BS EN 15282:2007

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

The European Standard EN 15282:2007 has the status of a British Standard

ICS 25.220.50; 23.020.10; 13.060.01

British Standards

National foreword

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A list of organizations represented on STI/36 can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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English Version

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

Emaux vitrifiés - Conception de réservoirs en acier, boulonnés et revêtus d'émail vitrifié pour le stockage ou le traitement des eaux ou des effluents d'eaux usées principales

Emails und Emaillierungen - Gestaltung von verschraubten Stahlbehältern für die Speicherung oder Behandlung von Wasser oder kommunalen und industriellen Abwässern und Abwasserschlamm

This European Standard was approved by CEN on 3 February 2007.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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Foreword

This document (EN 15282:2007) has been prepared by Technical Committee CEN/TC 262 “Metallic and other inorganic coatings”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2007, and conflicting national standards shall be withdrawn at the latest by September 2007.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard establishes the requirement 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.

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

This European Standard applies where:

a) the tank is cylindrical and symmetrical on plan and is mounted on a load-bearing base substantially at or above ground level;

b) the multiple of the tank diameter in meters and the wall height in meters has a value 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 negligible friction force in the tank wall; the stored material may be undergoing treatment as part of a municipal or industrial effluent treatment process;

e) the internal pressure 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 should 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 European Standard),

k) the temperature of the tank wall during operation is within the range - 50 ºC to + 100 ºC under all operating conditions.

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

It does not apply to chemical reaction vessels.

It does not apply to tanks fitted with floating roofs.

It does not cover resistance to fire.

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 101, *Ceramic tiles — Determination of scratch hardness of surface according to Mohs*

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 10209:1996, *Cold rolled low carbon steel flat products for vitreous enamelling — Technical delivery conditions*

EN 14430:2004, *Vitreous and porcelain enamels — High voltage test*

EN 14483-1:2004, *Vitreous and porcelain enamels — Determination of resistance to chemical corrosion — Part 1: Determination of resistance to chemical corrosion by acids at room temperature*

EN 14483-2:2004, *Vitreous and porcelain enamels — Determination of resistance to chemical corrosion — Part 2: Determination of resistance to chemical corrosion by boiling acids, neutral liquids and/or their vapours*

EN 14483-3:2004, *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*

EN 14483-4:2004, *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*

EN ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method (ISO 2178:1982)*

EN ISO 8289:2001, *Vitreous and porcelain enamels — Low voltage test for detecting and locating defects (ISO 8289:2000)*

ISO 2747, *Vitreous and porcelain enamels — Enamelled cooking utensils — Determination of resistance to thermal shock*

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, V*itreous and porcelain enamels — Determination of resistance to abrasion — Part 2: Loss in mass after sub-surface abrasion*

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

ANSI/AWWA D103-97, *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, 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 organisation 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 organisation responsible for stating the form and specification of the component to be designed

3.5
design life
service life intended by the designer

3.6
discontinuity
defect area or spot that allows an electric current to pass when tested with the low voltage or high voltage test apparatus used in accordance with 10.3.2.2

3.7
enamel supplier
person or organisation 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 the panel

3.11
liquid
bulk substance that exerts substantially the same vertical and horizontal pressures and has no fixed form

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 organisation that manufactures the tank or parts of the tank

3.14
purchaser
person or organisation purchasing the tank from the supplier

NOTE 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 mending of worn, damaged or degraded parts

3.16
supplier
person or organisation 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 sheet

NOTE The vitreous enameller will normally be the manufacturer.

3.20
vitreous enamel
substantially vitreous, or glassy inorganic silica coating bonded to steel by fusion at a temperature above 750 ºC

NOTE 1 This coating is applied for protective purposes to the internal liquid contact surface of the steel and for functional and decorative purposes to the external surface of the steel.

NOTE 2 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 curved steel sheets and its subsequent fusion bonding.

4 Symbols and abbreviated terms

For the purposes of this document, the following symbols and abbreviations 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
$q_{w\,max}$	Maximum stagnation pressure due to wind
w	Proportion of dissolved solids in sludge
t	Shell plate thickness
ν	Poisson's ratio
γ	Partial load factor
ρ	Relative density of a liquid
σ	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^3, N/mm^3
- 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^3, kg/mm^3
- acceleration: km/s^2, m/s^2
- 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^2)

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 by the contracting parties.

