



Guideline for assessing the visual quality of enamelled and textured coated glass

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1 Scope of Application

This guideline applies to the assessment of the visual quality of fully or partially enamelled and printed glass that are produced by applying and firing inorganic colours, as fully tempered glass (FT) or heat-strengthened glass (HS). Furthermore, this guideline applies to the assessment of the visual quality of textured coated glass. For quality assurance and correct assessment of the products, it is necessary to inform the manufacturer about the **specific application, the design and visual requirements** in the purchase order.

This concerns, in particular, the following information:

- Indoor or outdoor use
- Use in see-through applications (for viewing from both sides, e.g. partition walls etc.)
- Application with direct backlighting
- Edge quality and any exposed edges (for exposed edges a ground or polished edge finishing is recommended. For arised edge treatment, a framed edge is assumed.)
- Further processing of single panes into insulating glass or laminated safety glass (LSG)
- Printing on position 1 for outdoor application

If multiple enamelled or textured coated glass panes are combined to make laminated glass/laminated safety glass or multi-pane insulating glass, each pane is assessed individually (as with single panes).

2 Methods / Instructions / Terms

2.1 General information

The enamel paint consists of inorganic substances that are responsible for colouration and are subject to minor variations. These substances are mixed with glass frit. During the thermal tempering process (FT, HS), the glass frit encloses the pigments and bonds with the glass surface. The final colouration can be seen only after this baking process is completed.

The paints are selected in such a way that when the temperature of the glass surface reaches around 600 – 620 °C, they bond with the surface within a few minutes. This temperature window is very narrow and not always exactly reproducible, especially when the panes are of different sizes and various colours are used. Moreover, the method of application is also a key factor in determining the colour impression. Since a thin layer of paint is applied in screen printing or digital printing, there is lower coverage (opacity) in these methods as compared to a product manufactured using the roller coating method, which has a thicker and hence a more densely applied layer of paint. The coverage (opacity) also depends on the paint selected.

The glass surface can be fully or partially printed using various methods of application. As a rule, the enamel is applied to the side that is not exposed to weathering agents (position 2 or more). Exceptions to this rule must be agreed upon with the manufacturer. For the application on position 1 (weather side), special paints are used. The ceramic paints (enamel) are largely scratch-resistant and acid-resistant to a certain extent; their lightfastness and adhesive strength correspond to the durability of ceramic enamel paints.

Clouding is possible in full-surface enamelling with translucent paints. These characteristics may become visible when the panes are backlit. It must be taken into consideration that in translucent paints, any medium (such as sealants, panel adhesives, insulations, brackets, etc.) that is applied directly to the rear face (painted side) may shine through. When metallic paints are used, ensure that they are not exposed to moisture. The use of these paints must be agreed upon with the manufacturer.

If the printed panes are additionally provided with functional coatings, for solar control and/or for thermal insulation, the relevant standards and guidelines for assessing the visual quality of the final product must be followed. This includes, among others, the EN 1096 and/or the guidelines for glass in the building and construction industry mentioned earlier. The printed surface is assessed according to this guideline. If printed decorations are used for covering, for instance, the profiles of glued façades, the structure may show through if the colours are very light. Suitable colours should be used in such cases. Moreover, when gluing on printed surfaces, it should be ensured that the necessary bonding and compatibility with the enamel is also tested. For use structural glazing façades, separate verifications may be required.



2.2 Methods

2.2.1 Roller coating method

The flat glass pane is passed underneath a fluted rubber roller that applies the enamel paint to the glass surface. This ensures an even and homogeneous spread of the paint over the surface (a prerequisite for this is: an absolutely flat glass surface), but in terms of application of paint (paint thickness, coverage/opacity), adjustment is possible only to limited extent. Typically, the fluted pattern of the roller is visible when the glass pane is examined from a very close range (on the painted side). However, normally, one can hardly see this “fluting” from the front side (viewed through the glass). Roller-coated enamel glass panes are, as a rule, **not** suitable for see-through applications, and therefore, such applications need to be discussed and agreed upon beforehand with the manufacturer (a so-called “starry sky” effect, with very small defects, can occur in the enamel). Due to the nature of this method of application, a certain “enamel overrun” is possible on all edges, which can be slightly corrugated, especially along the longitudinal edges (viewed in the direction of movement of the roller unit). However, the edge surface will generally remain clean.

