

## ***Guideline to Assess the Visual Quality of Enamelled Glass***



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# **Guideline to Assess the Visual Quality of Enamelled Glass**

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## **1.0 Scope**

This Guideline covers assessing the visual quality of fully or partially enamelled glass where ceramic paint is applied and fired to produce toughened safety glass (TSG) or heat-strengthened glass (HSG). This Guideline does not cover glass coated with organic paints, nor does it address aspects governed by the building code.

In principle, the notes and tolerances stated in Section 3 “Inspection” also apply to other types of paint, e.g. organic paints. However, this Guideline does not describe the specific properties of these paint types. Ceramic paints are also used for printing other “painted” glass that can be thermally toughened. This Guideline therefore also applies to these products.

If the products are to be properly assessed, the purchase order must inform the manufacturer of the specific area and scope of application, design and visual requirements. This must include the following information in particular:

- indoor and/or outdoor use
- use in vision areas (viewing from both sides, e.g. partitions)
- application with direct backlighting
- edge quality and absence of paint at the edge (for visible edges a ground or polished edge finish is recommended. For an arched version we assume a framed edge is used).
- further processing of the monolithic glass panes to produce e.g. insulating glass units (IGU) or laminated glass/laminated safety glass (LG/LSG) and/or printing oriented to the film
- printing on position 1 for outdoor application

If enamelled glass sheets are combined into LG/LSG or IGU, each enamelled sheet must be assessed individually (as for monolithic glass panes).

## 2.0 Methods/Notes/Terms and Definition

### 2.1 General

Enamel paint consists of inorganic substances which determine its colour and which are subject to minor variations. These substances are mixed with glass frit. During the thermal toughening process (for TSG, heat-soaked TSG and HSG) the glass frit surrounds the pigments and fuses with the glass surface. The final colour can be seen only after this firing process.

The paints are selected such that they fuse with the glass surface within a few minutes when the glass surface temperature is about 600 – 620 °C. This temperature window is very narrow and cannot always be exactly reproduced, especially with sheets of different sizes and different colours.

Furthermore, the application method is also crucial for the colour impression. Because the paint layer applied is thin, screen printing or digital printing has a lower hiding power than a product manufactured by a rolling method which applies a thicker paint layer which is therefore denser. The opacity depends also on the paint selected.

The glass sheet can be printed over its full surface or just part of it, using different application methods. As a rule, the enamel is applied to the side which is not exposed to the weather (position 2 or above). Any exception must be agreed with the manufacturer. Application on position 1, which is exposed to the weather, requires special paints. These ceramic (enamel) paints are largely scratch-resistant and to a certain extent acid-resistant; their light fastness and adhesion durability are equivalent to the durability of ceramic fused-on paints.

Full-surface enamelling with translucent paints may cause clouding. These characteristics can be detected visually by back-lighting the panes. It should be noted that any medium attached directly to the painted rear side (such as sealants, panel adhesive, insulation, or a bracket) may show through translucent paints.

When using metallic paints it must be ensured that they are not exposed to moisture. Use of these paints must be agreed with the manufacturer.

If printed sheets are coated with additional functional layers, perhaps for solar control or thermal insulation, they must comply with relevant standards and guidelines for assessing the visual quality of the end product. These could include EN 1096 and/or the guidelines for glass in building mentioned above. The printed surface will be assessed on the basis of the present Guideline. If printing is used to cover e.g. the profiles of bonded façades, the structure may shine through very light colours. Suitable colours must be used for this. Furthermore, if the printed surfaces are to be bonded, the compatibility and adhesion of the printed surfaces with the enamel must be checked, among other things. Separate evidence may also be required if printed surfaces are used in structural sealant glazing façade systems.

### 2.2 Methods

#### 2.2.1 Roller coating

The flat glass pane passes beneath a ribbed rubber roller which transfers the enamel paint onto the surface of the glass. This ensures a regular, even and homogeneous paint distribution over the entire surface. Typically, the ribbed pattern of the roller is visible if the pane is examined close up (from the enamelled side). However, these 'ribs' are usually barely visible when the glass is viewed from the front (looking through the pane). Rolled enamel glass is generally **not** suitable for use in vision areas, so such use must always be agreed with the manufacturer in advance. A "starry sky" effect (numerous very small imperfections or pearl lines) may appear in the enamel.

