
**Vitreous and porcelain enamels —
Glass-lined apparatus for process
plants —**

**Part 1:
Quality requirements for apparatus,
components, appliances and
accessories**

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*Émaux vitrifiés — Appareils émaillés pour les installations
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*Partie 1: Exigences de qualité relatives aux appareillages,
composants, appareils et accessoires*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

This second edition cancels and replaces the first edition (ISO 28721-1:2008), which has been technically revised. The main changes compared with the previous edition are as follows:

- the normative references have been updated;
- the subclause for “High-voltage test” (5.3) has been revised;
- the 7 kV test voltage for conductive or dissipative enamel according to 5.3 has been added to [Clause 10](#).

A list of all parts in the ISO 28721 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Vitreous and porcelain enamels — Glass-lined apparatus for process plants —

Part 1: Quality requirements for apparatus, components, appliances and accessories

1 Scope

This document specifies the quality requirements for apparatus, components, appliances and accessories of glass-lined steel (including semi-crystallized enamel coatings) and glass-lined steel castings used for process plants. It specifies the quality requirements and the tests to be carried out by the manufacturer as well as the actions to be taken to repair defects.

It is also applicable to glass-lined pumps, pump components and fittings.

It does not apply to glass-lined flanged steel pipes or glass-lined flanged steel fittings.

NOTE 1 Provisions for glass-lined flanged steel pipes and glass-lined flanged steel fittings are given in ISO 28721-4.

The test methods specified cover checking the enamel, the dimensional accuracy and the performance of apparatus and components.

This document is applicable to new apparatus and components as well as used items that have been re-enamelled.

It does not contain requirements regarding the chemical or physical properties of vitreous and porcelain enamels.

NOTE 2 Examples of test reports are given in [Annex A](#).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 780, *Packaging — Distribution packaging — Graphical symbols for handling and storage of packages*

ISO 2746, *Vitreous and porcelain enamels — High voltage test*

ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method*

ISO 28721-2, *Vitreous and porcelain enamels — Glass-lined apparatus for process plants — Part 2: Designation and specification of resistance to chemical attack and thermal shock*

ISO 28721-3, *Vitreous and porcelain enamels — Glass-lined apparatus for process plants — Part 3: Thermal shock resistance*

ISO 19496-1, *Vitreous and porcelain enamels — Terminology — Part 1: Terms and definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19496-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

4 Requirements

4.1 General

If the requirements given in this document are to be applied to glass-lined apparatus and components, this shall be stated as follows when ordering: "Manufactured in accordance with ISO 28721-1."

Requirements differing from those stated in this document may be agreed upon between the parties at the time of ordering.

4.2 Design and quality of enamel finish

The manufacturer shall be responsible for the appropriate design and construction.

The enamel quality (i.e. the type of enamel and, where relevant, the colour) shall be agreed upon between the interested parties at the time of ordering.

The characteristic composition of individual enamel layers shall correspond to that of specimens submitted for laboratory testing. The quality of the enamel shall meet the requirements specified in ISO 28721-2 and ISO 28721-3.

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4.3 Surface

The enamel coating shall have a uniform, smooth, fully-fused surface free from impurities.

4.4 Defects

4.4.1 General

Defects shall be examined visually (see 5.2). Typical defects are described in ISO 28721-5.

4.4.2 Defects unacceptable in the finished product

Defects unacceptable in the finished product are those that would render a component unusable. Such defects are typically as follows:

- a) defects which cannot be repaired by the means described in [Clause 7](#), such as:
 - 1) defects extending over an area with a diameter > 8 mm;
 - 2) defects on inaccessible spots;
 - 3) defects concerning vessels and columns as described in [4.4.4](#);
- b) collapsed lines in the cover coat;
- c) bubble lines, i.e. fused-in bubbles arranged in a distinct line;

- d) fused strain lines (recognizable as lines with colours different from that of the surrounding enamel);
- e) areas not properly fused (a rough surface similar to a sandblasted one);
- f) devitrified areas in vitreous enamel or over crystallized areas in semi-crystallized enamel (recognizable as a dull or a rough surface);
- g) pull-through of ground coat (recognizable as, for example, spot-like discolorations);
- h) cracks detectable by, for example, a statiflux test;
- i) spots with a diameter > 30 mm caused by grinding and polishing during the removal of impurities (see also 4.4.3 and 7.2).

4.4.3 Repairable defects

Repairable defects are imperfections in the enamel coating that allow, under certain circumstances (see below), further use of glass-lined equipment after repair. Common repairable defects are:

- a) depressions with a depth exceeding 25 % of the coating thickness;
- b) blisters, such as circular holes in the coating exposing the ground coat;
- c) areas with weak spots or defects detectable by high-voltage testing in accordance with 5.3;
- d) impurities in the enamel coating.