2.2.2 Screen printing method

In the screen printing method, a full-surface or partial-surface application of paint is possible. On a horizontal screen-printing table, the enamel paint is applied to the glass surface through a narrow-mesh screen using a doctor blade; in this process, the thickness of the applied paint can be influenced only marginally by the mesh width of the screen. The applied paint thickness is generally less than that in the roller coating method, and it will appear to be either opaque or translucent, depending on the colour chosen. For see-through applications, it is **absolutely** essential to discuss and agree upon beforehand with the manufacturer.

Typical for this production process, and therefore also permissible, are (depending on the colour chosen) the stripes or bands that appear both in the direction of printing and in the perpendicular direction, as well as occasionally occurring “spots of fogging”. Due to slight variations in coating thickness, the overall colour impression over the surface may vary, depending on the colour chosen. The occurrence of small variations in coating thickness is typical for the screen printing process. Resulting colour differences are permissible. The pane edges usually remain clean during screen printing, but there may be a slight bulging or beading of paint in the arrised area. Hence, it is necessary to specify any exposed edges beforehand so that the production process is appropriate for the application envisaged. Decorative printing on selected ornamental glass is possible, but this should always be discussed and clarified with the manufacturer.

2.2.3 Digital printing method

The ceramic ink is applied directly onto the glass surface using a method that works on a principle similar to that of an inkjet printer, wherein the thickness of the ink coating may vary. Here, the applied ink thickness is less than in the roller-coating or the screen-printing methods and, depending on the colour chosen, the coating appears either opaque or translucent. Unlike the screen-printing method, significantly higher printing resolutions are possible in the digital printing method. Appearance of barely visible stripes in the direction of printing are typical for this production process. The nature of this process makes it unavoidable. The pane edges usually remain ink-free during digital printing, but there may be a slight bulging or beading of ink in the arrised area. Hence, it is necessary to specify any exposed edges beforehand so that the production process is appropriate for the application envisaged.

The print edges are exactly straight in the printing direction and slightly serrated transverse to the printing direction. Ink spray mist along the print edges may occur. In spot, hole and text motifs, the print edges show a serration which can, like the ink spray mist, only be detected at a very close range.

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

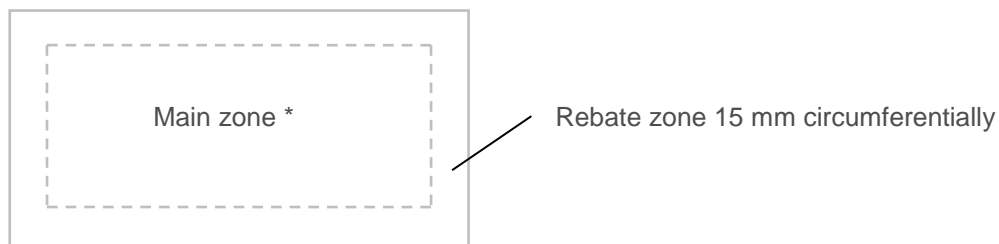
2.3 Textured coated glass

Glass surfaces (FT, HS or annealed float glass) can be printed with a masking based on specific templates. The masked panes are then covered with a thin film coating, (which is produced using the magnetron process). After the masking is removed, a textured thin film coating remains on the glass surface. In principle, the same conditions as with printed glass apply here.



3 Inspection

The assessment of the visual quality of enamelled and textured coated glasses is carried out by viewing them quickly from a distance of at least 3 meters and perpendicularly, or viewing them at a maximum angle of 30° to the perpendicular. The inspection must be done in normal daylight, without direct sunlight or backlight from the front or back, against a single-colour, opaque background. Viewing is always done through the untreated side of the glass onto the enamelled or textured coated pane. If the assessment is to be done from both sides in the case of glass that is ordered for see-through applications, this should be expressly discussed and agreed upon in advance with the manufacturer. The complaints must not be specially marked during the inspection. Defects that are not visible from the specified distance will not be assessed. When assessing the defects, a distinction is made between the rebate zone and the main zone as shown in the following diagram.



* If exposed edges are required when the order is placed, the rebate zone is omitted and the main zone extends to the edge of the pane.

When used as laminated glass/laminated safety glass, the tolerance resulting from the edge offset should also be taken into account in the position and design tolerance.