6.2 Information to be provided by the purchaser

The purchaser shall provide specification data to the supplier that shall include, but is not limited to the following.

a) Specification of the stored liquid that shall include, but not be limited to:

1) name and/or description;

2) relative density;

3) any relevant properties or characteristics particular to the liquid to be stored;

4) operating temperature range.

b) Environmental conditions that shall include, but not be limited to:

1) wind;

2) seismic;

3) snow;

4) ice;

5) temperature range.

c) The usage and planned dimensions of the tank that shall include, but not be limited to:

1) the rate of fill and discharge;

2) a summary describing the function and method of the process;

3) the net effects of the process on the tank or any of its components.

d) The planned location of all openings into the tank shell and roof.

e) Attached equipment:

1) method of attachment;

2) dead and live loads;

3) connections.

f) Proximity of other tanks and buildings.

6.3 Information to be provided by the designer

The designer shall provide essential data concerning the design limitations of the tank that shall include, but not be limited to the following:

a) the name and description of the stored liquid or liquids;

b) the range of values of relative density of the stored liquid or liquids;

c) the limits of the environmental criteria used in the design including, where relevant, the design wind speed, the design operating temperature range, the design snow load and the seismic zone and seismic coefficients;

d) the maximum access and superimposed loads used in the design;

e) a maintenance plan conforming to the requirements of ISO 15686-1;

f) guidance concerning change of use;

g) all relevant data assumed by the designer used in the design process.

7 Applicable standards

All activities specified in this European Standard shall be carried out under an appropriate quality management system. A quality management system conforming to EN ISO 9001 [1] will be deemed to satisfy the requirements.

The designer and client shall agree through consultation upon the applicable standards to be used for design. Where provision is not made within this European Standard, other European Standards or national standards may be specified.

The applicable standards agreed upon shall include, but not be limited to, standards providing details of parameters for the following design procedures:

a) hydrostatic loads;

b) wind loads;

c) seismic loads;

d) access loads;

e) snow loads;

f) rain loads;

g) load factors;

h) sheet strength calculations;

i) bolt strength calculations;

j) stability calculations;

k) foundation design.

8 Loads

8.1 General

All tanks and supporting structures shall be designed on a Limit State Design basis.

8.2 Contents

8.2.1 General

Loads due to the liquid shall be calculated considering:

a) the relative density of the defined range of liquids to be stored in the tank;

b) the geometry of the tank;

c) the maximum possible depth of the liquid in the tank.

If the liquid to be stored is sludge and unless reliable or measured data is provided, the value of the relative density of the sludge, ρ_s, may be estimated by simple proportion using the following equation:

$$\rho_s = 1 + w(\rho_{ds} - 1) \quad (1)$$

where

ρ_{ds} is taken as 1,9 in the case of municipal sewage sludge.

8.2.2 Freeboard

The freeboard used for design shall be as agreed between the client and the designer.

Where the tank is designed for seismic conditions sufficient freeboard shall be provided to contain the sloshing wave determined in accordance with EN 1998-4. This shall account for equipment or structural members in the top of the tank.

8.2.3 Hydrostatic pressure

Determine the hydrostatic pressure, p_n, in kPa, acting on the tank shell at depth H using the following equation:

$$p_n = H \times \rho \times g + p_h \quad (2)$$

8.2.4 Axial wall forces

Axial wall forces per unit shell width shall be determined taking account of the following:

a) tank dead weight;

b) imposed load;

c) axial tension and compression due to wind overturning moment;

d) axial tension and compression due to seismic actions.

8.2.5 Filling and discharging

The method of filling and discharging the liquid can affect the load and shall be considered by the designer. These influences include but are not limited to the following:

a) filling position - inlet stream impinging on the tank wall;

b) completion of discharge - risk of hydrodynamic ‘water hammer’ effect if outlet is closed rapidly;

c) fatigue - the effect of the frequency of filling and discharge cycles;

d) pressure and/or partial vacuum;

e) venting;

f) rapid changes in temperature.

8.3 Tank structure

Dead load shall be determined as the total weight of all structural components and permanent fittings.

8.4 Roof

The tank designer shall take account of all forces on the tank shell from the roof. These forces may include, but may not be limited to:

a) distributed in-plane and radial forces transmitted by structural roof members;

b) concentrated in-plane and radial forces resulting from structural features of the roof;

c) asymmetrical forces due to uneven distribution of imposed roof loads;

d) forces induced in the roof by differential settlement of the foundation.

8.5 Equipment loads

8.5.1 General

In the calculation of the total load on the tank the designer shall take into account the effect of the attached equipment for both static and dynamic loads.

8.5.2 Static load

The static load of any equipment attached to the tanks shall be determined as the weight of the equipment, including associated mounting fixtures and any liquid within the equipment as advised by the purchaser.

