

**LEEKKUUMUTUSETA SURVEANUMAD.
OSA 3: KAVANDAMINE**

**Unfired pressure vessels -
Part 3: Design**

EESTI STANDARDI EESSÕNA**NATIONAL FOREWORD**

See Eesti standard EVS-EN 13445-3:2016+A1+A2+A3+A4:2018 sisaldab Euroopa standardi EN 13445-3:2014 (V05, 07.2018) ning muudatuste A1:2015, A2:2016, A3:2017 ja A4:2018 ingliskeelset teksti.	This Estonian standard EVS-EN 13445-3:2016+A1+A2+A3+A4:2018 consists of the English text of the European standard EN 13445-3:2014 (Issue 05, 07.2018) and its amendments A1:2015, A2:2016, A3:2017 and A4:2018.
Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas.	This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation.
Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 10.09.2014, muudatused A1 25.03.2015, A2 31.08.2016, A3 30.08.2017 ja A4 28.03.2018	Date of Availability of the European standard is 10.09.2014, for A1 25.03.2015, A2 31.08.2016, A3 30.08.2017 and for A4 28.03.2018
Standard on kättesaadav Eesti Standardikeskusest.	The standard is available from the Estonian Centre for Standardisation.

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile standardiosakond@evs.ee.

ICS 23.020.30

Standardite reprodutseerimise ja levitamise õigus kuulub Eesti Standardikeskusele

Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonsesse süsteemi või edastamine ükskõik millises vormis või millisel teel ilma Eesti Standardikeskuse kirjaliku loata on keelatud.

Kui Teil on küsimusi standardite autorikaitse kohta, võtke palun ühendust Eesti Standardikeskusega: Koduleht www.evs.ee; telefon 605 5050; e-post info@evs.ee

The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, without a written permission from the Estonian Centre for Standardisation.

If you have any questions about copyright, please contact Estonian Centre for Standardisation:

Homepage www.evs.ee; phone +372 605 5050; e-mail info@evs.ee

English Version

Unfired pressure vessels - Part 3: Design

Réipients sous pression - Partie 3: Conception

Unbefeuerte Druckbehälter - Teil 3: Konstruktion

This European Standard was approved by CEN on 19 August 2014.

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-CENELEC 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-CENELEC Management Centre has the same status as the official versions.

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



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

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Contents

Page

Foreword.....	6
1 Scope	8
2 Normative references	8
3 Terms and definitions.....	9
4 Symbols and abbreviations	11
5 Basic design criteria	13
5.1 General	13
5.2 Corrosion, erosion and protection.....	13
5.3 Load cases.....	15
5.4 Design methods	19
5.5 Thickness calculations (DBF)	20
5.6 Joint coefficient.....	21
5.7 Design requirements of welded joints	22
6 Maximum allowed values of the nominal design stress for pressure parts	25
6.1 General	25
6.2 Steels (except castings), other than austenitic steels covered by 6.4 and 6.5, with a minimum rupture elongation, as given in the relevant technical specification for the material, below 30 %	26
6.3 Alternative route for steels (except castings), other than austenitic steels covered by 6.4 and 6.5, with a minimum rupture elongation, as given in the relevant technical specification for the material, below 30 %	26
6.4 Austenitic steels (except castings) with a minimum elongation after rupture, as given in the relevant technical specification for the material, from 30 % to 35 %	27
6.5 Austenitic steels (except castings) with a minimum rupture elongation, as given in the relevant technical specification for the material, from 35 %	27
6.6 Cast steels	28
7 Shells under internal pressure	29
7.1 Purpose.....	29
7.2 Specific definitions	29
7.3 Specific symbols and abbreviations.....	29
7.4 Cylindrical and spherical shells	29
7.5 Dished ends.....	30
7.6 Cones and conical ends.....	35
7.7 Nozzles which encroach into the knuckle region.....	43
8 Shells under external pressure	48
8.1 Purpose.....	48
8.2 Specific definitions	48
8.3 Specific symbols and definitions	48
8.4 General	51
8.5 Cylindrical shells.....	52
8.6 Conical shell	73
8.7 Spherical shells.....	81
8.8 Vessel ends	82
9 Openings in shells	83
9.1 Purpose.....	83
9.2 Specific definitions	83
9.3 Specific symbols and abbreviations.....	84
9.4 General.....	87
9.5 Isolated openings.....	99
9.6 Multiple openings.....	115
9.7 Openings close to a shell discontinuity	125

