulated glass units are installed at other altitudes and at different ambient temperatures and barometric pressure (high pressure and low pressure), some of the glass units will inevitably develop concavities or convexities and, consequently, also optical distortions. Multiple reflections may occur on the surface of insulated glass. They will often occur e.g. when the surface behind the glass is dark or if glass units have surface coating. This phenomenon is a law of physics that applies to all insulated glass.

Anisotropies

Anisotropy is a physical phenomenon occurring in thermally processed glass which is caused by the distribution of the internal tension of the glass. Depending on the viewing angle, it is visible in polarised light and/or when viewed through polarising glass as dark circles, stripes or areas. Polarised light usually occurs in daylight. The scope of polarisation depends on the weather, the position and angle of the sun. The phenomenon is visible from a small angle and in glass façades that are placed angularly in relation to each other.

Condensation on the outer surfaces (condensation on glass)

Condensed water occurs on the outer surface of glass when the temperature of the glass is lower than the temperature of the surrounding air. The occurrence of condensed water on the outer surface of insulated glass depends on the air humidity, the direction of movement of air, and the temperature of the outer surface of the glass. The occurrence of

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condensed water on the surface of insulated glass units that are facing indoors may result from high level of humidity, strong window lights, curtains, potted plants, flower boxes, blinds or inappropriately installed radiators etc. Insulated glass with high insulation capacity (low U-value) may temporarily develop condensed water on its outer surfaces if the outdoor air humidity is high and the air temperature is higher than the temperature of the outer surface of insulated glass.

Humidity patterns on the surfaces of glass

The gathering of humidity on the surface of glass may vary and show imprints left by rollers or fingers, labels, vacuuming, residues of sealant, lubricants or effects of the environment. Working with greasy or other organic materials creates a thin water-repellent layer on the glass. Usually these prints can be removed with regular window cleaning detergent. There may also be stronger imprints on the surface of the glass that form a chemical bond with the surface of the glass which is very difficult to remove. This can be done with an abrasive substance or by polishing the surface of the glass again later. The occurrence of such a pattern on the surface of the glass due to condensation does not indicate that the glass is of low quality. It does not affect the mechanical and physical qualities of the glass.

Built-in elements

The Supplier shall not under any circumstances be liable for compensating any added or built-in elements, such as e.g. posters, membranes, leaden glass, alarm systems, blinds etc. or for damage to insulated glass, if the damage is caused by the aforementioned added and/or built-in elements.

Signal glass

Patterns typical of signal glass may occur when viewed under certain light and from a certain angle. The visual occurrence of such patterns at the time of delivery or at a later date shall not constitute a reason for a complaint. A change in the tone of the pattern in the future shall not give a reason for a complaint, either.

3. Quality requirements of tempered and thermally toughened glass

The tempered glass units manufactured by Finnglass conform to the requirements of standard EN 12150 “Building Glass – Thermally toughened soda lime silicate safety glass” or alternatively, if specifically ordered by the customer, to standard EN 14179 “Glass in building. Heat soaked thermally toughened soda lime silicate safety glass”. The thermally toughened glass units manufactured by Finnglass are in compliance with standard EN 1863 “Glass in building. Heat strengthened soda lime silicate glass”.

Dimensions

Nominal thickness and thickness tolerances

Finnglass tempered glass has nominal thickness of 4–19 mm. The nominal thickness of glass for tempering is measured at the centre of each of the four edges. The thickness tolerances for glass are as follows:

Table 3.1. Thickness tolerances for tempered glass

Nominal thickness, mm	Thickness tolerance, mm		
	Float glass	Machine glass	Decorative glass
3	± 0.2	± 0.2	± 0.5
4	± 0.2	± 0.2	± 0.5
5	± 0.2	± 0.3	± 0.5
6	± 0.2	± 0.3	± 0.5
8	± 0.3	± 0.4	± 0.8
10	± 0.3	± 0.5	± 1.0
12	± 0.3	± 0.6	Not in production
15	± 0.5	Not in production	Not in production
19	± 1.0	Not in production	Not in production

Dimensions and tolerances

The maximum dimensions of glass tempered by Finnglass are 3000x4800 mm and the minimum dimensions are 200x350 mm. The tolerances of finished dimensions:

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Table 3.2. Thickness tolerances for tempered glass

Nominal dimension of width B or height H, mm	Tolerance t, mm	
	Nominal thickness of glass, $d \leq 12$	Nominal thickness of glass, $d > 12$
$B \text{ or } H \leq 2,000$	± 2.5	± 3.0
$2,000 < B \text{ or } H \leq 3,000$	± 3.0	± 4.0
$B \text{ or } H > 3,000$	± 4.0	± 5.0

Tolerances for diameters of round openings

The tolerances for the diameters of round openings are shown in the following table:

Table 3.3. Tolerances for position of openings in tempered glass

Nominal diameter \varnothing , mm	Tolerance, mm
$4 \leq \varnothing \leq 20$	± 1.0
$20 < \varnothing \leq 100$	± 2.0
$100 < \varnothing$	± 2.0

Tolerances for position of round openings

The tolerances for position of round openings are the same as the tolerances of width B and height H of glass panes. The position is measured in two-dimensional co-ordinate system from the centre of the opening to the edge of the pane.

