

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 shells	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