Core Standards in the Pressure Equipment Area

Workshop on the Pressure Equipment Directive

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Harmonized Standards[1)] in the Pressure Equipment Area

- EN 13445 - Unfired Pressure Vessels
- EN 13480 - Metallic Industrial Piping
- EN 12952 - Water Tube Boilers and Auxiliary Installations
- EN 12953 – Shell Boilers

[1)] Pressure equipment and assemblies which conform to the national standards transposing the harmonized standards the reference numbers of which have been published in the Official Journal of the European Communities shall be presumed to conform to the essential requirements referred to in Article 3 PED.

EN 13445 – Unfired Pressure Vessels[1)]

- 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 vessel parts constructed from spheroidal graphite cast iron

[1)] Figures and Tables from EN 13445 shown in this presentation are only intended for clarification of requirements of EN 13445 and do not necessarily correspond to the latest revision of the standard. Usage for other purposes, e.g. for design and manufacturing of pressure vessels, is not permitted. All rights of exploitation reserved worldwide for CEN national members.

EN 13445–1 General: Scope

- EN 13445 applies to unfired pressure vessels subject to internal pressure greater than 0,5 bar(g), but may be used for vessels operating a lower pressures, including vacuum.
- EN 13445 applies to maximum allowable temperatures for which creep effects need not be considered, i.e. for maximum allowable temperatures for which the corresponding maximum calculation temperature renders a relevant proof strength smaller than the 100000 h creep rupture strength (ferritic steels: approx. 380°C, austenitic steels: approx. 425°C)

EN 13445–1 General: Scope

EN 13445 is not applicable to

- Transportable pressure equipment
- Items specially designed for nuclear use
- Pressure equipment for generation of steam or superheated water at temperatures higher than 110°C
- Vessels of riveted construction
- Vessels of laminar cast iron or other material not included in Part 2 or Part 6
- Multilayered, autofrettaged or pre-stressed vessels
- Pipelines and industrial piping

EN 13445–2 Materials

- Currently limited to steels with sufficient ductility
- Minimum elongation after fracture

  ≥ 14% transverse or critical direction

  ≥ 16% longitudinal or less critical direction
- Specified minimum impact energy (Charpy-V), at a test temperature in accordance with Annex B but not higher than 20°C:

  ≥ 27 J ferritic steels, steels with 1.5 - 5.0 % Ni

  ≥ 40 J other (35 J for some austentic steels)
- Maximum carbon, phosphorus und sulfur contents for steels (e.g. for ferritic steel (not stainless) – max. values for cast analysis: C_{max}=0.23%, P_{max}=0.035%, S_{max}=0.025%)

EN 13445–2 Materials

Technical delivery conditions :

- European Standards

  e.g. EN 10028 (plate), EN 10222 (forging), EN 10216 (seamless pipe), EN 10217 (welded pipe), EN 10269 (fasteners)

- European Approval for Materials

- Particular Material Appraisal

Technical delivery conditions for welding consumables shall be in accordance with EN 12074 and prEN 13479-1.

