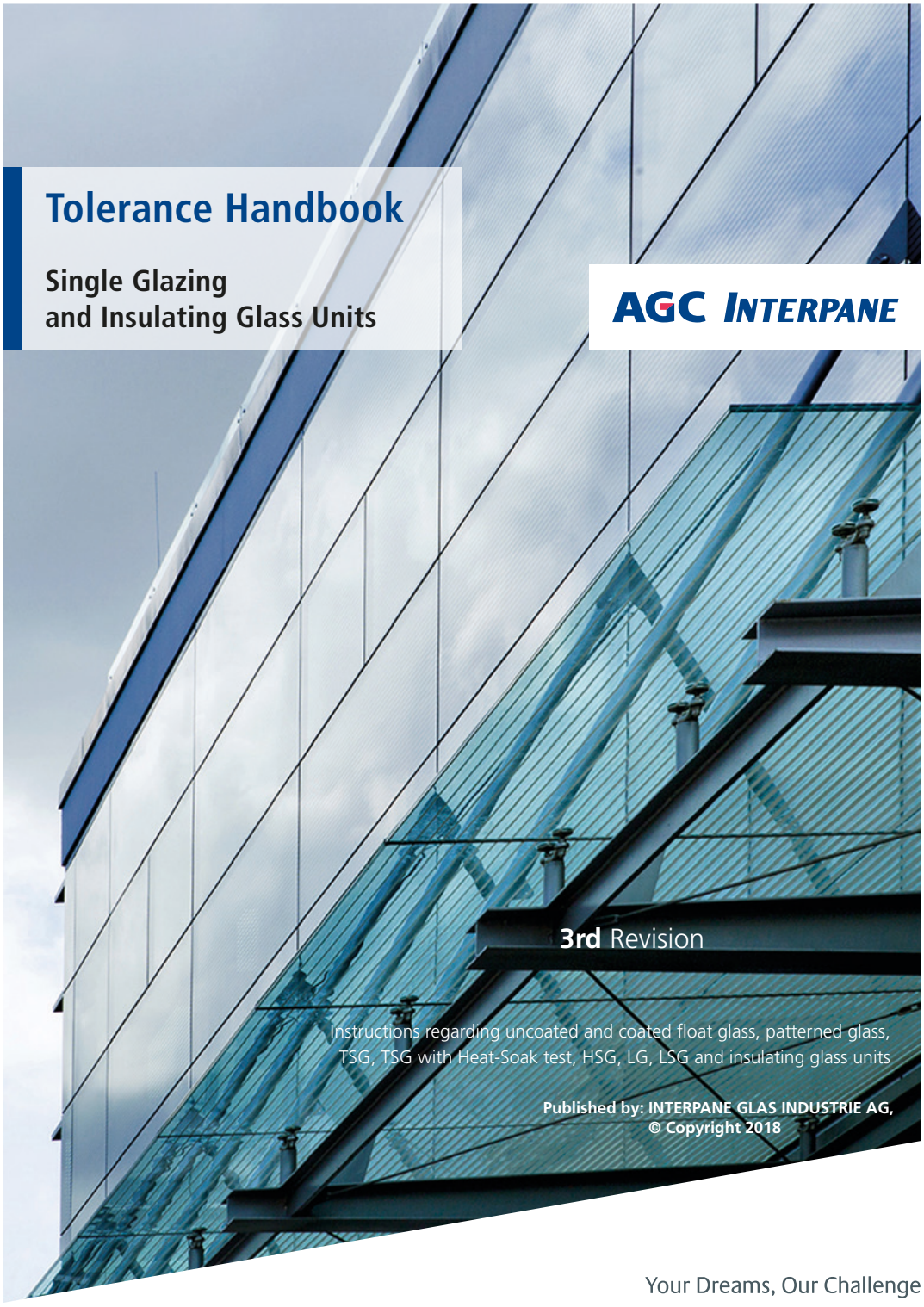
Tolerance Handbook

Single Glazing and Insulating Glass Units

AGC INTERPANE



3rd Revision

Instructions regarding uncoated and coated float glass, patterned glass, TSG, TSG with Heat-Soak test, HSG, LG, LSG and insulating glass units

Published by: INTERPANE GLAS INDUSTRIE AG,

Your Dreams, Our Challenge

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3rd Revision, September 2018

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Foreword

AGC INTERPANE counts among the most important manufacturers of float glass and refiners of sheet glass in Europe. The AGC INTERPANE product range comprises basic glass, high-quality coated thermal-insulation glass, sound-control and solar-control insulating glass, safety glass, and glazing for exterior and interior design.

This ***AGC INTERPANE Tolerance Handbook for Single Glazing and Insulating Glass Units*** contains regulations about the tolerances of basic-glass units (substrates), those of units processed from these latter, and those of the products manufactured by refining basic glass, such as thermally-toughened safety glass (TSG), thermally-toughened safety glass with Heat-Soak test (TSG-H), heat-strengthened glass (HSG), laminated glass (LG), laminated safety glass (LSG) and insulating glass units (IGU).

This Tolerance Handbook is based on the currently valid DIN and EN product standards. In this connection, we wish to explicitly draw attention to the fact that these regulations are often insufficient in practice. For this reason, the handbook also describes those properties of the products which are not characterized in the product standards. The relevant guidelines for the assessment of the visual quality of glass for the construction industry and of enamelled glass have also been worked into this handbook.

This Tolerance Handbook constitutes part of the General Terms and Conditions in the version most up-to-date at any given time.

Any quality demands additional to these, or any stricter tolerance requirements, must be communicated to AGC INTERPANE before an order is placed, and will only count as having been accepted if they are confirmed by us in writing. Special tolerances, and any tolerances for construction glass, must be agreed in writing before the placing of an order.

Regarding the assessment of visual quality there apply in the case of supplied sizes (jumbo sizes), the relevant basic-glass-unit product standards for float glass, LG, and LSG. In the case of final-cut sizes there apply the references and tolerance limits set out in the present Tolerance Handbook. In the case of products that have undergone further processing, e.g. TSG, TSG-H, HSG, LG, LSG or IGU, there applies the "Guideline to Assess the Visual Quality of Glass in Buildings", chapter 9.

References to Guidelines and Product Standards

This Tolerance Handbook contains both dated and undated references to, as well as determinations drawn from, other publications. These references are cited at the respectively appropriate points in the text. In the case of firm (i.e. dated) references, the guidelines or product standards in question belong, in the specific dated form, to this handbook, and any later revisions to same will have to be expressly worked into the handbook. In the case of undated references, there shall apply here the latest edition of the publication referred to existing at any given time.

This Tolerance Handbook forms a supplement to the AGC INTERPANE Glazing Guidelines. These are to be found in the current edition of the handbook "Design with Glass". To be downloaded at *www.interpane.com.*

Note:

In case of doubts the original version in German must be consulted. Especially for possible deviations of numbers and values or diagrams.

1 Basic Glass Units

To basic glass units there apply the following product standards and guidelines.

EN 572 Glass in Building – Basic Soda Lime Silicate Glass

Part 1: Definitions and General Physical and Mechanical Properties;
Part 2: Float Glass;
Part 3: Polished Wired Glass;
Part 4: Drawn Sheet Glass;
Part 5: Patterned Glass;
Part 6: Wired Patterned Glass;
Part 7: Wired or Unwired Channel-Shaped Glass
Part 8: Supplied and Final-Cut Sizes;
Part 9: Evaluation of Conformity / Product Standard, plus Nationally Specific Appendices

In the product standards listed above there can be found the maximum dimensional tolerances for the different glass products.

Also described in these standards are the requirements in terms of quality and of visually perceptible faults in basic-glass products.

1.1 Nominal Thicknesses

As an excerpt from EN 572 Part 8, we list in Table 1 below the maximum dimensional tolerances (d) for the nominal thicknesses of float glass and patterned glass.

	Dimensional Tolerance (d) [mm]	
Nominal Thickness [mm]	Float Glass	Patterned Glass
3	± 0.2	± 0.5
4		
5		
6		
8	± 0.3	± 0.8
10		± 1.0
12		–
15	± 0.5	–
19	± 1.0	–

Table 1: Dimensional tolerances for the nominal thicknesses of float glass and patterned glass

1.2 Dimensional Tolerances for Supplied Sizes (Jumbo Sizes)

As an excerpt from EN 572 Part 8, we list the following dimensional tolerances (t) for width (W) and length (H), and the following limit deviations as regards differences between diagonals (v), for supplied sizes (jumbo sizes) of float glass and patterned glass.

	Dimensional Tolerance (d) in [mm]	
Nominal Thickness [mm]	Float Glass	Patterned Glass
3	± 4.0	± 3.0
4		
5		
6		
8		± 4.0
10		
12		–
15		–
19	± 5.0	–

Table 2: Dimensional tolerances (t) for width (W) and length (H) of float glass and patterned glass

	Limit on the Difference between Diagonals (v) [mm] for Supplied Sizes (Jumbo Sizes) of Float Glass and Patterned Glass	
Nominal Thickness [mm]	(H, W) ⩽ 3000	(H, W) > 3000
3	⩽ 4.0	⩽ 5.0
4		
5		
6		
8	⩽ 5.0	⩽ 6.0
10		
12		
15	⩽ 6.0	⩽ 8.0
19		

Table 3: Limit on the difference between diagonals (v) for float glass and patterned glass

2 Cutting to size

2.1 Dimensional Tolerances for Length, Width and Squareness

Listed below are the dimensional tolerances (t) for width (W) and length (H), and the limit on the difference between diagonals (v), for final-cut sizes of float glass and patterned glass where these are cut to size by hand-working or by machine-aided production.

Wired glass is left out of consideration here. Regarding dimensional tolerances and limit deviations for wired glass, EN 572-8 should be consulted.

For jumbo sizes of float glass and patterned glass Table 2 and Table 3 should be used.

Description of Glass	Dimensional Tolerance (t) [mm] for Final-Cut Sizes	Difference between Diagonals (v) [mm]
Thickness ≤ 6 mm and (W and H) ≤ 2000 mm	± 1.0	≤ 1.0
6 mm < Thickness ≤ 12 mm, or 2000 mm < (W or H) ≤ 3500 mm	± 2.0	≤ 2.0
6 mm < Thickness ≤ 12 mm and 3500 mm < (W or H) ≤ 5000 mm	± 3.0	≤ 3.0
Thickness > 12 mm or (W or H) > 5000 mm	± 4.0	≤ 4.0

Table 4: Nominal dimensional tolerances (t) re length (H) and width (W) for final-cut sizes and limit on the difference between diagonals (v)

Tolerances re squareness are described via the limit on the difference between diagonals (v).

The above-named dimensional tolerances (t) apply where there is no break-off long of, or short of, the ideal specified dimension.

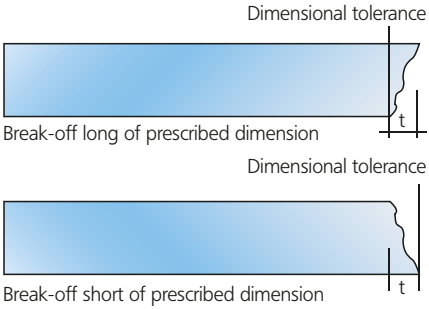


Fig. 1: Oblique glass break-off

AGC INTERPANE recommends that, where glass thickness is ≥ 15 mm, at least one ground-to-size edge be executed (see chapter 3.1).

Glass-Thickness in mm	Maximum Dimensional Tolerance (t) [mm]
4, 5, 6	± 1.0
8, 10, 12	± 2.0
15	+5 / -3
19	+6 / -3

Table 5: Dimensional tolerance (t) for oblique glass break-off

2.2 Cut-Back in Custom-Modelled Panes

Custom-modelled panes made from float glass or patterned glass, and HSG, TSG, thermally-toughened safety glass with Heat-Soak test, LG, LSG and insulating glass with an acute angle < 20° are, for technical production reasons, always executed with a cut-back.

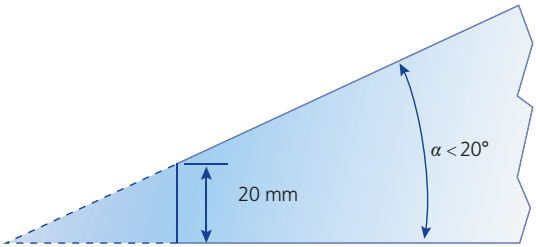


Fig. 2: Cut-back

Please take note that the acute angle of the cut-back is "butt-joined".

3 Processing
3.1 Edge-Working Quality Standards

The description of edge-working is based on DIN 1249, Part 11 and EN 12150, Part 1. These product standards can be consulted for clarification of the concepts and definitions involved. It applies as a general principle that, for technical production reasons, smooth-ground edges may also be polished.

In the cases of LG and LSG elements composed of two or more glass units, the edges of the individual panes may be executed, according to above-listed product standards, as cut edges, arrissed edges, sawn edges, edges cut by abrasive waterjet, ground-to-size edges, smooth-ground edges, or polished edges. As a rule, the whole package is processed at the glass edge. Except in the case of LG or LSG made from thermally-toughened glass, in which case the individual panes are processed separately and subsequently laminated. In the case of TSG or HSG no subsequent processing (e.g. edge-working, drilling) is possible. In the case of combinations from non-thermally toughened glass units subsequent processing is permissible.

3.1.1 Cut Edge
The cut edge is the unworked glass edge which arises in the process of cutting sheet glass. Its edges are sharp. Delicate wavy tracks can occur obliquely to the edges of this cut edge (so-called "Wallner lines"). Generally, the cut edge forms a clean, flat break. However, there can sometimes occur, mainly in the case of thicker panes and non-rectangular panes, irregularly-running breaks (e.g. breaks that lie long of, or short of, the ideal specified dimension). Particularly protuberant instances of non-flatness can be rectified by grinding.

3.1.2 Arrissed Edge
The arrissed edge is a cut edge, the edges of which have been broken using a grinding tool.

The tolerances to be taken as a basis here are those set out in Tables 4 and 5.

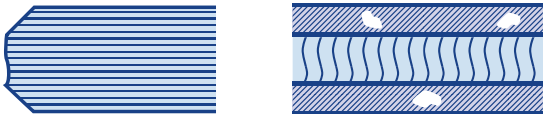


Fig. 3: Arrissed edge

Typical application: for glazing units which it is intended will be refined by thermal toughening.

3.1.3 Sawn Edge
The sawn edge is an edge created in the 90 right angle or 45 bevel angle of the pane using a radial arm saw or band saw, with inflow and outflow tracks at its beginning and at its end. Where this type of edge is applied, tolerances are to be agreed and coordinated with AGC INTERPANE.

3.1.4 Waterjet Cut Edge
An edge created by abrasive (jet) cutting of the glass pane. The edges in this case are not sharp. Nor are the edge surfaces flat or level. Edges cut by abrasive waterjet present a frosty, opaque appearance. Where this type of edge is applied, tolerances are to be agreed and coordinated with AGC INTERPANE.

3.1.5 Ground-to-Size Edge

The pane of glass is brought to the required dimensions by grinding the surface of the edge. The ground-to-size edge can also be executed with broken edges (i.e. in a way that corresponds to the arrissed edge). Blank areas and flakes are permissible.

Fig. 4: Ground-to-size edge

3.1.6 Smooth-Ground Edge

The glass edge is processed by grinding across its whole surface. Grinding is also applied to the edge areas (i.e. in a way that corresponds to the arrissed edge).

Smooth-ground edge surfaces present the appearance of surfaces made frosty and opaque by grinding. Blank areas and flakes are not permissible. The corners of the edges can, if required, be bevelled across the whole width of the arriss so as to produce a frosty, opaque appearance.

Fig. 5: Smooth-ground edge

Typical application: for Structural Glazing Units with visible edges.

3.1.7 Polished Edge

The polished edge is a smooth-ground edge which is further refined by polishing. A certain amount of polishing traces are permissible. The surface of a polished edge presents a glossy appearance.