Isolated impurities, such as fire clay particles shall be removed. Dust-like impurities on the surface may be accepted. Scale fused into the surface shall be removed where it extends parallel to the surface over a distance of more than 3 mm and/or is not a flat particle or is not fused parallel to the surface.

The maximum permissible number of defects repaired by plugging shall be as given in Tables 1 and 2.

Further requirements, such as the maximum level of pores or use without plugging, shall be agreed upon between the interested parties at the time of ordering.

Defects as defined in 4.4.3 a) and 4.4.3 b) shall be repaired as described in 7.1.

Specifications regarding defects in various types of apparatus and components are given in 4.4.4 to 4.4.6.

Table 1 — Maximum permissible number of plugged enamel defects in vessels

Nominal volume m ³	Maximum permissible number of defects			
	Agitator vessels			Other vessels
	Type AE		Types BE and CE ^a	
	Lower part of vessel	Main cover		
up to 4	0	0	0	0
over 4 to 10	1	1	1	1
over 10 to 20	—	—	2	3
over 20 to 32	—	—	3	4
over 32 to 40	—	—	4	5
over 40 to 80	—	—	—	6
over 80	—	—	—	7

^a Assembly covers shall be delivered without any plugs.

Table 2 — Maximum permissible number of plugged enamel defects in columns

Nominal diameter of column mm	Maximum permissible number of defects for unit lengths		
	up to 2 000 mm	over 2 000 mm up to 5 000 mm	over 5 000 mm
up to 600	0	0	0
over 600 to 1 200	0	1	2
over 1 200	1	2	3

4.4.4 Vessels and columns

Tables 1 and 2 list the number of repairable defects to be covered with plugs. Exceptions apply in the following cases:

- outlet nozzles and agitator nozzles, including the complete neck area around the nozzle, shall not be repaired by plugging (this also applies to other nozzles with a nominal diameter of 150 mm or less, including the neck area, which extends out 30 mm beyond the inner nozzle diameter);
- convex and concave surfaces with a radius of 75 mm or less shall not be repaired by plugging;
- seal areas (gasket bearing surfaces) shall not be repaired by plugging.

4.4.5 Accessories

Accessories such as agitators, baffles, thermo pipes, probes, inlet pipes, washers, manhole covers and dip-pipes shall not be repaired by plugging (see 7.1).

4.4.6 Fittings and pump components

Fittings and pump components shall not be repaired by plugging (see 7.1).

4.5 Coating thickness

The thickness of enamel coatings on steel substrates shall range from 1,0 mm to 2,2 mm, with the following exceptions:

- maximum values may be exceeded by 0,2 mm on concave surfaces;
- the enamel coating may be 0,2 mm thinner than the specified minimum value in limited areas and on convex surfaces;
- coatings on small parts with very small radii ≤ 5 mm, such as valve stems or rotors of pumps, may have a minimum thickness of 0,6 mm.

Any changes in thickness shall be smooth.

4.6 General tolerances

General tolerances and tests for the concentricity of agitators (see 5.7.1 and 5.7.2) shall be agreed upon between the interested parties.

NOTE Examples of tolerances for vessels other than agitator vessels, agitator vessels and columns are given in DIN 28005-2, DIN 28006-2 and DIN 28007-2, respectively. DIN 28159 gives tolerances for agitator ends and DIN 2873 gives permissible angular misalignments for flange surfaces.

4.7 Finish

Unless otherwise agreed, non-enamelled surfaces, except for those which are not to be coated, such as fitting surfaces, shall be protected by a primer.

Details shall be agreed upon between the interested parties at the time of ordering.

Corrosion protection of parts without a primer coating, e.g. connecting elements, shall be agreed upon between the interested parties at the time of ordering.

5 Testing

5.1 General

Tests carried out in accordance with this document shall be conducted only by skilled personnel and shall be documented.

NOTE Examples of test report formats are given in [Annex A](#).

The surfaces to be tested shall be clean, dry, sufficiently illuminated and easily accessible.

The components tested and the test reports shall be marked to allow proper identification. It is at the customer's discretion to have his/her own inspectors verify the test results by repeating the tests at the manufacturing site as described below.

Details of testing shall be agreed upon between the interested parties at the time of ordering.

5.2 Visual examination

The surfaces of glass-lined apparatus and components shall be checked visually. Optical instruments, such as magnifying glasses, may be used for closer examination.

5.3 High-voltage test

High-voltage tests shall be conducted in accordance with ISO 2746. When the enamelling of a component is complete, the manufacturer shall run a high-voltage test at 20 kV.