8.5.3 Dynamic load

The dynamic forces of any equipment shall be determined where applicable, which may include but are not limited to:

a) starting and operating forces from any rotating or moving piece of equipment mounted on the tank;

b) forces imposed on the tank or attachments from installed process equipment (e.g. forces from restraining cables of floating aerators);

c) forces imposed on the tank or attachments due to the operation of installed process equipment (e.g. forces on attached baffle plates due to forced movement of the tank contents).

8.6 Access

Loads due to access equipment such as walkways and platforms shall be determined taking account of the type of access required.

a) Where access is for cleaning and repair only, the superimposed load shall be taken as not less than 0,75 kN/m^2.

b) Where access is required for operational procedures, the superimposed load shall be taken as not less than 3,0 kN/m^2.

Where a roof is fitted with hand-railing, the area within the hand-railing shall be considered as accessible.

8.7 Environmental

8.7.1 General

Environmental loads shall be determined taking into account the design life of the tank.

8.7.2 Seismic

Where relevant, seismic action shall be determined from the applicable standard.

The designer shall consider the following as a minimum requirement:

a) horizontal acceleration;

b) vertical acceleration;

c) sloshing of the contents;

d) anchorage method;

e) dynamic ground response.

NOTE Guidance on the determination of seismic actions can be found in the International Building Code, ANSI/AWWA D103-97 and EN 1998-1 and EN 1998-4. When applying ANSI/AWWA D103-97 in locations outside North America, zones determined from the Uniform Building Code 1997 may be taken as equivalent. For the purposes of this European Standard, the loads determined according to ANSI/AWWA D103-97 may be considered as characteristic loads.

8.7.3 Wind

The wind speed and pressure to be used for design shall be determined from the applicable standard for the site location.

8.7.4 Snow

Where applicable the load induced by snow shall be determined from the applicable standard for the site location.

8.7.5 Ice

Where applicable, the load induced by ice on roofs shall be determined from the applicable standard for the site location.

8.8 Ancillary items

The designer shall take account of the forces from ancillary items such as ladders, platforms, valves, machinery etc.

9 Design

9.1 General

The design of the tank shall be carried out using a Limit State Design approach. Design life assessment shall be based on ISO 15686-1.

9.2 Steel

9.2.1 Specification

The steel used shall have a specification as agreed between the manufacturer, the designer and the steel supplier having due regard to the requirement of the enamelling process.

NOTE Steels conforming to the requirements of EN 10111 [2] and EN 10149-1 [3], (including grades DD 11, S235, S420 and S460) and ASTM A1011 [4] and other standards can be used successfully for vitreous enamelling with appropriate pre-treatments.

9.2.2 Effects of the enamelling process

The designer shall take account of the effects of the vitreous enamelling process on the strength properties of the steel, and shall make details of such effects available to the client on request.

The effect of the enamelling process shall be assessed and monitored over a period of time using a regular and documented testing regime from which steel strength properties can be predicted with a 95 % confidence level.

Where regular and documented testing is not carried out, the yield and tensile strengths of the enamelled steel used for design purposes shall be reduced by 30 % from the guaranteed minimum strengths confirmed by the steel manufacturer.

9.3 Tank

9.3.1 Load factors

Load factors used in design shall be taken from Table 1.

Table 1 — Load factors

Basic load case	Maximum load factor γ
Dead load	1,4
Liquid load	1,4
Imposed load	1,6
Wind load	1,4
Seismic load [a]	1,4
Wind load acting with seismic load and liquid load combined	1,2
Seismic load acting with wind and liquid load combined [a]	1,2
Stability	1,7
Any load when the action is beneficial to the load case being considered	1,0
[a] Seismic actions need not be considered to act under test conditions.	

9.3.2 Tank walls

9.3.2.1 General design

The walls of the tank shall be designed to resist the most demanding load combination.

The tank walls shall be designed to resist the forces and moments due to the connection to the foundation including any non-linear and stability effects.

NOTE For the purpose of this standard, wall friction forces due to the stored liquid are small and may safely be ignored.

9.3.2.2 Hoop force

The hoop force used in the determination of the shell plate thickness and vertical bolted joint configuration shall take into account hydrostatic pressure and hydrodynamic pressure due to seismic action.

9.3.2.3 Static

Determine the hydrostatic hoop force per unit height, F_H, in kNm^{-1}, at any level using the equation:

$$F_H = p_n \times \frac{D}{2} \quad (3)$$

9.3.2.4 Seismic

The design method employed by the designer shall take account of the following as a minimum requirement.

a) Hydrodynamic hoop forces.

b) Shell axial compression forces.

c) Lateral and vertical anchorage forces.

d) Dynamic ground response profile.