The corners of the edges can, if required, be bevelled across the whole width of the arriss so as to produce a frosty, opaque appearance.

Fig. 6: Polished edge

Typical application: for Structural Glazing Units with visible edges.

3.1.8 Bevelled Edge

The bevelled edge forms a $45° \leqslant \alpha < 90°$ angle with the glass surface. The edges can be either "smooth-ground" or "polished".

The bevelled edge terminates in a residual edge standing perpendicular to the glass surface. Except where otherwise agreed, this residual edge should amount to 1/3, or not more than 2 mm, of the original glass thicknesses and should be either smooth-ground or polished and arrissed.

Fig. 7: Bevelled edge

3.1.9 Arris Tolerance for Ground-to-Size, Smooth-Ground and Polished Edges

Fig. 8: Arris tolerance

The tolerances vary depending upon the specific type of edge-working concerned.

The edge-working standards apply also to TSG, TSG-H, HSG, LG and LSG made from thermally toughened and non-thermally toughened glass units.

For technical production reasons, glazing units undergo, prior to any toughening process, at least an arrissing (arris grinding above).

3.2 Edge-Working

3.2.1 Standard Tolerances

Listed below are the dimensional tolerances (t) for width (W) and length (H) and the limit on the difference between diagonals (v), for glazing with arrissed, ground-to-size, smooth-ground, and polished edges.

Description of Glass	Dimensional Tolerance (t) [mm] for Final-Cut Sizes	Difference between Diagonals (v) [mm]
Thickness ⩽ 6 mm and (W and H) ⩽ 2000 mm	± 1.0	⩽ 1.0
6 mm < Thickness ⩽ 12 mm, or 2000 mm < (W or H) ⩽ 3500 mm	± 2.0	⩽ 2.0
6 mm < Thickness ⩽ 12 mm and 3500 mm < (W or H) ⩽ 5000 mm	± 3.0	⩽ 3.0
Thickness > 12 mm or (W or H) > 5000 mm	± 4.0	⩽ 4.0

Table 6: Nominal dimensional tolerances (t) re length (H) and width (W) and limit on the difference between diagonals (v)

The nominal dimensions for the width and length of the end product must not amount to sums either greater or smaller than the nominal dimensions plus or minus the dimensional tolerance (t). Limit deviations are listed in Table 6.

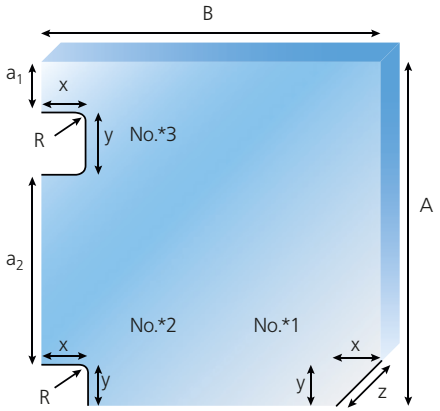
The rectangularity of rectangular glass panes is described by the difference between their diagonals. The difference between the two longitudinal diagonals of the glass pane must not be greater than the difference between diagonals (v) stipulated in Table 6.

3.3 Corner Cut-Off and Corner and Edge Cut-Outs

Edge cut-outs and corner cut-outs must be provided with a radius (R) which is either larger than or equal to the thickness of the glass, but must measure in every case at least 10 mm. The cut-offs/cut-outs are to be sized in such a way that minor construction tolerances in the substructure can be balanced out. The dimensions of the cut-offs/cut-outs must not exceed one third of the length of the pane edge concerned.

No specific tolerances for this type of processing are stipulated in the applicable product standards.

For width (W) and height (H) tolerances for each respective glass-type and/or edge-execution please consult the corresponding sections.



A = Height
B = Width
a1 = Distance between glass edge and cut-out
a_2 = Spacing between two cut-outs
x = Width of cut-out/cut-off
y = Height of cut-out/cut-off
z = Corner cut-off
R = Radius

No.*1 Corner cut-off
No.*2 Corner cut-out
No.*3 Edge cut-out

Fig. 9: Diagrammatic representation of corner cut-offs and corner and edge cut-outs

3.3.1 Corner Cut-Off Arrissed

A corner cut-off (see Fig. 9 No.*1) is smaller than 100 mm (x) x 100 mm (y).
Larger corner cut-offs are classified, acc. to the List of Shapes, as "special forms".
Tolerance for the dimensions of the corner cut-off (z) ± 4 mm

3.3.2 Corner Cut-Off Ground

A corner cut-off (see Fig. 9 No.*1) is smaller than 100 mm (x) x 100 mm (y).

Larger corner cut-offs are classified, acc. to the List of Shapes, as "special forms".

3.3.2.1 Standard Tolerance

Tolerance for the dimensions of the corner cut-off (z) ± 2 mm.

3.3.2.2 Special Tolerance

The tolerance for the dimensions of the corner cut-off (z) is ± 1 mm

The production work takes place at the CNC Machining Centre.

3.3.3 Corner Cut-Off Polished

A corner cut-off (see Fig. 9 No.*1) is smaller than 100 mm (x) x 100 mm (y).

Larger corner cut-offs are classified, acc. to the List of Shapes, as "special forms".

The production work for the polished corner cut-off takes place at the CNC Machining Centre.

Tolerance for the dimensions of the corner cut-off (z) ± 1 mm

3.3.4 Corner Cut-Out Arrissed

Corner cut-out see Fig. 9 No.*2
Tolerance (x, y) ± 4 mm

3.3.5 Corner Cut-Out Ground

Corner cut-out see Fig. 9 No.*2

3.3.5.1 Standard Tolerance

The minimum dimensions for the internal radius vary depending on the glass thickness

Glass thickness ⩽ 10 mm → R 10 mm
Glass thickness ⩾ 12 mm → R 15 mm

Tolerance (x, y) ± 3 mm

3.3.5.2 Special Tolerance

Tolerance (x,y) ± 1.5 mm, the production work takes place at the CNC Machining Centre

3.3.6 Corner Cut-Out Polished

Corner cut-out see Fig. 9 No.*2

Minimum dimensions for internal radius R =15 mm

The production work for the polished corner cut-out takes place at the CNC Machining Centre.

Tolerance (x, y) ± 1 mm

3.3.7 Edge Cut-Out Arrissed

Edge cut-out see Fig. 9 No.*3

3.3.7.1 Standard Tolerances for Hand-Working – Cut-Out Dimensions

Cut-Out Dimensions (x, y) [mm]	Tolerance (t) [mm]
⩽ 500	± 5
> 500 to ⩽ 1000	± 6

Table 7: Edge cut-out tolerances for hand-working (arrissed)

Positional tolerance (a1, a2) ± 3 mm

3.3.7.2 Special Tolerances for Machine-Working – Cut-Out Dimensions

The minimum dimensions for the internal radius vary depending on the glass thickness
Glass thickness ⩽ 10 mm → R 10 mm
Glass thickness ⩾ 12 mm → R 15 mm

Positional tolerance (a1, a2) ± 1.5 mm

Cut-Out Dimensions (x, y) [mm]	Tolerance (t) [mm]
⩽ 3500	± 2
> 3500	± 3

Table 8: Edge cut-out tolerance, CNC machining centre arrissed

3.3.8 Edge Cut-Out Ground or Polished

Edge cut-out see Fig. 9 No. *3

The production work for the ground or polished edge cut-out takes place at the CNC Machining Centre.

Minimum dimensions for internal radius R =15 mm

Dimensional tolerance (x, y) ± 1 mm
Positional tolerance (a1, a2) ± 1 mm

Important Note:

Within an order, depending on customer requirements (e.g. rectangular panes or custom-modelled panes), different types of working and processing may be applied. Any differences in the visual appearance of the processed edge that may result thereby are a matter of production-technological necessity and cannot be avoided. They represent no legitimate grounds for a complaint about the product.

3.4 Cut-Outs in the Glass Surface

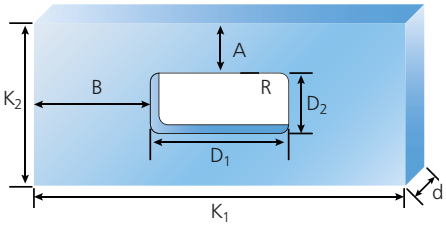
Listed below are the specifications and tolerances for both the position and the dimensions of cut-outs executed in the glass surface.

Cut-outs in the glass surface are produced, using a milling tool, in the CNC Machining Centre. It is an inevitable part of such a production process that certain longitudinal groove-marks or similar traces will be left by the cutting tool on the glass-edge, some of which may remain visible.

Minimum dimensions for internal radius R = 15 mm.

3.4.1 Specifications and Tolerances Re the Position of Cut-Outs in the Glass Surface

Cut-out tolerances are determined and dictated by the technical conditions of production.



A, B = Distance between the respective edge and the beginning of the cut-out
D_1, D_2 = Cut-out dimensions
K_1, K_2 = Lengths of glass-edge
d = Glass thickness
R = Radius

Fig. 10: Position of cut-out in glass surface

The length or width of the cut-out must be greater than, or equal to, the glass thickness:

$$D_1, D_2 \geq d$$

The distance of a cut-out from the glass edge must not be less than half of the size of the cut-out itself (D1, D2):

$$A \geq D_2/2,$$
$$B \geq D_1/2$$

The size of a cut-out must not exceed 1/3 of the length of the respective pane edge:

$$D_1 \leq K_1/3$$
$$D_2 \leq K_2/3$$

3.4.2 Tolerances for Cut-Outs at the Glass-Edge and in the Glass Surface in LG and LSG

These tolerances are dependent on the respective technical circumstances.

Please clarify these specific technical conditions with AGC INTERPANE when placing an order.

Important Note:

Within an order, depending on customer requirements, different types of working and processing may be used to execute cut-outs in the glass surface. Any differences in the visual appearance of the worked-on edges that may result thereby are a matter of production-technological necessity and cannot be avoided. They represent no legitimate grounds for a complaint about the product.

3.5 Drill-Holes

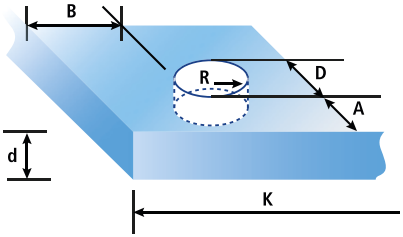
Listed below are the specifications and tolerances for both the position and the dimensions of drill-holes.

As a general rule, drill-holes with a diameter of ⩾ 100 mm are produced at a CNC Machining Centre.

For special drill-holes, e.g. for undercut-drilling systems, tolerances are to be agreed on a case-to-case basis

3.5.1 Specifications and Tolerances for the Position of Drill-Holes

Drill-hole tolerances are determined and dictated by the technical conditions of production.



A, B = Distance between the respective edge and the beginning of the drill-hole
D = Drill-hole diameter
K = Lengths of glass edge
d = Glass thickness
R = Radius

Fig. 11: Positioning of drill-hole

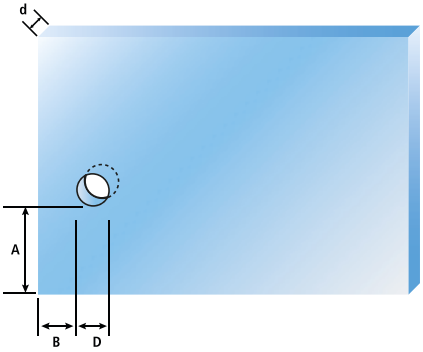
Due to the need to lay an intermediate layer of fasteners in the direction of the glass edge, the diameter of the drill-hole should be at least 4 mm larger than that of the fastener – except in the case where specifications resulting from the design and construction of the glazing unit require or make necessary some other dimensioning of these intermediate layers of fasteners.

The diameter (D) of the drill-hole is to be sized in such a way that spacing tolerances can be balanced out. If more than four drill-holes are executed next to or over one another, then the required minimum spacings increase accordingly.

Drill-holes in the glass corner area must be asymmetrically positioned (at least a 5 mm difference between A and B as regards their distance from the glass edge).

Where this proves NOT to be possible, AGC INTERPANE recommends that the drill-holes, on account of the increased risk of glass breakage in units using thermally-toughened glass, be executed with the addition of a stress-reducing incision. It must, however, be noted that it is the user of the end-product's own responsibility to clarify the question of whether such a measure is permissible under the applicable building and construction regulations.

3.5.1.1 Distances of Drill-Holes from Glass-Edges



A, B = Distance between glass-edge and drill-hole
D = Drill-hole diameter
d = Glass thickness

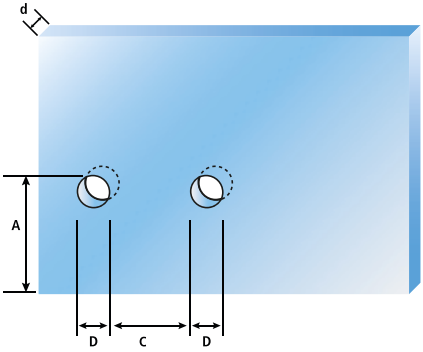
Fig. 12: Distances between drill-holes and glass-edges

	d < 8 mm	**8 mm ⩽ d ⩽ 12 mm**	**d = 15 mm**	**d = 19 mm**
Minimum drill-hole diameter	D ⩾ d	D ⩾ d	D ⩾ 18 mm	D ⩾ 25 mm
Edge area - distance from one glass-edge, in the case where **A, B ⩾ D/2**	A ⩾ 2 d	A ⩾ 2,5 d	A ⩾ 30 mm	A ⩾ 40 mm
Corner area - distance from two glass-edges, in the case where **D ⩾ 1.5 d**	A ⩾ 2 d + 5 mm B ⩾ 2 d or B ⩾ 2 d + 5 mm A ⩾ 2 d	A ⩾ 2.5 d + 5 mm B ⩾ 2 d or B ⩾ 2.5 d + 5 mm A ⩾ 2 d	A ⩾ 30 mm B ⩾ 45 mm or B ⩾ 30 mm A ⩾ 45 mm	A ⩾ 40 mm B ⩾ 60 mm or B ⩾ 40 mm A ⩾ 60 mm
Corner area - distance from two glass-edges, in the case where **D < 1.5 d**	A ⩾ 5 d B ⩾ 2.5 d + 5 mm or B ⩾ 5 d A ⩾ 2.5 d + 5 mm			

Table 9: Distances between the drill-holes and the glass-edges

3.5.1.2 Spacing of Drill-Holes Vis-a-Vis One Another

The same criteria apply regarding spacing between two drill-holes as apply regarding the distance to be maintained between a drill-hole and the glass-edge.



A = Distance from glass-edge
C = Distance between the drill-holes
D = Drill-hole diameter
d = Glass thickness

Fig. 13: Spacing between the drill-holes

	d < 8 mm	8 mm ⩽ d ⩽ 12 mm	d = 15 mm	d = 19 mm
Minimum drill-hole diameter	D ⩾ d	D ⩾ d	D ⩾ 18 mm	D ⩾ 25 mm
Edge area - Distance from glass edge	A ⩾ 2 d	A ⩾ 2.5 d	A ⩾ 30 mm	A ⩾ 40 mm
Spacing between drill-holes	C ⩾ 2 d	C ⩾ 2 d	C ⩾ 45 mm	C ⩾ 60 mm

Table 10: Spacing between the drill-holes

3.5.1.3 Position of Drill-Holes

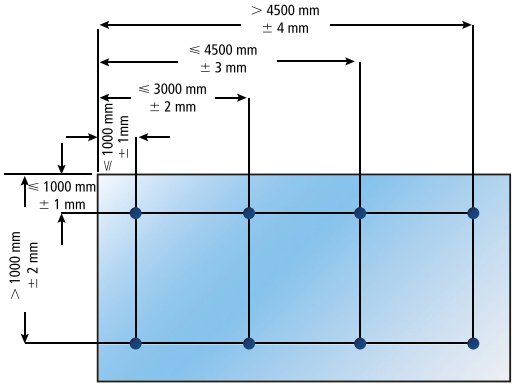


Fig. 14: Position and tolerance of drill-holes

In the case of construction glass a tolerance re positioning between the drill-holes of ± 1 mm can be maintained.