Flatness

Limits to the scope of overall and local bow

Table 3.4. The highest permitted values of the deformations of overall and local bow:

Glass type	Overall bow, mm/m	Local bow, mm/300 mm
Float glass	3	0.3
Other	4	0.5

Limits to the scope of end bow

Table 3.5 The highest permitted values for end bow of horizontally processed heat-toughened glass

Glass type	Glass thickness mm	Max. bow mm
Float glass	4...5	0.4
	6...19	0.3
Other	4...19	0.5

Visual quality of tempered glass

Optical phenomena

During horizontal toughening the hot glass bends when it touches the rollers, and therefore the flatness of the glass surfaces decreases. This phenomenon is called "roller wave" and it is visible in reflection. This phenomenon may cause optical distortions when looking through the glass. In order to lessen the effect, it is advisable to use thicker glass in applications if possible. To a certain extent, the effect can also be lessened by adjusting the parameters of the hardening oven.

In case of glass that is thicker than 8 mm (in case of coated glass, starting from 6 mm), patterns or roller imprints may be visible on the surfaces when viewed from a certain angle. This is caused by the glass coming to contact with the furnace rollers (they may be better visible, when the glass is moist or the background has a high contrast).

Anisotropy may also occur as a result of unequally distributed inner tensions of the heat-treated glass. Depending on the viewing angle, anisotropy may appear as dark circles and stripes under polarised light.

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Normal daylight always includes some polarised light. The degree of polarisation depends on the weather and the location of the sun. The double refraction of light is most noticeable in case of low viewing angle or if glass façades are located angularly in relation to each other.

Principles of evaluation

In evaluating the visual quality of tempered glass the following principles shall be considered:

- Defects smaller than 0.5 mm on clear, mass-painted and coated float glass or on tempered glass with surface treatment shall not be considered. The maximum size of permitted irregularities related to defects is 3 mm.
- Defects smaller than 1.0 mm on clear, mass-painted tempered glass made of decorative glass shall not be considered.
- Evaluation of tempered glass made of clear, mass-painted coated float glass shall be performed from a distance of 1 metre from the surface of the glass.
- Evaluation of tempered glass made of clear, mass-painted decorative glass shall be performed from a distance of 1.5 metres from the surface of the glass at the height of the middle part.
- Evaluation shall be performed from the angle that corresponds to conventions of general use of room, generally the method of evaluating perpendicularly to the glass surface shall be used. Evaluation shall be performed in normal diffused light (e.g. in cloudy weather) without direct backlight (e.g. sunlight) or artificial light.

The following defects shall be looked at in evaluation:

- Filamentous scratches that are not discernible with a fingernail
- Bubbles and inclusions
- Crystallised inclusion (substance particle of non-melted mass of glass)
- External flat damage on the edge of arressed glass
- Small chip on the edge of arressed glass that does not affect the strength of the glass.

Evaluation criteria

In order to determine whether the deviations detected during evaluation are permitted, the location, size and frequency of the defects per one unit of tempered glass shall be taken into consideration. The criteria for evaluating defects apply without exceptions to tempered products made of clear, mass-painted or coated float glass and decorative glass.

The evaluation criteria for permitted defects according to their location and frequency of occurrence are presented in the tables.

Table 3.6 Permitted defects in different areas of tempered float glass

Area*	Filamentous scratches (not discernible)	Closed bubbles	Crystallised inclusions	Flat defect** on the arressed edge of glass	Small chips** on the arressed edge of glass
Seal (V)	Permitted	Permitted	Permitted	Permitted	Permitted
Edge (S) 5% of glass measures	Permitted, except when accumulated	$\varnothing \leq 0.5$ mm, permitted area ≤ 3 mm	$\varnothing \leq 0.5$ mm	Not permitted	Not permitted
				Permitted, if V = S	Permitted, if V = S
Middle part (K)	Permitted if not accumulated or no longer than ≥ 150 mm	Not permitted	Not permitted	-	-

*V = valid only in case glass is installed inside the frame on all sides. In case of structures without a frame and complete glass doors, only evaluation criteria on the edges and middle part applies (the edges have to be at least phase grinded).

** Not more than 15% of the nominal thickness of the glass.

Due to the nature of the thermal tempering process, a change of the chemical and mechanical properties of the surface (spot formation and roller imprints) cannot be avoided in this glass type.

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Table 3.7. Permitted defects per one unit of tempered decorative glass:

Unit	Filamentous scratches (not discernible)	Oval sealing bubble	Closed round bubble	Bubble	Flat damage on the arrissed edge of glass	Small chips* on the arrissed edge of glass
1 m ²	Permitted on the whole surface	Width ≤ 1 mm, Length ≤ 20 mm 1 item permitted	$3 \leq \varnothing < 5$ mm 1 item permitted	$3 \leq \varnothing < 5$ mm	Permitted	Permitted
Whole glass surface		Width ≤ 1 mm, Length ≤ 10 mm Permitted on the whole surface, except when accumulated	$\varnothing < 3$ mm Permitted on the whole surface, except when accumulated	Permitted on the whole surface, except when accumulated		

* Not more than 15% of the nominal thickness of the glass.

Since decorative glass involves a special production process, oval and round inclusions and bubbles are part of the characteristics of the product. Changes in the patterns of decorative glass are not always avoidable and hence they shall not constitute a reason for complaint.

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4. Quality requirements of silk screen printed glass

Silk screen printed glass units manufactured by Finnlass conform to European standard EN 12150 “Building Glass: Thermally toughened soda lime silicate safety glass”, standard EN 14179 “Glass in building. Heat soaked thermally toughened soda lime silicate safety glass” or standard EN 1863 “Glass in building. Heat strengthened soda lime silicate glass”.

This guideline applies to the visual quality evaluation of full surface or partial surface enamelled and silk screen printed glass which is manufactured as tempered safety glass or heat-strengthened glass by applying mineral-based colours.