Design of tanks for seismic resistance shall be in accordance with EN 1998-4, or Section 12 of ANSI/AWWA D103-97.

NOTE Where design is in accordance with ANSI/AWWA D103-97, the loads determined should be considered as characteristic loads, factored using load factors from Table 1 and compared to limit state capacities and buckling resistances determined in accordance with this European Standard.

9.3.2.5 Bolted joints

Bolts subject to shear forces shall be designed such that they are able to transmit forces between the connected shell plates. The bolt shall be proportioned such that the joint shear plane does not pass through any part of the thread or the thread run-out.

The vertical bolted joints between shell plates shall be designed to transfer the design hoop force between adjacent shell plates.

The vertical bolted joint shall be designed taking account of, as a minimum, the following.

a) Tensile stress on any net section through any structurally continuous sequence of bolts.

b) Bearing stress on the connected steel plates.

c) Bearing stress on the bolts.

d) Shear stress in the bolts.

The hole bearing strength of the steel may be determined by test or may be taken from the applicable standard for the steel being used. Where the bearing strength is determined by test, details of the test methods shall be made available to the client on request.

Bearing strength and shear strength of the bolts shall be taken from the applicable standard for the bolts being used.

9.3.2.6 Axial wall forces

The designer shall consider the effects of axial wall forces on the axial buckling resistance of the tank shell. The effects of axial load combined with external wind pressure, roof live loads and any internal partial vacuum due to operational procedures or to the effects of wind induced suction at roof vents, shall also be considered.

The critical axial buckling resistance shall be determined by rigorous analysis. Critical buckling strengths determined in accordance with EN 1993-4-2 may be considered to satisfy this requirement.

Alternatively the critical axial buckling resistance, $\sigma_{z,cr}$, in MPa, may be determined using the following equation:

$$\sigma_{z,cr} = 0{,}3 \times E \times \frac{t}{r} \tag{4}$$

NOTE Second order effects can be present due to irregularities in the shell, particularly with large diameter tanks, and the designer should take account of these effects where relevant.

9.3.2.7 External wind pressure

The designer shall consider the effects of external wind pressure on the following with the tank in the empty condition:

a) external pressure buckling;

b) circumferential bending of the tank shell caused by wind pressure variation;

c) shell axial tension and compression;

d) overturning resistance of the tank hold down system.

The designer shall take account of the proximity of other tanks and buildings.

The resistance to external wind pressure buckling may be determined by rigorous analysis. Resistance to external wind pressure buckling determined in accordance with EN 1993-4-1 or EN 1993-1-6 may be taken to satisfy this requirement.

Alternatively the critical external buckling pressure, $q_{\mathrm{r,cr}}$, in MPa, may be determined using the equation:

$$q_{\mathrm{r,cr}} = 0{,}8 \times \frac{Et^2}{lr} \sqrt[4]{\left(\frac{1}{1-\upsilon^2}\right)^3 \frac{t^2}{r^2}} \qquad (5)$$

This equation should be applied to the shell between the top shell stiffener and the first intermediate shell stiffener or the base of the tank where no intermediate shell stiffeners are fitted, and to each successive portion between any subsequent intermediate shell stiffeners. Where the portion of shell under consideration is of non-uniform thickness, the mean thickness should be used.

When comparing this resistance to the applied wind pressure, the wind pressure should be taken as equal to the maximum wind pressure in the radial direction applied equally around the full 360° circumference of the tank.

The designer may consider a reduced wind speed when designing for test conditions.

NOTE The effect of the vitreous enamel coating may be included in the calculation of shell stiffness in radial buckling design.

9.3.2.8 Top shell stiffener

For open top tanks, the top shell stiffener shall be proportioned such as to provide sufficient support to prevent radial buckling of the tank shell. The top shell stiffener may be proportioned by rigorous analysis taking account of both ring buckling and bending effects. A top shell stiffener proportioned in accordance with EN 1993-4-1 may be deemed to satisfy this requirement.

Alternatively, the top shell stiffener, I_{z} ,in m^4, may be proportioned using the equation:

$$I_{\mathrm{z}} = \frac{q_{\mathrm{w_{max}}} H_{\mathrm{o}} r^3}{6E} \qquad (6)$$

Additionally, for tanks fitted with a roof, the size of the top shell stiffener shall take account of the magnitude and distribution of the forces imposed by the roof structure and any fittings.