3.5

3.5.2 Diameter of Cylindrical Drill-Holes

For the diameter of a drill-hole there apply the following tolerances:

3.5.2.1 Tolerances for Drill-Holes

The tolerances for drill-hole diameters are:

D ⩽ 24 mm element thickness: ± 2.0 mm
D > 24 mm element thickness: ± 2.5 mm

The tolerances regarding the positioning of the drill-hole are:

In the case of non-thermally toughened glass: ± 1.5 mm
In the case of TSG / TSG with Heat-Soak test / HSG: ± 2.5 mm

3.5.3 Diameters of Countersunk Holes

Diameter E: +1.5 mm / -1.0 mm

Minor Diameter
D ⩽ 30 mm: ± 1.0 mm
D > 30 mm: ± 2.0 mm

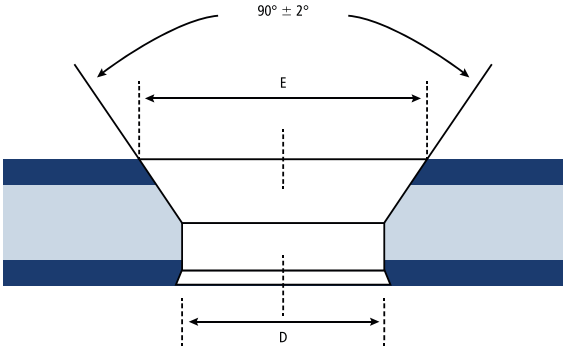


Fig. 15: Diagram of countersunk hole tolerances

D ⩽ 120 mm: ± 1.0 mm
D > 120 mm: ± 2.0 mm

These tolerances, dictated by conditions of production, are to be taken into account in addition to the constructional and assembly-technical tolerances. It should furthermore be noted that the tolerances necessitated by the offsets in LG / LSG need also to be taken into account when calculating drill-hole tolerances.

3.5.4 Diameters of Countersunk Holes in LG / LSG Made from Thermally Toughened Glass

The cylindrical drill-hole in the second pane in the laminate is to be executed with a diameter 4 mm larger than the minor diameter (D) of the initial drill-hole.

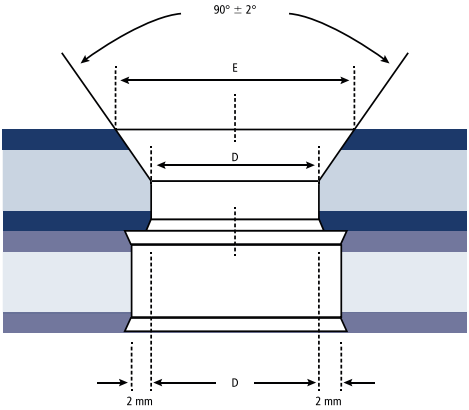


Fig. 16: Diagram of countersunk hole tolerances in LG/LSG

Important Note:

Within an order, depending on customer requirements, different types of working and processing may be used to execute drill-holes. Any differences in the visual appearance of the worked-on edges that may result thereby are a matter of production-technological necessity and cannot be avoided. They represent no legitimate grounds for a complaint about the product.

4 TSG, Thermally-Toughened Safety Glass with Heat-Soak Test and HSG

Thermally-toughened safety glass as per EN 12150-1/-2

Thermally-toughened safety glass with Heat-Soak test as per EN 14179-1/-2

Heat-strengthened glass as per EN 1863-1/-2 (National Technical Approval Z-70.3-55)

4.1 Straightness

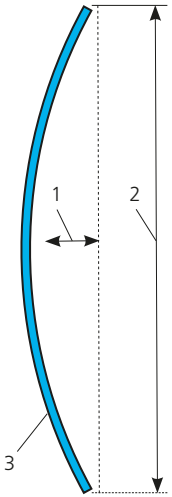
Deviation from straightness depends on the glass type, the glass thickness, the other dimensions and the side-to-side ratio of the pane. This deviation appears in the form of warping. The latter is divided into three categories:

- Overall bow
- Wave or roller wave distortion and
- Edge Lift

4.1.1 Standard Tolerance for TSG, Thermally-Toughened Safety Glass with Heat-Soak Test and HSG

4.1.1.1 Overall Bow

The pane of glass is placed, at room temperature, vertically on its long side on two blocks, which are positioned a quarter of the edge-length from the corners. The warp is established, by the application of a sharp-edged measure or a taut wire, as the maximum distance from the concave surface of the pane (see Fig. 17). It is measured along the glass edges and along the diagonal. The resulting figure for overall bow is expressed as deflection (D) in millimetres, divided by the measured length (W or H) of the glass edge or the diagonal in metres. The permissible tolerances for measured overall bow (t_G) are given in Table 11.



$$t_G = \frac{D}{\text{W or H or the diagonal}} \quad \frac{mm}{m}$$

Key
1 Deformation (D) for calculating of overall bow t_G
2 W or H, or the diagonal
3 Thermally-toughened glass

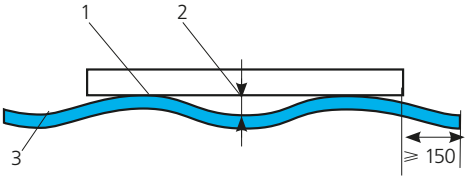
Fig. 17: Test for overall bow

4.1.1.2 Wave or Roller Wave Distortion

The roller wave is to be measured by means, for example, of a 300 to 400 mm long sharp-edged measure, which is applied perpendicularly to the roller wave and bridges the apices of the waves in question (see Fig. 18). The distance between the sharp-edged measure and the glass surface is then measured using a feeler gauge. This measurement procedure is to be repeated at several points on the glass.

Roller waves may only be measured on panes of > 600 mm, and not within a prohibited area of 150 mm from the pane edges.

The permissible tolerances for measured warp in the form of roller waves (t_W) are listed in Table 11.

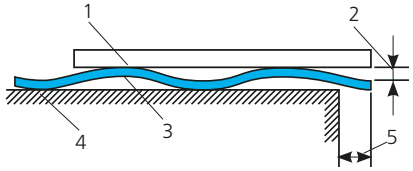


Key
1 Straight edge
2 Wave or roller wave distortion s t_W
3 Thermally-toughened glass

Fig. 18: Measurement of wave or roller wave distortion

4.1.1.3 Edge Lift

The glass must be laid on a flat surface, in such a manner that the unevenness of the glass edge extends by 50 mm to 100 mm beyond the edge of the surface it is laid on. The measuring rod is to be placed across the apices of the roller waves and the gap between the measuring rod and the glass is to be measured using a feeler gauge (see Fig. 19). The permissible tolerances for non-flatness of edges t_K are listed in Table 11.



Key
1 Straight edge
2 Edge lift
3 Thermally-toughened glass
4 Flat support
5 Overhang of 50 mm to 100 mm

Fig. 19: Measurement of edge lift

Limitation of Overall Bow, Roller Waves and Edge Lift				
Type of Glass TSG/HSG Made From	Glass Thickness [mm]	Highest Permissible Degree of Warp		
		Non-Flatness of Edge Lift t_K [mm]	Overall Bow t_G [mm]	Roller Wave t_W [mm]
Float glass	3	0.5	3*	0.3
	4 – 5	0.4		
	6 – 19	0.3		
Patterned Glass	4 – 10	0.5	4	0.5

* In the case of square and almost-square pane-shapes with a side-to-side ratio lying between 1:1 and 1:1.3, deviation from straightness will necessarily be greater than in the case of narrower rectangular pane-shapes. Especially in the case of glass-thicknesses of ⩽ 6 mm there must be consultation and coordination with AGC INTERPANE.

Table 11: Highest permissible levels of overall bow, roller waves and edge lift for thermally-toughened glazing units

So as to be able to comply with the above-named tolerances, the following minimum glass-thicknesses, depending on external pane dimensions, are also to be complied with.

Minimum Glass Thickness	Maximum Dimensions	Maximum Side-to-Side Ratio
3 mm *	1000 mm x 1500 mm	1:10
4 mm	1500 mm x 2500 mm	1:10
5 mm	2000 mm x 3000 mm	1:10
6 mm	2800 mm x 4500 mm	1:10
8 mm to 12 mm	2800 mm x 6000 mm	1:10
15 mm **	2800 mm x 6000 mm	1:10
19 mm **	2600 mm x 4500 mm	1:10
Minimum Dimensions	200 mm x 300 mm	

* not as TSG-H ** not as HSG
In the case of a glass-thickness of 4 mm with Heat-Soak test there must, as soon as possible, be consultation and coordination with AGC INTERPANE.

Table 12: Maximum external pane dimensions of thermally-toughened glazing units

For custom-modelled panes, printed glass units etc. it may be possible, where required, to agree, after consultation, on stricter tolerances.

It is to be noted that these dimensions and side-to-side ratios relate exclusively to the production-technological possibilities resulting from the operational preconditions applying within the manufacturing process.

The glass thicknesses and configurations actually required must comply with the building regulations and other legal requirements applying in the countries concerned.

HSG made from patterned glass is delivered only according to the stipulations of EN 1863.

4.1.2 Special Tolerances for TSG, Thermally-Toughened Safety Glass with Heat-Soak Test and HSG

These tolerances apply only to TSG, thermally-toughened safety glass with Heat-Soak test, and HSG made from clear float glass.

Limitation of Overall Bow, Roller Waves and Edge Lift				
Type of Glass TSG/HSG Made From	Glass Thickness [mm]	Highest Permissible Degree of Warp		
		Overall Bow t_G [mm/m]	Roller Wave t_W [mm]	Non-Flatness of Edges t_K [mm]
Float glass	6 –12	2*	0.15	0.25

* In the case of almost-square pane-shapes with a side-to-side ratio lying between 1:1 and 1:1.3, deviation from straightness will necessarily be greater than in the case of narrower rectangular pane-shapes and amounts to 3 mm/m.

Table 13: Highest permissible levels of overall bow, roller waves and edge lift for thermally-toughened glazing units (special tolerances)

So as to be able to comply with the above-named special tolerances, the following minimum glass- thicknesses, depending on external pane dimensions, are also to be complied with.

Minimum Glass Thickness	Maximum Dimensions	Maximum Side-to-Side Ratio
6 mm	2400 mm x 4000 mm	1:10
8 mm	2600 mm x 5000 mm	1:10
10 mm	2600 mm x 5400 mm	1:10
12 mm	2600 mm x 5400 mm	1:10
Minimum Dimensions	200 mm x 300 mm	

Table 14: Overview of glass thicknesses for special tolerances

For rectangular, clear-glass, non-coated, non-printed HSG, TSG and TSG with Heat-Soak test it may, where this is required, be possible to agree on less strict tolerances than those listed in Table 13. These depend, among other factors, upon glass thickness and dimensions of the pane.

4.2 Marking

4.2.1 Thermally-Toughened Safety Glass (TSG)

Every TSG pane is to be provided, at the very least, with the marking
„EN 12150-1" and
„Name or trademark of the manufacturer".

The marking, according to this product standard, must be permanently and indelibly imprinted.

4.2.2 Thermally-Toughened Safety Glass with Heat-Soak Test

TSG panes with Heat-Soak test are to be provided, at the very least, permanently with the marking
„EN 14179-1" and
„Name or trademark of the manufacturer".

The marking, according to this product standard, must be permanently and indelibly imprinted.

4.2.3 Heat-Strengthened Glass (HSG)

Every HSG pane is to be provided, at the very least, with the marking
„EN 1863-1" and
„Name or trademark of the manufacturer".

The marking, according to this product standard, must be indelibly imprinted on the pane.

4.3 Glass Breakage

Thermally-toughened safety glass (TSG) can contain nickel sulphide inclusions which, once the glazing is installed, may result in spontaneous glass breakages. The risk of such spontaneous breakages can be reduced by a Heat-Soak test. Even such a test, however, will not exclude this risk of spontaneous breakage completely.

The cause of the breakage is to be proven by the user. This applies especially to glass-breakages due to inclusions of foreign bodies (e.g. nickel sulphide inclusions).

4.4 Visual Assessment

The inspection principles and tolerances applying here are established in the "Guideline to Assess the Visible Quality of Glass in Buildings" reproduced in chapter 9.

5 Screen-Printing, Digital Printing and Enamel

There apply as supplementary references here:

EN 12150
Glass in Building –
Thermally-Toughened Soda Lime Silicate Safety Glass –
Part 1: Definition and Description;
German version EN 12150-1

EN 14179
Glass in Building -
Heat-Soaked Thermally-Toughened Soda Lime Silicate Safety Glass –
Part 1: Definition and Description;
German version EN 14179-1

EN 1863
Glass in Building -
Heat strengthened soda lime silicate glass –
Part 1: Definition and Description;
German version EN 1863-1

The guidelines listed below are also used for the assessment of the optical quality of digitally-printed panes.

5.1 Visual Quality of Enamelled and Printed Glazing Units

This chapter contains the "Guideline for assessing the visual quality of enamelled glass".

These "Guidelines" were drawn up and published by:
Bundesverband Flachglas e.V., Troisdorf.
Latest edition: March 2014

5.1.1 Applicability

This guideline applies to the assessment of the visual quality of fully or partially enamelled glass produced by applying and baking of ceramic paints, as toughened safety glass or as heat-strengthened glass.

This guideline does not apply for coloured glass according to EN 16477 or for glass with other printing methods. Building code aspects have not been covered by this guideline.

The references and tolerances stated in the section 5.1.3 "Inspection" apply as a general principle for other paint types too, for example organic paints. The specific properties of these paint types are not described in this guideline.

So-called lacquered glass that can be thermally tempered is coated with ceramic paints.

This guideline is therefore valid for these products too.

For assessment of the products, it is necessary to inform the manufacturer about both the specific application and design / visual requirements in the purchase order. This applies in particular to the following information:

- Indoor and/or outdoor use
- Use for see-through purposes
  (viewing from both sides, e.g. partitions etc.)
- Application with direct backlighting
- Edge quality and absence of paint at the edge
  (forexposed edges a ground or polished edge finish is recommended. For an arrissed version, a framed edge is assumed).
- Further processing of the single glass units, e.g. to make multi-pane insulating glass units (IGU) or LG/LSG and/or printing oriented to the film
- Printing on Position 1 for outdoor application

If enamelled glass sheets are combined to make LSG or IGU, each enamelled sheet is assessed individually (as for single glass units).

5.1.2 Methods/Instructions/Definitions

5.1.2.1 General

The enamel paint consists of inorganic materials which are responsible for coloration and which are subject to minor fluctuations. These materials are mixed with glass frit. During the thermal tempering process (TSG, ESG-H and HS), the glass frit encloses the pigments and bonds with the glass surface. The final colour can only be seen after this baking process.

The paints are selected such that they bond with the surface within a few minutes at a glass surface temperature of about 600 – 620 °C. This temperature window is very narrow and, with sheets of different sizes and colours in particular, cannot be exactly reproduced every time.

Furthermore, the method of application is also crucial for the colour impression. Due to the thinly applied paint layer, screen printing or digital printing has a lower covering capacity than a product manufactured by a rolling method with a thicker and hence more densely applied paint layer. The covering capacity is also dependent on the paint selected.

The glass surface can be enamelled over its full surface or just partly by different application methods. The enamel is as a rule applied to the side facing away from the weather effects (position 2 or more). Exceptions must be agreed upon with the manufacturer. For application on position 1 (weather side), special paints are used. The ceramic paints (enamel) are largely scratch-resistant and to a certain extent acid-resistant; their light/adhesion permanence matches the durability of ceramic fused-on paints.

In the case of full-surface enamelling with translucent paints, clouding is possible. These features can become visible when the sheets are backlit. It must be borne in mind that with translucent paints any materials (such as sealant, panel adhesive, insulation, brackets, etc.) directly applied to the rear face (painted side) may shine through.