The following standards are also applied:

- EN 12150 for tempered safety glass
- EN 1863 for heat-strengthened glass
- EN 14179 for HST-TSG
- EN BS 6206
- EN 1096 – 1

For the assessment of product suitability, the Supplier shall be informed about the **intended purpose of use** of glass when placing the order. This applies particularly to the following specifications:

- Use of product indoors
- Heat-soak testing requirements for printed or enamelled tempered glass (use in façades)
- Use in visible objects (viewed from both sides e.g. partitions, different glass façades etc.)
- Direct background illumination
- Edge quality and possibly freestanding visible edges (in case of freestanding edges the edge type must be ground or polished)
- Further processing of single-unit glass panes into insulated glass or laminated safety glass (approved colours only)
- Reference point for silk screen printed glass

If enamelled and/or silk screen printed glass is further processed into laminated safety glass and/or insulated glass, each pane shall be assessed individually.

Explanations/Notes/Terms

Enamelled glass and/or silk screen printed glass

The glass surface has been fully enamelled using various application methods. The colour is always evaluated through the glass which has non-enamelled side.

If the glass is intended to be viewed from both sides, we recommend using a full-size sample.

The enamelled side is usually the side that is not exposed to weather. Depending on the production process and the colour of enamelled glass, its intensity of light transmission is either lower or higher and thus it is not opaque. Light colours always give a higher transmission than dark colours. In case of major differences in the luminance or high luminous intensities (daylight) between the usual viewing side and the rear side, optical light/dark shadows become visible in the glass when viewed from the rear side.

The aforementioned are production-related factors resulting from tolerances of the thickness of coating and cannot be avoided, but they may however be considered disturbing, if the glass is used in places where it will be viewed from both sides.

In order to achieve the best possible outcome for cases in which the glass will be viewed from both sides, there are various production processes available, including:

Silk screen printing:

- lowest coating thickness
- highest light transmission (depending on colour)

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- best colour consistency, although pinholes, shadows and squeegee streaks cannot be ruled out.

Continuous rolling:

- medium coating thickness
- low light transmission (depending on colour)
- good colour consistency on the outside, but the surface structure is oriented in rolling direction due to micro groove system of the roller: It is noticeable when viewed from the rear side: fine lines are visible in backlight.

Continuous pouring:

- highest coating thickness
- lowest light transmission (depending on colour)
- good colour consistency viewed from the outside, but due to very high permitted tolerances of the coating thickness, shadows are noticeable when viewed in backlight.

The Client shall always consult the Supplier in cases in which the glass is intended to be installed in a visible place (to be viewed from both sides), as enamelled/silk screen printed glass is generally not a good choice for backlit applications. Exceptions and specific details, which are listed below, depend of the manufacturing method.

Continuous rolling:

The flat glass pane is placed under a grooved rubber roller that spreads the enamel paint on the glass surface without any solvents, so it is an environmentally sound method. The outcome is even colour distribution (an absolutely flat surface is a prerequisite for this, i.e. cast glass cannot be rolled as a rule), but the spreading of the colour (thickness, covering capacity) is only adjustable to a limited degree. Typically the roller grooves remain visible (on the coated side). However, normally the grooves are not noticeable from the front (viewed through the glass – see the section on the evaluation procedure).

When bright colours are used, materials (sealants, panel adhesives, insulations etc.) attached directly to the rear side (coated side) may remain visible. Roller applied enamelled glass is as a rule not suitable for visible places, so the use of glass in such places shall be discussed with the Supplier (pinholes). A slight “coating over-run” will occur on all edges as a result of the manufacturing process, and slight waving may occur particularly along the edges perpendicular to the roller. In general, however, the edge surfaces remain defect-free.

Continuous pouring

The glass pane passes horizontally through a so-called “pouring curtain” (paint mixed with solvent) which spreads the colour on the glass surface. By adjusting the thickness of the pouring curtain and the running speed of the colour mix, the thickness of the paint coating can be controlled over a relatively large area. As the pouring lip is slightly uneven, lengthwise stripes of different thickness may be generated.

The “coating over-run” at the edges is substantially greater than with the continuous rolling process.

Silk screen printing

The paint is printed on to the glass surface on a horizontal screen-printing table through a close meshed screen using a squeegee, although the thickness of the paint being spread can only be influenced marginally by adjusting the mesh size of the screen. Hence the paint coating is thinner than with continuous rolling or the casting process, and the colour appears more or less translucent depending on the selected tone. Materials (sealants, panel adhesives, insulations etc.) attached directly to the rear side (coated side) may be visible.

Slight streaks in the direction of printing but also transverse to it, as well as sporadically occurring “patches” due to screen cleaning during the manufacturing process are common in the production process (depending on paint and application).

The location of the silk screen print will be selected according to the size and shape of the pane (reference point & clear edge). Up to 4 mm of unprinted edge may occur due to tolerances with respect to glass and screens. Coating over-run on the edge depends on the process.

Printing on light-structured glass is possible but the Supplier shall always be consulted first.

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Edge Quality

If coating over-run on edges and arrisses is not required, the Client shall mention it, and it can only be done for polished edges.

