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**Vitreous and porcelain enamels —  
Design of bolted steel tanks for the  
storage or treatment of water or  
municipal or industrial effluents and  
sludges**

*Émaux vitrifiés — Conception de réservoirs en acier boulonnés pour  
le stockage ou le traitement des eaux ou des effluents d'eaux usées  
urbains ou industriels*

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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](http://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](http://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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 107, *Metallic and other inorganic coatings*.

This second edition cancels and replaces the first edition (ISO 28765:2008), which has been technically revised.

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# Vitreous and porcelain enamels — Design of bolted steel tanks for the storage or treatment of water or municipal or industrial effluents and sludges

## 1 Scope

This International Standard establishes the requirements for the design and use of vitreous-enamel-coated bolted cylindrical steel tanks for the storage or treatment of water or municipal or industrial effluents and sludges.

It applies to the design of the tank and any associated roof and gives guidance on the requirements for the design of the foundation.

It applies where

- a) the tank is cylindrical and is mounted on a load-bearing base substantially at or above ground level;
- b) the product of the tank diameter in metres and the wall height in metres lies within the range 5 to 500;
- c) the tank diameter does not exceed 100 m and the total wall height does not exceed 50 m;
- d) the stored material has the characteristics of a liquid, exerting a negligible frictional force on the tank wall; the stored material may be undergoing treatment as part of a municipal or industrial effluent treatment process;
- e) the internal pressure in the headspace above the liquid does not exceed 50 kPa and the internal partial vacuum above the liquid does not exceed 10 kPa;
- f) the walls of the tank are vertical;
- g) the floor of the tank is substantially flat at its intersection with the wall; the floor of the tank may have a rise or fall built in to allow complete emptying of the tank contents, the slope of which does not exceed 1:100;
- h) there is negligible inertial and impact load due to tank filling;
- i) the minimum thickness of the tank shell is 1,5 mm;
- j) the material used for the manufacture of the steel sheets is carbon steel (tanks constructed of sheets made from aluminium or stainless steel are outside the scope of this International Standard);
- k) the temperature of the tank wall during operation is within the range  $-50\text{ }^{\circ}\text{C}$  to  $+100\text{ }^{\circ}\text{C}$  under all operating conditions.

This International Standard also gives details of procedures to be followed during installation on site and for inspection and maintenance of the installed tank.

It does not apply to chemical-reaction vessels.

It does not cover resistance to fire.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

## ISO 28765:2016(E)

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

ISO 2746:2015, *Vitreous and porcelain enamels — High voltage test*

ISO 2859-1, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 4532, *Vitreous and porcelain enamels — Determination of the resistance of enamelled articles to impact — Pistol test*

ISO 6370-2, *Vitreous and porcelain enamels — Determination of the resistance to abrasion — Part 2: Loss in mass after sub-surface abrasion*

ISO 8289:2000, *Vitreous and porcelain enamels — Low voltage test for detecting and locating defects*

ISO 15686-1, *Buildings and constructed assets — Service life planning — Part 1: General principles and framework*

ISO 28706-1:2008, *Vitreous and porcelain enamels — Determination of resistance to chemical corrosion — Part 1: Determination of resistance to chemical corrosion by acids at room temperature*

ISO 28706-2:2008, *Vitreous and porcelain enamels — Determination of resistance to chemical corrosion — Part 2: Determination of resistance to chemical corrosion by boiling acids, boiling neutral liquids and/or their vapours*

ISO 28706-3:2008, *Vitreous and porcelain enamels — Determination of resistance to chemical corrosion — Part 3: Determination of resistance to chemical corrosion by alkaline liquids using a hexagonal vessel*

ISO 28706-4:2008, *Vitreous and porcelain enamels — Determination of resistance to chemical corrosion — Part 4: Determination of resistance to chemical corrosion by alkaline liquids using a cylindrical vessel*

ISO 28763:2008, *Vitreous and porcelain enamels — Regenerative, enamelled and packed panels for air-gas and gas-gas heat exchangers — Specifications*

EN 15771, *Vitreous and porcelain enamels — Determination of surface scratch hardness according to the Mohs scale*

EN 1993-1-6, *Eurocode 3 — Design of steel structures — Part 1-6: Strength and Stability of Shell Structures*

EN 1993-4-1, *Eurocode 3 — Design of steel structures — Part 4-1: Silos*

EN 1993-4-2, *Eurocode 3 — Design of steel structures — Part 4-2: Tanks*

EN 1998-4, *Eurocode 8 — Design of structures for earthquake resistance — Part 4: Silos, tanks and pipelines*

EN 10209:2013, *Cold rolled low carbon steel flat products for vitreous enamelling — Technical delivery conditions*

ANSI/AWWA D 103, *Factory-Coated Bolted Steel Tanks for Water Storage*

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

#### 3.1

##### brief

working document which specifies at any point in time the relevant needs and aims of the project, the resources to be provided by the client, the details of the project and any applicable design requirements within which all subsequent briefing (when needed) and designing can take place



**3.2****client**

person or organization that requires a tank to be provided, altered or extended and is responsible for initiating and approving the brief

**3.3****defect**

break in the surface of the vitreous enamel

**3.4****designer**

person or organization responsible for stating the shape and specification of the component to be designed

**3.5****design life**

service life intended by the designer

**3.6****discontinuity**

weakness within the vitreous enamel coating that is detected by spark testing

**3.7****enamel supplier**

person or organization supplying materials for use by the vitreous enameller in the enamelling process

