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©2006 Nederlands Normalisatie-instituut
Postbus 5059, 2600 GB Delft
Telefoon (015) 2 690 390, Fax (015) 2 690 190

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Foreword

This document (EN 13445-3:2002 and EN 13445-3:2002/A4:2005) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

EN 13445-3:2002 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of an identical text or by endorsement, at the latest by November 2002, and conflicting national standards shall be withdrawn at the latest by November 2002. EN 13445-3:2002/A4:2005 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2006, and conflicting national standards shall be withdrawn at the latest by January 2006.

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, B, C, E, F, G, J, P and Q are normative and the Annexes D, H, I, K, L, 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, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and 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.

NOTE This Part applies to design of vessels before putting into service. It may be used for in service calculation or analysis subject to appropriate adjustment.

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*

EN ISO 4014:2000, *Hexagon head bolts — Product grades A and B (ISO 4014:1999).*

EN ISO 4016:2000, *Hexagon head bolts — Product grade C (ISO 4016:1999).*

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

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

3.15a
maximum permissible pressure for normal operating load cases
pressure obtained with the analysis thickness e_a at the calculation temperature for a given component, using the relevant design formulae or procedures

3.15b
maximum permissible pressure for testing load cases
pressure obtained with the minimum possible fabrication thickness e_{min} at the test temperature for a given component, using the relevant design formulae or procedures and $z = 1$

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 and EN 764-3:2002.

3.22
weld throat thickness of a fillet weld
height of the inscribed isosceles triangle measured from the theoretical root point

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
a	weld throat thickness	mm
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)	mm³ [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] mm³ 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 Part 3 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.

7.4 Cylindrical and spherical shells

7.4.1 Conditions of applicability

The rules in 7.4.2 and 7.4.3 are valid for e/D_e not greater than 0,16. The rules for spheres apply also to spherical parts of shells, hemispherical ends, the central zones of torispherical ends, and that part of a sphere used to join a cone and a cylinder (a knuckle of r/D_i = 0,5).

NOTE 1 The rules in 7.4.2 and 7.4.3 may be used for larger ratios if accompanied by a detailed fatigue analysis.

NOTE 2 The thickness given by this section is a minimum. Thickness may have to be increased at junctions with other components, or to provide additional reinforcement at nozzles or openings, or to carry non-pressure loads.

7.4.2 Cylindrical shells

The required thickness shall be calculated from one of the following two equations:

$$e = \frac{P \cdot D_i}{2f \cdot z - P} \tag{7.4-1}$$

or

$$e = \frac{P \cdot D_e}{2f \cdot z + P} \tag{7.4-2}$$

For a given geometry and for normal operating load cases:

$$P_{max} = \frac{2f \cdot z \cdot e_a}{D_m} \tag{7.4-3}$$

For testing load cases f, z and e_a are replaced by f_{test}, 1 and e_{min}, respectively, according to definition in 3.15 b.

7.4.3 Spherical shells

The required thickness shall be calculated from one of the following two equations.

$$e = \frac{P \cdot D_i}{4f \cdot z - P} \tag{7.4-4}$$

or

$$e = \frac{P \cdot D_e}{4f \cdot z + P} \tag{7.4-5}$$

For a given geometry and for normal operating load cases:

$$P_{max} = \frac{4f \cdot z \cdot e_a}{D_m} \tag{7.4-6}$$

For testing load cases f, z and e_a are replaced by f_{test}, 1 and e_{min}, respectively, according to definition in 3.15 b.

7.5 Dished ends

7.5.1 Specific symbols and abbreviations

The following symbols and abbreviations apply in addition to or modify those in 7.3.

D_e is the outside diameter of the cylindrical flange;

D_i is the inside diameter of the cylindrical flange;

e_b is required thickness of knuckle to avoid plastic buckling;

e_s is required thickness of end to limit membrane stress in central part;

e_y is required thickness of knuckle to avoid axisymmetric yielding;

f_b is design stress for buckling equation;

h_i is inside height of end measured from the tangent line;

K is shape factor for an ellipsoidal end as defined in equation (7.5-18);

N is a parameter defined by equation (7.5-12);

R is inside spherical radius of central part of torispherical end;

X is ratio of knuckle inside radius to shell inside diameter;

Y is a parameter defined by equation (7.5-9);

Z is a parameter defined by equation (7.5-10);

β is a factor given by Figures 7.5-1 and 7.5-2 or by the procedure in 7.5.3.5.

7.5.2 Hemispherical ends

The required thickness of a hemispherical end is given by the equations in 7.4.3. The mean radius of the end shall be nominally the same as that of the cylinder to which it is welded. The thickness of the cylinder up to the tangent line shall be kept at or above the minimum for the cylinder in accordance with to 7.4.2.

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