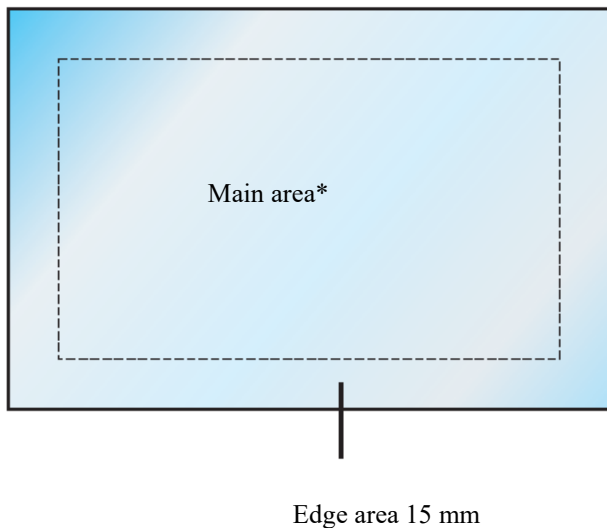
Visual evaluation of silk screen printed glass

The visual evaluation of enamelled and silk screen printed glass is carried out from a distance of at least 3 m and in 90° angle towards the glass, in normal daylight without direct sunlight or backlight.

Evaluation shall always be carried out from the untreated side of the glass or from both sides in case the glass will be placed in a visible location. Matt grey light-protected background shall be placed at a distance of 50 cm behind the glass pane being evaluated. The defects must not be particularly marked for the evaluation.

Defects that are not noticeable from that distance will not be evaluated

The visual evaluation of defects typical of float glass shall be performed in accordance with the evaluation guidelines for tempered safety glass. When defects are evaluated, the edge area and main area shall be separated as shown in the figure below.



* If visible edges were requested when the order was placed, the edge area will be omitted and the main area will extend to the edge of the pane. The visual quality requirements are specified in the tables below.

Figure 4.1.

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Table 4.1. Permitted defects and tolerances for full surface or partial surface enamelled glass

Defect	Main area	Edge area
Defects in enamel: points and/or lines	Surface: max. 25 mm ² Quantity: max. 3, none of which ≥ 25 mm ²	Width: max. 3 mm, sporadically 5 mm Length: not limited
Clouding/misty areas/shadows	Not permitted	Permitted / not limited
Water stains	Not permitted	Permitted / not limited
Enamel over-run at the edges	Not evaluated	* Permitted
Dimensional tolerance for edge enamelling and partial enamelling. See figure 7. drawing. Enamel width:	Depending on width of enamel: Tolerance:	
≤ 100 mm	± 1,5 mm	
≤ 500 mm	± 2,0 mm	
≤ 1,000 mm	± 2,5 mm	
≤ 2,000 mm	± 3,0 mm	
≤ 3,000 mm	± 4,0 mm	
≤ 4,000 mm	± 5,0 mm	
Positional tolerance of enamel** (only for partial enamelling)	Print size: ≤ 200 cm: ± 2 mm Print size: > 200 cm: ± 4 mm	
Colour deviations	See section 5.	

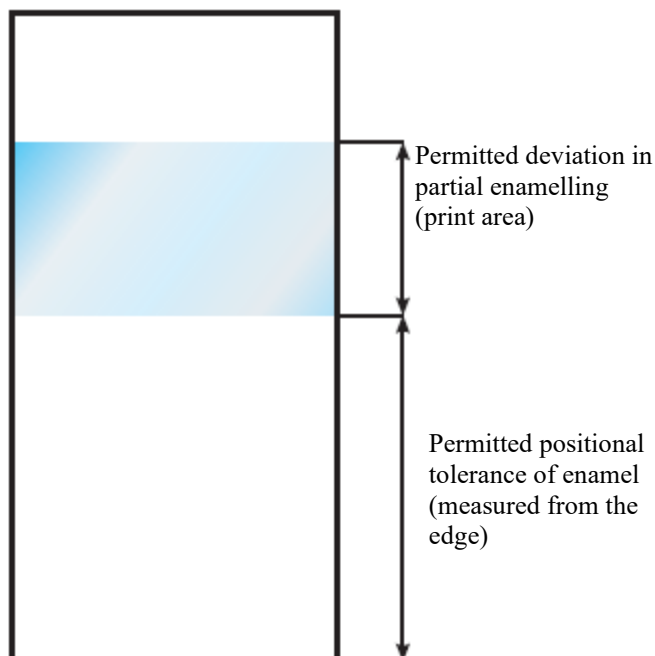


Figure 4.2.

* Defects ≤ 0.5 mm (“pinholes” = minute defects in silk screen print) are permitted and are generally not taken into account. Defects can be corrected by using non-tempered enamel or organic color after tempering, but organic varnishes shall not be used unless the glass is used to manufacture insulated glass and the defect is located under the sealant. Corrected defect shall not be visible if looked at from a distance of 2 m.

** Permitted positional tolerance of enamel is measured from the reference point.

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Table 4.2. Permitted defects and tolerances for silk screen printed glass

Defect	Main area	Edge area
Defects in enamel: points and/or lines	Surface: max. 25 mm ² Quantity: max. 3, none of which ≥ 25 mm ²	Width: max. 3 mm, sporadically 5 mm Length: not limited
Clouding/misty areas/shadows	Permitted	Permitted / not limited
Water stains	Not permitted	Permitted / not limited
Enamel over-run at the edges	Not evaluated	* Permitted
Permitted deviation of printed image (b). See figure 13. Printed area: <div style="margin-left: 20px;"> ≤ 100 mm ≤ 500 mm ≤ 1,000 mm ≤ 2,000 mm ≤ 3,000 mm ≤ 4,000 mm </div>	According to size of print area: <div style="margin-left: 20px;"> ± 1.0 mm ± 1.5 mm ± 2.0 mm ± 2.5 mm ± 3.0 mm ± 4.0 mm </div> See figure 3 and figure 4.	Not limited
Number of defects per image ***		
Positional tolerance of screen print (a)**. See figure 3.	Print size: ≤ 200 cm: ± 2 mm Print size: > 200 cm: ± 4 mm	
Resolution (c and d) ****. See figure 3. <div style="margin-left: 20px;"> ≤ 30 mm ≤ 100 mm > 100 mm </div>	According to size of print area: <div style="margin-left: 20px;"> ± 0.8 mm ± 1.2 mm ± 2.0 mm </div>	
Colour deviations	See figure 5.	