When metallic paints are used, it must be ensured that they are not exposed to moisture. The use of these paints must be agreed upon with the manufacturer.

If printed sheets are additionally provided with functional coatings, for solar control and/or for thermal insulation, the appropriate standards and guidelines for assessing the visual quality of the final product (chapter 9) must be complied with. Including EN 1096 and/or the previously mentioned guidelines for glass in the building industry. The printed glass surface will be assessed according to the stipulations of these guidelines.

5.1.2.2 Methods

5.1.2.2.1 Rollercoating Method

The plane glass sheet is passed underneath a fluted rubber roller that applies the enamel paint to the glass surface. This ensures a uniform and homogeneous paint distribution over the full surface.

A typical characteristic is that the fluted roller pattern is visible if viewed close up (painted side). From the front side (viewed through the glass, for the method of viewing see chapter 5.1.3), this "fluting" is however practically invisible under normal conditions. Rolled enamel glass is generally not suitable for see-through purposes, so these applications must be agreed upon beforehand with the manufacturer. A so-called "starry sky" (with very small defects) can occur in the enamel.

With this method, a "paint overhang" may occur at the edges, and might be slightly wavy at the longitudinal edges in particular (in the rolling direction of the roller). However, the edge surface will generally remain paint-free. The installation situation must therefore be agreed upon beforehand with the manufacturer. The enamel paint can be optionally applied used a spray gun.

5.1.2.2.2 Pouring Method

The glass pane passes horizontally through a so-called "pouring curtain" and the full surface is covered with paint. By adjusting the paint quantity and the throughput speed, the thickness of the applied paint layer can be controlled within a relatively large range. However, slight unevenness in the spout lip creates the risk of causing stripes of varying thickness in the longitudinal direction (pouring direction). Using this type of glass for see-through purposes urgently requires prior agreement with the manufacturer.

The "paint overhang" at the edges is considerably more than in the rollercoating method and only avoidable with great effort. If paint-free visible edges are required, this must be specified in the purchase order.

5.1.2.2.3 Screen Printing Method

Unlike in the previously described methods, a full-surface or partial-surface application of paint is possible. On a horizontal screen printing table, the paint is applied to the glass surface through a narrow-mesh screen using a squeegee; in this process, the applied paint thickness can be influenced by the mesh width of the screen and the thread diameter. The applied paint layer is therefore generally thinner than with the roller-coating and pouring methods, and it will be opaque or translucent, depending on the selected paint.

Slight stripes both in the printing direction and transversely to it, as well as occasionally occurring slight blurring, are typical for this production process, depending on the paint.

The sheet edges remain free of paint during screen printing as a rule, but can have in the arrissed area a slight paint bead, making it necessary to specify free edges for production matching the application.

With this method, multi-colour printing is possible. For example, so-called double screen printing, in which two different colours can be discerned depending on the surface being viewed. Tolerances, e.g. for equal coverage, must be clarified with the manufacturer.

Printing of selected ornamental glass types is possible, but must always be clarified with the manufacturer.

5.1.2.2.4 Digital Printing Method

The ceramic paint is applied directly onto the glass surface using a method having a similar principle to an inkjet printer, with the thickness of the paint coating being variable. The applied paint layer is therefore generally thinner than with rollercoating, pouring or screen printing, and depending on the selected paint it will be opaque or translucent.

A high print resolution of up to 360 dpi is currently possible.

Barely visible stripes in the printing direction are typical for this production process. They are not always avoidable due to production technology reasons. The sheet edges remain free of paint during digital printing as a rule, but can have in the arrissed area a slight paint bead, making it necessary to specify free edges for production matching the application.

The print edges are exactly straight in the printing direction and slightly serrated transversely to the printing direction. Paint spray mist along the print edges can occur. With spot, hole and text motifs, the print edges show a serration which can, like the paint spray mist, only be discerned from close up.

The digital printing method is particularly suitable for complex multi-colour grid designs or images, less so for single-colour and full-surface printing.

5.1.3 Inspection

Generally speaking, during inspection the view through the glass onto the enamelling is crucial, and the defects must not be specially marked.

The glazing must be inspected from a distance of at least 3 metres away and perpendicularly, or at a maximum viewing angle of 30° from the perpendicular. Inspections are carried out in diffuse daylight (such as overcast sky) without direct sunlight or artificial illumination, against a single-colour and opaque background. If special applications have been previously agreed upon, they must be applied as inspection conditions.

In the case of use as LG/LSG, the tolerance resulting from the offset must be noted in addition to the positional and design tolerances.

Depending on the pattern, a so-called "moiré" can occur in motifs applied by a screen printing method.

The moiré effect (a French word meaning "marbled") becomes apparent from the superimposing of additional and visible rough grid patterns on regular and fine grid patterns. Their appearance is similar to the resultant patterns resembling those due to interference. This effect is due to physical conditions.

If prints are used for covering, for example of profiles in structural glazing, it is possible in the case of very bright colours that the structure can shine through. Suitable colours must therefore be used here.

The guideline is used exclusively for assessing the enamelling of the visible area if the glass is installed. For assessment of the glass, the "Guideline to Access the Visible Quality of Glass in Buildings" is used.

5.1.3.1 Defect Types/Tolerances for Enamelled Glass

Defect-Types/Tolerances for Entirely or Partially Enamelled Glass	
Defect Type	**Permissible Defects**
Punctual Defective Spots in Enamel *	Ø 0.5 - 1.0 mm, max. 3 per m², at distances of ⩾ 100mm Ø 1.0- 2.0mm, max. 2 per pane
Hairline Scratches and Baked-In Foreign Bodies	Permissible up to 10 mm in length
Clouding **	Not permissible
Water Marks	Not permissible
Paint Overhang at the Edges	Permissible in framed sheets and for holes provided with additional mechanical brackets or covers, otherwise not. In unframed sheets with ground or polished edge: ● In the rollercoating method, permissible on the chamfer, not permissible on the edge ● Permissible in the pouring method ● Not permissible in the screen printing method ● Not permissible in the digital printing method Due to the digital printing method, very small paint splashes only discernible from close up can occur in the immediate area of the print edges.
Unprinted glass border	Screen printing and digital printing permissible up to 2 mm
Linear structures in the print	Permissible
Enamel positional tolerance (a) *** see Fig. 20	Sheet Size ⩽ 2000 mm: ± 2.0 mm Sheet Size ⩽ 3000 mm: ± 3.0 mm Sheet Size > 3000 mm: ± 4.0 mm
Tolerance of dimensions for partial enamelling (b) see Fig. 20	Edge length of printed area — Tolerance range ⩽ 1000 mm — ± 2.0 mm ⩽ 3000 mm — ± 3.0 mm > 3000 mm — ± 4.0 mm
Design geometry (c) (d) see Fig. 20	Depending on size Edge length of printed area — Tolerance range ⩽ 30 mm — ± 0.8 mm ⩽ 100 mm — ± 1.0 mm ⩽ 500 mm — ± 1.2 mm ⩽ 1000 mm — ± 2.0 mm ⩽ 2000 mm — ± 2.5 mm ⩽ 3000 mm — ± 3.0 mm > 3000 mm — ± 4.0 mm
Colour deviations	The colours are assessed through the glass (enamel paint on position 2). Colour deviations in the range of ΔE ⩽ 5 (float) or ΔE ⩽ 4 (low iron glass) with the same glass thickness are permissible (see also Chapter 5.1.4).

* Defects of ⩽ 0.5 mm ("starry sky" or "pinholes" = very small defects in the enamel) are permissible and generally not taken into account. Repairs to defects using enamel paint before the tempering process or with organic paint after the tempering process are permissible.
However, organic varnish may not be used in the vicinity of the edge-seal of an insulating glass unit.
** In fine designs (grid pattern with partial areas of less than 5 mm), a so-called moiré effect can occur. For this reason, consultation with the manufacturer is necessary.
*** The positional tolerance of the enamel is to be measured from the reference point.

Table 15: Defect-types/tolerances for enamelled glass

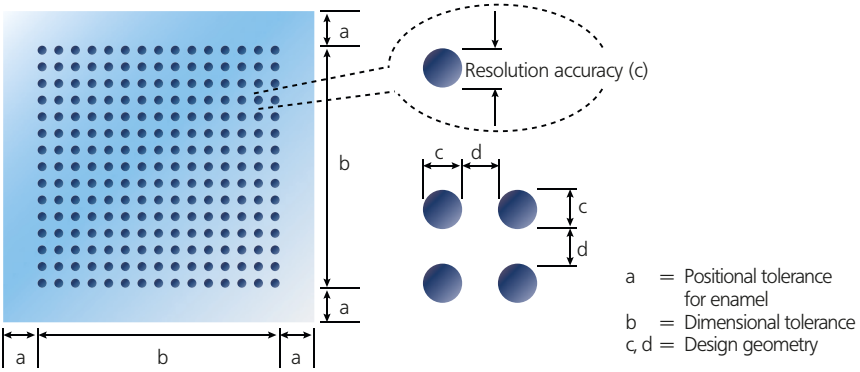


Fig. 20: Positional and design tolerances for printed glazing units

With regard to geometric figures or so-called shadow masks with a size below 3 mm or progressions from 0 – 100 %, the following remarks apply:

- If dots, lines or figures of this size are lined up at short intervals, the human eye reacts very sensitively.
- Tolerances in the geometry or spacing in the tenth of a millimetre range stand out as major deviations.
- In any case, these applications have to be checked for feasibility with the manufacturer. The production of a 1:1 sample is recommended.

5.1.4 Assessing the Colour Impression

Colour deviations cannot generally be ruled out, as they can be caused by several unavoidable influences.

Due to the influences named below, there might be a recognizable colour difference between two enamelled glass panes under specific light and viewing conditions, which the observer might assess as being "disturbing" or "not disturbing" on a very subjective basis.

5.1.4.1 Type of the Basic Glass and Influence of the Colour

The natural colour of the glass, which depends substantially on the glass thickness and the glass type (e.g. tinted glass, low-iron glass etc.), leads to a changed colour impression of the enamelling (enamelling on position 2). Additionally, different coatings can be added to this glass, such as solar control coatings (increase of the surface's light reflection) or reflection-reducing coatings, or the glass can be slightly embossed, e.g. structured glass. Colour deviations in the enamelling cannot be ruled out, due to fluctuations in paint manufacture and in the baking process.

5.1.4.2 Type of Light with which the Object is Viewed

The light conditions are continuously changing depending on the season, the time of day and the prevailing weather. This means that the spectral colours of the light that impinge via the various media (air, first surface, glass body) on the paint are present to a varying degree in the visible spectrum range (380 nm – 780 nm).

The first surface already reflects a part of the impinging light, more or less depending onthe angle of incidence. The "spectral colours" impinging on the paint are partially reflected or absorbed respectively by the paint (pigments). As a result, the colour has a differing appearance depending on the light source, on the position from which it is viewed and on the background.

5.1.4.3 Observer or Type of View

The reactions of the human eye to various colours are very different. While a very minor colour difference in shades of blue is clearly perceived, colour differences in shades of green are perceived less clearly.

Tolerances for colour identicality in prints on glass should be selected so that an observer can barely detect any colourdeviations under normal conditions. There is no standard stipulating this.

The tolerances represent a compromise between productivity and the requirement for a good visual impression of the insulating glass units for a building with a normal installation situation.

In view of the variation in natural light, the position of the observer in respect of viewing angle and distance, the ambient colour, the colour neutrality and the degree of reflection by the surface, the tolerance values may only be used as a general guide.

All the circumstances should be individually considered at the location and for the appropriate building – in particular the building in its specific surroundings.

Colours are presented objectively for a production check using the CIE L*a*b* system, with the standardized reference light type D65 and a viewing angle of 10° being taken as the basis.

The targeted position in the a, b colour coordinate system, and also the brightness characterized by the letter L, are subject to minor production-related fluctuations.

If the customer requires an objective evaluation standard for the colour coordinates, the procedure must be agreed upon with the manufacturer beforehand.

The general course of action is defined below:

- Provision of samples for one or more paints
- Selection of one or more paints. Stipulation of tolerances for each paint in consultation with the customer. Measurement values taken as the basis must be determined with glass-specific colour measuring equipment and under identical conditions (identical colour system, identical light type, identical geometry, same person viewing). Feasibility check by the supplier with regard to compliance with the specified tolerance (volume of order, availability of raw materials etc.)
- Manufacture of a 1:1 production sample and approval by the customer
- Production to order within the specified tolerances
- The purchase order for large quantities of an identical paint for one order should be placed once only, and not in sub-purchase orders.

5.1.5 Other Relevant Information

The other properties of the products can be found in the national regulations of building inspection authorities and in the valid standards, in particular:

EN 12150
EN 1863
EN 14179
EN 14449

- Enamelled and printed glass with non-organic colours can only be manufactured as thermally-toughened safety glass (TSG, TSG-H), or heat-strengthened glass (HSG).
- Subsequent processing of the glass, regardless of type, will affect the characteristics of the product perhaps substantially and is not permissible.
- Enamelled glazing units can be used as monolithic panes, or can be further processed into LSG or IGU. The specified identification of the sheets is in accordance with standards.
- Enamelled sheets can corrode under the effects of moisture and must therefore be protected from moisture during both transport and storage.

5.2 Enamelled and Printed Glazing: Resistance to Weather

The degree to which enamelled and printed glazing is resistant to weather is significantly influenced by environmental conditions (e.g. whether it is installed in an urban area of high population density or near the sea).

Depending on weather conditions and air pollution through such aggressive substances as SO_2, NO_2, Cl and flue dust, it can happen that glass surfaces and glass-enamel surfaces begin to become relatively unsightly after only a few months (paint surface's loss of gloss).

Installation in damp areas, such as showers or swimming pools, is refused. Due to permanent exposure to an acidic medium, a rapid attack of the ceramic paint on the glass surface is to be expected.

6 Laminated Glass and Laminated Safety Glass

The requirements regarding quality apply to flat laminated glass and flat laminated safety glass in building as per EN 14449.

The following basic products are used in the manufacture of LSG:

- Float glass: EN 572 Part 2
- Drawn sheet glass: EN 572 Part 4
- Patterned glass: EN 572 Part 5
- TSG: EN 12150 Part 1
- HSG: EN 1863 Part 1
- Other sheet glasses

The glass can be:
- Colourless or coloured,
- Transparent, translucent, opaque or opalescent,
- Coated or enamelled,
- Surface-treated, e.g. sand-blasted or etched.

The interlayers, e.g. polyvinyl buteral (PVB) interlayers, can be:
- Colourless or coloured,
- Transparent, translucent, or opaque.

6.1 Nominal Thicknesses

6.1.1 Thickness Tolerance

The dimensional tolerances for the thickness of laminated glass must not exceed the sum of the dimensional tolerances of the individual glass panes as defined in the basic-glass-unit product standards (e.g. EN 572-2).

If the total thickness of the interlayer is $\leqslant$ 2 mm, there applies an additional maximum dimensional tolerance of $\pm$ 0.1 mm. In the case where the manufacturing process necessitates additional layers of interlayer there is to be taken into account for interlayers of $>$ 2 mm a maximum dimensional tolerance of $\pm$ 0.2 mm.

Nominal thickness for standard PVB interlayer: 0.38 mm and 0.76 mm. The nominal thicknesses of other interlayers may deviate from these figures (e.g. sound-control interlayers with 0.5 mm or SentryGlas® with 0.89 mm).

Example:
A laminated glazing unit, manufactured from two panes of float glass with a nominal thickness of 3 mm and an interlayer of 0.5 mm. The maximum dimensional tolerance for float glass with a nominal thickness of 3 mm is $\pm$ 0.2 mm; the maximum dimensional tolerance for the interlayer is $\pm$ 0.1 mm. Therefore, the nominal thickness amounts to 6.5 mm and the maximum dimensional tolerance to $\pm$ 0.5 mm.