EN 13445–2 Materials: Grouping System

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [h]	Thickness mm		Material group to CR ISO 15608	Notes
							min.	max.		
1	plate and strip	EN 10028-2	elevated temperature properties	P235GH	1.0345	N	0	150	1.1	a
2	plate and strip	EN 10028-2	elevated temperature properties	P265GH	1.0425	N	0	150	1.1	a
3	plate and strip	EN 10028-2	elevated temperature properties	P295GH	1.0481	N	0	150	1.2	a
4	plate and strip	EN 10028-2	elevated temperature properties	P355GH	1.0473	N	0	150	1.2	a
5	plate and strip	EN 10028-2	elevated temperature properties	16Mo3	1.5415	N	0	150	1.1	a, f
6	plate and strip	EN 10028-2	elevated temperature properties	13CrMo4-5	1.7335	NT	0	60	5.1	a
7	plate and strip	EN 10028-2	elevated temperature properties	13CrMo4-5	1.7335	NT, QT	60	100	5.1	a
8	plate and strip	EN 10028-2	elevated temperature properties	13CrMo4-5	1.7335	QT	100	150	5.1	a
9	plate and strip	EN 10028-2	elevated temperature properties	10CrMo9-10	1.7380	NT	0	60	5.2	a
10	plate and strip	EN 10028-2	elevated temperature properties	10CrMo9-10	1.7380	NT, QT	60	100	5.2	a
11	plate and strip	EN 10028-2	elevated temperature properties	10CrMo9-10	1.7380	QT	100	150	5.2	a
12	plate and strip	EN 10028-2	elevated temperature properties	11CrMo9-10	1.7383	NT, QT	0	60	5.2	a
13	plate and strip	EN 10028-2	elevated temperature properties	11CrMo9-10	1.7383	QT	60	100	5.2	a
14	plate and strip	EN 10028-3	fine grain steel normalised	P275N	1.0486	N	0	150	1.1	a
15	plate and strip	EN 10028-3	fine grain steel normalised	P275NH	1.0487	N	0	150	1.1	a
16	plate and strip	EN 10028-3	fine grain steel normalised	P275NL1	1.0488	N	0	150	1.1	a
17	plate and strip	EN 10028-3	fine grain steel normalised	P275NL2	1.1104	N	0	150	1.1	a
18	plate and strip	EN 10028-3	fine grain steel normalised	P355N	1.0562	N	0	150	1.2	a
19	plate and strip	EN 10028-3	fine grain steel normalised	P355NH	1.0565	N	0	150	1.2	a
20	plate and strip	EN 10028-3	fine grain steel normalised	P355NL1	1.0566	N	0	150	1.2	a
21	plate and strip	EN 10028-3	fine grain steel normalised	P355NL2	1.1106	N	0	150	1.2	a
22	plate and strip	EN 10028-3	fine grain steel normalised	P460N	1.8905	N	0	150	1.3	a
23	plate and strip	EN 10028-3	fine grain steel normalised	P460NH	1.8935	N	0	150	1.3	a
24	plate and strip	EN 10028-3	fine grain steel normalised	P460NL1	1.8915	N	0	150	1.3	a
25	plate and strip	EN 10028-3	fine grain steel normalised	P460NL2	1.8918	N	0	150	1.3	a
26	plate and strip	EN 10028-4	low temperature properties	11MnNi5-3	1.6212	N, NT	0	50	9.1	a
27	plate and strip	EN 10028-4	low temperature properties	13MnNi6-3	1.6217	N, NT	0	50	9.1	a
28	plate and strip	EN 10028-4	low temperature properties	15NiMn6	1.6228	N, NT, QT	0	50	9.1	a
29	plate and strip	EN 10028-4	low temperature properties	12Ni14	1.5637	N, NT, QT	0	50	9.2	a

EN 13445–2 Materials: Annex B

Requirements for prevention of brittle fracture

- Method 1: Technical requirements applicable to all metallic materials, but limited to certain thicknesses for which experience exist.
- Method 2: Technical requirements only applicable to C, CMn and low alloy ferritic steels with a minimum yield strength $\leq$ 460 N/mm^2.
- Method 3: Application of fracture mechanics. Only general guidance is given on the use of this method which shall only be used in agreement with the parties concerned.

EN 13445–2 Materials: Annex B Method 1

Material	Impact energy KV	Impact test temperature T_{KV}	Reference thickness e_B	Remarks
Ferritic steel, 1,5 % to 5 % inclusive Ni alloyed steels	27 J	T_R	For as welded ≤ 30 mm	$R_p \leq 310$ N/mm^2
	27 J	T_R [a]	For post weld heat treated ≤ 60 mm	310 N/mm^2 < R_p ≤ 460 N/mm^2
9 % Ni alloyed steels	40 J	–196 °C	—	—
Weld materials [d] for austenitic steels and castings made from austenitic steels [b]	40 J [c]	–196 °C [d]	any	—
Austenitic-ferritic stainless steels	40 J	T_M	≤ 30 mm [e]	Limited to $T_M \geq -30$ °C

[a] Production test plates shall be tested at $T_{KV} = T_R$. Impact values in the weld, HAZ and parent material of 27 J are required. For the extent of non-destructive testing see testing group 1, EN 13445-5.

[b] See Table B.4 for lowest minimum metal temperature T_M of solution annealed austenitic steels.

[c] If higher impact values are required in the material specification, these requirements shall be fulfilled for the weld material at $T_{KV} = -196$ °C, if $T_R \leq -196$ °C.

[d] For $T_R \leq -196$ °C testing shall be at $T_{KV} = -196$ °C. Requirements for base material shall be as given in the appropriate material standard.