* Defects ≤ 0.5 mm (“pinholes” = minute defects in silk screen print) are permitted and are generally not taken into account.

*** Defects must not be located closer than 250 mm to each other. Serial defects are not permitted (recurrence at the same location on panes in a row)

** The positional tolerance of the printed image is measured from the reference point.

**** The tolerance can accumulate.

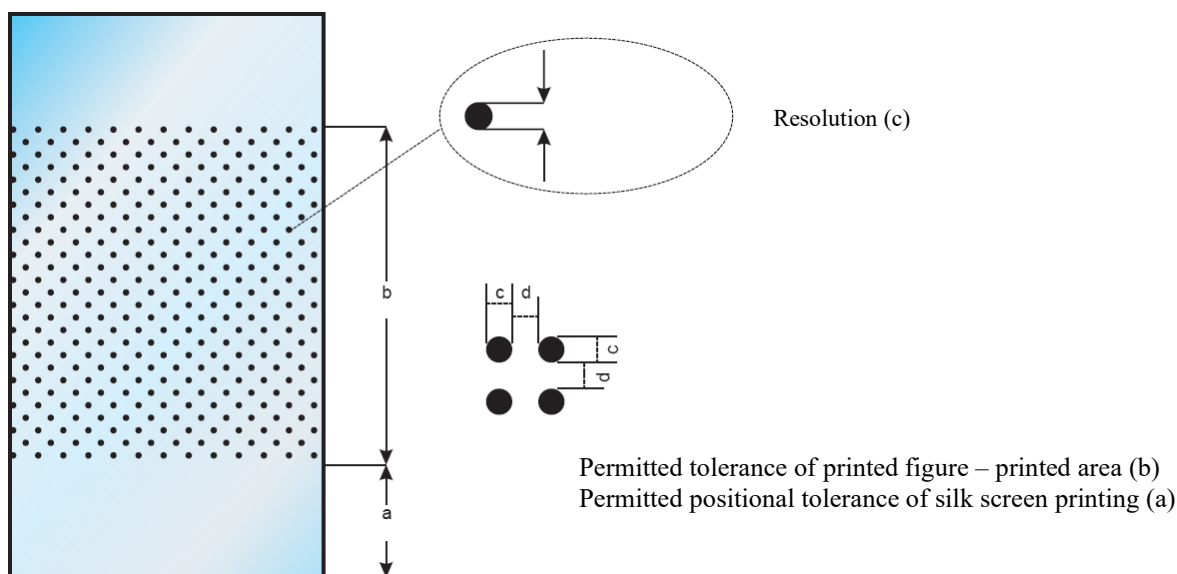


Figure 4.3.

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Serial defects (in glass units with identical dimensions and print)

Defects in the same place in up to 3 similar glass units shall not be considered a serial defect. However, a defect in 3 glass units with identical dimensions and print shall be considered a serial defect.

For geometrical patterns and/or aperture masks under 3 mm or classification from 0–100% and in case of film-butting, the aforementioned tolerances can be perceived as disturbing. We recommend a 1:1 sample viewing:

- Tolerances of the geometry or of the distance in the 1/10 of a millimetre range are considered serious deviations.
- Regarding these applications the Supplier shall always be consulted with respect to feasibility.

Table 4.2 can in principle also be used for the evaluation of “misprints”.

