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Neogrevane tlaļ ne posode - 3. del: Konstruiranje

Unfired pressure vessels - Part 3: Design

Unbefeuerte Druckbehälter - Teil 3: Konstruktion

Récipients sous pression non soumis a la flamme - Partie 3: Conception

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This European Standard was approved by CEN on 23 May 2002.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Contents

Foreword

This document (EN 13445-3:2002) has been prepared by Technical Committee CEN/TC 54, "Unfired pressure vessels", 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of an identical text or by endorsement, at the latest by November 2002, and conflicting national standards shall be withdrawn at the latest by November 2002.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 97/23/EC.

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

In this standard the Annexes A, E, F, G, H, J, L, P and Q are normative and the Annexes B, C, D, I, K, M, N and O are informative.

This European Standard consists of the following Parts:

— *Part 1: General.*

— *Part 2: Materials.*

— *Part 3: Design.*

— *Part 4: Fabrication.*

— *Part 5: Inspection and Testing.*

— *Part 6: Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron.*

CR 13445-7, *Unfired pressure vessels - Part 7: Guidance on the use of conformity assessment procedures.*

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

1 Scope

This Part of this European Standard specifies requirements for the design of unfired pressure vessels covered by EN 13445-1:2002 and constructed of steels in accordance with EN 13445-2:2002.

EN 13445-5:2002, Annex C specifies requirements for the design of access and inspection openings, closing mechanisms and special locking elements.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies (including amendments).

EN 286-2:1992, *Simple unfired pressure vessels designed to contain air or nitrogen — Part 2: Pressure vessels for air braking and auxiliary systems for motor vehicles and their trailers.*

EN 288-8:1995, *Specification and approval of welding procedures for metallic materials — Part 8: Approval by a pre-production welding test.*

prEN 764-1:2001, *Pressure equipment — Terminology — Part 1: Pressure, temperature, volume, nominal size*

EN 764-2:2002, *Pressure equipment — Part 2: Quantities, symbols and units*

EN 764-3:2002, *Pressure equipment — Part 3: Definition of parties involved*

EN 1092, *Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN-designated.*

EN 1591-1:2001, *Flanges and their joints - Design rules for gasketed circular flange connections – Calculation method.*

EN 1708-1:1999, *Welding - Basic weld joint details in steel – Part 1: Pressurized components*

ISO 261:1998, *ISO general purpose metric screw threads — General plan.*

EN ISO 4014, *Hexagon head bolts — Product grades A and B (ISO 4014:1999).*

EN ISO 4016, *Hexagon head bolts — Product grade C (ISO 4016:1999).*

3 Terms and definitions

For the purposes of this Part of this European Standard, the terms and definitions given in EN 13445-1:2002, EN 13445-2:2002 and the following apply:

3.1
action
imposed thermo-mechanical influence which causes stress and/or strain in a structure, e.g. an imposed pressure, force, temperature

3.2
analysis thickness
effective thickness available to resist the loadings in corroded condition

3.3
assumed thickness
thickness assumed by the designer between the minimum required shell thickness e and the shell analysis thickness e_a

3.4
calculation pressure
differential pressure used for the purpose of calculations of a component

[prEN 764-1:2001]

3.5
calculation temperature
temperature used for the purpose of calculations of a component

[prEN 764-1:2001]

3.6
chamber
single fluid space within a unit of pressure equipment

[prEN 764-1:2001]

3.7
component
part of pressure equipment or assembly which can be considered as an individual item for the calculation

[prEN 764-1:2001]

3.8
cryogenic applications
applications involving liquefied gases at low temperature

3.9
design pressure
pressure at the top of each chamber of the pressure equipment chosen for the derivation of the calculation pressure of each component

[prEN 764-1:2001]NOTE Any other location may be specified.