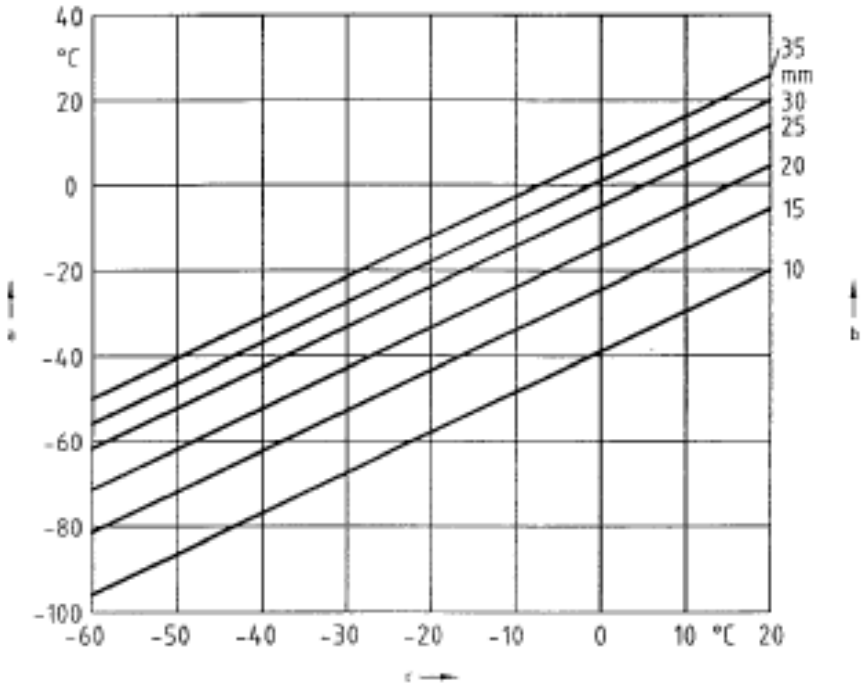
[e] Actual thickness

EN 13445–2 Materials: Annex B Method 2

Partent Material, welds and HAZ shall be meet the energy KV at impact test temperature T_{KV}. Table B.5 shows which figure shall be used to determine the impact test temperature T_{KV} or the design reference temperature T_R.

Specified minimum yield strength of base material N/mm²	Required impact energy KV (on 10 mm × 10 mm test pieces) J	Figure defining required T_{KV}	
		Non welded and post-weld heat treated	As welded
< 310	27	B.1	B.2
> 310, ≤ 360	40	B.1	B.2
	27	B.3	B.4
> 360, ≤ 460	40	B.1	B.2
	27	B.3	B.5

EN 13445–2 Materials: Annex B Method 2



Key
a design reference temperature T_R
b thickness
c material impact test temperature T_{KV}

Figure B.4-2 — Design reference temperature and impact test temperature as welded (AW) condition, for $R_e \leq 310$ N/mm^2 : 27 J, and for 310 N/mm^2 < $R_e \leq 460$ N/mm^2: 40 J

EN 13445–2 Materials: Annex B 4.2

Production test plates

- Weld production test plate shall be performed in accordance with clause 8 of EN 13445-4.
- The following requirements are additional to the requirements to clause 8 of EN 13445-4. In addition to this a weld production test plate[1)] is required according to welding procedure specification for T_{KV} equal to or above -30°C, if the material thickness is greater than 12mm.
- For T_{KV} below -30°C, a weld production test plate[1)] is required if the material thickness is greater than 6mm.
- The impact energy requirements of method 1 or 2 shall be met.

[1)] on a longitudinal seam per vessel

EN 13445–3 Design: Basic Criteria

- The requirements specified in clauses 7 to 16 (DBF) provide satisfactory design for pressure loading of non-cyclic nature, i.e. when the number of full pressure cycles is less than 500. Then no fatigue analysis is necessary and the standard requirements of non destructive testing given in EN 13445-5 shall be applied.
- For n_i pressure cycles at a pressure P_i less than the full pressure P, the number of equivalent full pressure cycles is given by:

$$n_{eq} = \Sigma n_i \cdot \left(\frac{P_i}{P_{\max}} \right)^3$$

- If a fatigue analysis is required it can be performed according to clause 17 (simplified fatigue analysis, rules only for cyclic pressure, conservative) or clause 18 (detailed fatigue analysis, normally by usage of FEM). NDT requirements according to Annex G of EN 13445-5 shall be used.

EN 13445–3 Design: Basic Criteria

Weld joint coefficient z for governing welded joints:

z	1	0,85	0,7
Testing group	1, 2	3	4

- For exceptional and testing conditions, a value of 1 shall be used irrespective of the testing group.
- The amount of NDT in accordance with EN 13445-5 depends on the testing group used for the vessel or the part of the vessel.
- Pressure vessels to testing group 4 are intended to non-cyclic operations and are limited to 500 full pressure cycles or equivalent pressure cycles.
- For testing group 4, the maximum nominal design stress for normal operating load cases shall be multiplied by 0,9.

EN 13445–3 Design: Basic Criteria

Governing welded joints are

- Longitudinal or helical welds in cylindrical shells
- Longitudinal welds in a conical shell
- Any main weld in spherical shell/head and main welds in a dished head

Not governing welded joints are

- Circumferential welds between a cylindrical or conical shell and a cylinder, cone, flange or end other than hemispherical
- Welds attaching nozzles to shells
- Welds subjected exclusively to compressive stress

EN 13445–3 Design: Allowable stress

Maximum allowable nominal design stresses:

	Normal operating load cases	Testing and exceptional l..c.
Steels other than austentic	$f = \mathrm{Min}\left[\frac{R_{p0.2/T}}{1.5}; \frac{R_{m/20}}{2.4}\right]$	$f_{test} = \frac{R_{p0.2/Ttest}}{1.05}$
Austenitic steels $35 > A \geq 30\%$	$f = \frac{R_{p1.0/T}}{1.5}$	$f_{test} = \frac{R_{p1.0/Ttest}}{1.05}$
Austentitc steels $A \geq 35\%$	$f = Max\left[\frac{R_{p1.0/T}}{1.5}; Min\left[\frac{R_{p1.0/T}}{1.2}; \frac{R_{m/T}}{3.0}\right]\right]$	$f_{test} = \mathrm{Max}\left[\frac{R_{p1.0/Ttest}}{1.05}; \frac{R_{m/Ttest}}{2.0}\right]$
Cast steels	$f = \mathrm{Min}\left[\frac{R_{p0.2/T}}{1.9}; \frac{R_{m/20}}{3.0}\right]$	$f_{test} = \frac{R_{p0.2/Ttest}}{1.33}$
The yield strength R_{eH} may be used in lieu of $R_{p0.2}$ if the latter is not available		

EN 13445–3 Design: DBF

Clause 7: DBF for shells under internal pressure - iterative or direct calculation of the required wall thicknesses

- Cylindrical and spherical shells
- Dished ends
- Cones and conical ends
- Nozzles in the knuckle region

Clause 8: DBF for shells under external pressure - iterative or direct calculation of the required wall thicknesses and stiffeners

- Cylindrical shells
- Conical shells
- Spherical shells
- Vessel ends

EN 13445–3 Design: DBF

Clause 9: Openings in shells

Clause 10: Flat ends

Clause 11: Flanges

- Flanges that conform to an EN standard for pipework flanges (e.g. EN 1092-1) with pressure-temperature ratings may be used as pressure vessel components without any calculation under particular conditions.
- Flange calculation in clause 11 is based on Taylor-Forge method
- Alternative rules for narrow face gasket flange design in Annex G are most appropriate when: a) thermal cycling is important, b) bolt stress is controlled by use of a tightening procedure, c) there are significant additional loadings (forces or moments) or d) leak tightness is of special importance.

EN 13445–3 Design: DBF

Clause 12: Bolted domed ends (Alternative Rules according to Annex G)

Clause 13: Heat exchanger tubesheets (Alternative Rules according to Annex J)

Clause 14: Expansion bellows

Clause 15: Pressure vessels of rectangular section

Clause 16: Additional non-pressure loads

- Local loads on nozzles in spherical or cylindrical shells
- Line loads
- Lifting lugs
- Horizontal vessels on saddle supports, or on ring supports
- Vertical vessels on bracket supports, with supporting legs, with skirts, with ring support
- Global loads