Geometry of the pattern (resolution) Evaluation: number of defects per figure

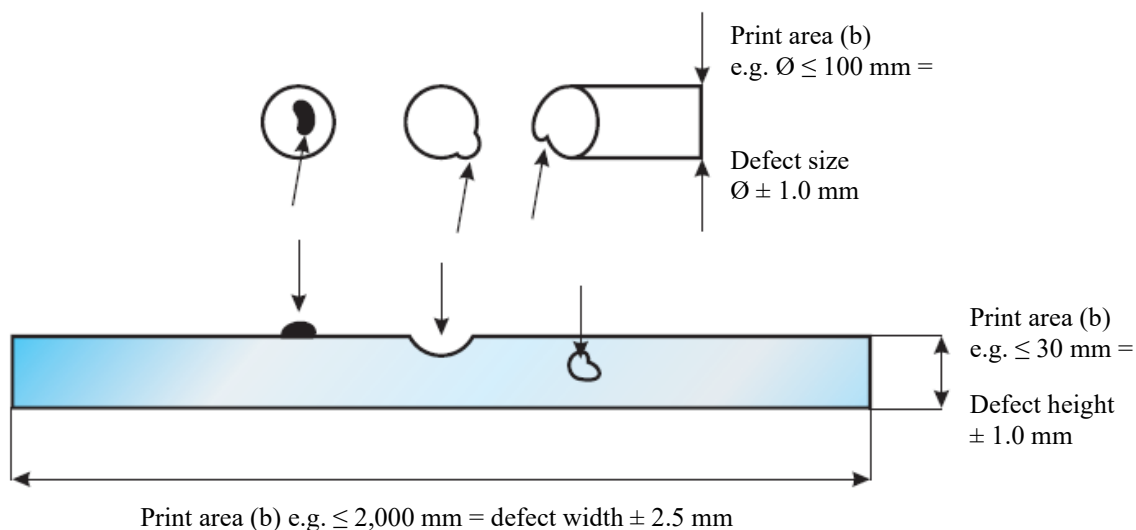


Figure 4.4.
Evaluation of geometrical figures

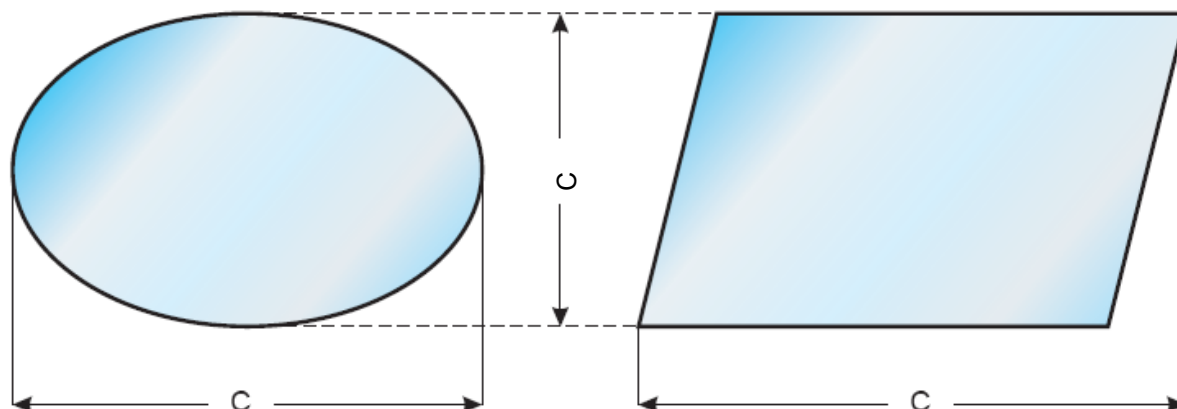


Figure 4.5.

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Special enamels

Metallic paints, acid-etch type tints, slip resistant coatings or multi-coloured prints can also be used on surfaces. The respective particular properties or the product's appearance shall be agreed on in detail with the Supplier. The following permitted variation of definitions shall not concern the methods used for covering them. We recommend sample viewing.

Metallic paints may, due to the manufacturing process and pigmentation, lead to considerable differences in colour-rendition, and a uniform appearance of adjacent glass units cannot be provided. This is a product-specific characteristic of metallic paints and one that makes for a "lively" façade even from different viewing angles.

Evaluation of the perceived colour

In general, colour deviations cannot be ruled out, as they may occur due to several factors that cannot be avoided. Below is a description of factors due to which noticeable colour differences may occur (which may be rated subjectively by the viewer as either disturbing or non-disturbing).

Type of base glass and influence of colour

Generally the base glass is float glass, i.e. the surface is flat and reflects light effectively. In addition, the glass may have various coatings such as solar control layer (increases the reflection of light from the surface) or coatings that decrease reflection, or it can also be slightly embossed such as for example in the case of decorative glass.

In addition to the above, the inherent colour of the glass needs to be taken into account which depends above all on the thickness and type of glass (e.g. body-tinted glass, coloured glass etc.).

Note on later deliveries:

Enamel paint consists of inorganic substances which are responsible for the coloration and are subject to minor variation. These substances have been mixed with the glass flux in order to fuse the colour with the glass surface during tempering and thus create an inseparable connection with it. The final coloration can only be seen after tempering.

Paints are "adjusted" to make them melt into the surface within 2–4 minutes while the temperature of the glass surface is approx. 600–620 °C. This temperature window is very narrow and cannot be constantly maintained particularly in case of large glass panes.

Furthermore, the spreading method is also essential for the perceived colour. Due to the thin coating, silk screen printing provides a lower covering capacity compared with products manufactured using continuous rolling with thicker and therefore denser colour.

Type of light in which the object is viewed

The lighting conditions are constantly changing depending on the season, time of day and prevailing weather. That means that the spectral colours that may be shown in different ways (air, outer surface, glass body) occur in varying intensities within the range of the visible spectrum (400–700 nm). The first surface will reflect part of the light, largely depending on the angle of the light.

The spectral colours falling on the coating will be partially reflected or absorbed by the paint (colour pigment). Hence the colour appears different depending on the light source.

The viewer or the method of viewing

The human eye reacts very differently to various colours. While a very small colour difference becomes drastically noticeable in the case of blue tints, colour differences with green tints are less obvious.

Additional variable factors include the viewing angle, size of the object and particularly the distance between two objects.

Objective visual observation and evaluation of colour differences is not possible due to the aforementioned reasons. To achieve objective evaluation, the colour differences shall be measured under precisely determined conditions (glass type,

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colour, source of light). In cases in which the Client demands objective evaluation standard for a specific colour, the entire process shall be agreed on beforehand with the Supplier. As a general rule it means the following:

- Sampling of one or more colours
- Selection of one or more colours
- Predefinition of tolerances per colour by the Client, e.g. permitted colour deviation:
 $\Delta L^* \leq \dots \Delta C^* \leq \dots \Delta H^* \leq \dots$ in the CIELAB colour system measured source of light D 65 (daylight) using d/8° sphere geometry, 10° standard colorimetric observer, gloss included.
- Checking for feasibility on the part of the Supplier with respect to adherence to the default tolerance (size of order, availability of raw materials etc.).
- Producing a 1:1 production sample and approval by the Client
- Manufacturing of the order within the defined tolerances. If no particular evaluation standard has been agreed upon, $\Delta E^* \leq 3.00$ applies as measured using the measurement procedure described above.