9.3.2.9 Intermediate shell stiffener

The intermediate shell stiffener(s) may be proportioned by rigorous analysis such as to provide sufficient support to prevent radial buckling of the ring or group of rings of the tank shell over which it can be shown to be effective. Intermediate shell stiffener(s) proportioned in accordance with EN 1993-4-1 may be deemed to satisfy this provision.

Alternatively the intermediate shell stiffeners, I_{z} ,in m^4, may be proportioned using the equation:

$$I_z = \frac{q_{w_{max}} l r^3}{3E} \qquad (7)$$

where

l is the distance between intermediate stiffener rings or between the lowest intermediate stiffener ring and the bottom of the tank.

9.3.2.10 Thermal

The design of the tank structure shall consider the consequences of thermal effects (displacement, strain, curvatures, stresses, forces and moments) due to the temperature difference between the stored liquid and the tank structure and/or between the external environment and the tank structure. The designer shall also consider the effects of ice formation on the surface of the stored liquid.

9.3.2.11 Internal pressure

For roofed tanks, the designer shall take account of the effects of internal pressure on the design and thickness of the tank walls.

9.3.2.12 Internal vacuum

For open top tanks, the designer shall take in to account the partial vacuum generated on the inside of the tank due to the effects of wind, and shall combine these with the external wind pressure when designing the tank shell.

For roofed tanks, the designer shall take into account internal vacuum resulting from the operating conditions and the influence of wind pressures and suctions on any roof vents, and shall combine these with the external wind pressure when designing the tank shell. These effects shall be considered with the tank in the empty condition.

9.3.3 Tank roof

As a minimum requirement the designer shall take account of the following:

a) dead load;

b) live load - snow, access, wind, rain, seismic;

c) internal pressure and vacuum;

d) roof openings;

e) compression and tension in any structural stiffening member fitted to the tank at its interface with the roof.

9.3.4 Attachment of walls to floor

The connection between the tank wall and the tank base shall be designed to transmit the vertical forces in the tank walls and horizontal shear forces and bending moments due to liquid loads, wind loads, seismic loads and internal pressure to the foundation.

9.3.5 Tank floor

9.3.5.1 Concrete

Unless a surface coating or treatment is to be applied, the concrete used to form the floor of the tank shall be waterproof.

9.3.5.2 Vitreous enamelled steel plates

All vitreous enamelled floor plates shall be fully bolted along all seams. The number of bolts shall be sufficient to ensure a waterproof seal in conjunction with a suitable sealant material.

NOTE A suitable seal is such that it adequately protects the bolted joint and is flexible, whilst curing chemically to form an homogenous barrier.

9.3.5.3 Foundation

Where the supplier is responsible for complete design and supply of the tank including the foundation, the client shall provide the supplier with site soils survey data as necessary.

The manufacturer shall furnish plans for the connection of the tank to the foundation including shear loads where critical if requested by the purchaser, containing all relevant details to allow a foundation design for the specific site conditions to be carried out. The foundation shall be designed in accordance with the applicable standard. An exclusion zone for reinforcing bars may be specified in the foundation at the location of the tank connection in order to facilitate the installation of the holding down system or to prevent the risk of establishing a galvanic cell.

As a minimum requirement the designer shall take into account the following:

a) dead load;

b) live load;

c) tank/foundation interaction forces (moments and shears), including any non-linear and stability effects;

d) expansion of the tank shell under load;

e) environmental loads (wind and seismic);

f) thermal expansion;

g) soil conditions at the proposed construction site and the potential for differential settlement.

9.3.6 Ancillary items

Where ancillary items are required for access or safety, the client and the supplier shall agree upon the applicable standard.

9.3.7 Cathodic protection

Where routine inspection and maintenance is impractical due to access limitations, commercial factors or ongoing process requirements then it may be beneficial for the client to consider the installation of a suitable cathodic protection system to provide additional security. The cathodic protection system shall be designed and installed by an engineer registered to a national or international organization (e.g. NACE).

The designer of the cathodic protection system shall take account of:

a) the electrical resistivity of the stored liquid;

b) the area of exposed steel surface;

c) the electrical connectivity between the tank contents, the tank structure, foundation concrete, foundation reinforcing steel and submerged ancillary steel items;

d) the current density required to inhibit corrosion when selecting the material for a sacrificial anode.

NOTE Sacrificial anode type cathodic protection systems provide a relatively simple, low cost, manageable and easy to install solution.

9.4 Openings

9.4.1 Access manway

For roofed tanks, at least one low level access manway shall be provided. The location shall be agreed between the client and the supplier.

For open top tanks, the positions for any required access manways shall be agreed between the client and the supplier.

Any removable cover shall be attached with a hinge or other supporting device.