**3.8****freeboard**

distance between the top of the cylindrical-tank vertical shell wall and the surface of the contained liquid at the specified operating level

**3.9****headspace pressure**

pressure within a roofed tank above the stored liquid

**3.10****inspection area**

area inside a boundary 25 mm from any panel edge or hole and outside a boundary 25 mm from any opening or hole within the body of a panel

**3.11****liquid**

bulk substance that exerts substantially the same vertical and horizontal pressures and has no fixed shape

**3.12****maintenance**

combination of all technical and associated administrative actions during the service life to retain a tank or its parts in a state in which it can perform its required function

**3.13****manufacturer**

person or organization that manufactures the tank or parts of the tank

**3.14****purchaser**

person or organization purchasing the tank from the supplier

Note 1 to entry: The purchaser can also be the client.

**3.15**

**rectification**

return of a tank or its parts to an acceptable condition by the renewal, replacement or repair of worn, damaged or degraded parts

**3.16**

**supplier**

person or organization that supplies the tank or parts of the tank

**3.17**

**service life**

period of time after installation during which the tank or its parts meets or exceeds the performance requirements

**3.18**

**tank**

cylindrical, vertical shell for containing liquid, with or without a roof, which is constructed from vitreous-enamelled curved steel panels bolted together on the construction site and mounted on a base which may also form the floor of the container

**3.19**

**vitreous enameller**

person undertaking and controlling the process of preparing the steel sheets and applying the vitreous-enamel coating to the surfaces of the steel sheets

Note 1 to entry: The vitreous enameller will normally be the manufacturer.

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**3.20**

**vitreous enamel**

substantially vitreous, or glassy inorganic silica coating bonded to metallic substrate by fusion at a temperature above 480 °C

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Note 1 to entry: This coating is applied for protective functional and/or aesthetic purposes.

Note 2 to entry: This coating is produced by the proprietary formulation of silica glass, minerals and clays to produce a sprayable medium, dry or suspended in water on to the surface of the metallic substrate, and its subsequent fusion bonding.

**4 Symbols and abbreviated terms**

For the purposes of this document, the following symbols and abbreviated terms apply.

$D$	tank diameter
$E$	Young's modulus of elasticity
$F_H$	static hoop force
$g$	acceleration due to gravity
$H$	depth of liquid at point under consideration, measured from the liquid surface at the maximum possible filling level
$H_0$	total vertical wall height
$l$	length of shell between intermediate stiffeners
$I_z$	second moment of area of a stiffener
$p_n$	static liquid pressure at a specified depth

$p_h$	headspace pressure
$r$	tank radius
$q_{r,cr}$	critical external buckling pressure
$q_{wmax}$	maximum stagnation pressure due to wind
$w$	proportion of dissolved solids in sludge
$t$	shell plate thickness
$\nu$	Poisson's ratio
$\gamma$	partial load factor
$\rho$	relative density of a liquid
$\sigma$	stress
$\sigma_{z,cr}$	critical axial buckling resistance
cr	(subscript) critical
ds	(subscript) dissolved solids
h	(subscript) headspace
max	(subscript) maximum value
n	(subscript) normal to the tank wall
s	(subscript) sludge
w	(subscript) wind
z	(subscript) coincident with the central axis of a shell of revolution
$\varphi$	(subscript) coincident with the radial axis of a shell of revolution

## 5 Units

The use of one of the following sets of consistent units is recommended:

- dimensions: m, mm
- unit weight: kN/m<sup>3</sup>, N/mm<sup>3</sup>
- forces and loads: kN, N
- line forces and line loads: kN/m, N/mm
- pressures and area-distributed actions: kPa, MPa
- unit mass: kg/m<sup>3</sup>, kg/mm<sup>3</sup>
- acceleration: km/s<sup>2</sup>, m/s<sup>2</sup>
- membrane-stress resultants: kN/m, N/mm

- bending-stress resultants: kNm/m, Nmm/mm
- stresses and elastic moduli: kPa, MPa (1 MPa = 1 N/mm<sup>2</sup>)

## 6 Information and requirements to be agreed and documented

### 6.1 General

For the safe design and manufacture of the tank and associated parts, the specification shall be agreed between the contracting parties.

### 6.2 Information to be provided by the purchaser

The purchaser shall provide the supplier with a specification that shall include, but not be limited to, the following:

- a) The specification of the stored liquid, that shall include, but not be limited to, the following:
  - 1) the name and/or a description of the liquid;
  - 2) the relative density;
  - 3) any relevant properties or characteristics particular to the liquid to be stored;
  - 4) the operating-temperature range.
- b) The environmental conditions, that shall include, but not be limited to, the following:
  - 1) wind;
  - 2) seismic action; <https://standards.iteh.ai/catalog/standards/sist/8aa08ba1-ecec-4266-b539-f6d150f96923/iso-28765-2016>
  - 3) snow;
  - 4) ice;
  - 5) temperature ranges.
- c) The use and planned dimensions of the tank, that shall include, but not be limited to, the following:
  - 1) the rates of fill and discharge;
  - 2) a summary describing the purpose of the tank and its method of operation;
  - 3) the net effects of the process on the tank or any of its components;
  - 4) the tank dimensions.
- d) The planned location of all openings in the tank shell and roof.
- e) Attached equipment:
  - 1) method of attachment;
  - 2) dead and live loads;
  - 3) connections.
- f) The proximity of other tanks and buildings.