

Recipientes a presión no sometidos a llama. Parte 3:
Diseño (Ratificada por la Asociación Española de
Normalización en junio de 2021.)

UNE-EN 13445-3:2021

Recipientes a presión no sometidos a llama. Parte 3: Diseño (Ratificada por la Asociación Española de Normalización en junio de 2021.)

Unfired pressure vessels - Part 3: Design (Endorsed by Asociación Española de Normalización in June of 2021.)

Réipients sous pression non soumis à la flamme - Partie 3: Conception (Entérinée par l'Asociación Española de Normalización en juin 2021.)

En cumplimiento del punto 11.2.5.4 de las Reglas Internas de CEN/CENELEC Parte 2, se ha otorgado el rango de documento normativo español UNE al documento normativo europeo EN 13445-3:2021 (Fecha de disponibilidad 2021-05-12)

Este documento está disponible en los idiomas oficiales de CEN/CENELEC/ETSI.

Este anuncio causará efecto a partir del primer día del mes siguiente al de su publicación en la revista UNE.

La correspondiente versión oficial de este documento se encuentra disponible en la Asociación Española de Normalización (Génova 6 28004 MADRID, www.une.org).

Las observaciones a este documento han de dirigirse a:

Asociación Española de Normalización

Génova, 6
28004 MADRID-España
Tel.: 915 294 900
info@une.org
www.une.org

© UNE 2021

Prohibida la reproducción sin el consentimiento de UNE.

Todos los derechos de propiedad intelectual de la presente norma son titularidad de UNE.

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 13445-3

May 2021

ICS 23.020.30

Supersedes EN 13445-3:2014

English Version

Unfired pressure vessels - Part 3: Design

Réceptacles sous pression non soumis à la flamme -
Partie 3: Conception

Unbefeuerte Druckbehälter - Teil 3: Konstruktion

This European Standard was approved by CEN on 24 February 2021.

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, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, 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: Rue de la Science 23, B-1040 Brussels

Contents

	Page
European foreword	7
1 Scope.....	8
2 Normative references.....	8
3 Terms and definitions	9
4 Symbols and abbreviations	12
5 Basic design criteria.....	14
5.1 General.....	14
5.2 Corrosion, erosion and protection.....	14
5.3 Load cases	17
5.4 Design methods	24
5.5 Thickness calculations (DBF)	26
5.6 Joint coefficient.....	27
5.7 Design requirements of welded joints	28
6 Maximum allowed values of the nominal design stress for pressure parts	31
6.1 General.....	31
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 %.....	32
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 %.....	32
6.4 Austenitic steels (except castings) with a minimum rupture elongation, A%, as given in the relevant technical specification for the material, such as $30\% \leq A\% < 35\%$	33
6.5 Austenitic steels (except castings) with a minimum rupture elongation, A%, as given in the relevant technical specification for the material, such as $A\% \geq 35\%$	33
6.6 Cast steels.....	34
6.7 Nominal design stress of anchor bolting	35
7 Shells under internal pressure	35
7.1 Purpose.....	35
7.2 Specific definitions	35
7.3 Specific symbols and abbreviations.....	36
7.4 Cylindrical and spherical shells	36
7.5 Dished ends	37
7.6 Cones and conical ends	42
7.7 Nozzles which encroach into the knuckle region	51
8 Shells under external pressure.....	55
8.1 Purpose.....	55
8.2 Specific definitions	55
8.3 Specific symbols and definitions	56
8.4 General.....	59
8.5 Cylindrical shells	60
8.6 Conical shell	80
8.7 Spherical shells	88
8.8 Vessel ends	89
9 Openings in shell	89