9.4.2 Pipe connections

The size of pipe connections and point of attachment to the tank shall be agreed between the client and the supplier.

9.4.3 Overflows

The tank shall be equipped with an overflow of a capacity and at a location to be agreed between the client and the supplier. The overflow shall be designed such that it does not produce any negative pressure inside the tank and roof structure, and that there can be no contamination of the inlet water by back-syphoning.

A suitable air gap can be necessary between the overflow and the inlet connection. This shall be the subject of agreement between the purchaser and the supplier.

9.4.4 Reinforcement of manways and pipe connections in the tank shell

All openings having a minimum dimension greater than 100 mm cut into any section of the tank that are subject to hydrostatic pressure shall be reinforced.

The minimum nett cross sectional area of the reinforcing allowing for any bolt holes shall not be less than the product of the maximum vertical dimension of the hole cut into the tank shell and the minimum design shell thickness. In addition to the saddle(s), only those elements of the reinforcing neck that fall within a distance of 4 times the thickness of the neck from the shell plate may be considered as a part of the reinforcing area.

9.4.5 Connections in the roof

9.4.5.1 General

The size of the roof opening and pipe connections and point of attachment shall be specified and agreed between the client and supplier.

Access opening over 250 mm shall be provided with a suitable safety device to prevent unauthorised access.

9.4.5.2 Venting

Where the roof forms a gas-tight seal to the tank, the roof shall be fitted with a vent or pressure/vacuum relief device, of a capacity to prevent the pressure/vacuum exceeding the design limits of the tank shell or roof under the most extreme normal operating conditions.

The design of venting of closed tanks shall take into account all relevant operational conditions including but not limited to the following.

a) Adding and extracting liquids.

b) Build-up of internal pressure or vacuum from environmental or process factors.

c) Screening to prevent ingress of birds, animals or insects.

d) Symmetry of the air flow from the tank plan area.

NOTE Vents fitted with screens require regular inspection and cleaning in order to maintain their efficiency.

9.5 Effects of accidents

9.5.1 Risk assessment

The client shall provide all relevant history of the potential risk involved in dealing with the product to allow due account to be taken by the designer of the tank and supporting structure. The designer shall consider at least the following where applicable.

9.5.2 Explosions

The potential damage from an explosion should be limited or avoided by the choice of appropriate measures such as:

a) incorporating sufficient pressure relief measures;

b) incorporating suppression measures;

c) details of maintenance and cleaning routines;

d) safe selection of electronic equipment to avoid possible ignition sources.

9.5.3 Uncontrolled fluctuation in input stream characteristics

The client shall make the designer aware of any history of significant accidental fluctuations of input stream characteristics from the agreed specification in respect of temperature, chemical nature, flow rate and any other characteristic likely to affect the tank design.

10 Vitreous enamel coating

10.1 Vitreous enamel

The vitreous enameller shall specify the requirements of all raw materials to be used in the vitreous enamelling process and ensure that they will produce a coating that will meet the minimum quality requirements listed in Table 2 and Table 3 when processed through the intended vitreous enamelling plant. The vitreous enameller or the enamel supplier shall carry out tests and record conformity of the enamelled materials in accordance with Table 2, and shall make certified copies of these records available for subsequent inspection.

All raw material used in the production of vitreous enamel coated panels shall meet the specification as described in this section and shall be agreed between the manufacturer and the material supplier having due regard to the requirements of the enamelling process.

10.2 Coating

The vitreous enamel coating shall meet the minimum quality requirements shown in Table 2.

The client shall satisfy himself that the vitreous enamel coating is suitable for the intended purpose.

Prior to coating the steel shall be free of all oil, lubricants and other contaminants.

10.3 Vitreous enamel quality

10.3.1 Preparation and testing frequency

Test specimens of vitreous enamelled steel shall be prepared and tested at least at the minimum inspection frequency specified in Table 2 to ensure that the enamel meets the relevant quality requirements set out in Table 2.

10.3.2 Inspection

10.3.2.1 Sampling procedure

Inspection shall be carried out using a sampling procedure conforming to the requirements of ISO 2859-1. Testing apparatus shall be calibrated using calibration instruments having an accuracy of ± 1 %. Testing apparatus shall have valid calibration records.

10.3.2.2 Finished panels

10.3.2.2.1 General

Tests shall be carried out within the inspection area of the finished panel and shall meet the specification as set out in Table 3. For the purpose of these tests, any panel surface coming into contact with the stored liquid shall be treated as an inside surface.

Finished panels shall be inspected following the enamelling process, manufacturers shall carry out inspection on both inside and outside surface under good daylight or equivalent artificial lighting.