6.1.2 Measuring of Thickness

The thickness of the pane is to be calculated as the mean value of all measurements carried out at the middle points of all its sides. The measurements are to be carried out assuming a measurement-uncertainty of 0.01 mm, and the mean value is then to be rounded up or down to the nearest 0.1 of a mm.

The individual measurements, rounded up or down to the nearest 0.1 of a mm, must also lie within the maximum dimensional tolerance.

In the case of laminated glass which encloses patterned glass, the measurements must be carried out using a thickness-measuring device equipped with a measuring plate.

6.2 Maximum Dimensional Tolerances for Width and Length

The glass pane must not be larger than the nominal dimension plus the uppermost maximum dimensional tolerance (t) or smaller than the nominal dimension minus the lowest maximum dimensional tolerance (t), see Fig. 21.

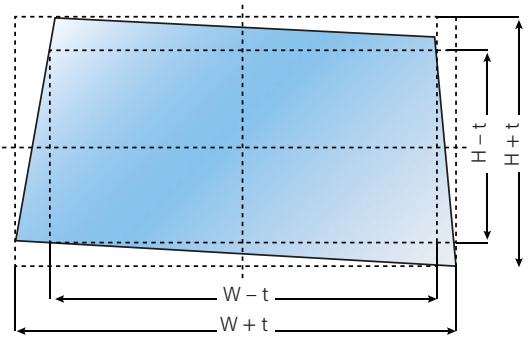


Fig. 21: Maximum dimensional tolerances for dimensions of rectangular panes

The squareness of rectangular glass panes is indicated by reference to the difference between the diagonals. The difference between the two diagonals must not be greater than the maximum dimensional tolerance for this difference between diagonals as specified in Table 16.
Insofar as any component part of the laminated glass is a thermally-toughened glass, Table 17 must be taken into account.

	Maximum Dimensional Tolerances (t) [mm] for Width (W) or Length (H) from Non-Thermally-Toughened Glass						
Manner of Edge Execution	**Cut and Arrissed**			**Ground-to-Size, Smooth-Ground or Polished and Bevelled**			**Difference between Diagonals (v) [mm]**
Thickness of Element (mm) Final-Cut Sizes	**⩽ 6 mm**	**8 mm to 12 mm**	**> 12 mm**	**⩽ 26**	**⩽ 40**	**> 40**	
⩽ 2000	± 1.0	± 1.0	± 2.0	+ 1.0 – 2.0			⩽ 1.0
2000 mm to 3500 mm	± 2.0	± 2.0	± 3.0	+ 1.0 – 3.0	+ 1.0 – 3.0	+ 1.0 - 3.0	⩽ 2.0
3500 mm to 5000 mm	–	± 3.0					⩽ 3.0
> 5000 mm	–	± 4.0	± 4.0	–	–	–	⩽ 4.0

Table 16: Maximum dimensional tolerances for width and length of LG and LSG glazing units made from non-thermally-toughened glass (information drawn from EN ISO 12 543 part 5)

	Maximum Dimensional Tolerances (t) [mm] for Width (W) or Length (H) from Thermally-Toughened Glass				
Manner of Edge Execution	**Arrissed**			**Ground-to-Size, Smooth-Ground or Polished**	**Difference between Diagonals (v) [mm]**
Thickness of Element (mm) Final-Cut Sizes	**⩽ 6 mm**	**8 mm to 12 mm**	**>12 mm**	**General**	
⩽ 2000	± 1.0	± 1.0	± 2.0	± 2.0	⩽ 1.0
2000 mm to 3500 mm	± 2.0	± 2.0	± 3.0		⩽ 2.0
3500 mm to 5000 mm	–	± 3.0		+ 3.0 – 2.0	⩽ 3.0
> 5000 mm	–	± 4.0	± 4.0	+ 4.0 – 2.0	⩽ 4.0

Table 17: Maximum dimensional tolerances for width and length of LG and LSG glazing units made from thermally-toughened glass (information drawn from EN ISO 12 543 part 5)

The maximum dimensional tolerances listed above do not apply to fire-resistant laminated glass and fire-resistant laminated safety glass.

In these cases the maximum dimensional tolerances must be set in consultation with AGC INTERPANE.

6.3 Displacement Tolerance

For production-technological reasons the individual panes may become misaligned with one another. Every such displacement must remain within the maximum dimensional tolerances listed in Tables 16 and 17.

6.3.1 LG and LSG Made from Non-Thermally-Toughened Glass

Displacement tolerances apply only for glazing units with cut or arrissed edges and lie within the tolerances for width and length (Table 16).

6.3.2 LG and LSG Made from Thermally-Toughened Glass

Displacement tolerances (d) apply for all types of edge-working possible in the case of these products and are listed in the following table. Width (W) and length (H) must be considered separately from one another and must lie within the maximum dimensional tolerances (t) which have, according to Table 17, to be complied with.

Nominal Dimensions (W) or (H) [mm]	Maximum Permissible Displacement (d) [mm]
W, H ≤ 1000	2.0
1000 < W, H ≤ 2000	3.0
2000 < W, H ≤ 4000	4.0
W, H > 4000	6.0

Table 18: Maximum permissible displacement (d)

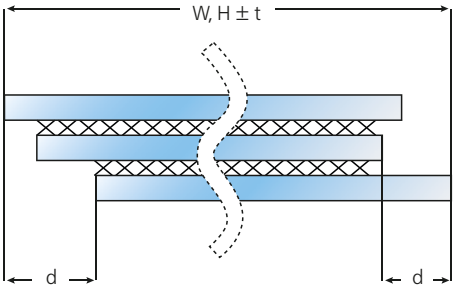


Fig. 22: Displacement

6.4 Marking

LG and LSG final-cut sizes can be marked. Multiple markings are possible. The marking must be legible and permanent. Whether a marking is required by the customer or not must be stated at the time of the placing of the order.

In the case of LSG combinations consisting of TSG, TSG with Heat-Soak Test or HSG, at least one of the two thermally-toughened or heat-strengthened panes must be provided with a stamp or seal to this effect.

6.5 Bullet- and Explosion-Resistant Glazing

Laminated safety glass with bullet- and explosion-resistant properties must be marked in accordance with AVCP System 1.

6.6 Special Tolerances for LG and LSG Construction Glass Units Made from HSG

By "construction glass" is meant: products for the application of which there may be required stricter tolerances with regard to the chosen construction.

For LG and LSG construction glass units made from HSG the following special maximum dimensional tolerances may be complied with.

	Maximum Dimensional Tolerances (t) [mm] for Width (W) or Length (H)			
Product	**LG-LSG 12/2 made from 2 x HSG**	**LG-LSG 16/2 made from 2 x HSG**	**LG-LSG 20/2 made from 2 x HSG**	**LG-LSG 24/2 made from 2 x HSG**
Characteristics Width or Length				
⩽ 2000 mm	± 2.0			
⩽ 3000 mm	± 2.0			
⩽ 4000 mm	± 2.5			
⩽ 5000 mm	± 3.0			
Position of Drill-Holes Vis-à-vis One Another	± 1.0			
Offset at Edge and Drill-Hole	1.0			
Edge quality	Ground-to-Size, Smooth-Ground, Polished			
Pane shape	Rectangular Pane-Shapes			
Minimum Dimensions	300 mm x 450 mm			
Maximum Dimensions	2600 mm x 4200 mm			

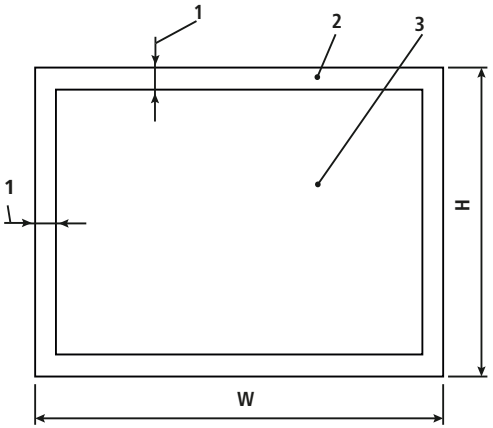
Table 19: Special maximum dimensional tolerances for LG and LSG construction glass units made from HSG

6.7 Assessment of the Visual Quality of LG and LSG

The basis for the assessment of visual quality here is EN ISO 12543-6: "Appearance".

As a supplement to this there also applies chapter 9 the "Guideline to Assess the Visual Quality of Glass in Buildings". Inspections are to be carried out according to the stipulations of this latter guideline.

The description of those areas of the fully-processed LG or LSG which are to be assessed is to be carried out in accordance with the stipulations of EN ISO 12543-6.



Key
1 Width of Edge Area
2 Edge Area
3 Vision Area
W Width of Pane
H Height of Pane

Fig 23: Definition of areas in LG and LSG

6.7.1 Defects in the Edge Area in the Case of Framed Glass Edges

The edge area must be inspected according to the stipulations of the "Guideline to Assess the Visual Quality of Glass in Buildings" and must be found to contain no defects which measure more than 5 mm in diameter or 5% of the edge area.

For pane sizes with an area smaller than 5 m^2 the width of the edge area amounts to 15 mm. For panes with an area greater than 5 m^2 the width of the edge area is increased to 20 mm.

6.7.2 Laminated Glass with Exposed Glass Edge

For areas of application involving an exposed glass edge, laminated glass or laminated safety glass may only be used with

- arrissed edge,
- smooth-ground edge,
- polished edge, or
- bevelled edge.

The required edge-quality is to be stated at the time of placing the order. The technical conditions of manufacture are such that certain negative visual effects on the edge on which the pane rests on the ground, along with interlayer residues in the arris area and interlayer overhangs in LSG final-cut sizes, are unavoidable. In the case of outdoor glazing, in which the interlayer finds itself permanently exposed to humidity at the glass edge, it is possible that certain visual alterations may occur within an edge zone of approximately 15 mm. These alterations are permissible. So as to prevent these optical/visual alterations, the construction should be carried out in such a manner that the structure itself, or the provision of an adequate system of ventilation, brings it about that permanent exposure of the film on the glass edge to moisture and dampness is avoided. As regards canopies, for example, this can be ensured by means of a laminated safety glass finished with stepped edges.

A necessary precondition for preserving the properties of the laminated glass throughout its entire service life is a proper and professional cleaning of the glass edges at appropriate intervals of time.

In the case of final-cut-size production of LSG, interlayer overhangs may be present particularly on the standing edge.

6.7.3 Punctual Defects in the Visible Area

When inspected in accordance with the stipulations of the "Guideline to Assess the Visual Quality of Glass in Buildings" the permissibility of punctual defects shall be dependent upon:

- the size of the defect;
- the frequency of the defect's occurrence;
- the size of the pane;
- the number of panes forming components of the laminated glass unit.

The number of permissible defects in a single pane must match the details given in Table 20. Defects that are smaller than 0.5 mm need not be taken into account.

Defects that are larger than 3 mm are not permissible.

Please note: Punctual defects in laminated glass are in each case permissible or impermissible quite regardless of the thickness of the individual glazing unit concerned.

Size of Defect (d) [mm]		> 0.5 < d ⩽ 1.0	1 < d ⩽ 3			
Size of Pane (A) [m^2]		For All Sizes	A ⩽ 1	1 < A ⩽ 2	2 < A ⩽ 8	A > 8
Number of permissible defects	2-paned	No limit, but a cluster of defects must not arise	1	2	1 / m^2	1.2 / m^2
	3-paned		2	3	1.5 / m^2	1.8 / m^2
	4-paned		3	4	2 / m^2	2.4 / m^2
	⩾ 5-paned		4	5	2.5 / m^2	3 / m^2

NOTE: A cluster of defects is said to arise when four or more defects are located at a distance of < 200 mm from one another. This tolerated distance is reduced to 180 mm in the case of laminated glass composed of three panes, to 150 mm in the case of laminated glass composed of four, and to 100 mm in the case of laminated glass composed of five or more panes.

Table 20: Permissible punctual defects in LG and LSG

6.7.4 Linear Defects in the Visible Area

When inspected in accordance with the stipulations of the "Guideline to Assess the Visual Quality of Glass in Buildings" linear defects must comply with the details given in Table 26.

6.7.5 Coloured Interlayers

Coloured interlayers and matt PVB interlayers can, over time, as a result of weather and other environmental influences (e.g. ultra-violet radiation), lose some of their intensity of colour. It is possible, therefore, that there may become noticeable certain differences of colour between already-installed glazing units and subsequent deliveries of glass of the same type. This represents no ground for any complaint about the product.

6.7.6 LSG with Stepped-Edges

As a general rule, in all LSG glazing units with stepped-edges the interlayer overhangs are cut off in the stepped area. In the case of double-paned LSG units this is a generally practicable procedure and can be agreed upon.

In LSG glazing units which consist of three or more glass panes, and in which the middle pane or panes is/are in a recessed position vis-à-vis the outer ones, the interlayer is cut off in the case where the step width is equal to the thickness of the glass of the single middle pane or where the step depth is equal to the combined glass-thicknesses of the several middle panes. In the case of all other "step" sizes, specific agreement must be come to about the interlayer cut-off.

Even in cases where the removal of the interlayer is feasible as described above and as shown in Fig. 24, conditions of production are nonetheless such that the presence of interlayer residues is never completely avoidable. This presence of residues, then, shall represent no legitimate grounds for complaints about the product. In the case of edge-steppings that have been executed in ways divergent from that described above, interlayer residues will not be able to be removed from the stepped-edge area. This represents no ground for any complaint about the product.

Conditions of production are such that interlayer residues may be present at the glass edges. These residues may also be subject to deformation by support points along the edge on which the pane stands on the ground. This too shall represent no legitimate grounds for complaints about the product.

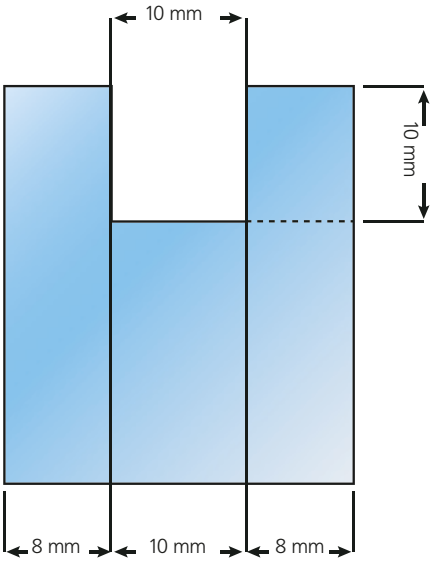


Fig. 24: LSG with stepped-edge cut-back

7 Coated Glass as per EN 1096

7.1 Homogeneity of Colour

(Taken, with minor amendments, from "Code of Practice", January 2005 Edition, GEPVP – European Association of Flat Glass Manufacturers).

7.1.1 Applicability

This Code of Practice describes a method for allowing an objective evaluation of the colour of coated glass, as defined in EN 1096-1, when used in facades.

It provides a method for measuring colour differences within the same glass pane and between two adjacent panes in the same façade. Specific requirements are given for coated glass, dependent upon its light transmittance and reflectance.

Guidance is also provided on angle dependency, reflection from the interior and transmission.

7.1.2 Introduction

It is known that facades incorporating coated glass can present different shades of the same colour, an effect that may be amplified when the facade is viewed from different angles. Possible causes of differences in colour here include slight variations in the colour of the substrate onto which the coating is applied and a slight variation in the thickness of the coating itself. Furthermore, in the case of highly selective coatings even a very slight variation in thickness can create a difference in colour, visible due to the high sensitivity of the human eye.

The purpose of this document is to avoid any subjective approaches that may have been used in the past. Section 7.1.3 describes in detail the procedure for in-situ measurement of the colour of coated glass in facades.

All measured values concern the finished glass product as installed in the façade and not the single components. Only products with the same configuration (e. g. thickness, coating type, etc.) shall be compared.