10	Flat ends	133
10.1	Purpose.....	133
10.2	Specific definitions	133
10.3	Specific symbols and abbreviations.....	133
10.4	Unpierced circular flat ends welded to cylindrical shells.....	135
10.5	Unpierced bolted circular flat ends.....	142
10.6	Pierced circular flat ends	146
10.7	Flat ends of non-circular or annular shape.....	150
11	Flanges.....	154
11.1	Purpose.....	154
11.2	Specific definitions	154
11.3	Specific symbols and abbreviations.....	154
11.4	General.....	157
11.5	Narrow face gasketed flanges	161
11.6	Full face flanges with soft ring type gaskets	176
11.7	Seal welded flanges	179
11.8	Reverse narrow face flanges	179
11.9	Reverse full face flanges.....	182
11.10	Full face flanges with metal to metal contact	186
12	Bolted domed ends.....	189
12.1	Purpose.....	189
12.2	Specific definitions	189
12.3	Specific symbols and abbreviations.....	189
12.4	General.....	189
12.5	Bolted domed ends with narrow face gaskets.....	189
12.6	Bolted domed ends with full face joints	191
13	Heat Exchanger Tubesheets.....	193
13.1	Purpose.....	193
13.2	Specific definitions	193
13.3	Specific symbols and abbreviations.....	193
13.4	U-tube tubesheet heat exchangers	196
13.5	Fixed tubesheet heat exchangers	210
13.6	Floating tubesheet heat exchangers.....	238
13.7	Tubesheet characteristics.....	255
13.8	Maximum permissible tube to tubesheet joint stress	262
13.9	Maximum permissible longitudinal compressive stress for tubes.....	263
13.10	Design of tubesheet flange extension with a narrow face gasket.....	266
13.11	Design of tubesheet flange extension with a full face gasket.....	269
13.12	Special tube-to-tubesheet welded joints	272
14	Expansion bellows.....	275
14.1	Purpose.....	275
14.2	Specific definitions	275
14.3	Specific symbols and abbreviations.....	277
14.4	Conditions of applicability	279
14.5	U-shaped unreinforced bellows	281
14.6	U-shaped reinforced bellows.....	295
14.7	Toroidal bellows.....	303
14.8	Fabrication.....	310
14.9	Inspection and testing.....	312
14.10	Bellows subjected to axial, lateral or angular displacements.....	314
15	Pressure vessels of rectangular section.....	319
15.1	Purpose.....	319
15.2	Specific definitions	319
15.3	Specific symbols and abbreviations.....	319
15.4	General.....	321

15.5	Unreinforced vessels.....	321
15.6	Reinforced vessels	329
15.7	Openings.....	334b
16	Additional non-pressure loads	335
16.1	Purpose.....	335
16.2	Specific definitions	335
16.3	Specific symbols and abbreviations.....	336
16.4	Local loads on nozzles in spherical shells	337
16.5	Local loads on nozzles in cylindrical shells	347
16.6	Line loads	355
16.7	Lifting lugs.....	361
16.8	Horizontal vessels on saddle supports	365
16.9	Horizontal vessels on ring supports.....	379
16.10	Vertical vessels on bracket supports	384
16.11	Vertical vessels with supporting legs.....	389
16.12	Vertical vessels with skirts	391
16.13	Vertical vessels with ring supports.....	422
16.14	Global loads.....	433
17	Simplified assessment of fatigue life.....	438
17.1	Purpose.....	438
17.2	Specific definitions	438
17.3	Specific symbols and abbreviations.....	440
17.4	Conditions of applicability	441
17.5	General.....	442
17.6	Determination of allowable number of pressure cycles	447
17.7	Assessment rule	472
17.8	Design and manufacture	472
17.9	Testing	473
18	Detailed assessment of fatigue life	474
18.1	Purpose.....	474
18.2	Specific definitions	474
18.3	Specific symbols and abbreviations.....	477
18.4	Limitations	479
18.5	General.....	481
18.6	Welded material.....	483
18.7	Unwelded components and bolts.....	488
18.8	Elastic-plastic conditions.....	491
18.9	Fatigue action.....	493
18.10	Fatigue strength of welded components.....	496
18.11	Fatigue strength of unwelded components	517
18.12	Fatigue strength of steel bolts.....	522
19	Creep design	525
19.1	Purpose.....	525
19.2	Specific definitions	525
19.3	Specific symbols and abbreviations.....	525
19.4	Design in the creep range	526
19.5	Nominal Design stress in the creep range	526
19.6	Weld joint factor in the creep range.....	531
19.7	Pressure loading of predominantly non-cyclic nature in the creep range	531
19.8	Design procedures for DBF	531
20	Design rules for reinforced flat walls.....	535
20.1	General	535
20.2	Stayed flat walls	535
20.3	Specific definitions for stayed flat walls.....	535
20.4	Required thickness of stayed flat walls.....	535
20.5	Required dimensions and layout of staybolts and stays	535
20.6	Requirements for threaded staybolts	536
20.7	Requirements for welded-in staybolts and welded stays.....	536
20.8	Tables for stayed flat walls	537
20.9	Figures for Stayed Flat Walls.....	538