10.3.2.2.2 Inside surface

The inside panel surface shall be inspected for defects as shown in Table 3.

10.3.2.2.3 Outside surface

The outside panel surface shall be inspected for defects as shown in Table 3.

10.3.2.3 Enamel thickness

The thickness of the enamel shall be measured using an approved instrument having a measurement range of 0 µm to 500 µm. The thickness of the enamel on any panel shall be maintained within the range shown in Table 3. Panels having an enamel thickness outside these limits shall be rejected.

10.3.2.4 Enamel colour

The colour of the enamelled sheet surfaces and colour tolerances shall be agreed by the interested parties. Conformity shall be determined using a colour comparator.

10.3.3 Site rectification

The manufacturer shall provide a procedure for site rectification and site touch-up of damaged coatings.

Table 2 — Minimum quality requirement for vitreous enamel for use in various liquid storage tank applications

APPLICATION GUIDE				Potable water (ANSI/NSF 61)	Potable water (DWI listed, Reg 31)	Borehole/brackish/sea water	Storm/fire water	Filter tanks	Municipal sludge/sludge cake storage	- roof and top ring	- cylinders	Municipal sludge treatment	Liquid leachate	- roof and top ring	- cylinders	Municipal mesophyllic digester	- roof and top ring	- cylinders	Thermophylic/pasteurisation digester	Industrial effluent process/treatment
Test method	**Property**	**Minimum quality requirement**	**Minimum inspection frequency**																	
EN 14483-1:2004 Clause 9	Resistance to chemical corrosion by citric acid at room temperature	Class A	Monthly or with each batch				●								●					
		Class A+		●	●			●	●		●									
		Class AA				●				●			●	●			●	●		●
EN 14483-1:2004 Clause 10	Resistance to chemical corrosion by sulphuric acid at room temperature	Class A+	Monthly or with each batch			●				●			●	●				●		●
		Class AA															●			
EN 14483-1:2004 Clause 11	Resistance to chemical corrosion by hydrochloric acid at room temperature	10 % solution for 15 min	Monthly or with each batch																	
		Class A+				●				●			●	●				●		●
		Class AA															●			
EN 14483-2:2004 Clause 10	Resistance to chemical corrosion by boiling citric acid	Max mass loss after 2,5 h	Annually																	
		5 g/m²					●								●					
		3 g/m²		●	●			●	●		●									
		1,5 g/m²				●				●			●	●				●		●
		0,75 g/m²															●			
EN 14483-2:2004 Clause 12	Resistance to chemical corrosion by boiling hydrochloric acid	Max mass loss after 7 days.	Annually																	
	Vapour phase	8 g/m²				●				●			●	●				●		●
		7 g/m²															●			
EN 14483-2:2004 Clause 13	Resistance to chemical corrosion by boiling distilled or de-mineralized water	Max mass loss after 48 h	Annually																	
	Liquid phase	5 g/m²		●	●		●	●	●		●				●					
		2,5 g/m²				●				●			●	●			●	●		●
	Vapour phase	7,5 g/m²				●				●			●	●				●		●
		5 g/m²															●			

APPLICATION GUIDE

Test method	Property	Minimum quality requirement	Minimum inspection frequency	Potable water (ANSI/NSF 61)	Potable water (DWI listed, Reg 31)	Borehole/brackish/sea water	Storm/fire water	Filter tanks	Municipal sludge/sludge cake storage	- roof and top ring	- cylinders	Municipal sludge treatment	Liquid leachate	- roof and top ring	- cylinders	Municipal mesophylic digester	- roof and top ring	- cylinders	Thermophylic/pasteurisation digester	Industrial effluent process/treatment
EN 14483-3:2004 Clause 9	Resistance to chemical corrosion by standard detergent solutions	Max. mass loss after 24 h	Annually																	
		5 g/m^2				●				●			●	●				●		●
		2,5 g/m^2															●			
EN 14483-4:2004 Clause 9	Resistance to chemical corrosion by hot sodium hydroxide	Max. mass loss after 24 h	Annually																	
		7 g/m^2		●	●		●	●	●		●				●					
		6 g/m^2				●				●			●	●			●	●		●
ISO 2747	Resistance to thermal shock	300 °C	Annually			●				●			●	●			●	●		●
ISO 4532	Resistance to impact: pistol test	Max damage <2 mm in diameter after 24 h	Monthly or with each batch																	
		20 N force		●	●		●	●	●		●				●					
		40 N force				●				●			●	●			●	●		●
ISO 6370-2	Determination of the resistance to abrasion	Max mass loss 45 g/m^2	Annually			●				●			●	●			●	●		●
EN 101	Scratch hardness of surface according to Mohs	Mohs 5	Monthly or with each batch	●	●	●	●	●	●	●	●		●	●	●		●	●		●
EN 10209:1996 Annex D	Adherence level	Class 2	Monthly or with each batch	●	●	●	●	●	●	●	●		●	●	●		●	●		●

NOTE Consult with supplier for suitability for specific applications. All applications subject to concentration and temperature considerations of the stored liquid.