3.10
design temperature
temperature chosen for the derivation of the calculation temperature of each component

[prEN 764-1:2001]

3.11
differential pressure
pressure for which the algebraic value is equal to the difference of pressure on both sides of a component

[prEN 764-1:2001]

3.12
governing weld joint
main full penetration butt joint the design of which, as a result of membrane stresses, governs the thickness of the component

3.13
load case
combination of coincident actions

3.14
main joint
weld joint assembling main pressure bearing parts

3.15
maximum permissible pressure
pressure obtained with the analysis thickness at the calculation temperature for a given component from the design by formulae

3.16
minimum possible fabrication thickness
minimum possible thickness after fabrication

3.17
nominal design stress
stress value to be used in the formulae for the calculation of pressure components

3.18
nominal thickness
thickness as specified on the drawings

3.19
test pressure
pressure at which the equipment is subjected for test purposes

[prEN 764-1:2001]

3.20
test temperature
temperature at which the pressure test of the pressure equipment is carried out

[prEN 764-1:2001]

3.21
volume
internal volume of a chamber, including the volume of nozzles to the first connection (flange, coupling, weld) and excluding the volume of internal permanent parts (e.g. baffles, agitators)

NOTE EN 13445-1:2002 and EN 13445-2:2002 have adopted terminology, symbols and definitions of prEN 764-1:2001, EN 764-2:2002:2002 and EN 764-3:2002:2002.

4 Symbols and abbreviations

For the purposes of this Part of this European Standard, the general symbols and abbreviations shall be in accordance with EN 13445-1:2002, EN 13445-2:2002 and Table 4-1:

Table 4-1 — Symbols, quantities and units [c]

Symbol	Quantity	Unit
e	required thickness	mm
e_n	nominal thickness	mm
e_{min}	minimum possible fabrication thickness	mm
e_a	analysis thickness	mm
c	corrosion or erosion allowance	mm
f	nominal design stress	MPa or N/mm²
f_d	maximum value of the nominal design stress for normal operating load cases	MPa or N/mm²
f_{exp}	maximum value of the nominal design stress for exceptional load cases	MPa or N/mm²
f_{test}	maximum value of the nominal design stress for testing load cases	MPa or N/mm²
n_{eq}	number of equivalent full pressure cycles (see 5.4.2)	-
P	calculation pressure	MPa or N/mm² [a]
P_d	design pressure	MPa or N/mm² [a]
P_{max}	maximum permissible pressure	MPa or N/mm² [a]
PS , P_s	maximum allowable pressure	MPa or N/mm² [a]
P_{test}	test pressure	MPa or N/mm² [a]
R_{eH}	minimum upper yield strength	MPa or N/mm²
R_m	minimum tensile strength	MPa or N/mm²
$R_{m/t}$	minimum tensile strength at temperature t in °C	MPa or N/mm²
$R_{p0,2}$	minimum 0,2 % proof strength	MPa or N/mm²
$R_{p0,2/t}$	minimum 0,2 % proof strength at temperature t in °C	MPa or N/mm²
$R_{p1,0}$	minimum 1,0 % proof strength	MPa or N/mm²
$R_{p1,0/t}$	minimum 1,0 % proof strength at temperature t in °C	MPa or N/mm²
t	calculation temperature	°C
t_d	design temperature	°C
t_{test}	test temperature	°C
TS_{max}, TS_{min}	maximum/minimum allowable temperatures	°C
V	volume of a vessel (or a chamber)	mm^3 [b]
z	weld joint coefficient	—
ν	Poisson's ratio	—

[a] MPa or N/mm² for calculation purpose only, otherwise the unit may be bar (1 MPa = 1 N/mm²).

[b] mm^3 for calculation purpose only, otherwise the unit should be litre.

[c] Formulae used in this standard are dimensional.

5 Basic design criteria

5.1 General

The requirements in clause 5 shall apply when:

a) the materials and welds are not subject to localized corrosion in the presence of products which the vessel is to contain; and

b) the design is outside the creep range. Unless otherwise specified in the relevant clauses, design requirements are applicable up to 370 °C for ferritic steels and 425 °C for austenitic steels.

NOTE This will be changed when the section on creep design is prepared.

5.2 Corrosion, erosion and protection

5.2.1 General

Whenever the word "corrosion" is used in this standard it shall be taken to mean corrosion, oxidation, scaling, abrasion, erosion and all other forms of wastage.