9.1	Purpose.....	89
9.2	Specific definitions.....	90
9.3	Specific symbols and abbreviations.....	91
9.4	General	94
9.5	Isolated openings.....	105
9.6	Multiple openings	123
9.7	Openings close to a shell discontinuity.....	134
10	Flat ends	142
10.1	Purpose.....	142
10.2	Specific definitions.....	142
10.3	Specific symbols and abbreviations.....	143
10.4	Unpierced circular flat ends welded to cylindrical shells.....	144
10.5	Unpierced bolted circular flat ends.....	151
10.6	Pierced circular flat ends	154
10.7	Flat ends of non-circular or annular shape	159
11	Flanges	163
11.1	Purpose.....	163
11.2	Specific definitions.....	163
11.3	Specific symbols and abbreviations.....	164
11.4	General	166
11.5	Narrow face gasketed flanges.....	170
11.6	Full face flanges with soft ring type gaskets.....	186
11.7	Seal welded flanges	189
11.8	Reverse narrow face flanges.....	189
11.9	Reverse full face flanges	192
11.10	Full face flanges with metal to metal contact.....	196
12	Bolted domed ends.....	199
12.1	Purpose.....	199
12.2	Specific definitions.....	199
12.3	Specific symbols and abbreviations.....	199
12.4	General	199
12.5	Bolted domed ends with narrow face gaskets.....	199
12.6	Bolted domed ends with full face joints.....	201
13	Heat Exchanger Tubesheets.....	203
13.1	Purpose.....	203
13.2	Specific definitions.....	203
13.3	Specific symbols and abbreviations.....	203
13.4	U-tube tubesheet heat exchangers	206
13.5	Fixed tubesheet heat exchangers.....	220
13.6	Floating tubesheet heat exchangers	249
13.7	Tubesheet characteristics	267
13.8	Maximum permissible tube to tubesheet joint stress	274
13.9	Maximum permissible longitudinal compressive stress for tubes.....	275
13.10	Design of tubesheet flange extension with a narrow face gasket.....	278
13.11	Design of tubesheet flange extension with a full face gasket.....	282
13.12	Special tube-to-tubesheet welded joints	285
14	Expansion bellows	289
14.1	Purpose.....	289
14.2	Specific definitions.....	289
14.3	Specific symbols and abbreviations.....	291
14.4	Conditions of applicability.....	293
14.5	U-shaped unreinforced bellows	295
14.6	U-shaped reinforced bellows.....	310
14.7	Toroidal bellows	319

14.8	Fabrication	325
14.9	Inspection and testing.....	327
14.10	Bellows subjected to axial, lateral or angular displacements	329
15	Pressure vessels of rectangular section.....	335
15.1	Purpose.....	335
15.2	Specific definitions	335
15.3	Specific symbols and abbreviations.....	335
15.4	General.....	337
15.5	Unreinforced vessels	337
15.6	Reinforced vessels.....	346
15.7	Openings.....	355
16	Additional non-pressure loads.....	357
16.1	Purpose.....	357
16.2	Specific definitions	357
16.3	Specific symbols and abbreviations.....	358
16.4	Local loads on nozzles in spherical shells	359
16.5	Local loads on nozzles in cylindrical shells	370
16.6	Line loads	379
16.7	Lifting lugs	385
16.8	Horizontal vessels on saddle supports.....	391
16.9	Horizontal vessels on ring supports.....	406
16.10	Vertical vessels on bracket supports.....	411
16.11	Vertical vessels with supporting legs	416
16.12	Vertical vessels with skirts.....	418
16.13	Vertical vessels with ring supports	451
16.14	Global loads on cylindrical shells.....	462
17	Simplified assessment of fatigue life.....	474
17.1	Purpose.....	474
17.2	Specific definitions	474
17.3	Specific symbols and abbreviations.....	477
17.4	Conditions of applicability.....	479
17.5	General.....	480
17.6	Determination of allowable number of pressure and thermal cycles.....	488
17.7	Assessment rule.....	513
17.8	Design and manufacture.....	513
17.9	Testing.....	514
18	Detailed assessment of fatigue life	515
18.1	Purpose.....	515
18.2	Specific definitions	515
18.3	Specific symbols and abbreviations.....	519
18.4	Limitations	521
18.5	General.....	522
18.6	Welded material	525
18.7	Unwelded components and bolts	530
18.8	Elastic-plastic conditions	534
18.9	Fatigue action	536
18.10	Fatigue strength of welded components	540
18.11	Fatigue strength of unwelded components	560
18.12	Fatigue strength of steel bolts	565
19	Creep design.....	568
19.1	Purpose.....	568
19.2	Specific definitions	568
19.3	Specific symbols and abbreviations.....	568
19.4	Design in the creep range.....	569