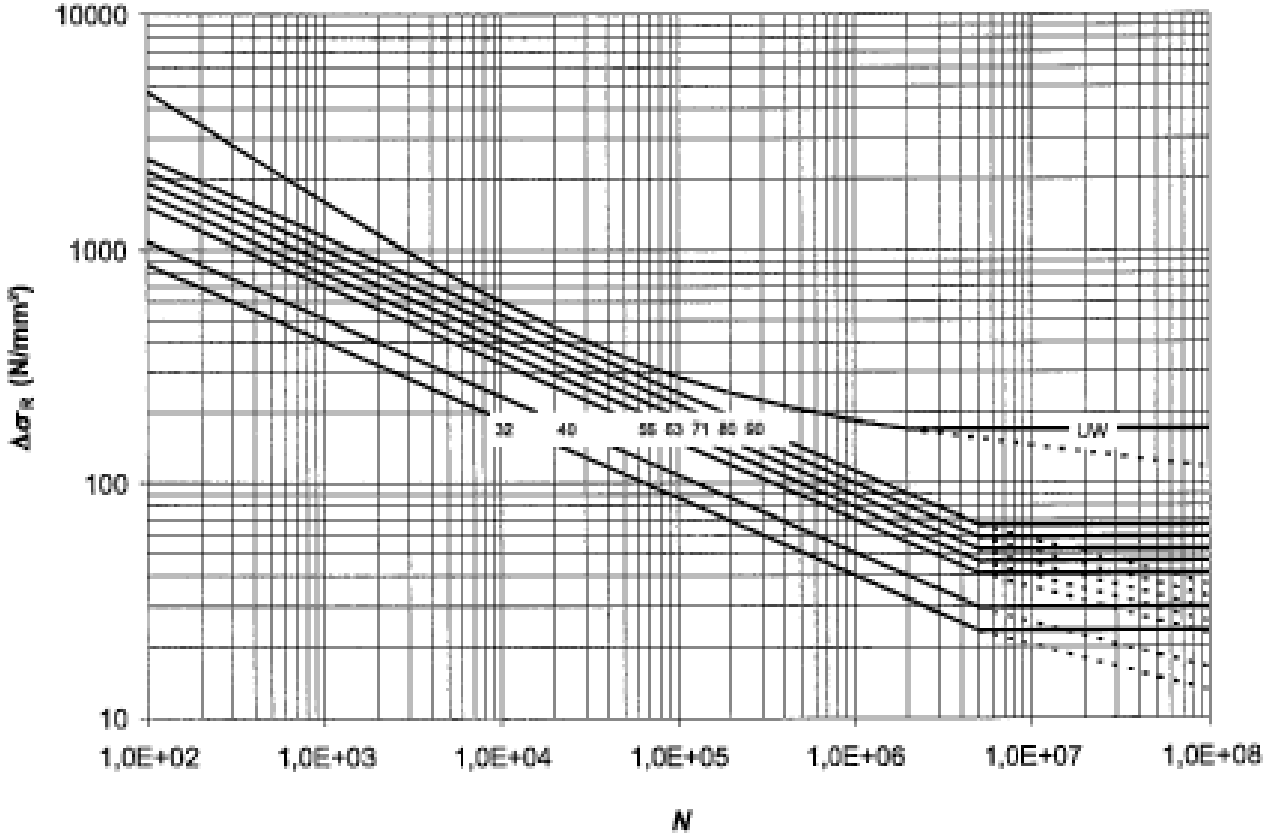
EN 13445–3 Design: Fatigue

Clause 17: Simplified assessment of fatigue life

- Simplified assessment of fatigue damage due to pressure fluctuations
- ΔP shall be obtained by applying the simplified cycle counting method or the reservoir cycle counting method and considering fluctuations of pressure instead of stress (details on the methods are given in clause 18).
- The stress range $\Delta\sigma$ is calculate by usage of a value η which is given in Table 17-1, and is defined as ratio of the maximum structural stress to the nominal design stress.
- The total fatigue damage is calculated to $D = \frac{n_1}{N_1} + \frac{n_2}{N_2} + ... = \sum_1^k \frac{n_j}{N_j} \leq 1$

EN 13445–3 Design: Fatigue

Clause 17: Fatigue design curves



EN 13445–3 Design: Fatigue

Clause 17: Classification of welded joints

(c) Branch connections

Detail No.	Joint type	Sketch of detail	Class testing group 1 or 2	Class testing group 3	Comments	Relevant details in Table 17-1
3	All types	(a) 	71 80	 63	Full penetration welds: — as welded — if weld toes dressed — in all cases	OS2.1 to OS3.3
		(b) 	63 71	 63	Partial penetration welds, with weld throat ≥ 0,8 x thinner thickness of connected walls: — as welded — if weld toes dressed — in all cases	

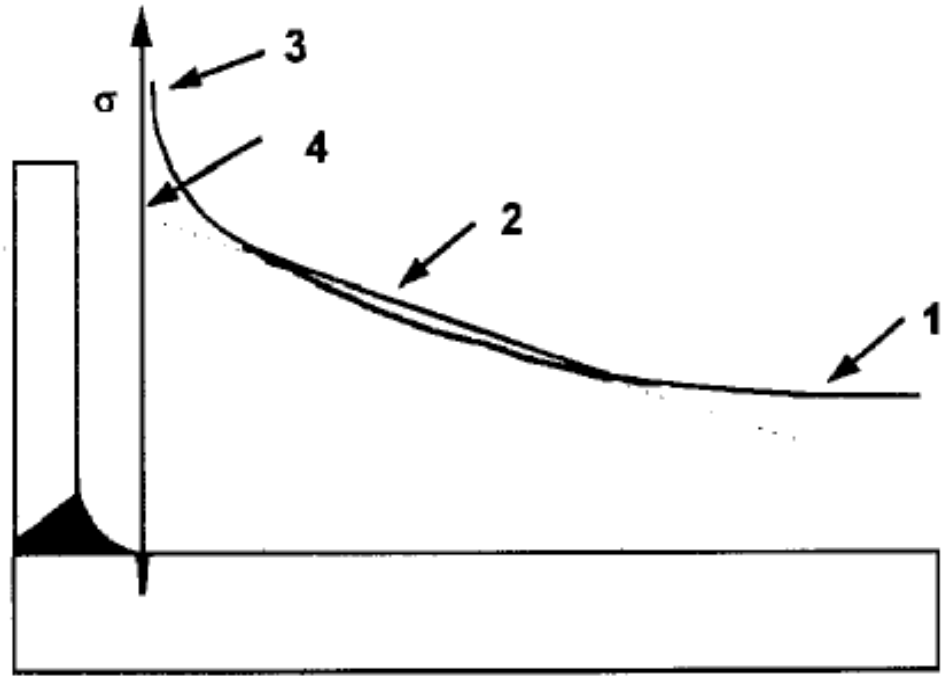
EN 13445–3 Design: Fatigue

Clause 18: Detailed assessment of fatigue life

- Detailed assessment of fatigue damage due to fluctuations of all loads (pressure, thermal, mechanical loads, etc..), determination of the stresses usually by FEM, linear damage accumulation model as in clause 17.
- $\Delta\sigma$ shall be obtained by applying the simplified cycle counting method or the reservoir cycle counting method .
- Total stresses to be used for unwelded regions, allowable cycle number for a given stress range calculated iteratively.
- Structural stresses to be used for welded regions, allowable cycle number for a given stress range calculated directly.
- Classification of welded joints
- Structural equivalent stress range or structural principal stress range can be used for welded regions, the latter may result in a higher number of cycles.

