

DIN EN 13445-3:2015-12 (E)

Unfired pressure vessels - Part 3: Design

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
Issue 2 (2015-07) 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	320
Issue 2 (2015-07)	15.5 Unreinforced vessels	320
15.6	Reinforced vessels	326
15.7	Openings	333
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
Issue 2 (2015-07)	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	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 ZA (informative) Relationship between this European Standard and the Essential Requirements of the EU Pressure Equipment Directive 97/23/EC	865