Due to the nature of this manufacturing process a "colour overrun" is possible on all edges of the pane. This overrun may be slightly corrugated especially on the long edges (viewed in the direction in which the roller unit moves). However, the edge surface usually remains paint-free. If paint-free visible edges are explicitly required, this must be specified in the purchase order. For this reason, the installation position should be agreed with the manufacturer in advance. The enamel paint can be optionally applied using a spray gun.

#### 2.2.2 "Curtain" coating

The glass pane passes horizontally through a "coating curtain" which covers the entire glass surface with paint. The thickness of the paint layer can be controlled over a relatively wide area by adjusting the paint quantity and throughput speed. However, as the pouring spout is slightly uneven, there is a risk that lengthways streaks of varying thickness appear (viewed in the pouring direction). Vision glass applications must always be agreed with the manufacturer in advance. The "colour overrun" at the edges is significantly greater than with roller coating and can only be eliminated with great effort. If paint-free visible edges are required, this must be specified in the purchase order.

### **2.2.3 Screen printing**

Unlike the methods described above, with screen printing the surface can be fully or partially coated. The paint is applied to the glass surface on a horizontal screen printing table through a narrow-mesh screen using a squeegee blade. The thickness of the paint applied depends on the mesh width of the screen and the thread diameter. The paint layer is generally thinner than with roller coating and curtain coating, and depending on the colour chosen appears either opaque or translucent.

This manufacturing process is characterised by slight streaks both in the direction of print and also across it, as well as by occasional spots of haze, depending on the paint used. As a rule, the edges of the glass panes remain free from paint during screen printing, but may display a slight beading in the arrissed area. It is therefore imperative that visible edges are specified to produce the appropriate end result compliant to the application.

This process can be used for multi-colour printing such as “double screen printing”, where two different colours can be seen depending on the surface being viewed. The manufacturer should always be consulted on issues of tolerances (e.g. of congruency).

It is possible to print onto selected types of patterned glass, but the manufacturer must always be consulted in advance.

Please also check or agree the durability and availability of the screen with the manufacturer if your building project is over a long timescale.

### **2.2.4 Digital printing**

The ceramic paint is applied directly onto the glass surface using a method similar to inkjet printing. The thickness of the paint layer may vary. The layer deposited by this process is thinner than with roller coating, curtain or screen printing, and depending on the colour chosen will appear either opaque or translucent. Unlike screen printing, digital printing offers much higher print resolution.

This manufacturing process is characterised by barely visible streaks in the direction of print. These cannot be avoided due to the production process. As a rule, the edges of the glass panes remain free from paint during digital printing, but may display a slight beading in the arrissed area. It is therefore imperative that visible edges are specified to produce the appropriate end result compliant to the application.

The print edges are exactly straight in the direction of print and slightly serrated across the direction of print. There may be paint spray mist along the printed edges. With dot, hole and text motifs, the printed edges display a serration which, like the spray mist, is only visible if viewed close up.

Digital printing is best suited to complex multi-colour grid designs or images and less suited to monochrome full-surface printing.

## **3.0 Inspection**

The glass is generally inspected looking through the pane onto the enamel. Any defects must not be specially marked. The glass unit must be inspected from a point at least 1 m from and perpendicular to the glass surface, or at a max. 30° viewing angle from the perpendicular. Inspections are carried out under diffuse daylight conditions (e.g. overcast sky) without direct sunlight or artificial lighting against a single-colour opaque background. If any special applications have been agreed in advance, these must be used as inspection conditions.

For LG/LSG, in addition to the position and design tolerances, any applicable tolerance resulting from offset must be taken into account.

Depending on the pattern, a “moiré” effect may occur in motifs applied by screen printing. The moiré effect (from French “moirer” „clouding; marbling”) becomes apparent if regular fine grids are overlaid with additional, apparently coarse grids. Their appearance is similar to the patterns caused by interference. This is a physical effect.

The present Guideline relates exclusively to assessing the enamelling of the visible area of the glass in its installed condition. Assessment of glass is based on the “Guideline to Assess the Visual Quality of Glass in Buildings”.