EN 13445–3 Design: Fatigue

Clause 18: Stress distribution at a structural discontinuity



1 Nominal stress

2 Structural stress

3 Notch stress

4 Extrapolation to give structural stress at potential crack initiation site.

EN 13445–3 Design: DBA

Annex B (normative) DBA – direct route

- As a complement and as an alternative to DBF
- Flexibility due to the partial safety factor concept (for actions and for resistances)
- Avoids uncertainties in stress categorisation due to direct addressing of the relevant failure modes (e.g. via elastic-plastic FEA)
- Failure modes considered are: a)Gross plastic deformation, b)Progressive deformation, c)Fatigue, d)Instability, e)Static equilibrium.
- New, innovative method for DBA, some principals might be adapted by other codes (e.g. ASME VIII Div.2)
- Further information (DBA manual): see http://ped.eurodyn.com via links JRC and DBA

Annex C (normative) DBA – method based on stress categories

EN 13445-3 Design: Annexes

- Annex A (norm.): Design requirements for pressure bearing welds
- Annex B (norm.): DBA – direct route
- Annex C (norm.): DBA – method based on stress categories
- Annex D (inf.): Verification of the shape of vessels subject to external pressure
- Annex E (norm.): Procedure for calculating the departure from the true circle of cylinders and cones
- Annex F (norm.): Allowable external pressure for vessels outside circularity tolerance
- Annex G (norm.): Alternative rules for flanges and gasketed flange connections
- Annex H (inf.): Gasket factors m and y
- Annex I (inf.): Additional information on heat exchanger tubesheet design
- Annex J (norm.): Alternative methods for the design of heat exchanger tubesheets

EN 13445–3 Design: Annexes

- Annex K (inf.): Additional information on expansion bellows design
- Annex L (inf.): Basis for design rules related to non-pressure loads
- Annex M (inf.): Measures to be adopted in service
- Annex N (inf.): Bibliography to clause 18
- Annex O (inf.): Physical properties of steel
- Annex P (norm.): Classification of weld details to be assessed using principal stresses
- Annex Q (norm.): Simplifies procedure for fatigue assessment of unwelded zones
- Annex ZA (inf.): Clauses of this European Standard addressing essential requirements or other provisions of the EU directives

EN 13445–4 Fabrication

Scope

- Materials traceability
- Manufacturing tolerances
- Welding requirements
- Production tests
- Forming requirements
- Heat treatment
- Repairs and finishing operations

EN 13445–4 Fabrication: Welding

- Welding procedure specifications (WPS) shall be in accordance with EN 288-2.
- Welding procedure approval test for pressure retaining welds shall be performed in accordance with EN 288-3 or by pre-production tests in accordance with EN 288-8 (additional requirements are given in clause 7.3 of EN 13445-4).
- Welding procedure approval test for other than pressure retaining welds directly attached to the pressure vessel may be acceptable by holding welding procedure approval records carried out in accordance with EN 288-6 and EN 288-7.
- Welders and welding operators shall be approved to EN 287-1 or EN 1418 resp.
- The manufacturer shall include the preheating temperatures in the WPS.

EN 13445–4 Fabrication: Production test

- Production test plates apply only to governing welds
- For vessels in testing group 4 no production test plates are required
- Example of requirements: production test plate are required for material group 1.1, 1.2 and 8.1:
  - Longitudinal weld, one test plate per vessel if z = 1.0
  - One test plate per 100m of longitudinal weld if z = 0.85

  After 10 consecutive test plates have successfully pasted the test,

  - One test plate per 100m of longitudinal weld if z = 1.0
  - One test plate per 1000m of longitudinal weld if z = 0.85
- The required testing of production test plates are dependent on the material and the thickness.

EN 13445–4 Fabrication: Forming

- Temperature requirements for cold forming and hot forming for the different materials
- Requirements for heat treatment after cold and hot forming for the different materials
- No mechanical tests are required for cold formed products without heat treatment.
- Requirements for hot formed or cold formed products with heat treatment: Formed products shall be individually tested until the manufacturer has passed 30 test coupons within the appropriate material group. Thereafter the tests are performed per batch (a batch is defined by products of the same cast and the same final heat treatment).