19.5	Nominal Design stress in the creep range	570
19.6	Weld joint factor in the creep range	574
19.7	Pressure loading of predominantly non-cyclic nature in the creep range	574
19.8	Design procedures for DBF	574
20	Design rules for reinforced flat walls	578
20.1	General	578
20.2	Stayed flat walls.....	578
20.3	Specific definitions for stayed flat walls.....	578
20.4	Required thickness of stayed flat walls	578
20.5	Required dimensions and layout of staybolts and stays	578
20.6	Requirements for threaded staybolts	579
20.7	Requirements for welded-in staybolts and welded stays	579
20.8	Tables for stayed flat walls.....	580
20.9	Figures for Stayed Flat Walls	580
21	Circular flat ends with radial reinforcement ribs	584
21.1	Purpose.....	584
21.2	Specific definitions	584
21.3	Specific symbols and abbreviations	586
21.4	Ends without additional peripheral bending moment.....	587
21.5	Ends with additional peripheral bending moment	589
21.6	Openings	593
21.7	Welds.....	593
21.8	Central Ring	594
22	Static analysis of tall vertical vessels on skirts	595
22.1	Purpose.....	595
22.2	Specific definitions.....	595
22.3	Specific symbols and abbreviations.....	595
22.4	Loads	596
22.5	Load combinations.....	600
22.6	Stress analysis of pressure vessel shells and skirts	600
22.7	Design of joint between skirt and pressure vessel (at dished end or cylindrical shell)	601
22.8	Design of anchor bolts and base ring assembly	601
22.9	Foundation loads	601
22.10	Vortex shedding	602
Annex A (normative)	Design requirements for pressure bearing welds	606
Annex B (normative)	Design by Analysis – Direct Route	630
Annex C (normative)	Design by analysis — Method based on stress categories	662
Annex D (informative)	Verification of the shape of vessels subject to external pressure	684
Annex E (normative)	Procedure for calculating the departure from the true circle of cylinders and cones	691
Annex F (normative)	Allowable external pressure for vessels outside circularity tolerance	694
Annex G (normative)	Alternative design rules for flanges and gasketed flange connections	696
Annex H (informative)	Gasket factors m and y	746
Annex I (normative)	Additional information on heat exchanger tubesheet design	749
Annex J (normative)	Alternative method for the design of heat exchanger tubesheets	753
Annex K (informative)	Additional information on expansion bellows design.....	802
Annex L (informative)	Basis for design rules related to additional non-pressure loads	809
Annex M (informative)	In service monitoring of vessels operating in fatigue or creep service	811

Annex N (informative) Bibliography to Clause 18.....	814
Annex O (informative) Physical properties of steels	815
Annex P (normative) Classification of weld details to be assessed using principal stresses	823
Annex Q (normative) Simplified procedure for the fatigue assessment of unwelded zones.....	836
Annex R (informative) Coefficients for creep-rupture model equations for extrapolation of creep-rupture strength	837
Annex S (informative) Extrapolation of the nominal design stress based on time-independent behaviour in the creep range.....	844
Annex T (normative) Design by experimental methods	849
Annex U (informative) Guidance on negligibility of additional thermal cycles in fatigue and ratcheting assessment.....	863
Annex V (informative) Consider a buffer for unknown nozzle loads — Opening design for unknown nozzle loads.....	872
Annex Y (informative) History of EN 13445-3	873
Annex ZA (informative) Relationship between this European Standard and the essential requirements of Directive 2014/68/EU aimed to be covered	874

European foreword

This document (EN 13445-3:2021) 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 2021, and conflicting national standards shall be withdrawn at the latest by November 2021.

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

This document has been prepared under a standardization request 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.

List of all parts in the EN 13445 series can be found on the CEN website.

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 13445-3:2014. 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 13445:2021 each year, starting with the precedent as Issue 1, consolidating these Amendments and including other identified corrections.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this European Prestandard: 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 document specifies requirements for the design of unfired pressure vessels covered by EN 13445-1:2021 and constructed of steels in accordance with EN 13445-2:2021.

EN 13445-5:2021 EN 13445-5:2021, 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 are referred to in the text in such a way that some or all of their content constitutes requirements 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 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 764-1:2015+A1:2016, *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 1092-1:2018, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN-designated — Part 1: Steel flanges*

EN 1591-1:2013, *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 1990:2002¹⁾, *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 1991-1-4:2005²⁾, *Eurocode 1: Actions on structures — Part 1-4: General actions — Wind actions*

¹⁾ EN 1990:2002 is impacted by the stand-alone amendment EN 1990:2002/A1:2005 and the corrigendum EN 1990:2002/AC:2010.

²⁾ EN 1991-1-4:2005 is impacted by the stand-alone amendment EN 1991-1-4:2005/A1:2010 and the corrigendum EN 1991-1-4:2005/AC:2010.

EN 1991-1-6:2005, *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 10204:2004, *Metallic products — Type of inspection documents*

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

EN 12195-1:2010, *Load restraining on road vehicles — Safety — Part 1: Calculation of securing forces*

EN 13445-1:2021, *Unfired pressure vessels — Part 1: General*

EN 13445-2:2021, *Unfired pressure vessels — Part 2: Materials*

EN 13445-4:2021, *Unfired pressure vessels — Part 4: Fabrication*

EN 13445-5:2021, EN 13445-5:2021, *Unfired pressure vessels — Part 5: Inspection and testing*

EN 13445-8:2021, *Unfired pressure vessels — Part 8: Additional requirements for pressure vessels of aluminium and aluminium alloys*

EN 13555:2014, *Flanges and their joints — Gasket parameters and test procedures relevant to the design rules for gasketed circular flange connections*

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 document, the terms and definitions given in EN 13445-1:2021, EN 13445-2:2021 and the following apply:

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

NOTE EN 13445-1:2021 and EN 13445-2:2021 have adopted terminology, symbols and definitions of EN 764-1:2015+A1:2016, 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