Application Notes

- Applications with enamelling or partial enamelling and silk screen printing or partial silk screen printing in the interlayer of laminated safety glass shall be checked with the Supplier for feasibility. This applies particularly, if acid-etch tone is used in the interlayer, as the optical density of acid-etch tone may be drastically reduced and the effect of acid-etch tone only remains when used on surface 1 or 4.
- Enamelled and silk screen printed glass can only be manufactured as tempered safety glass or heat-strengthened glass.
- Any further processing of glass of any type may significantly affect the product's properties and is not permitted.
- Enamelled glass may be used as single panes or in combination as laminated safety glass or insulated glass. In this case the respective regulations, standards and directions shall be observed by the user.
- Enamelled glass as HST tempered safety glass can be heat soak tested. The user shall ensure the need for the heat soak test and inform the Supplier. The technical properties of enamelled glass are not comparable to those of unprinted or non-enamelled glass.

Side 1 enamelled

This colour system has been specially developed for decoration of float glass on surface 1. The colours have an increased resistance to chemicals and weathering. Generally, the guidelines for evaluation of silk screen printed glass are applicable. An exception is the inspection of glass on the screen-printed side or on both sides, if the glass is intended to be placed in a visible location.

A colour difference of $\Delta E^* \leq 3.0$ only applies at the time of delivery. The weathering will cause change in the appearance of the colour and will depend on the tone of colour. Hence the following additional colour tolerances and maximum pattern sizes shall be applied after the installation.

- Light tones: White enamel $\Delta E^* \leq 3$ (stripes ≤ 10 mm, dots ≤ 12 mm)
- Mid tones: blue, yellow, green, red enamel $\Delta E^* \leq 5$ (stripes ≤ 2 mm, dots ≤ 4 mm)
- Dark tones: grey, black (proportion of dark base colour at least 10%) $\Delta E^* \leq 10$.

Complaints concerning tone differences will only be accepted, if the changing of tones has taken place under ordinary environmental conditions in part of the building only and the Client or end user has complied with the following directions concerning cleaning:

- The façade shall be cleaned at least twice per year using industrial cleaning detergents. Cleaning detergents containing hydrochloric acid are not permitted.
- In polluted environment (e.g. big city centres or an industrial areas) the cleaning of glass surfaces using abrasive glass cleaner (e.g. Radora Brilliant) may be necessary.

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5. Quality requirements of laminated glass

Laminated glass manufactured by Finnnglass conforms to European standard EN 14449 “Building Glass. Laminated glass and laminated safety glass”.

Measurements

If laminated glass is rectangular, the first measurement is width B and the second measurement is height H as shown in figure 5.1.

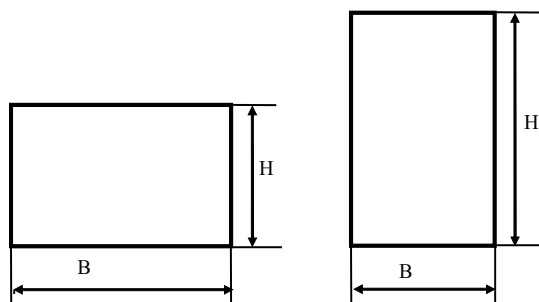


Figure 5.1. The width B and the height H regarding glass pane

Dimensions shall be given in millimetres. Each dimension shall be within the permitted tolerances.

Dimensions and methods for measuring rectangularity

In accordance with the nominal dimensions determined for width B and height H, the pane cannot be larger than a calculated rectangle formed when the nominal dimensions are decreased by the permitted minus tolerance. The sides of the calculated rectangles are parallel to each other and have a common centre. The limits of rectangularity are determined by these rectangles (see figure 2).

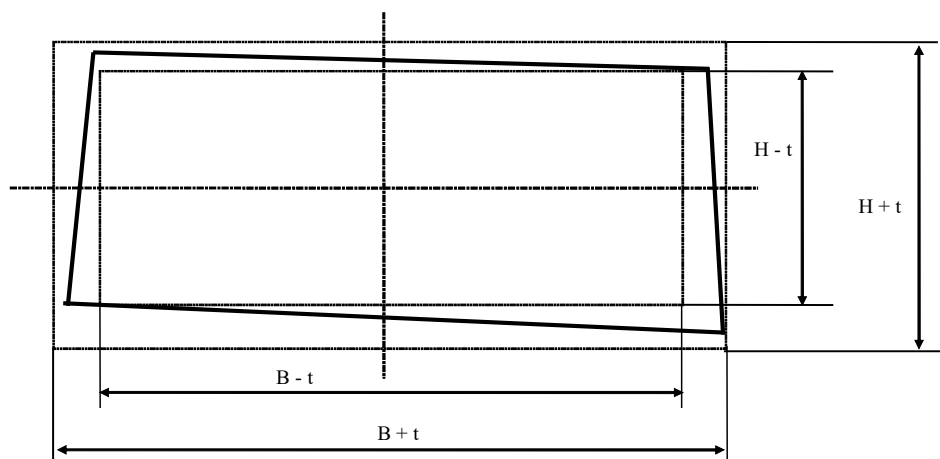


Figure 5.2. The dimensional tolerances of rectangularity

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Measurement tolerances

Tolerances for finished dimensions of width B and length H are given in table 5.1 in table 5.2 for sample item dimensions.