EN 13445–4 Fabrication: PWHT

Material group	Steel: Grade or type	Steel: According to	Heat treatment condition [a] of base material	Post weld heat treatment: Nominal thickness e_n [b] mm	Post weld heat treatment: Holding time min	Post weld heat treatment: Holding temperature °C
1.1	Unalloyed steels	EN 10028-2:2002 EN 10216-1:2002, EN 10216-2:2002, EN 10216-4:2002 EN 10217-1:2002, EN 10217-2:2002, EN 10217-4:2002 to EN 10217–6:2002 EN 10222-2:2002	N or NT	≤ 35[c]	30	550 to 600
1.2				> 35 ≤ 90	$e_n - 5$	
1.3	normalised fine grain steels	EN 10028-3:2002 EN 10216-3:2002 EN 10217-3:2002 EN 10222-4:2002		> 90	40 + 0,5 e_n	
1.2	16Mo3	EN 10028-2:2002 EN 10216-2:2002 EN 10217-2:2002, EN 10217-5:2002 EN 10222-2:2002	N or NT or QT	≤ 35[c]	30	550 to 620
				> 35 ≤ 90	$e_n - 5$	
				> 90	40 + 0,5 e_n	
5.1	13CrMo4-5[d]	EN 10028-2:2002 EN 10216-2:2002 EN 10222-2:2002	N or QT	≤ 15	30	630 to 680
				> 15 ≤ 60	2 e_n	
				> 60	60 + e_n	
5.2	10CrMo9-10[e] 11CrMo9-10[e]	EN 10028-2:2002 EN 10216-2:2002 EN 10222-2:2002	NT or QT	As specified for steel 13CrMo4-5		670 to 720

EN 13445–4 Fabrication: PWHT

Mechanical properties after heat treatment – limits for maximum and holding time without effect on strength of the base material:

- PWHT time not exceeding 3 h at required PWHT temperature for material in groups 1.1 and 1.2 (except 16Mo3)
- PWHT temperature at least 30°C below the maximum tempering temperature and PWHT time not exceeding 3 h for all other materials.

If the conditions above are not fulfilled, test coupons heat treated with the vessel or subjected to a simulated PWHT are required (Note: possible exception for material in groups 1.1 and 1.2 - except 16Mo3 -, depending on the actual yield and tensile strength as per the relevant material test certification).

EN 13445–5 Inspection and Testing

- Specification of the inspection and testing of individual or serially produced pressure vessels made of steels in accordance with EN 13445-2 predominantly subject to non-cyclic operation.
- Special provisions for cyclic operation are given in Annex G of this part and in EN 13445-3.
- Material traceability: The manufacturer shall have an identification system, so that all material subject to stress due to pressure and those welded thereto in the completed vessel can be traced to its origin.

EN 13445-5 Inspection and Testing: NDT

- NDT of welded joints for final acceptance purposes shall be performed on the testing group of the welded joints under consideration (i.e. testing group 1, 2, 3 and 4).
- Testing groups 1, 2 and 3 are subdivided into sub-groups 1a, 1b, 2a, 2b, 3a, 3b, in order to reflect the crack sensitivity of the material.
- Where combinations of testing groups 1, 2 and 3 occur, the following shall occur:
  - In each section (course), the testing group of the governing welded joints shall determine the minimum group for all the weld in that section (including nozzle welds)
  - The testing group of the weld between two welded sections shall be the higher one
  - The minimum testing group between a welded and a seamless component, or between two seamless components, shall be determined by the available thickness at the weld. If it is greater than 1,17 (=1/0,85) times the minimum thickness, the testing group of the weld shall be 3 as a minimum requirement. Otherwise it shall be testing group 1 or 2.

EN 13445–5 Inspection and Testing: NDT

- Testing group 4 shall be used as a single testing group for the entire vessel.
- Testing group 4 shall be applicable only for:
  - Group 2 fluids
  - PS not greater than 20 bar
  - PS·V not greater than 20000 bar·L above 100°C, or PS·V not greater than 50000 bar·L equal or less 100°C
  - higher pressure test
  - maximum number of full pressure cycles less than 500
  - lower level of nominal design stress.
- NDT testing personal shall be qualified and certified in accordance with EN473.

EN 13445–5 Inspection and Testing: NDT

Requirements	Testing group [a]						
	1		2		3		4 [b,j]
	1a	1b	2a	2b	3a	3b	
Permitted materials [g]	1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Extent of NDT for governing welded joints [e,h]	100 %	100 %	100 % - 10% [d]	100 % - 10 % [d]	25 %	10 %	0 %
NDT of other welds	Defined for each type of weld in Table 6.6.2-1						
Joint coefficient	1	1	1	1	0,85	0,85	0,7
Maximum thickness for which specific materials are permitted	Unlimited [f]	Unlimited [f]	30 mm for groups 9.1, 9.2 16 mm for groups 9.3, 8.2 [i], 10	50 mm for groups 1.1, 8.1 30 mm for group 1.2	30 mm for groups 9.2, 9.1 16 mm for groups 8.2, 10	50 mm for groups 1.1, 8.1 30 mm for group 1.2	12 mm for groups 1.1, 8.1
Welding process	Unlimited [f]	Unlimited [f]	Fully mechanical welding only [c]		Unlimited [f]	Unlimited [f]	Unlimited [f]
Service temperature range	Unlimited [f]	Unlimited [f]	Unlimited [f]	Unlimited [f]	Unlimited [f]		Limited to (-10 to +200) °C for group 1.1 (-50 to+300) °C for group 8.1