NOTE 1 Stress corrosion cracking may occur under certain conditions of temperature and environment. A corrosion allowance is not an appropriate way of dealing with stress corrosion. Under such conditions, consideration shall be given to the materials used and the residual stresses in the fabricated vessel.

NOTE 2 It is impossible to lay down definite precautionary guidelines to safeguard against the effects of corrosion owing to the complex nature of corrosion itself, which may occur in many forms, including but not limited to the following:

- chemical attack where the metal is dissolved by the reagents. It may be general over the whole surface or localized (causing pitting) or a combination of the two;
- rusting caused by the combined action of moisture and air;
- erosion corrosion where a reagent otherwise innocuous flows over the surface at velocity greater than some critical value;
- high temperature oxidation (scaling).

Consideration should be given to the effect which corrosion (both internal and external) may have upon the useful life of the vessel. When in doubt, corrosion tests should be undertaken. These should be carried out on the actual metal (including welds or combination of metals) under exposure to the actual chemicals used in service. Corrosion tests should be continued for a sufficiently long period to determine the trend of any change in the rate of corrosion with respect to time.

NOTE 3 It is very dangerous to assume that the major constituent of a mixture of chemicals is the active agent, as in many cases small traces of a substance can exert an accelerating or inhibiting effect out of all proportion to the amount present. Fluid temperatures and velocities from corrosion test data should be equivalent to those met in operation.

5.2.2 Additional thickness to allow for corrosion

In all cases where reduction of the wall thickness is possible as a result of surface corrosion or erosion, of one or other of the surfaces, caused by the products contained in the vessel or by the atmosphere, a corresponding additional thickness sufficient for the design life of the vessel components shall be provided. The value shall be stated on the design drawing of the vessel. The amounts adopted shall be adequate to cover the total amount of corrosion expected on either or both surfaces of the vessel.

A corrosion allowance is not required when corrosion can be excluded, either because the materials, including the welds, used for the pressure vessel walls are corrosion resistant relative to the contents and the loading or are reliably protected (see 5.2.4).

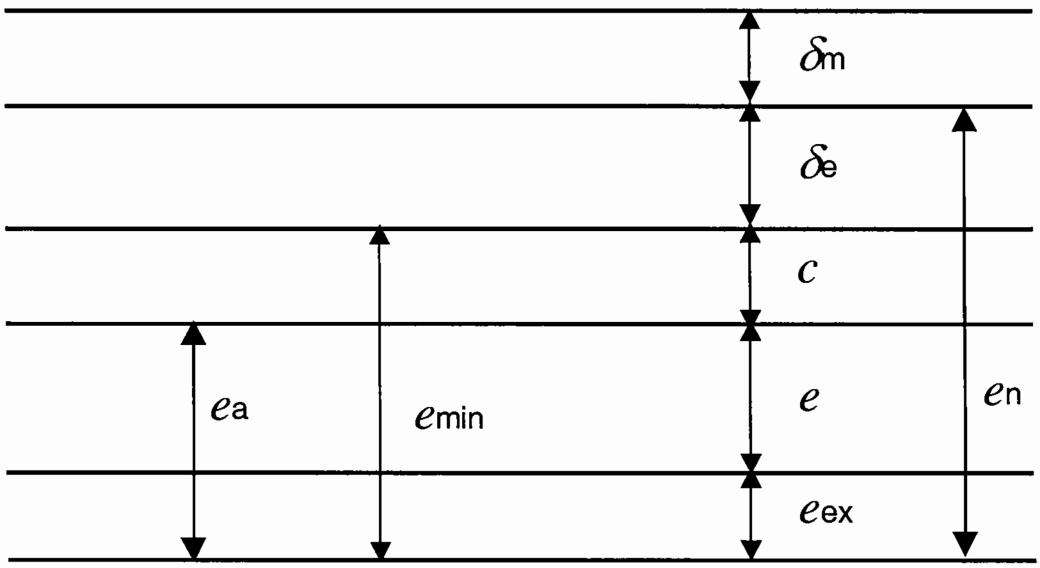
No corrosion allowance is required for heat exchanger tubes and other parts in similar heat exchanger duty, unless a specific corrosive environment requires one.