For subsequent tests, a voltage of maximum 12 kV shall be used.

By customer request, and with the agreement of the manufacturer, particular areas may be re-checked with a higher voltage. Totally glass-lined components shall be tested with pulsed DC voltage.

Exceptions apply in the following cases:

- a) enamelled probes shall be tested with a DC voltage of 7 kV;
- b) for components coated with conductive or dissipative enamel, the manufacturer shall run a high-voltage test at 7 kV; they shall be appropriately marked by the manufacturer.

5.4 Testing for cracks

Areas where cracks are presumed to have formed shall be sprayed with electrostatically charged talcum powder to make cracks more visible. Even fine cracks will then be clearly revealed.

5.5 Coating thickness measurement

Measurement of the coating thickness shall be carried out in accordance with ISO 2178, using a measuring instrument accurate to 5 % of the actual value. The thickness shall be measured using spot checks. Extra measurements shall, however, be taken at critical spots such as small radii, uneven surfaces and localized increases in thickness.

5.6 Measurement of dimensions

The following dimensions shall be measured and recorded:

- a) the inside diameter and any out-of-roundness of the vessel;
- b) the diameter and any out-of-roundness of the assembly flange and main flange;
- c) any wavelike distortion of the sealing surfaces of the assembly flange and main flange;
- d) the out-of-plane angle of the sealing surfaces of the nozzles;
- e) the compensation thickness of the gaskets;
- f) the distances between the support ring, the brackets and the legs and a reference plane in each case;
- g) any variations in the distances between points on the support ring circumference, individual brackets and individual legs and a reference plane in each case;
- h) agreement of the support element dimensions (i.e. the thickness and outer diameter of the support ring) with the drawing;
- i) the ground clearance of the agitator;
- j) agreement of the jacket nozzle dimensions with the drawing.

Additional measurements may be made at the discretion of the customer.

The manufacturer shall measure and document the actual dimensions. The forms included in [Annex A](#) may be used for this purpose.

5.7 Determination of the concentricity of agitators and pump rotors

5.7.1 General

Details of the determination of the concentricity of impellers and pump rotors after assembly shall be agreed upon between the interested parties.

NOTE A method for determining the concentricity of impellers and pump rotors is given in DIN 28161.

5.7.2 Agitators

The maximum eccentricity of agitators that are supplied separately shall be documented. The measurements shall be performed by the manufacturer after machining and with the impellers still in the lathe.

5.7.3 Pump rotors

The concentricity of pump rotors shall be determined by the manufacturer and, if requested, the manufacturer shall document the results.

5.8 Performance testing

The manufacturer shall check the performance of the glass-lined components after assembly. Particular attention shall be paid to the proper performance of moving components (see also [5.7.1](#)).

Further tests covering the performance of mechanical seals or test runs with power measurement may be agreed upon between the interested parties at the time of ordering.

5.9 Completeness check

A completeness check, including the outside coating, shall be carried out to ensure compliance with the order.

6 Manufacturing stages and inspections

Inspections shall be conducted when the glass-lined components are at the manufacturing stages shown in [Table 3](#).

If the customer requests that the tests be carried out by his/her representative, the manufacturer shall give sufficient notice of the times at which the components concerned will be at the manufacturing stages at which they are to be inspected.

Table 3 — Stages at which testing is to be carried out

Glass-lined component	Tests in accordance with subclauses							
	5.2 Visual examination	5.3 High-voltage test	5.4 Test-ing for cracks	5.5 Coating thickness measurement	5.6 Measurement of dimensions	5.7 Concentricity of agitators and pump rotors	5.8 Performance testing	5.9 Completeness check, including outside coating
Agitator vessels	First test after enamelling, if possible prior to welding of elements such as jacket or support structure				Measure roundness and dimensions possibly altered by firing after enamelling. Measure other dimensions after assembly.	—	After installation	
	Second test after assembly, together with performance testing							
Components and agitator ordered together with the agitator vessel	After enamelling and machining					Agitators: after installation	After installation	Before delivery
Accessories and agitators ordered separately	After enamelling and machining					Agitators: after enamelling and machining	—	
Storage vessels, columns and other apparatus	After enamelling					—	—	
Pumps and pump components	Casing and components: after enamelling, prior to assembly				After assembly	Pump rotors: after assembly	After assembly	
Fittings	Casing and components: after enamelling, prior to assembly					—	After assembly	

7 Repairing defects

7.1 Repairing with plugs

Defects in the enamel shall be repaired with tantalum plugs and polytetrafluoroethylene (PTFE) gaskets. Examples of plugs are given in [Figures 1](#) and [2](#).

The type of plug and the use of other plug or gasket materials shall be agreed upon between the interested parties at the time of ordering.