This guideline is intended solely for the purpose of assessing the enamelling or textured coating of the visible area in the installed condition. For assessment of the glass, the "Guideline for the Assessment of the Visual Quality of Glass for the Building and Construction Industry" (Richtlinie zur Beurteilung der visuellen Qualität von Glas für das Bauwesen) is used.

The requirements for visual quality are given in the following tables:



Table 1: Types of defects/ tolerances for full-surface or partial-surface enamelled glass

Type of defect	Main zone	Rebate zone
Defects in the enamel*	Area: max. 25 mm ² Number: max. 3/m ² , of which none ≥ 25 mm ²	Width: max. 3 mm, occasionally 5 mm Length: no limit
Light scratches (only visible with changing incidence of light)	permissible up to 10 mm length	permissible / no restriction
Clouding	not permissible	permissible / no restriction
Water stains	not permissible	permissible / no restriction
Enamel overrun at the edges	omitted	<ul style="list-style-type: none"> permissible in framed panes not permissible in exposed edges (prerequisite: ground or polished edge)
Tolerance of dimensions for partial enamelling** Enamel width: ≤ 100 mm ≤ 500 mm ≤ 1000 mm ≤ 2000 mm ≤ 3000 mm ≤ 4000 mm	Depending on width of enamelling ± 1.5 mm ± 2.0 mm ± 2.5 mm ± 3.0 mm ± 4.0 mm ± 5.0 mm	
Enamel positional tolerance** (for partial enamelling only)	Pane size ≤ 200 cm: ± 2.0 mm Pane size > 200 cm: ± 4.0 mm	
Colour deviations	see point 4	

* Defects ≤ 0.5 mm (“starry sky” or “pinholes” = smallest defects in the enamel) are permissible and are generally not considered.

The rectification of defects with enamel paint **before** the tempering process or with organic paint **after** the tempering process is permissible. However, organic paint must not be used if the glass is going to be further processed into insulating glass and the defect is located in the area of the edge seal of the insulating glass. The rectified defects must not be visible from a distance of 3 m.

** The enamel positional tolerance is measured from the reference point.



Table 2: Types of defects/tolerances for decoratively printed and textured coated glass

Type of defect	Main zone	Rebate zone
Defects in the enamel*	Area: max. 25 mm ² Number: max. 3/m ² , of which none ≥ 25 mm ²	Width: max. 3 mm, occasionally 5 mm Length: no limit
Defects in the textured coating ****	Area: max. 25 mm ² /m ² Number: any, but in total $25 \leq \text{mm}^2/\text{m}^2$	Width: max. 3 mm, occasionally 5 mm Length: no limit
Light scratches (only visible with changing incidence of light)	permissible up to 10 mm length	permissible / no restriction
Clouding**	not permissible	permissible / no restriction
Water stains	not permissible	permissible / no restriction
Enamel overrun at the edges	omitted	<ul style="list-style-type: none"> permissible in framed panes not permissible in exposed edges (prerequisite: ground or polished edge)
Geometry of the figure (resolution accuracy) Edge length of printed area: ≤ 30 mm ≤ 100 mm ≤ 500 mm ≤ 1000 mm > 1000 mm	Edge finishing at least ground (KGN) ± 0.8 mm ± 1.0 mm ± 1.2 mm ± 2.0 mm ± 4.0 mm	no restrictions
Repeatability (permissible offset) for two- or multi-color double printing	± 1.0 mm	
Design position tolerance ***	Print size ≤ 200 cm: ± 2 mm Print size > 200 cm: ± 4 mm	
Colour deviations	see point 4	

* Defects ≤ 0.5 mm (“starry sky” or “pinholes” = smallest defects in the enamel) are permissible and are generally not considered.

** In fine decorative designs, moiré effect can occur. For this reason, it is necessary to consult the manufacturer on this. This effect caused by physical properties.

*** The design position tolerance is measured from the reference point.



**** Punctiform defects ≤ 1 mm (“starry sky” or “pinholes” or punctiform coating in the originally masked areas of the glass panes as well as linear defects ≤ 0.2 mm are permissible and are generally not considered.

Large-scale designs are assembled from several parts. The seams between these parts may be visible under certain viewing conditions. These seams are unavoidable in terms of production technology and do not constitute a reason for complaint.

For geometric figures or the so-called dot masks below 3 mm in size or progressions from 0 - 100%, the following remarks apply:

- If dots, lines or figures of this size are lined up together with very little spacing between them, the human eye reacts very “critically”.
- Tolerances of geometry or spacing in the range of tenths of a millimetre stand out as major deviations.
- In any case, these applications must be checked for feasibility with the manufacturer. Production of a 1:1 sample is recommended.