This corrosion allowance does not ensure safety against the risk of deep corrosion or stress corrosion cracking, in these cases a change of material, cladding, etc. is the appropriate means.

Where deep pitting may occur, suitably resistant materials shall be selected, or protection applied to the surfaces.

5.2.3 Inter-relation of thickness definitions

The inter-relation of the various definitions of thickness is shown in Figure 3-1.



Key

e is the required thickness;

e_n is the nominal thickness;

e_{min} is the minimum possible fabrication thickness ($e_{min} = e_n - \delta_e$);

e_a is the analysis thickness ($e_a = e_{min} - c$);

c is the corrosion or erosion allowance;

δ_e is the absolute value of the possible negative tolerance on the nominal thickness (e.g. taken from the material standards);

δ_m is the allowance for possible thinning during manufacturing process;

e_{ex} is the extra thickness to make up to the nominal thickness.

Figure 3-1 — Relationship of thickness definitions

5.2.4 Linings and coatings

Only completely impervious, sufficiently thick and chemically stable layers with an average life not less than that of the pressure vessel shall be considered to be reliable protection against corrosion, but thin layers (like painting, electroplating, tinning, etc.) and coatings which are known to have to be renewed during the lifetime of the pressure vessel components shall not be used. For plastic coatings the suitability shall be justified, taking into account, among other factors, the risk of diffusion. The test of corrosion protection outlined in EN 286-2:1992 is not considered to be adequate for the pressure vessels covered by this standard.

Vessels may be fully or partially lined (or coated) with corrosion-resistant material. Linings should be integrally bonded to the vessel base metal. Loose or intermittently attached linings may be used taking the following into consideration:

— sufficient ductility of the lining to accommodate any strain likely to be imposed on it during service and testing conditions, differential thermal expansion being taken into consideration;

— for non-metallic coatings, the surface finish of the base material.

Provided contact between the corrosive agent and the vessel base material is excluded, no corrosion allowance needs be provided against internal wastage of the base material.

5.2.5 Wear plates

Where severe conditions of erosion and abrasion arise, local protective or wear plates shall be fitted directly in the path of the impinging material.

5.3 Load cases

5.3.1 Actions

In the design of a vessel the following actions shall be taken into account, where relevant:

a) internal and/or external pressure;

b) maximum static head of contained fluid under operating conditions;

c) weight of the vessel;

d) maximum weight of contents under operating conditions;

e) weight of water under hydraulic pressure test conditions;

f) wind, snow and ice loading;

g) earthquake loading;

h) other loads supported by or reacting on the vessel, including loads during transport and installation.

When necessary, consideration shall be given to the effect of the following loads in cases where it is not possible to demonstrate the adequacy of the proposed design e.g. by comparison with the behaviour of other vessels:

i) stresses caused by supporting lugs, ring, girders, saddles, internal structures or connecting piping or intentional offsets of median lines on adjacent components;

j) shock loads caused by water hammer or surging of the vessel contents;

k) bending moments caused by eccentricity of the centre of the working pressure relative to the neutral axis of the vessel;

l) stresses caused by temperature differences including transient conditions and by differences in coefficients of thermal expansion;

m) stresses caused by fluctuations of pressure, temperature, and external loads applied to the vessel;

n) stresses caused by the decomposition of unstable fluids.

5.3.2 Classification of load cases

a) Normal operating load cases

Normal operating load cases are those acting on the pressure vessel during normal operation, including start-up and shutdown;

b) Exceptional load cases

Exceptional load cases are those corresponding to events of very low occurrence probability requiring the safe shutdown and inspection of the vessel or plant. Examples are pressure loading of secondary containment or internal explosion;

c) Testing load cases

Testing load cases are those related to tests after manufacture;

5.3.3 Failure modes considered in this Part

a) gross plastic deformation (GPD);

b) plastic instability (burst);

c) elastic or plastic instability (buckling);

d) progressive deformation (PD);

e) fatigue.

NOTE 1 For more detailed information on failure modes see Annex B.

NOTE 2 Plastic instability is covered by the limits on GPD.