EN 13445–5 Inspection and Testing: NDT

TYPE OF WELL [a]			TESTING [b]	EXTENT FOR TESTING GROUP						
				1a	1b	2a [i]	2b [i]	3a	3b	4
				EXTENT FOR PARENT MATERIALS [l,m,n]						
				1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Full penetration butt weld	1	Longitudinal joints	RT or UT MT or PT	100 % 10 %	100 % 10 % [d]	(100-10) % 10 %	(100-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	0 0
	2a	Circumferential joints on a shell	RT or UT MT or PT	100 % 10 %	25 % 10 % [d]	(100-10) % 10 %	(25-10) % 10 % [d]	10 % 10 %	10 % [c] 10 % [d]	0 0
	2b	Circumferential joints on a shell with backing strip [k]	RT or UT MT or PT	NA NA	100 % 10 %	NA NA	25 % 10 %	NA NA	25 % 10%	0 0
	2c	Circumferential joggle joint [k]	RT or UT MT or PT	NA NA	100 % 10 %	NA NA	25 % 10 %	NA NA	25 % 10%	0 0
	3a	Circumferential joints on a nozzle di > 150 mm or e> 16 mm	RT or UT MT or PT	100 % 10 %	25 % 10 % [d]	(100-10) % 10 %	(25-10) % 10 % [d]	10 % 10 %	10 % [c] 10 % [d]	0 0
	3b	Circumferential joints on a nozzle di > 150 mm. or e > 16 mm with backing strip [k]	RT or UT MT or PT	NA NA	100 % 10 %	NA NA	25 % 10 %	NA NA	25% 10%	0 0
	4	Circumferential joints on a nozzle $d_i \leq 150$ mm and $e \leq 16$ mm	RT or UT MT or PT	0 100 %	0 10 %	0 (100-10) %	0 10 %	0 10 %	0 10 %	0 0
	5	All welds in spheres, heads and hemispherical heads to shells	RT or UT MT or PT	100 % 10 %	100 % 10% [d]	(100-10) % 10 %	(100-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	0 0
	6	Assembly of a conical shell with a cylindrical shell angle ≤ 30 °	RT or UT MT or PT	100 % 10 %	25 % 10 % [d]	(100-10) % 10 %	(25-10) % 10 % [d]	10 % 10 %	10 % 10 % [d]	0 0
	7	Assembly of a conical shell with a cylindrical shell angle > 30 °	RT or UT MT or PT	100 % 10 %	100 % 10 % [d]	(100-25) % 10 %	(100-25) % 10 % [d]	25 % 10 %	10 % 10 % [d]	10 % 0

EN 13445–5 Standard hydrostatic test

- For a vessel according to testing group 1, 2 and 3 the test pressure shall not be less than that determined by the following: or

$$P_t = 1.25 \cdot PS \cdot \frac{f_a}{f_t} \qquad P_t = 1.43 \cdot PS$$

, whichever is the greater, where

P_t is the test pressure

PS is the maximum allowable working pressure

f_a is the nominal design stress for design conditions at test temperature

f_t is the nominal design stress for design conditions at the max. allow. temperature

- The ratio (f_a/f_t) to be used shall be the greatest ratio of those permitted based on the material for the main pressure envelope elements.
- In all cases for each component of the vessel the test pressure shall be limited such that it does not generate a design stress greater than that given in EN 13445-3 for testing conditions, by reducing the test pressure, if necessary.

EN 13445–5 Insp. and Testing: Annexes

- Annex A (norm.): Inspection and testing of serially produced vessels (Note: limitations given in A.2)
- Annex B (norm.): Detailed dimensional requirements for pressure vessels
- Annex C (norm.): Access and inspection openings, closing mechanisms and special locking elements
- Annex D (inf.): Leak testing
- Annex E (inf.): Acoustic emission
- Annex F (norm.): Standard hydrostatic test in case of static head acting in service or testing
- Annex G (norm.): Inspection and testing of pressure vessels subjected to cyclic loads
- Annex H (inf.): Declaration of compliance with this standard
- Annex ZA (inf.): Clauses of this European Standard addressing essential requirements or other provisions of the EU directives

Comparative Study on Pressure Equipment Standards

- A consortium of European partners, leaded by TUV Austria, is currently performing a "Comparative Study on Pressure Equipment Standards" on behalf of the European Commission. The study will compare the economic and non-economic implications in the application of (a) the EN 13445 (European Harmonized Standard for Unfired Pressure Vessels) and, (b) the internationally used ASME Boiler & Pressure Vessel Code plus major related codes when appropriate (TEMA, WRC bulletin), for the design, manufacture, inspection and acceptance testing of a 9 benchmark example unfired pressure vessels.
- Results will be available in spring 2004.