Table 5.1. Tolerances for finished dimensions

Tolerances for width B (t) and height H			
Nominal dimension B v. H mm	Nominal thickness H ≤ 8 mm	Nominal thickness > 8 mm	
		Each glass pane < 10 mm	At least one glass pane ≥ 10 mm
< 1,100	+2.0 -2.0	+2.5 -2.0	+3.5 -2.5
< 1,500	+3.0 -2.0	+3.5 -2.0	+4.5 -3.0
< 2,000	+3.0 -2.0	+3.5 -2.0	+5.0 -3.5
< 2,500	+4.5 -2.5	+5.0 -3.0	+6.0 -4.0
> 2,500	+5.0 -3.0	+5.5 -3.5	+6.5 -4.5

Table 5.2. Tolerances for sample items

Tolerances for width B (t) and height H			
Tolerance B v. H	Nominal thickness H ≤ 8 mm	Nominal thickness > 8 mm	
		Each glass pane < 10 mm	Each glass pane ≥ 10 mm
Max. 6,000 x 3,210	+5.0 -3.0	+6.0 -4.0	+8.0 -6.0

Displacement

Displacement is the misalignment at any one edge of the glass panes making up the laminated glass (see figure 3).

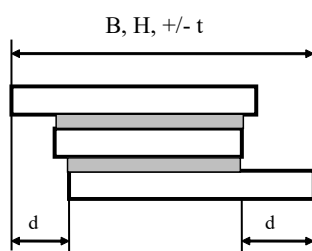


Figure 7.3. Displacement in the laminated glass

The maximum permitted displacement is presented in table 5.3. Width B and height H shall be considered separately.

Table 5.3. Maximum permitted displacement

Nominal dimension B v. H, mm	Maximum permitted displacement d, mm
B, H < 1,000	2.0
1,000 < B, H ≤ 2,000	3.0
2,000 < B, H ≤ 4,000	4.0
B, H > 4,000	6.0

Thickness

Nominal thickness

The nominal thickness of laminated glass is the sum of the nominal thicknesses of the constituent glass panes and lamination membranes.

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Thickness tolerances

The thickness tolerance of laminated glass shall not exceed the sum of the thickness tolerances of the constituent glass panes. The tolerances of glass panes are specified in the basic products standard EN 572, parts 2–6. The thickness tolerance of the interlayer shall not be taken into account if the total interlayer thickness is < 2 mm. If the total interlayer thickness is > 2 mm a tolerance of ± 0.2 mm applies.

EXAMPLE: Laminated glass made from two panes of float glass with nominal thickness of 3 mm and an interlayer of 0.5 mm. According to EN 572-2, the tolerance of 3 mm float glass is ± 0.2 mm. Therefore, the nominal thickness of laminated glass is 6.8 mm and the tolerance is ± 0.4 mm.

Measurement of thickness

The thickness of the pane shall be calculated as the mean value of measurements taken at the centres of the four sides. The measurements shall be performed at an accuracy of 0.01 mm and the mean value is then rounded to the nearest 0.1 mm. After rounding to an accuracy of 0.1 mm, individual measurements shall correspond to the determined tolerances.

Visual quality

Inspection methods

The laminated glass to be inspected shall be placed in vertical position and parallel to a matt grey background and in diffuse daylight or equivalent lighting conditions. The viewer shall stand at a distance of 2 m from the glass and look at the glass at an angle of 90° (with the matt background on the other side of the glass). Defects shall be permitted if they are not visible in those conditions at that distance.

If laminated glass has been installed without a frame, the PVB interlayer may absorb water at a maximum distance of 15 mm from the edge, which may change the tone of PVB (usually grey). This is not a reason for a complaint.

Spot defects on the surface of laminate

The permissibility of spot defects depends on the following:

- size of the defect;
- frequency of the defects;
- size of the pane;
- number of panes as components of a laminated glass unit.

FURTHER INFORMATION: Permissibility of spot defects in laminated glass does not depend on the thickness of individual panes. Defects with a diameter of less than 0.5 mm are not considered. Defects with a diameter of greater than 3 mm are not permitted.

Table 5.4. Permitted spot defects on visible surface

Size of defect, mm		0.5<d≤1.0	1.0<d≤3.0			
			All sizes	A≤1	1<A≤2	2<A≤8
Number of permitted defects	2 panes	No limitation, but accumulation of defects is not permitted. *	1	2	1/m ²	1.2/m ²
	3 panes		2	3	1.5/m ²	1.8/m ²
	4 panes		3	4	2/m ²	2.4/m ²
	≥ 5 panes		4	5	2.5/m ²	3/m ²

*) An accumulation of defects occurs if four or more defects are located at a distance of < 200 mm from each other. This distance is reduced to 180 mm for laminated glass consisting of three panes, to 150 mm for laminated glass consisting of 4 panes and to 100 mm for laminated glass consisting of five or more panes.

The number of permitted defects in the table may increase by 1 for each individual interlayer which is thicker than 2 mm.

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Line defects in visible surface

Line defects are not permitted in glass panes with an area of under 5 m². One line defect is permitted in glass panes with an area of 5 m²–8 m². Two line defects are permitted in glass panes with an area of over 8 m².

Line defects are permitted when their estimated length is less than 30 mm using the evaluation method described above.

Defects in the edge area of framed glass

Defects with a diameter of less than 5 mm are permitted in edge areas. For panes with an area of under 5 m² the edge area is 12 mm. For panes with an area of over 5 m² the edge area is 20 mm. If bubbles are present in the edge area, the bubbled area shall not exceed 5% of the edge area.

Vents

Vents are not permitted. Breakage of laminated glass after installation shall not be covered by the Supplier's warranty.

Defects in the interlayer

Pullback of interlayer is allowed 6 mm from the edge. Creases and streaks are not permitted in the visible area.

Defects on the edge area of unframed glass

If laminated glass is installed without frames, its edges may be

- ground edges;
- polished edges;
- bevelled edges.

According to these terms, vents, bubbles, interlayer defects and shrinkage are permitted if they are not visible when the inspection method described above is complied with.

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