7.1.3 'In Situ' Colour Measurement

7.1.3.1 General

The following paragraphs explain the procedures used on site for measuring the colour of the glass product.

Chapter 7.1.5 Annex A contains information on the perception, quantification and measurement of colour.

7.1.3.2 Colour Differences Within the Same Glass Pane

For colour differences within the same glass pane, the parameters L*, a* and b* shall be measured using a portable colorimeter. The measurements shall be undertaken at a minimum of three points in each zone in which a colour-difference has been noted. An example is shown in Figure 25.

For final-cut sizes and thermally-toughened glazing units, measurements shall not be undertaken at any point within 10 cm of an edge. This is due to the potential for the colour near to the edge to differ slightly from the colour in the centre. Furthermore, the measurements may be affected by the proximity to the frame of the insulating glass unit.

The values ΔL*, Δa* and Δb* shall be calculated based on the difference between the average values for each zone, in accordance with equations (1), (2) and (3), respectively.

$\Delta L^* = L^*\text{ (Zone 2)} - L^*\text{ (Zone 1)}$ (1)
$\Delta a^* = a^*\text{ (Zone 2)} - a^*\text{ (Zone 1)}$ (2)
$\Delta b^* = b^*\text{ (Zone 2)} - b^*\text{ (Zone 1)}$ (3)

The values ΔL*, Δa* and Δb* must meet the requirements given in section 7.1.3.4.

The value ΔE* shall not be determined (see section 7.1.5.2 A.2).

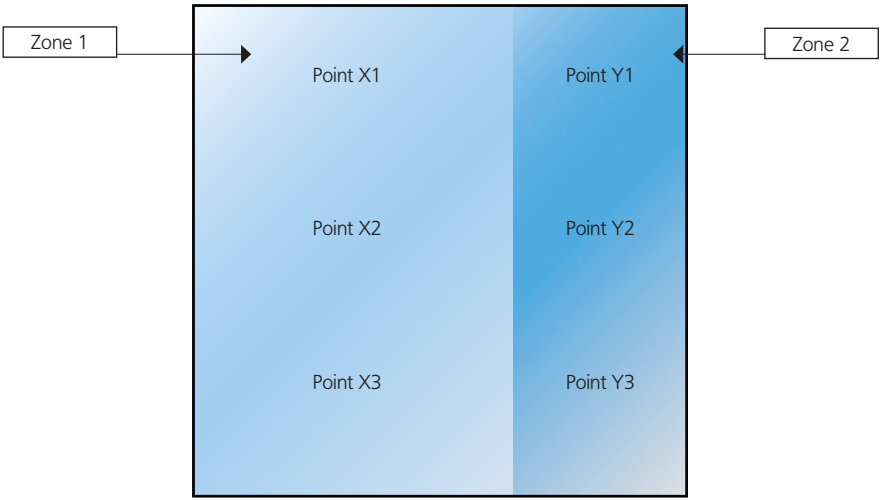


Fig. 25: Example of measurements undertaken at a minimum of three points in each area displaying a colour difference

7.1.3.3 Colour Differences Between Two Adjacent Panes in the Same Façade

For colour differences between two adjacent panes, the parameters L*, a* and b* shall be measured with a portable colorimeter. For each panedisplaying a colour difference, the measurements shall be undertaken at a minimum of three points (i.e. along a diagonal). An example is shown in Figure 26.

Note 1. The reference pane may be compared with any of the four adjacent panes – above, below, to the left, or right.
Note 2. The comparison should only be undertaken for panes of the same glass type, composition and background conditions and situated on the same elevation.

The mean values of L*, a* and b* shall be determined for each pane. Table 21 shows a detailed example.

Pane Y Y = 1,2,3, …	**L***	**a***	**b***
Measuring Point 1	L^*_{Y1}	a^*_{Y1}	b^*_{Y1}
Measuring Point 2	L^*_{Y2}	a^*_{Y2}	b^*_{Y2}
Measuring Point 3	L^*_{Y3}	a^*_{Y3}	b^*_{Y3}
Mean Value	$L^*_{glass\ Y} = (L^*_{Y1} + L^*_{Y2} + L^*_{Y3})/3$	$a^*_{glass\ Y} = (a^*_{Y1} + a^*_{Y2} + a^*_{Y3})/3$	$b^*_{glass\ Y} = (b^*_{Y1} + b^*_{Y2} + b^*_{Y3})/3$

Table 21: Example of how to determine the mean values of L, a* and b* for a single pane (e.g. Y)*

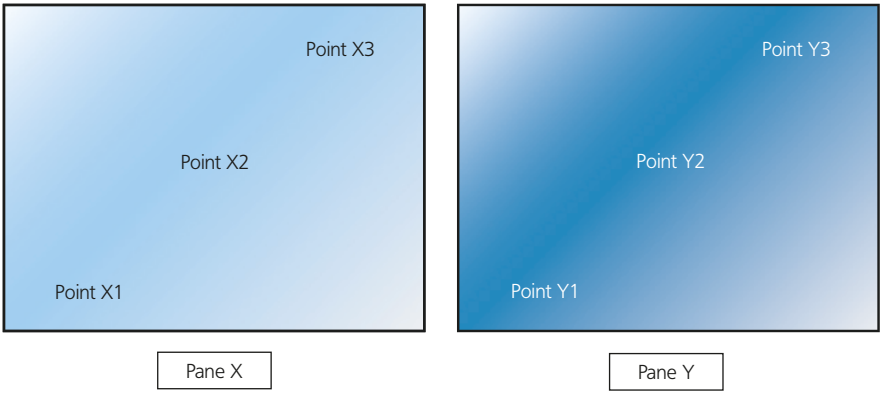


Fig. 26: Example of measurements undertaken at a minimum of three points for each pane displaying a colour difference

The values ΔL*,Δa* and Δb* shall be calculated based on the difference between the values for each pane, in accordance with equations (4), (5) and (6), respectively.

$$\Delta L^* = L^*_{(Pane\ Y)} - L^*_{(Pane\ X)} \quad (4)$$
$$\Delta a^* = a^*_{(Pane\ Y)} - a^*_{(Pane\ X)} \quad (5)$$
$$\Delta b^* = b^*_{(Pane\ Y)} - b^*_{(Pane\ X)} \quad (6)$$

where X is the reference pane.

7.1.3.4 Requirements Regarding Colour

The values ΔL*, Δa* and Δb* determined in accordance with Sections 7.1.3.2 and 7.1.3.3 shall meet the requirements given in Table 22.

The values ΔL*, Δa* and Δb* must meet the requirements given in section 7.1.3.4.

The value ΔE* shall not be determined (see section 7.1.5.2 A.2).

ΔL*	4.0
Δa*	3.0
Δb*	3.0

Table 22: Requirements regarding colour

7.1.4 Other Considerations

7.1.4.1 Dependence of Colour on Angle of Observation

The colour of solar-control glazing units, particularly those with a high degree of selectivity, varies with the angle of observation. These variations and deviations can only be measured in a laboratory on small pane-samples and should not be undertaken in situ.

Consequently, the homogeneity of colour of a façade is to be assessed only by a visual observation carried out at an angle of no more than 45°. This is illustrated in Figure 27.

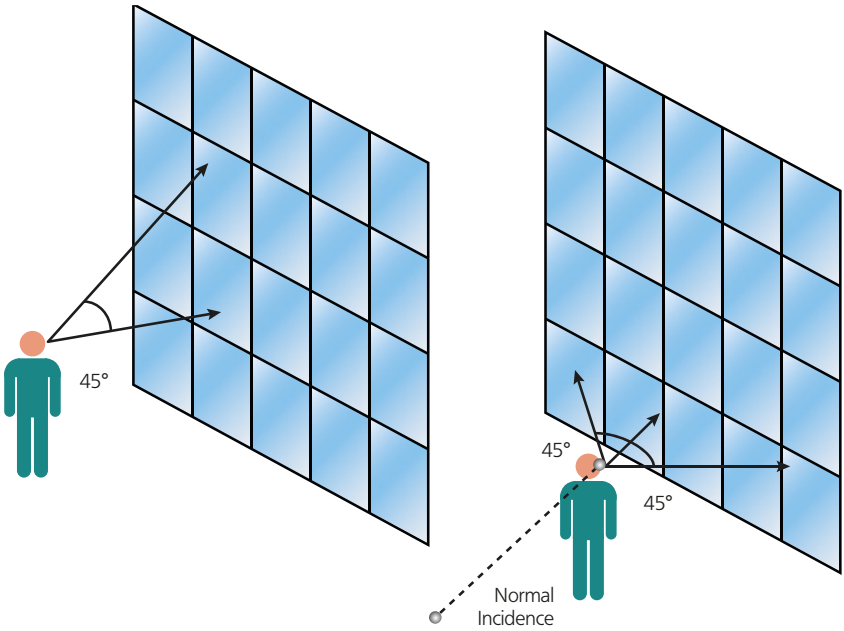


Fig. 27: Diagram illustrating the restrictions on angle for assessing the homogeneity of the colour

7.1.4.2 Colour in Reflectance from the Interior

Differences in colour when viewed from the interior are not considered a defect.

7.1.4.3 Colour in Transmittance

Although colour differences may also be observed in transmittance, they cannot be measured in situ as no device is available for this. This colour can only be assessed by visual observation.

7.1.5 Annex A (Informative):

Perception, Quantification and Measurement of Colour

7.1.5.1 A.1 The Perception of Colour

The perception of colour can be very subjective and linked to the impressions and perceptions of the individual,as the sensitivity of the human eye is very much an individual characteristic.

Furthermore, a variety of conditions affect how a colour looks when observing the façade of a building from the outside, including:

- luminosity (e.g. a dark or overcast sky might reveal colour differences not observed under direct sunlight)
- distance and angle of observation
- type and colour of mullions and transoms used in the facade
- distance between two adjacent glass panes
- the eye of the observer
- internal conditions (e.g. the absence of lighting in the building (dark background) may increase the perception of colour differences)
- external conditions (e.g. presence of other buildings that may be reflected by the glass)

Care should be taken to avoid observing the façade under conditions which are not representative for a building 'in use', or else due account should be taken of these factors during the assessment.

7.1.5.2 A.2 Quantification of Colour

As noted at 7.1.5.1 A.1, a visual observation of colour invariably has a subjective element. Therefore, it is very important to be able to quantify the colour of a façade in order to develop an approach independent of this subjectivity. Various methods have been devised in the past for quantifying colour and expressing it numerically with the aim of making this task easier and the results more accurate.

The method used by GEPVP is the L*a*b* colour-space method, defined by the CIE in 1976. Since the colour of an object is dependent upon the light source, the standard illuminant adopted by GEPVP is D65 (representing average daylight). The angle of observation used is 10°.

The L*a*b* colour space (also referred to as CIELAB) is one of the most popular colour spaces for measuring object colour and is widely used in a variety of fields. It provides a procedure for evaluating uniform colour differences in relation to visual differences and, moreover, it enables colour to be quantified.

This colorimetric system can be visualised by a three-dimensional colour space (see Fig. 28), wherein every colour is represented by a set of 3 co-ordinates: L*, a* and b*, where L* indicates the brightness and a* and b* the chromaticity coordinates. Positive values of a* indicate a position more in the red direction, and negative values one that is more in the green direction, while positive values of b* indicate a position more in the yellow direction and negative values one that is more in the blue direction. The centre of the space is achromatic (i.e. neutral).

Note. The parameters L, a* and b* can be used either for quantifying the aesthetics of a façade observed from the outside (in reflectance) or for characterizing the properties of light transmittance through a glass pane.*

The differences of colour can be quantified using tolerances on the parameters L*, a* and b*, which are noted as ΔL*, Δa* and Δb* respectively, and calculated as in the following equations:

$$\Delta L^* = L^*_{\text{Object 2}} - L^*_{\text{Object 1}}$$
$$\Delta a^* = a^*_{\text{Object 2}} - a^*_{\text{Object 1}}$$
$$\Delta b^* = b^*_{\text{Object 2}} - b^*_{\text{Object 1}}$$

In the field of colour measurement, it is common to refer to a ΔE* value, combining ΔL*, Δa* and Δb* values. It is the GEPVP position that this ΔE* value is not accurate enough in terms of glass colour evaluation. Therefore, only ΔL*, Δa* and Δb* values shall be considered.

Fig 28: Representation of the three-dimensional colour space

7.1.5.3 A.3 Measurement of Colour

The parameters L*, a* and b* can be measured not only by spectrophotometers used in the laboratory but also by colorimeters or spectro-colorimeters. These colorimeters can be portable instruments, suitable for use on site as instructed by the manufacturer. Whether used in a laboratory or on site, these devices have a similar sensitivity to that of the human eye.

To ensure that measurement conditions are always the same in each case, the measurements should always be undertaken with the same light source and illumination method, regardless of whether it is day or night, indoors or outdoors. This ensures that simple and accurate measurements are undertaken which provide numerical values that are independent of external factors (as listed in 7.1.5.1 A.1).

Note. Portable colorimeters used on site are limited to the measurement of colour in reflectance, with an angle of observation corresponding to the vertical. Laboratory instruments, on the other hand, can measure the characteristics of glass panes in both transmittance and reflectance from various different angles of observation.

Normative References:

EN 1096-1: Glass in Building – Coated glass – Part 1: Definitions and classification
CIE Publication No. 15: 2004 – Colorimetry

7.2 Visual Assessment

Assessment of defects is to be carried out according to EN 1096 Part 1.

Regulation	**Single glazing, coated**	
	EN 1096-1	
Conditions of Inspection	From at least 3 m distance; without artificial lighting; normal angle of view; reflectance from outside; transmittance from inside; length of inspection: max. 20 s	
Zone	Main Zone	Edge Zone (5 % of Width or Hight)
Inclusions, Bubbles, Spots, Stains etc.	max. 1 per m^2: > 2 mm ≤ 3 mm	
	Higher concentrations not permitted	Higher concentrations permitted provided not in "through-view" area
Scratches or Extended Linear Defects	> 75 mm not permitted	> 75 mm permitted if distance from one another > 50 mm
	≤ 75 mm tolerated, provided density in particular areas does not constitute a disturbance of vision	
Hairline Scratches	See "scratches", since not defined	

Table 23: Assessment of visual quality of coated glass according to EN 1096

8. Insulating Glass Units (IGU) as per EN 1279

Supplementary references here are the "Guideline to Assess the Visual Quality of Glass in Buildings" and the AGC INTERPANE Glazing Guidelines, Handbook Building with Glass".

8.1 Maximum Dimensional Tolerance / Misalignment

As maximum dimensional tolerances there apply the tolerances listed below, with the addition of a possible offset measure. Please note that the maximum dimensional tolerances for the intermediate products for insulating glass may, where necessary, need to be adjusted vis-à-vis the tolerances in the above-named chapters.

Description of Glass	Maximum Dimensional Tolerance t [mm]	Misalignment d [mm]
All Pane Thicknesses ⩽ 6 mm and (W and H) ⩽ 2000 mm	± 2.0	⩽ 2.0
6 mm < Thickest Pane ⩽ 12 mm, or 2000 mm < (W or H) ⩽ 3500 mm	± 3.0	⩽ 3.0
Pane Thickness ⩽ 12 mm and 3500 mm < (W or H) ⩽ 5000 mm	± 4.0	⩽ 4.0
Pane Thickness > 12 mm or (W or H) > 5000 mm	± 5.0	⩽ 5.0

Table 24: Maximum dimensional tolerances (t) in mm for IGU

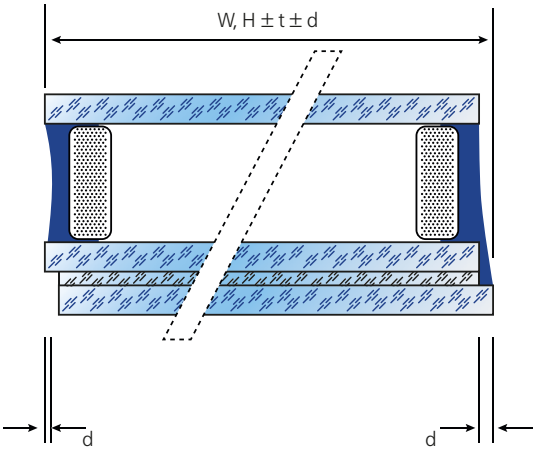


Fig. 29: Dimensional-/misalignment tolerance in double- and triple-glazed insulating glass, rectangular panes

For special formats (custom-modelled panes) tolerances are to be established on a case-by-case basis.