## Types of defect / tolerances for enamelled glass

Admissible punctual defects in the enamel*	Ø 0.5 – 1.0 mm, max. 3 per m <sup>2</sup> , with spacing ≥ 100 mm Ø 1.0 – 2.0 mm, max. 2 per sheet	
Hairline scratches and baked-in contamination	admissible up to 10 mm length	
Clouding **	not admissible	
Water stains	not admissible	
Colour overrun at the edges	Admissible in framed panes and for holes provided with additional mechanical brackets or covers, otherwise not admissible.  In unframed panes with ground or polished edge: <ul style="list-style-type: none"> <li>• Roller coating – admissible on the chamfer, not admissible on the edge</li> <li>• Curtain coating – admissible</li> <li>• Screen printing – not admissible</li> <li>• Digital printing – not admissible</li> </ul> Due to the digital printing method, very small ink splashes only discernible from close up can occur in the immediate area of the printed edges.	
Unprinted glass border	Screen printing and digital printing admissible up to 2 mm (minimum "KGN" edge working (smooth ground edge))	
Linear structures in the print	admissible	
Enamel position tolerance (a) see Figure 1 ***	Pane size ≤ 2000 mm: ± 2.0 mm Pane size > 2000 mm: ± 3.0 mm Pane size > 3000 mm: ± 4.0 mm Minimum KGN edge working (smooth ground edge)	
Dimensional tolerance for partial enamelling (b) see Figure 1	Edge length of printed area:	Tolerance range (minimum KGN edge working (smooth ground edge)):
	≤ 1000 mm	± 2.0 mm
	≤ 3000 mm	± 3.0 mm
	> 3000 mm	± 4.0 mm
Shape tolerance (c) (d) see Figure 1	Depending on size	Tolerance range:
	≤ 30 mm	± 0.8 mm
	≤ 100 mm	± 1.0 mm
	≤ 500 mm	± 1.2 mm
	≤ 1000 mm	± 2.0 mm
	> 1000 mm	± 3.0 mm
Colour variations	Colours are assessed through the glass (enamel paint on position 2). Colour variations in a range of ΔE ≤ 5 (float) or ΔE ≤ 4 (low iron glass) with the same glass thickness are admissible (see also Section 4).	

\* Defects of ≤ 0.5 mm ("starry sky/pearl lines" or "pinholes" = very small enamel defects) are admissible and not normally taken into account. Repair of defects using enamel paint before toughening is admissible.

\*\* Delicate finishes (grid pattern with sections smaller than 5 mm) may engender a "moiré" effect. This must therefore be agreed with the manufacturer.

\*\*\* The enamel position tolerance is measured from the reference point which must be agreed with the manufacturer.

Table 1

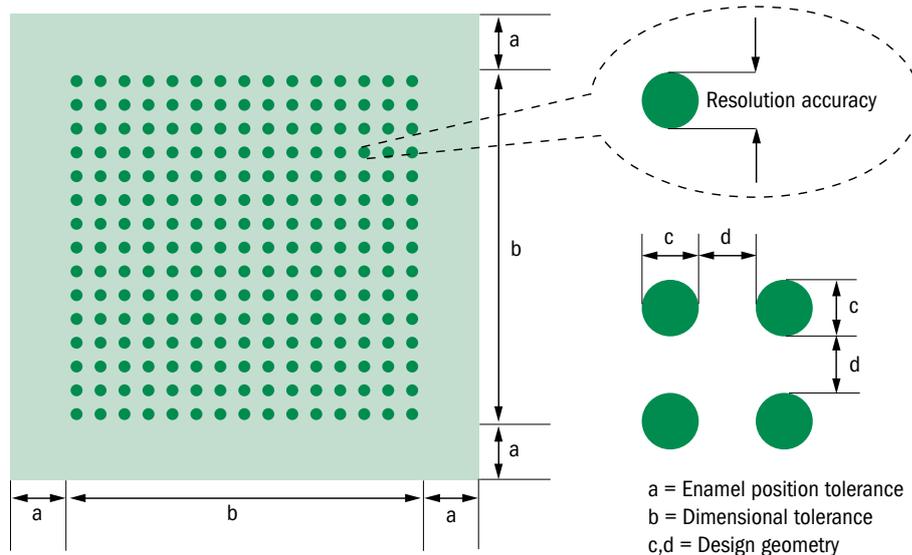


Figure 1  
 Position and design tolerances for the dimensions of printed glass

**The following notes apply to geometric figures or so-called aperture masks with a size below 3 mm or progressions from 0 – 100 % :**

- The human eye is very sensitive to dots, lines or figures of this size lined up close together.
- Tolerances in the geometry or spacing in the tenth of a millimetre range will therefore appear to be major variations.
- The feasibility of such applications must therefore always be agreed with the manufacturer. We recommend producing a 1:1 sample.