21	Circular flat ends with radial reinforcement ribs	541
21.1	Purpose.....	541
21.2	Specific definitions	541
21.3	Specific symbols and abbreviations.....	543
21.4	Ends without additional peripheral bending moment.....	544
21.5	Ends with additional peripheral bending moment	546
21.6	Openings.....	548
21.7	Welds.....	548
21.8	Central Ring.....	548
22	Static analysis of tall vertical vessels on skirts.....	550
22.1	Purpose.....	550
22.2	Definitions.....	550
22.3	Specific symbols and abbreviations.....	551
22.4	Loads.....	552
22.5	Load combinations	555
22.6	Stress analysis of pressure vessel shells and skirts.....	558
22.7	Design of joint between skirt and pressure vessel (at dished end or cylindrical shell).....	558
22.8	Design of anchor bolts and base ring assembly.....	558
22.9	Foundation loads	559
Annex A (normative) Design requirements for pressure bearing welds.....		560
Annex B (normative) Design by Analysis – Direct Route		584
Annex C (normative) Design by analysis - Method based on stress categories.....		614
Annex D (informative) Verification of the shape of vessels subject to external pressure.....		633
Annex E (normative) Procedure for calculating the departure from the true circle of cylinders and cones.....		640
Annex F (normative) Allowable external pressure for vessels outside circularity tolerance		643
Annex G (normative) Alternative design rules for flanges and gasketed flange connections		645
Annex GA (informative) Alternative design rules for flanges and gasketed flange connections		692
Annex H (informative) Gasket factors m and y		755
Annex I (informative) Additional information on heat exchanger tubesheet design		758
Annex J (normative) Alternative method for the design of heat exchanger tubesheets.....		762
Annex K (informative) Additional information on expansion bellows design.....		807
Annex L (informative) Basis for design rules related to additional non-pressure loads		813
Annex M (informative) In service monitoring of vessels operating in fatigue or creep service.....		815
Annex N (informative) Bibliography to Clause 18		818
Annex O (informative) Physical properties of steels		819
Annex P (normative) Classification of weld details to be assessed using principal stresses		827
Annex Q (normative) Simplified procedure for the fatigue assessment of unwelded zones		840
Annex R (informative) Coefficients for creep-rupture model equations for extrapolation of creep-rupture strength		841
Annex S (informative) Extrapolation of the nominal design stress based on time- independent behaviour in the creep range		845
Annex T (normative) Design by experimental methods.....		851
Annex Y (informative) History of EN 13445-3.....		864
Annex ZA (informative) Relationship between this European Standard and the essential requirements of Directive 2014/68/EU aimed to be covered		865

Foreword

This document (EN 13445-3:2014) 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 December 2014, and conflicting national standards shall be withdrawn at the latest by December 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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(s).

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

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*.
- Part 8: *Additional requirements for pressure vessels of aluminium and aluminium alloys*.
- CEN/TR 13445-9, *Unfired pressure vessels* — Part 9: *Conformance of EN 13445 series to ISO 16528*
- Part 10: *Additional requirements for pressure vessels of nickel and nickel alloys*

Although these Parts may be obtained separately, it should be recognised that the Parts are inter-dependant. As such the manufacture of unfired pressure vessels requires the application of all the relevant Parts in order for the requirements of the Standard to be satisfactorily fulfilled.