The bonding of insulating glass units into or onto frame systems is not part of the subject of the present chapter.

In the case of the building of design glass / patterned glass into the insulating glass unit, the orientation of the pattern should be set in relation to a single edge.

Maximum and minimum dimensions as well as maximum glass thicknesses and weights are to be coordinated with the respective AGC INTERPANE plant.

8.2 Edge Seal

The execution of the edge seal corresponds to the system specification "AGC INTERPANE Insulating Glass Units" as per EN 1279.

The uncovered area of the edge seal is to be assessed in accordance with the "Guideline to Assess the Visible Quality of Glass in Buildings" cited in Chapter 9 – specifically in accordance with 9.1.4.1.3 "Assessment of the Visible Area of the Insulating Glass Unit Edge Seal".

8.3 Thickness Tolerance at the Edge Seal

The actual thickness must be measured at every corner of the glazing unit and in the vicinity of the middle points of the edges between its outer glass surfaces. The measurements are to be taken to the precise 0.01 of a millimetre and are then to be rounded up or down the nearest 0.1 of a millimetre. The thickness data resulting from these measurements must not deviate from the nominal thickness stated by the manufacturer of the insulating glass units by more than the tolerances listed in the following table:

	Pane	IGU Thickness Tolerance*
Double-Glazing	Where All Panes Consist of Float Glass	± 1.0 mm
	Where One Pane is Laminated, Consists of Patterned Glass, or is Thermally Toughened	± 1.5 mm
Triple-Glazing	Where All Panes Consist of Float Glass	± 1.4 mm
	Where One Pane is Laminated, Consists of Patterned Glass, or is Thermally Toughened	+ 2.8 mm / -1.4 mm

* Where, in the case of float glass, a glazing component proves to have a nominal thickness of more than 12 mm or, in the case of laminated glass, proves to have a nominal thickness of 20 mm, the manufacturer of the IGU should be consulted.

Table 25: Thickness tolerances of insulating glass units as per EN 1279-1 (FprEN 1279-1:2016)

8.4 Edge Stripping

Depending on the coating system ("low-e coatings"), the coating is, as a rule, removed as far as possible, by grinding, in the edge-seal area of an insulating glass unit. This can result in traces of working or machining remaining visible, so that this area of the glass surface appears different from the non-stripped area. This also applies to the glass overhang in insulating glass with stepped edges (see chapter 8.8).

Contact between the butyl and the coating may give rise to an optically recognizable coloured line (a so-called "colour line"). Depending on the coating-type, this line will be red, green, blue etc. This arises due to the "interference coating system". A so-called "white line" may also emerge; i.e., there appears between the coating and the primary sealant a light-coloured band that is not itself coated. These effects can become visible where the insulating glass unit is installed without edge-seal covering.

In the case of a standard insulating glass unit, edge stripping measures, as a rule, 8 mm ± 2 mm.

8.5 Spacer Bars

Non-flexible, hollow-moulding spacer bars and flexible spacer bars are both used. In the case of the non-flexible, hollow-moulding spacer bars the corners can be bent, welded or joined. Depending on the manufacturing technique used, drill-holes for gas-filling may be visible in the spacer bar. Depending on the spacer-bar type, the colouring, and the manner of execution of the corners, differences in optical appearance can result.

According to EN 1279 no marking on the spacer-bar moulding is required. Should, however, further certifications come to apply (e.g. RAL/GMI, IGCC, CEKAL) it may become necessary to undertake some such special marking.

Details regarding parallel positioning and displacement of the spacer bars are listed in the "Guideline for Visual Assessment of Glass in Buildings" (Chapter 9).

8.6 Stepped Insulating Glass

The dimensional tolerances for the stepped-edge overhang in insulating-glass glazing are:

± 3 mm for a stepped-edge overhang of up to 100 mm and ± 4 mm for a stepped-edge overhang of between 100 mm and 250 mm.

8.7 Applying Silicone to Stepped Edges & Edge Quality with Single Panes and Insulating Glass Units (IGU)

(according to Customer Information n. 001_en)

8.7.1 Applying Silicone to Stepped Edges

The stepped edge of insulating glass units can be coated with silicone. As the silicone is applied manually (silicone passivation), it is no alternative for enameling such a stepped edge.

A small amount of reams or contaminated glass edges are therefore not avoidable. In addition, colour differences between the secondary sealant and the sealant used for passivation will occur.

The thickness of such a silicone coating may vary within the same surface. The absolute production tolerance is normally 4 mm.

Unless otherwise specified, the 2K-Silicone IG 25 HM+black from the company SIKA and the 2K-Silicone DC 3363 from the company Dow Corning are used. A subsequent processing to structural glazing constructions is possible with sealants or adhesives from the companies SIKA and Dow Corning. The products SG 500 or DC 993, which have corresponding approvals in accordance with European guidelines (EOTA guidelines), are recommended. As a general principle, the respective manufacturer of the silicone should be consulted in this case.

The stepped edge must be free from dust, dirt and grease before the subsequent processing of the IGU.

The manufacturer of the whole system (e.g. window, façade) must ensure that all materials that come into contact directly or indirectly with one another are in fact mutually compatible with one another. The proof of a possible adhesion on the stepped edge is also to be provided by him. The manufacturer is also responsible for requesting the necessary proofs of the individual manufacturers or test, if necessary.

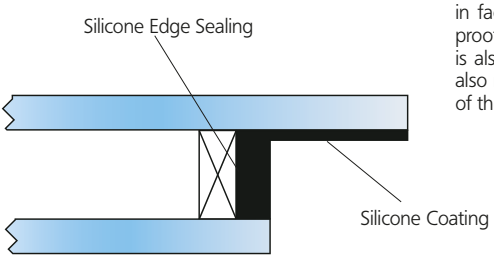


Fig. 30: Silicone application on stepped glass-edges

8.7.2 Edge Quality

With IGU it is possible that residues remain on the edges of the single panes due to the previous processing stages (e.g. sealant on the pane edges, coating residues with coatings of final cut sizes or similar).

This is to be taken into consideration if these surfaces are used for bonding.

Therefore, we recommend very meticulous examination of the bonding surfaces before subsequent processing or sealing on-site.

The edges must be free from dust, dirt and grease and must be cleaned before subsequent processing, if necessary. In addition, eventually existing coating residues must be eliminated. Please note the remarks given by the manufacturers of the sealants and adhesives.

8.8 Additional Inserts in the Edge Seal (Structural Glazing Application)

Additional inserts in the edge-seal (hereinafter called the "U-profiles") of insulating glass units (IGU) represent a special solution in façade construction. This type of glazing is, as a general rule, a structural-glazing (SG) application which must be assessed according to the stipulations of the ETAG 002 (European Technical Approval Guideline).

In the case, however, where, for example, it is planned to fit U-profiles only at two mutually facing edges of the pane and the other two edges are fastened in the manner prescribed by DIN 18008-2 for "linearly-supported glazing", it may be assumed that the glazing in question represents not a structural-glazing construction but rather a glazing construction mechanically supported on two sides. If, however, the two edges which are sustained by U-profiles are taken into account in structural-engineering calculations, the edge-seal must be sized accordingly.

The insulating glass units with U-profiles in the edge seal produced by the firm AGC INTERPANE do not represent a (fully tested) structural glazing system. They are functioning IGUs with additional inserts in the edge seal and these latter meet all requirements set by EN 1279-5.

8.8.1 Execution Using U-Profiles

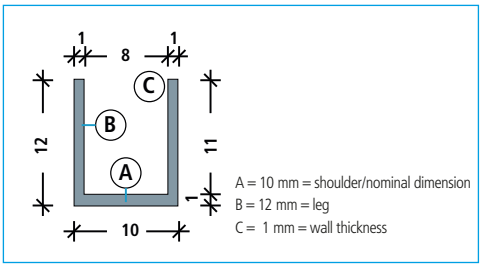
AGC INTERPANE recommends that short lengths of U-profiles, measuring between 100 mm and 200 mm in length, be employed. The maximum length of a U-profile should not exceed 1000 mm. The spacing between the U-profiles should then be $\geqslant$ 5 mm. The remaining support between the U-profiles is usually removed after setting.

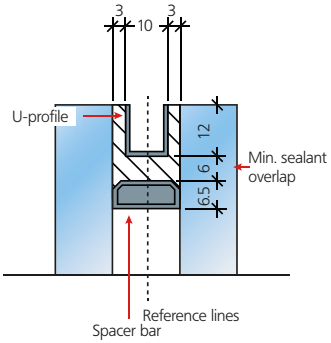
The minimum distance of the U-profiles to the corner area of the insulating glass units should be $\geqslant$ 100 mm. In individual cases, and after special consultation, a distance of 50 mm is also possible.

AGC INTERPANE generally recommends that, in the case of U-profiles mounted on the upper horizontal glass edge, the profile (which should be of a maximum length of 1000 mm) be placed on the outer edge of the glass, so as to ensure continuous drainage at the pane edges.

It should be noted that the lengths of the resulting residual mounting-pieces are rounded down to the nearest 10 mm. This has, in turn, an effect on the spacing between the U-profile (or residual part thereof) and the glass edge and will be adjusted and aligned by AGC INTERPANE using production-technological means.

The dimensions of the sealant overlap (silicone) between spacer bar and U-profile must be assumed to be the standard dimensions of at least 6 mm.





- Length U-profile **100 mm – 200 mm** acc. to indication
- Minimum distance between glass edge and U-profile **3 mm**
- Cavity at least **16 mm**
- Min. sealant overlap **6 mm**
- Tolerance positioning U-profile **± 2 mm** related to the **reference lines**
- Positional tolerance **± 5 mm**

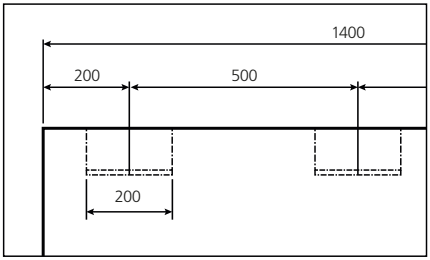


Fig. 31: Tolerances and model of execution for U-profiles

For every project there should be consultation with the INTERPANE Technical Advisory Service!

Further information can be found in the document Customer Information E-002.

There also apply here the AGC INTERPANE Glazing Guidelines.

The competent sales advisor must be contacted, prior to the placing of the order, regarding the exact positioning and manner of execution of the U-profiles. Only once written confirmation has been given of the agreed manner of execution shall the order in question count as having been accepted by AGC INTERPANE.

9 Visual Assessment

9.1 Guidelines to Assess the Visual Quality of Glass in Buildings

This guideline was prepared by:

- Technical Advisory Board of the Institut des Glaserhandwerks für Verglasungstechnik und Fensterbau (Institute of the Glazing Trade for Glazing Technology and Window Manufacture), Hadamar

and by

- the Technical Committee of the Bundesverband Flachglas (Federal Association for Architectural Glazing), Troisdorf

Last updated: May 2009

9.1.1 Scope

This guideline applies to assessment of the visible quality of architectural glass units (used in building shells and in finishing of buildings/structures). The assessment is made according to the following testing principles with the help of the allowable discrepancies specified in the table at the end of Section 9.1.3.

The glass surfaces which remain visible after installation are the subject of assessment. Glass products constructed of coated glass, tinted glass, laminated sheet or tempered glass (toughened safety glass, heat-strengthened glass) can also be assessed with the help of the table in section 9.1.3.

The guideline does not apply to specially constructed glass units, such as glass units with elements installed in the gas-filled cavity or in the laminate, glass products using ornamental glass, wired glass, special security glazings (attack-resistant glazing), fire-resistant glazings and non-transparent glazings. These glass products are to be assessed with reference to the materials used, to the production procedures and to the relevant information from the manufacturer.

The assessment of the visible quality of the edges of glass products is not the subject of this guideline. The rebate zone does not apply as an assessment criterion to edges without frames in constructions that are not framed on all sides. The intended use must be indicated in the order.

Special conditions should be agreed upon for inspecting the outward appearance of glass in facades.

9.1.2 Inspection

In testing, the visibility through the pane, i.e. the view of the background, is the generally applicable criterion, not the appearance in reflection. The discrepancies may not be specially marked.

The glazing units are to be tested according to the table 26 in chapter 9.1.3, from a distance of about 1 metre from the inside to the outside and at a viewing angle which corresponds to the normal usage of the room.

The test is carried out under diffuse daylight conditions (e.g. overcast sky), without direct sunlight or artificial lighting.

The glazing units in rooms (indoor glazing) are to be inspected with normal (diffuse) illumination intended for the use of the rooms and at a viewing angle that is preferably vertical to the surface.

If glazings are assessed from the outside, they must be examined in installed condition, taking into consideration the usual viewing distance.

Inspection conditions and viewing distances arising from requirements in product standards for the viewed glazings may differ from this and are not taken into consideration by this guideline.

The inspection conditions described in these product standards often cannot be adhered to at the building.

9.1.3 Allowable Discrepancies for the Visible Quality of Architectural Glass Products

Table prepared for float glass, TSG, TSG-H, HSG, LG, LSG, coated or uncoated, as well as combinations of these glazing units into double-glazed insulating glass units.

Zone	Permissible Per Unit:	
R	External shallow damage to the edge or conchoidal fractures which do not affect the glass strengthand which do not project beyond the width of the edge seal.	
	Internal conchoidal fractures without loose shards, which are filled by the sealant.	
	Unlimited spots or patches of residue or scratches.	
E	**Inclusions, bubbles, spots, stains etc.:** Pane area ≤ 1 m²: Pane area > 1 m²:	 max. 4 cases, each < 3 mm Ø max. 1 case, each < 3 mm Ø per meter of perimeter
	Residues (spots) in the cavity: Pane area ≤ 1 m²: Pane area > 1 m²:	 max. 4 cases, each < 3 mm Ø max. 1 case, each < 3 mm Ø per meter of perimeter
	Residues (patches) in cavity:	max. 1 case ≤ 3 cm²
	Scratches: total of individual lengths:	max. 90 mm – Individual length: max. 30 mm
	Hairline Scratches:	not allowed in higher concentration
M	**Inclusions, bubbles, spots, stains etc.:** Pane area ≤ 1 m²: 1 m² < Pane area ≤ 2 m²: Pane area > 2 m²:	 max. 2 cases, each < 2 mm Ø max. 3 cases, each < 2 mm Ø max. 5 cases, each < 2 mm Ø
	Scratches: total of individual lengths:	max. 90 mm – Individual length: max. 30 mm
	Hairline Scratches:	not allowed in higher concentration
E+M	Maximum number of allowable discrepancies as in zone E Inclusions, bubbles, spots, stains etc. of dimensions 0.5 – 1.0 mm are allowable without any area-related limitation, except when they appear in higher concentration. "Higher concentration" means that at least 4 inclusions, bubbles, spots, stains etc. are located within a circle with a diameter of ≤ 20 cm.	

Comments:
Discrepancies of dimensions ≤ 0.5 mm will not be taken into account. The optically distorted fields they cause may not be more than 3 mm.