## 4.0 Assessing the colour impression

Colour variations cannot generally be ruled out, as they can be caused by several unavoidable factors.

Due to the factors listed below, there might be a recognisable colour difference between two enamelled glass panes under specific light and viewing conditions, which the observer might subjectively assess as 'irritating' or 'not irritating'.

### 4.1 Type of basic glass and influence of colour

The intrinsic colour of the glass, which depends substantially on the glass thickness and the type of glass (e.g. body-tinted glass, low-iron glass etc.), gives rise to a change in the colour impression of the enamel (with enamel on position 2). Furthermore, different coatings may have been added to this glass, such as solar control coatings (increase of the light reflection of the surface) or reflection-reducing coatings, or the glass can be slightly embossed, e.g. structured glass. Colour variations in the enamelling cannot be ruled out, due to fluctuations during paint manufacture and the firing process.

### 4.2 Type of light for viewing the object

The light conditions change continuously depending on the season, the time of day and the prevailing weather. This means that the spectral colours of the light which are transmitted through the various media (air, first surface, glass body) and strike the paint are present to varying degrees in the visible spectral range (380 nm – 780 nm).

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

### 4.3 Observer or viewing mode

The human eye reacts to different colours in very different ways. While we perceive a very minor colour difference in shades of blue clearly, we perceive colour differences in shades of green less clearly.

Tolerances for colour consistency in prints on glass should be specified in such a way that any colour variations can be barely detected by an observer under normal conditions. No specific standards have been firmly established here.

The tolerances are a compromise between productivity and the requirement for the glass units in a building to make a good visual impression under normal installation conditions. The colour impression may also vary from manufacturer to manufacturer, despite being the same colour (as defined by colour codes such as RAL, NCS, etc.).

Given the variation in natural light, the position of the observer in terms of viewing angle and distance, the ambient colour, the colour neutrality and surface reflectance, the tolerance values may only be used as a general guide. All on-site circumstances should be considered individually for each relevant building – in particular the building in its specific surroundings.

Colours are shown for a production check objectively using the CIE L\*a\*b\* system, based on the standardised D65 reference light and a 10° viewing angle.

The desired position in the a, b colour coordinate system and the lightness characterised by the letter L, are subject to minor fluctuations resulting from the production process. If the customer requires an objective benchmark for evaluating the colour coordinates, the procedure for this must be agreed with the manufacturer in advance.

The general course of action is defined as follows:

- Providing samples of one or more paints
- Selection of one or more paints Specification of tolerances for each paint in consultation with the customer. The underlying measurement values must be determined using glass-specific colour measuring equipment, under identical conditions (identical colour system, light type and geometry, and the same observer). Feasibility check by the supplier for compliance with the specified tolerance (order volume, availability of raw materials, etc.)
- Manufacture of a 1:1 production sample and approval by the customer
- Production to order within the specified tolerances
- Within a single order, only one purchase order should be placed for large quantities of an identical colour, rather than using sub-purchase orders

## 5.0 Other notes

Other product characteristics are specified in the national building code regulations and the applicable standards, in particular: DIN EN 12150, DIN EN 1863, DIN EN 14179, DIN EN 14449

Enamelled glass can be produced only as TSG, heat soaked TSG or HSG.

Subsequent processing of the glass, regardless of type, may have a major impact on the characteristics of the product and is **not** permitted.

Enamelled glass can be used in the form of monolithic glass panes or processed into LG/LSG or IGU. The mandatory marking of the panes must comply with the relevant product standards. Enamelled sheets can corrode under the effects of moisture and must therefore be protected from moisture during transport and storage.

- [1] DIN EN 1096 „Glass in building – Coated glass“
- [2] DIN EN 12150 „Glass in building – Thermally toughened soda lime silicate safety glass“
- [3] DIN EN 14449 „Glass in building – Laminated glass and laminated safety glass“
- [4] BF-Bulletin 006/2019 “Guideline to assess the visual quality of glass in buildings“
- [5] DIN EN 1863 „Glass in building – Heat strengthened soda lime silicate glass“
- [6] DIN EN 16477 „Glass in building – Painted glass for internal use“
- [7] DIN EN 14179 „Glass in building – Heat soaked thermally toughened soda lime silicate safety glass“

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