Corrections to the standard interpretations where several options seem possible are conducted through the Migration Help Desk (MHD). Information related to the Help Desk can be found at <http://www.unm.fr/en13445@unm.fr>. A form for submitting questions can be downloaded from the link to the MHD website. After subject experts have agreed an answer, the answer will be communicated to the questioner. Corrected pages will be given specific issue number and issued by CEN according to CEN Rules. Interpretation sheets will be posted on the website of the MHD.

This document supersedes EN 13445-3:2009. This new edition incorporates the Amendments which have been approved previously by CEN members, and the corrected pages up to Issue 5 without any further technical change. Annex Y provides details of significant technical changes between this European Standard and the previous edition.

Amendments to this new edition may be issued from time to time and then used immediately as alternatives to rules contained herein. It is intended to deliver a new Issue of EN 13445:2014 each year, consolidating these Amendments and including other identified corrections. . Issue 5 (2018-07) includes the corrected pages listed in Annex Y.

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, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This Part of this European Standard specifies requirements for the design of unfired pressure vessels covered by EN 13445-1:2014 and constructed of steels in accordance with EN 13445-2:2014.

EN 13445-5:2014, 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

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.

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 764-1:2004, *Pressure equipment — Terminology — Part 1: Pressure, temperature, volume, nominal size*

EN 764-2:2012, *Pressure equipment — Part 2: Quantities, symbols and units*

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

EN 837-1:1996, *Pressure gauges — Part 1: Bourdon tube pressure gauges — Dimensions, metrology, requirements and testing*

EN 837-3:1996, *Pressure gauges — Part 3: Diaphragm and capsule pressure gauges — Dimensions, metrology, requirements and testing*

EN 1092-1:2007, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN-designated — Part 1: Steel flanges*

EN 1591-1:2011, *Flanges and their joints — Design rules for gasketed circular flange connections — Calculation method*

EN 1708-1:2010, *Welding — Basic weld joint details in steel — Part 1: Pressurized components*

EN 1990, *Eurocode — Basis of structural design*

EN 1992-1-1:2005, *Eurocode 2 — Design of concrete structures — Part 1-1: General rules and rules for buildings*

EN 1991-1-4:2005, *Eurocode 1: Actions on structures — Part 1-4: General actions — Wind actions*

EN 1991-1-6, *Eurocode 1 — Actions on structures — Part 1-6: General actions — Actions during execution*

EN 1998-1:2004, *Design of structures for earthquake resistance — Part 1: General rules, seismic actions and rules for buildings*

EN 10222-1:1998, EN 10222-1:1998/A1:2002, *Steel forgings for pressure purposes — Part 1: General requirements for open die forgings*

EN 13445-1:2014, *Unfired pressure vessels — Part 1: General*

EN 13445-2:2014, *Unfired pressure vessels — Part 2: Materials*

EN 13445-4:2014, *Unfired pressure vessels — Part 4: Fabrication*

EN 13445-5:2014, *Unfired pressure vessels — Part 5: Inspection and testing*

EN 13445-8:2014, *Unfired pressure vessels — Part 8: Additional requirements for pressure vessels of aluminium and aluminium alloys*

EN ISO 4014:2011, *Hexagon head bolts — Product grades A and B* (ISO 4014:2011)

EN ISO 4016:2011, *Hexagon head bolts — Product grade C* (ISO 4016:2011)

EN ISO 15613:2004, *Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test*

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

3 Terms and definitions

For the purposes of this Part of this European Standard, the terms and definitions given in EN 13445-1:2014, EN 13445-2:2014 and the following apply:

NOTE EN 13445-1:2014 and EN 13445-2:2014 have adopted terminology, symbols and definitions of EN 764-1:2004, EN 764-2:2012 and EN 764-3:2002.

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 loading depending on the load case, see 5.3.2

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 the design calculations for a component
[EN 764-1:2004]

3.5 calculation temperature

temperature used for the purpose of the design calculations for a component
[EN 764-1:2004]

3.6 chamber

fluid space within a unit of pressure equipment
[EN 764-1:2004]

3.7 component

part of pressure equipment which can be considered as an individual item for the calculation
[EN 764-1:2004]