4 Assessing the Colour Impression

In principle, colour deviations cannot be ruled out, as they can occur due to several unavoidable influences. Due to the influences mentioned below, under certain light and viewing conditions, a noticeable colour difference may prevail between two enamelled glass panels, which the observer may very subjectively classify as “disturbing” or even “not disturbing”.

4.1 Type of basic glass and influence of the colour

The intrinsic colour of the glass, which depends essentially on the glass thickness and the type of glass (e.g. body tinted glass, low-iron glass, etc.), leads to a changed colour impression of the enamel (enamelling on position 2). In addition, this glass can be treated with different coatings, such as solar control coatings (increasing the light reflection of the surface), reflection-reducing coatings, or it even slightly embossed, like for instance, textured glass. Colour deviations during enamelling cannot be ruled out due to variations in the paint manufacturing and the firing process.

If, within a facade, single-printed glass is combined with glass that has also been provided with a second print (barrier print), then the occurrence of colour deviations between single-printed and double-printed glass is very likely. We always recommend production of a 1:1 sample for such applications.

4.2 Type of light in which the object is viewed

Lighting conditions are constantly different depending on the season, the time of day and the prevailing weather. This means that the spectral colours of the light which impinge on the colour through the various media (air, first surface, glass body) are present in varying degrees in the range of the visible spectrum (380 - 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” impinging on the colour are partially reflected or absorbed by the colour (colour pigments). As a result, the colour appears different depending on the light source and the position from where it is viewed as well as the background.

4.3 Observer or type of view

The human eye reacts very differently to different colours. While even a very minor colour difference in blue tones is strikingly noticeable, colour differences in green colours are perceived less clearly.

Tolerances for colour consistency of prints on glass should be chosen in such a way that an observer can hardly notice any colour deviations under normal conditions. This is not stipulated in any standard.

The tolerances represent a compromise between productivity and the requirement for the visual impression of the glass units in a building with a normal installation situation. It may also happen that despite being the same colour (defined by the colour code RAL, NCS or similar), the colour impression may differ from manufacturer to manufacturer.

Given the variation in natural light, the position of the observer in respect of the viewing angle and distance, ambient colour, colour neutrality and reflectance of the surface, the tolerance values should only be used as a guide. All circumstances should be evaluated individually on site, for the relevant object - especially the object in its specific environment.



Colours are objectively represented for production inspection in the CIE L*a*b* system, based on the standardized reference illuminant D65 and a viewing angle of 10°. The desired position in the a, b colour coordinate system, as well as the brightness characterized by the letter L, are subject to minor production-related variations. In cases where the customer requires an objective evaluation standard for the colour coordinates, the procedure must be agreed upon with the supplier beforehand.

The basic process is defined below:

- Provision of samples of one or more colours
- Selection of one or more colours. Definition of tolerances for each colour in consultation with the customer. The measurement values on which these are based must be determined using glass-specific colour measurement instruments and under identical conditions (same colour system, same illuminant, same geometry, same observer). Feasibility check by the supplier regarding compliance with the specified tolerances (scope of work, availability of raw materials, etc.)
- Manufacture of a 1:1 production sample and approval by the customer
- Production of the order within the specified tolerances
- Purchase orders for large quantities of the same colour for one order should be placed once only and not in partial purchase orders.

5 Other Information

The other characteristics of the products can be found in the respective European standards or their drafts. These are:

- DIN EN 12150
- DIN EN 14179
- DIN EN 1863
- DIN EN 14449

However, the manufacturer reserves the right to make production-related variations and changes in line with the state-of-the-art technology.

- Special colours, e.g., with metallic effect, anti-slip coatings or combinations of several colours can be produced on request. The special characteristics or appearance of the product in each case must be clarified with the manufacturer.
- Enamelled and screen-printed glass can be manufactured only as tempered safety glass or heat-strengthened glass.
- Subsequent processing of the glass, regardless of the type of processing, may significantly affect the properties of the product, and is not permissible.
- Enamelled glass can be used as a monolithic pane or in conjunction with laminated safety glass or insulating glass. The prescribed labelling of the panes is done according to the product standards.
- Enamelled panes are likely to corrode when exposed to moisture, and must therefore be protected from moisture during transport and storage.