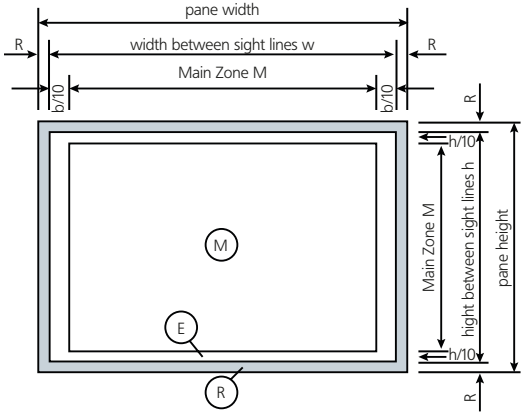
Allowable discrepancies for three-layer thermal insulating glass, laminated sheet and laminated safety glass:
The allowable frequency of discrepancies in the zones E and M is increased by 25% per additional glass unit and per laminated glass pane over the above values. The result is always rounded up.

Toughened safety glass, heat-strengthened glass, laminated sheet and laminated safety glass of toughened safety glass and / or heat-strengthened glass:

1. The local roller waves on the glass surface (except for toughened safety glass and heat-strengthened glass of ornamental glass) - may not exceed 0.3 mm relative to a length of 300 mm.

2. The warp relative to the total glass edge length (except for toughened safety glass and heat-strengthened glass of ornamental glass) may not be greater than 3 mm per 1000 mm glass edge length. Greater warps may occur for square or near square formats (up to 1 : 1.5) and for single panes with a nominal thickness < 6 mm.

Table 26: Allowable discrepancies regarding visual quality



R = Rebate Zone:
the visually concealed area in the installed state (no limits on discrepancies, with the exception of mechanical damage to the edges)

E = Edge Zone:
circumambient 10 % of the respective see-through width and height of the pane (here, the assessment need not be very stringent)

M = Main Zone:
(most stringent assessment)

Fig. 32: Division of zones for visual quality

9.1.4 General Comments

9.1.4.1 Visual Properties of Glass Products

9.1.4.1.1 Intrinsic Colour

All materials used in glazing products have an intrinsic colour, which is determined by the raw materials and becomes increasingly evident with increasing thickness. Coated glass is used for functional reasons. Coated glass also has its intrinsic colour. This intrinsic colour can differ for transmittance and/or reflectance.

Fluctuations in the colour impression are possible due to the iron oxide content of the glass, the coating process, the coating itself, variation in the glass thickness and the unit construction and cannot be avoided

9.1.4.1.2 Differences in Colour for Coatings

An objective assessment of the differences in colour with coatings requires the difference in colour to be measured or examined under conditions that have been previously exactly defined (glass type, colour, illuminant). Such an assessment cannot be the subject of this guideline. (For further information see the information sheet "Farbgleichheit transparenter Glaser im Bauwesen", published by the Association of Window and Façade Manufacturers, VFF.)

9.1.4.1.3 Assessment of the Visible Section of the Edge Seal of the IGU

Features on the glass and spacer resulting from production processes can be recognisable in insulating glass units in the visible section of the edge seal. By definition, this sectionis not included in the area between the sight lines that is subject to assessment. If the edge seal of the insulating glass unit is exposed on one or more sides due to design requirements, features resulting from production processes may be visible in the area of the edge seal.

The permissible deviation of the spacer(s) in relation to the parallel straight glass edge or to other spacers (e.g. in three-layer insulating glass) is 4 mm up to an edge length of 2.5 m. For longer edge lengths the permissible deviation is 6 mm. For two-layer insulating glass the tolerance of the spacer is 4 mm up to an edge length of 3.5 m and 6 mm for longer edge lengths. If the edge seal of the insulating glass unit is exposed due to design requirements, typical features of the edge seal may become visible that are not covered by this guideline. In such cases individual arrangements must be agreed on.

Special frame designs and edge seal designs for insulating glass must be coordinated with the respective glazing system.

9.1.4.1.4 Insulating Glass Units with Internal Muntins

Muntins can occasionally cause clattering noises due to environmental influences (e.g. effects specific to multiple glazing), shaking or manually excited vibrations.

Visible sawcuts and slight removal of paint near the sawcuts are caused by the production process. In assessing deviations from right angles and misalignment within the glazing zones, the manufacturing and installation tolerances and the overall impression are to be taken into account.

Effects of temperature-dependent changes in the length of muntins in the gas-filled cavity are fundamentally unavoidable. Misalignment of muntins caused by production cannot be ruled out.

9.1.4.1.5 Damage to External Surfaces

The cause of mechanical or chemical damage to the external surfaces recognised after installation should be determined. These discrepancies can also be assessed according to the criteria of section 3.

In addition, the following standards and guidelines also apply:

- Technical guidelines of the glazing trade
- VOB/C ATV DIN 18 361 "Glazing Works"
- Product standards that apply to the viewed glazing products
- Leaflet on how to clean glass, issued by the Federal Association for Architectural Glazing (amongst others)
- Guidelines on handling multilayer insulating glass), issued by the Federal Association for Architectural Glazing

and the relevant technical information and installation instructions of the manufacturers.

9.1.4.1.6 Physical Properties

Some inevitable physical phenomena that occur in the visible glass surface may not be taken into account when assessing the visual quality. These phenomena are:

- Interference effects
- Effects specific to insulating glass
- Anisotropy
- Condensation on the external surfaces of the panes
- Wetting of glass surfaces

9.1.4.2 Explanation of Terms

9.1.4.2.1 Interference Effects

In insulating glass units of float glass, interference effects may cause spectral colours to appear. Optical interference is due to superposition of two or more light waves at a single point.

The effects are evident as more or less intensively coloured zones, which change when pressure is applied to the glass. This physical effect is reinforced by the plane-parallel surfaces of the glass. The parallel surfaces ensure an undistorted view through the glass. Interference effects occur at random and are not to be influenced.

9.1.4.2.2 Effects Specific to Insulating Glass

An insulating glass unit includes a volume of air or other gas, hermetically sealed by the edge seal. The state of the gas is essentially determined by the altitude of the manufacturing site, and the barometric pressure and air temperature at the time and place of manufacture. If the insulating glass unit is installed at another altitude, or when the temperature or barometric pressure changes (high or low pressure conditions), the panes are forced to deflect inwards or outwards, resulting in optical distortion.

Multiple reflections can also occur in varying intensity at the surfaces of glass units.

These reflections can be seen particularly well if the background viewed through the glazing is dark.

This effect is a physical property of all insulating glass units.

9.1.4.2.3 Anisotropy

Anisotropy is a physical property of heat-treated glass resulting from the internal distribution of stresses. It is possible that dark rings or stripes can be perceived, which varywith the viewing angle, if the glass is viewed in polarised light and/or through polarising glasses.

Polarised light is present in normal daylight. The extent of polarisation depends on the weather conditions and the position of the sun. The effect of birefringence is more evident at an oblique viewing angle or for glass panes mounted at right angles to one another across a façade corner.

9.1.4.2.4 Condensation on the External Surfaces of Panes

Condensation can occur on the external glass surfaces when the glass surface is colder than the adjacent air (cf. condensation on car windows).

The extent of condensation on the external surfaces of a glass pane is determined by the U-value, the air humidity, air movement and the indoor and outdoor temperatures.

Condensation on the indoor surface of a glass unit is promoted by insufficient air circulation, e.g. due to deep window recesses, curtains, flowerpots, window-boxes, blinds, unfavourably positioned heating radiators and lack of ventilation.

Condensation can form at times on the outdoor surface of insulating glass units with high thermal insulation, when the ambient relative humidity is high and the ambient air temperature is higher than the surface temperature of the pane.

9.1.4.2.5 Wetting of Glass Surfaces

The wetting of glass surfaces can differ under the effects of rollers, fingers, labels, paper grain, vacuum suction holders, sealant residues, silicone compounds, smoothing agents, lubricants or environmental influences. This can become evident when the glass surfaces are affected by condensation, rain, or cleaning water.

9.2 Supplements to Guideline to Cover the Format: Giga Lites

There are taken into account here glass-formats with surface areas of > 5 m². Listed in the following table are only those data which the original table needs, in this respect, to be supplemented.

Zone	Permissible Per Unit:		
E	**Residues (patches) in cavity:**		
	Pane surface area up to 5 m² per additional initiated 5 m²	**Quantity** max. 1 case per 1 case	**Diameter/Area** ⩽ 3 cm² ⩽ 3 cm²
	Scratches:		
	Pane surface area up to 5 m² > 5 m²	**Individual length** max. 30 mm max. 30 mm	**Sum of all individual lengths** max. 90 mm proportional extrapolation
	Note: Basis for the "proportional extrapolation" is the sum of all individual lengths of panes with surface areas of up to 5 m², not the individual lengths of the scratches		
	Hairline Scratches: not allowed in higher concentration		
M	**Inclusions, bubbles, spots, stains etc.:**		
	Pane surface area > 2 m² ⩽ 5 m² > 5 m²	**Quantity** max. 5 cases proportional extrapolation	**Diameter/Area** ⩽ 2 mm ⩽ 2 mm
	Note: Basis for the "proportional extrapolation" is the number of individual defects of panes with surface areas of 2 m² up to 5 m², and not their diameter.		
	Scratches:		
	Pane surface area up to 5 m² > 5 m²	**Individual length** max. 15 mm max. 15 mm	**Sum of all individual lengths** max. 45 mm proportional extrapolation
	Note: Basis for the "proportional extrapolation" is the sum of all individual lengths of panes with surface areas of up to 5 m², not the individual lengths of the scratches		

Table 27: Supplements to guideline to cover large-format IGU (Giga Lites)

9.3 Visual Assessment of Patterned Glass

The following table is to be used in the assessment of patterned glass. In addition, the product specifications of the respective manufacturers are to be complied with.

In the case of patterned glass units, where several panes are used together side by side on one surface, it is essentially impossible to guarantee a symmetry of pattern. The orientation of the pattern must be stated at the time of placing the order. If no such statement is made, the glass will be manufactured with the pattern orientation running parallel to the upper edge. Due to technical production factors design misalignments or slight colour-differences are possible in patterned and coloured glass.

Permissible Discrepancies per unit or m²
Patterned Glass, Clear or Tinted, Enamelled or Surface-Treated

Unit	Hairline scratches** not palpable	Seeds closed	Bubbles closed	Inclusions crystalline	Flat edge damage* Arrissed edge	Slight flaking* Arrissed edge
per m² of glass surface	permissible over whole surface	L ⩽ 20 mm W ⩽ 1 mm permissible 1 incidence	⩾ 3 mm to 5 mm permissible 1 incidence	⩾ 3 mm to 5 mm permissible over whole surface but not in accumulated form	permissible	permissible
		L ⩽ 10 mm W ⩽ 1 mm permissible over whole surface but not in accumulated form	< 3 mm permissible over whole surface but not in accumulated form			

* Not deeper than 15% of the pane thickness into the glass volume.
** Hairline scratches, i.e. damage to the surface that cannot be felt with the fingernails.

Table 28: Tolerances for patterned glass

Since patterned glass is produced by an individual process, ball- or line-shaped inclusions and the formation of small bubbles are an expression of the character and good quality of the individual artifacts.

Deviations from the set ornamental pattern due to changes of roller and misalignment of the pattern element are not, in every case, to be excluded and therefore represent no grounds for complaint about the product.

10 Luminous and Solar Characteristics

The calculation of the luminous and solar characteristics is to be carried out in accordance with EN 410, the calculation of the U_g value in accordance with EN 673. EN 1096-4 states the permissible tolerances for the declared values for coated glass. For the luminous and solar parameters a tolerance of +/- 3% is absolutely permissible. For the emissivity a tolerance of +0.02 is permissible as per EN 1096.

In accordance with RAL GMI quality-testing stipulations a tolerance of 0.01 is taken into account.

The nominal values cited refer to the testing / inspection conditions and the sphere of application of the respective product standard(s). Any deviation from perpendicularity will lead to changes in these values.

10.1 Insulating Glass

In EN 1279 "Glass in Building – Insulating Glass Units", tolerances for the luminous and solar characteristics for insulating glass units are not stated.

However, taking into account the permissible tolerances for coated glass as per EN 1096, the permissible tolerance for insulating glass units can, depending on the configuration, be calculated on the basis of EN 410.

To the U_g-value there applies ± 0.1 W/(m²K).

11. Glossary

11.1 Definition of Defects According to Product Standards

Defect	LG/LSG EN 12543-6	Coated Float EN 1096-1	FLOAT EN 572-2	PATTERNED EN 572-5
Defects of homogeneity		Still-recognizable deviations in colour, reflectance or transmittance within a single pane or from pane to pane		
Spots/stains		Defects in the coating which are larger than merely punctual defects; they are often irregularly formed and partly of a "mottled" structure.		
Punctual defect	This type of defect comprises non-transparent spots and stains, bubbles and foreign bodies	Punctual disturbances of vision both when looking through the glass and when looking onto it. NOTE: Dirty spots, pin-prick-like defects, and scratches all count as "punctual defects"	Centre or nucleus which is generally surrounded by a corona of distorted glass. NOTE: Punctual defects can be solid inclusions, bubbles etc.	
Corona			Area of local distortion, which normally surrounds a central punctual defect	
"Nesting"		Accumulation of very small defects which make an impression of spots or stains		
"Pinprick" defects		Punctual defect in the coating where the coating is partially or totally absent and which generally stand out, in "through-view", from the coating.		
Scratches	Linear damage to the external surface of the laminated glass.	Large number of linearly extended grooves, the visibility of which depends on their length, depth, width, and position.		
Dirty spots		Defects which, in "through-view", generally appear dark against the surrounding coating.		

11.1

Defect	LG/LSG EN 12543-6	Coated Float EN 1096-1	FLOAT EN 572-2	PATTERNED EN 572-5
Hack	Sharply tapering rifts or crackswhich run out from one edge of the glass.			
Wrinkles/cockles	Distortion which arises through folds or creases in the interlayer and is visible after manufacture.			
Foreign bodies	Undesired object which has penetrated into the laminated glass during manufacture.			
Linear Defects	This type of defect comprises foreign bodies, scratches, grinding traces.		**(Linear/longitudinally extended defects)** Defects which can occur in or on the glass in the form of deposits, spots, scratches, which take in a certain longitude or surface.	**(Linear/longitudinally extended defects)** Defects which can occur in or on the glass in the form of deposits, spots, scratches, which take in a certain longitude or surface.
Bubbles	Usually air-bubbles which can occur in the glass or the interlayer.			
Non-transparent spots	Visible defects in the laminated glass (e.g. stannous spots, inclusions in the glass or interlayer)			
Other defects	Glass defects, like notches, and defects in the interlayer, such as folds or creases, contraction, bands.			
Grinding trace	Damage to the outer surface of the laminated glass			
Optical defect			Defect which can lead to distortions in the way objects look when seen through the glass	

Defect	LG/LSG EN 12543-6	Coated Float EN 1096-1	FLOAT EN 572-2	PATTERNED EN 572-5
Visible defect			Defect which changes the visual quality of the glass. NOTE: Visible defects comprise both punctual defects and linear/longitudinally extended defects.	Defect which changes the visual quality of the glass. NOTE: Visible defects comprise both punctual defects and linear/longitudinally extended defects.
Stripes or bars caused by non-homogeneity of interlayer	Distortion caused by production defects in the interlayer which remains visible after manufacture.			
Spherical or quasi-spherical punctual defect				Punctual defects whose larger dimension is smaller than or equal to double their smaller dimension.
Longitudinally extended punctual defect				Punctual defects whose larger dimension is more than double their smaller dimension.
Design defects				Deviation of the design, relative, for example, to a line or a straight edge.
Deviation from design				Deviation x from the design.

Table 29: Definitions of defects according to product standards

11.2 List of Figures

11.3 List of Tables

Legal Information and Disclaimer

AGC INTERPANE

AGC Interpane

Based in Lauenförde, AGC Interpane is a strategic alliance partner of AGC Glass Europe, the European branch of the world's leading flat glass manufacturer AGC. AGC Interpane produces Float and white glass, high-quality coated insulating glass, sound insulation and sun protection Insulating glass, safety glass, solar glass and glass for decorative applications. The industrial network comprises eleven plants in Europe. For more information, visit www.interpane.com. or www.agc-yourglass.com.

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