Table 3 — Requirements for finished vitreous enamelled panels for use in tanks for storage or treatment of water or municipal or industrial effluents and sludges

APPLICATION GUIDE																				
Test	**Specification**	**Min. inspection frequency**	**Inspection method**	Potable water (ANSI/NSF 61)	Potable water (DWI listed, Reg 31)	Borehole/brackish/sea water	Storm/fire water	Filter tanks	Municipal sludge/sludge cake storage	- roof and top ring	- cylinders	Municipal sludge treatment	Liquid leachate	- roof and top ring	- cylinders	Municipal mesophylic digester	- roof and top ring	- cylinders	Thermophylic/pasteurisation digester	Industrial effluent process/treatment
Enamel thickness	160 µm to 360 µm	Frequency determined in accordance with ISO 2859-1	EN ISO 2178				•								•					
	200 µm to 400 µm			•	•			•	•		•									
	260 µm to 460 µm					•				•			•	•				•		•
	300 µm to 500 µm																•			
Defects - Inside surface	No discontinuities	Every panel	EN ISO 8289:2001 Method A				•								•					
			EN 14430:2004 Test A Test voltage 900v	•	•			•	•		•									
			EN 14430:2004 Test A Test voltage 1100v			•				•			•	•				•		•
			EN 14430:2004 Test A Test voltage 1500v														•			
Defects - Outside surface	Max visible defect size 1 mm	Every panel	Visual inspection (see Note 2)	•	•	•	•	•	•	•	•		•	•	•		•	•		•
	Max 3 visible defects per m^2 total panel area	Every panel	Visual inspection (see Note 2)	•	•	•	•	•	•	•	•		•	•	•		•	•		•
Colour - Outside surface	Colour and colour tolerances shall be agreed between interested parties	Frequency determined in accordance with ISO 2859-1	Inspection using a colour comparator approved prior to production by the vitreous enameller	•	•	•	•	•	•	•	•		•	•	•		•	•		•

NOTE 1 Consult with supplier for suitability for specific applications. All applications subject to concentration and temperature considerations of the stored liquid.

NOTE 2 It is permissible, when agreed between the contracting parties, to rectify defects with a material approved by the vitreous enameller for the purpose, applied according to the rectification material manufacturer's instructions.

10.4 Protection during shipping

Panels shall be packed using a suitable membrane between the panels. To protect the panels from damage during shipment, the packed panels shall be protected by a suitable waterproof covering, secured with care taken to protect the panel edges.

10.5 Maintenance

The supplier shall provide documentation describing the procedures for inspection, maintenance and rectification of the vitreous enamel coating.

The inspection, maintenance and rectification of the vitreous enamel coating shall be carried out as described in the documentation supplied in order to ensure the design life.

Any inspection, maintenance and rectification work shall be carried out in accordance with the applicable safe working practices.

11 Installation

11.1 General guidance

The supplier shall provide guidance for the erection of the tank, and the tank shall be erected in accordance with such guidance.

Safe working practices shall be applied during installation.

The construction shall be by suitably qualified personnel skilled and experienced in the erection of bolted tanks and approved by the manufacturer.

Sealant shall be used to seal lap joints, bolt connections, sheet edges and tank joints to the foundation. Only sealant suitable for the application, supplied or recommended by the manufacturer shall be used. The sealant shall cure to a rubber-like consistency and have excellent adhesion to the enamel coating, have low shrinkage and be suitable for interior and exterior exposure.

NOTE A suitable seal is such that it adequately protects the bolted joint and is flexible, whilst curing chemically to form an homogenous barrier.

11.2 Foundations

Unless otherwise specified by the supplier, the design and construction of the foundation shall be carried out in accordance with the applicable standards. The client shall provide details of the site and soil conditions to the foundation designer.

11.3 Inspection of the vitreous enamel coating at the construction site

Following tank installation, the use of a low voltage wet swab tester on the inside panel surface is recommended. The test apparatus and procedure shall be approved by the vitreous enameller.

12 Disinfection

Disinfection shall be carried out in accordance with procedures agreed between interested parties.

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