PD CEN/TR 13445-9:2011

BSI Standards Publication

Unfired pressure vessels

Part 9: Conformance of the EN 13445 series to ISO 16528

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National foreword

This Published Document is the UK implementation of CEN/TR 13445-9:2011. It supersedes PD CEN/TR 13445-9:2007 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PVE/1, Pressure Vessels.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Unbefeuerte Druckbehälter - Gegenüberstellung der EN 13445 Normenreihe und ISO 16528

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Management Centre: Avenue Marnix 17, B-1000 Brussels

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Foreword

This document (CEN/TR 13445-9:2011) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

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 supersedes CEN/TR 13445-9:2007.

The main differences between this edition and CEN/TR 13445-9:2007 are:

a) updating on the basis of the 2009 edition of EN 13445;

b) inclusion of full details for the following failure modes: creep rupture, creep - excessive deformations at mechanical joints or resulting in unacceptable transfer of load, creep instability

1 Scope

This CEN Technical Report details the conformance of the EN 13445 series for "Unfired pressure vessels" to ISO 16528-1 "Boilers and pressure vessels – Part 1: Performance requirements".

This Technical Report applies to vessels of steel construction.

It is envisaged that future editions will include spheroidal graphite cast iron and aluminium vessels.

2 Failure mode summary

Table 1 — Failure mode summary

STANDARD [a] : Unfired pressure vessels EN 13445:2009 Parts 1 to 5 and CR 13445-7	
FAILURE MODE SUMMARY [b]	
Failure modes according to ISO 16528-1 clause 6.2	**Addressed (Y / N / P) [c]**
Brittle fracture	Y
Ductile rupture	Y
Leakage at joints	Y
Elastic or plastic instability	Y
Creep rupture	Y
Additional failure modes according to ISO 16528-1 clause 6.1	**Addressed (Y / N / P) [c]**
Crack formation or ductile tearing due to excessive local strains	Y
Creep – excessive deformations at mechanical joints or resulting in unacceptable transfer of load	Y
Creep instability	Y
Erosion, corrosion	P
Environmentally assisted cracking, e.g. stress corrosion cracking, hydrogen induced cracking, etc.	P
Progressive plastic deformation	Y
Alternating plasticity	Y
Fatigue under elastic strains (medium and high cycle fatigue) or under elastic-plastic strains (low cycle fatigue)	Y
Environmentally assisted fatigue	P

[a] Provide full title of the standard and revision or addenda level.

[b] Failure modes addressed by this form (see ISO 16528-1).

[c] Y – failure mode addressed by standard
N – failure mode not addressed by standard
P – failure mode recognized but details not addressed.

3 Detailed failure mode checklists

Table 2 — Detailed failure mode checklists

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Brittle fracture
EXPLICIT DESIGN [d]
References [b] : **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Annex B "Requirements for prevention of brittle fracture"** **Method 1 and Method 2**
Comments [c] : **Method 1** **a) Technical requirements based on the choice of $T_R = T_{27J}$ as specified in harmonised European Material Standards and on the assumption that it is possible to achieve these minimum properties after fabrication. Calculated from the principles of fracture mechanics used for method 2 for C and CMn steels with yield strength < 460 MPa and** **b) based on operating experience for Ni-alloyed steels with Ni ≥ 3 % up to 9 %, for austenitic steels and for bolts and nuts.** **Method 2** **Method developed from the principles of fracture mechanics and from operating experiences.** **A more flexible approach than method 1 for derivation of technical requirements applicable to C, CMn and low alloy ferritic steels with a specified minimum yield strength ≤ 500 MPa and for** **austenitic-ferritic steels with a specified minimum yield strength ≤ 550 MPa. This method can be applied for these steels to a wider range of thicknesses and temperatures than method 1 because T_R shall not be equal to T_{27J} (see Figures B.2-1 to B.2-11). In addition, for ferritic steels with max 355 MPa in PWHT condition operation experience was considered for higher thicknesses.**
IMPLICIT DESIGN
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Annex B "Requirements for prevention of brittle fracture"** **Method 3.**
Comments: **Method 3 is the application of a fracture mechanics analysis.**

FABRICATION DETAILS [e]
References: **Design requirements for construction details are given in:** **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **and in Annex A "Design requirements for pressure bearing welds" of this Part.** **Manufacturing tolerances are given in:** **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication** **Clause 5: "Manufacturing tolerances"**
Comments: **Reference thickness is given in:** **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Annex B "Requirements for prevention of brittle fracture"** **Table B.4-1: "Reference thickness"**
MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Clause 4.1.6: Specified minimum impact energy measured on a Charpy-V-notch specimen at a test temperature in accordance with Annex B.** **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication** **Clause 8: "Manufacture and testing of welds – Production test"** **Testing of coupon plates with the same required impact energy as above.**
Comments: **Impact requirements are also specified for sub-sized Charpy-V-notch specimen if the base material is less than 10 mm thick.**
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 6: "Inspection and testing during fabrication", 6.6 "Non-destructive testing of welded joints".**
Comments: **There are four testing (examination) groups: 1 (full NDE), 2 (full NDE and reduction with successful experience, fully mechanised and/or automatic welding process), 3 (spot testing), 4 (visual examination only and higher test pressure).** **Acceptance criteria are based on EN ISO 5817:2007, level C (level B in critical areas when vessels are subjected to cyclic loads, see Annex G of EN 13445-5:2009).**

TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 10: "Final assessment", 10.2.3 "Proof test".**
Comments: **Higher pressure test for vessels with visual NDE only.**
USE / FAILURE HISTORY [i]
References:
Comments:

a Failure mode addressed by this form (See Table 1).

b Provide specific clause or paragraph references (including the title, if any) indicating where relevant rules can be found. These references need not be exhaustive, but should be detailed enough to establish that the standard adequately addresses the selected failure mode.

c Provide explanatory comments indicating the background for the approach employed or other material that might be useful. For example, brief description of failure theor(ies) used should be provided. References to academic papers and empirical testing methods used to establish rules are encouraged.

d Reference(s) to rules or requirements that directly affect how the standard addresses the selected failure mode, e.g. formulas for sizing wall thickness of components for resisting ductile burst.

e This section may be used to provide references and comments when design tables, empirically based rules or other approaches are employed whose derivation is not obvious. It may also be used to provide general information on design margins (safety factors) on material properties, etc. Many successful standards do not provide explicit design rules for certain failure modes yet do employ combinations of material control, temperature limits or other means to provide adequate protection against failure. This section may be used to provide information on how his standard indirectly addresses certain failure modes when explicit rules are not provided.

f References for fabrication details relevant to the selected failure mode, e.g. control of cylinder ovality, weld profiling, control of tolerances, etc. For example, control of cylinder ovality is important for prevention of buckling of externally loaded vessels. This section should be used to describe such fabrication controls relevant for the designated failure mode.

g Relevant requirements for base and welding materials, e.g. control of YS/UTS ratios, provisions for addressing strain hardening, applications of heat treatment, etc. Assuring that fabrication processes have not adversely affected material properties beyond acceptable limits can be important for preventing certain types of failures. This section should be used to describe such controls.

h References for NDT or visual inspection relevant to the selected failure mode. (If NDT is correlated to design factors, this should be noted).

i Provisions for final testing, i.e. hydrostatic or leak tests should be noted with specific information on normal test pressures and control of test lower and upper test pressures.

j An explanation shall be provided defining the limitations in the standard’s scope or application relative to ISO 16528-1:2007, Clause 6.2 failure mode(s) not addressed. References to data quantifying failure rates and other relevant experience may be provided. Likely sources include regulatory authorities, trade associations and insurers.

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Ductile rupture
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Clause 6: "Maximum allowed values of the nominal design stress for pressure parts"**
Comments [c] :
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B "Design by Analysis – Direct Route", Clause B.8.2: "Gross Plastic Deformation"** **Annex C "Design by Analysis – Method based on stress categories"**
Comments: **In Annex B, limit analysis is used. For ferritic steels, this analysis allows the use of a reduced safety factor versus the tensile strength at 20 °C.**
FABRICATION DETAILS [e]
References: **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication** **Clause 5: "Manufacturing tolerances"**
Comments:

MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Clause 4: "Requirements for materials to be used for pressure-bearing parts"**
Comments: **Requirements on ductility.**
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 6: "Inspection and testing during fabrication", 6.6 "Non-destructive testing of welded joints"**
Comments: **Acceptance criteria are based on EN ISO 5817: 2007, level C (level B in critical areas when vessels are subjected to cyclic loads, see Annex G).**
TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 10: "Final assessment", 10.2.3 "Proof test", 10.2.3.3 "Standard pressure test", 10.2.3.9 "Acceptance criteria"**
Comments: **During the proof test the vessel shall show no signs of general plastic yielding. No leaks from the pressure envelope.**
USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Leakage at joints
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Clause 11: "Flanges"**
Comments [c] : **Requirements for circular bolted flanged connections. The requirements are based on the Taylor Forge rules.** **Suggested values of the gasket factors are given in Annex H: "Gasket factors m and y".**
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex G "Alternative design rules for flanges and gasketed flange connections"**
Comments: **The purpose of these rules is to ensure structural integrity and leaktightness. They are most appropriate when a) thermal cycling is important b) bolt stress is controlled by the use of a defined tightening procedure c) there are significant additional loadings (forces or moments) d) leaktightness is a special importance (requirement of a specified leaktightness). Gasket factor values are provided for use with this annex.**
FABRICATION DETAILS [e]
References: **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication** **Clause 5: "Manufacture tolerances"**
Comments:

MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Clause 4: "Requirements for materials to be used for pressure-bearing parts".**
Comments:
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 6: "Inspection and testing during fabrication", 6.6 "Non-destructive testing of welded joints".**
Comments: **Acceptance levels based on EN ISO 5817:2007 level C (level B in critical areas when vessels are subjected to cyclic loads, see Annex G).**
TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 10: "Final assessment", 10.2.3 "Proof test", 10.2.3.3 "Standard hydrostatic test", 10.2.3.9 "Acceptance criteria"**
Comments: **During the proof test no leaks are permitted from the pressure envelope.**
USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Elastic or plastic instability
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Clause 8: "Shells under external pressure"**
Comments [c] : **This clause provides requirements for the design of stiffened and unstiffened cylinders, cones, spheres and dished ends.**
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B "Design by Analysis – Direct Route", Clause B.8.4: "Instability"**
Comments:
FABRICATION DETAILS [e]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex D "Verification of the shape of vessels subject to external pressure "** **Annex E "Procedure for calculating the departure from the true circle of cylinders and cones"** **Annex F "Allowable external pressure for vessels outside circularity tolerance".**
Comments:

MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Clause 4: "Requirements for materials to be used for pressure-bearing parts"**
Comments:
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 6: "Inspection and testing during fabrication", 6.6 "Non-destructive testing of welded joints".**
Comments: **Acceptance criteria based on EN ISO 5817:2007 level C (level B in critical areas when vessels are subjected to cyclic loads, see Annex G).**
TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 10: "Final assessment", 10.2.3 "Proof test", 10.2.3.3 "Standard hydrostatic test", 10.2.3.3.3 "Multi-compartment vessels".**
Comments:

USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Creep rupture
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Clause 19: "Creep design"**
Comments [c] : **Design by Formula (DBF)** **Extrapolation and Interpolation of creep properties given in the materials standards**
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B: "Design by Analysis – Direct Route"**
Comments: **Limit analysis.**
FABRICATION DETAILS [e]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex A: "Design requirements for pressure bearing welds"** **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication** **Clause 6: "Weld details"**
Comments: **Specific requirements for welded joints working in the creep domain (design allowing volumetric control, specific design for vessels made of more than one course)**

MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels - Part 2: Materials**
Comments: **In Annex C, a procedure for determining the weld creep strength reduction factor is given.**
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 6: "Inspection and testing during fabrication" and** **Annex F "Inspection and testing of pressure vessels or parts subject to creep"**
Comments: **Use of specific testing groups 1c and 3c for creep.**
TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 10: "Final assessment"**
Comments: **Use of time-independent characteristics for determining the test pressure**
USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Crack formation or ductile tearing due to excessive local strains
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Clause 1 to 21** **Annex A: "Design requirements for pressure bearing welds"**
Comments [c] : **All the rules of the Design by Formula section aim at limiting the strain concentrations.**
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B "Design by Analysis – Direct Route", Clause B.8.3: "Progressive Plastic Deformation (PD)", Clause B.8.5: "Fatigue failure (F)", Clause B.9.5 "Excessive Creep Strain"** **Annex C "Design by Analysis – Method based on stress categories"**
Comments: **The aforementioned design checks allow verifying the absence of strain concentrations.** **Annex C is limited to below the creep range. Extension to creep is in progress.**
FABRICATION DETAILS [e]
References: **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication** **Clause 5: "Manufacture tolerances".**
Comments:

MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Clause 1: "Scope" limited to ductile and creep ductile steels"** **Clause 4: "Requirements for materials to be used for pressure parts", 4.1.4 "Specified minimum elongation after rupture".**
Comments:
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 6: "Inspection and testing during fabrication", 6.6 "Non-destructive testing of welded joints".**
Comments: **Acceptance criteria based on EN ISO 5817:2007 level C (level B for creep and critical parts of vessels subject to cyclic loads).**
TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 10: "Final assessment", 10.2.3.3 "Standard hydrostatic test".**
Comments:

USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Creep – excessive deformations at mechanical joints or resulting in unacceptable transfer of load.
EXPLICIT DESIGN [d]
References [b] :
Comments [c] :
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B: "Design by Analysis – Direct Route"** **Clause B.9.5 "Excessive Creep Strain"**
Comments: **Use of the reference stress.**
FABRICATION DETAILS [e]
References: **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication**
Comments:

MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials**
Comments:
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing**
Comments:
TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing**
Comments:
USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Creep instability
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Clause 8: "Shells under external pressure"**
Comments [c] : **The rules apply in the creep range, only under the conditions given in clause 19 and under the assumption that shape deviation during creep will not exceed deviations stated in EN 13445-4:2009 Fabrication.**
IMPLICIT DESIGN [d]
References:
Comments:
FABRICATION DETAILS [e]
References: **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication – Clause 5: "Manufacturing tolerances"**
Comments:

MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials**
Comments:
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing**
Comments:
TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing**
Comments:
USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Erosion, corrosion
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Sub-Clause 5.2 "Corrosion, erosion and protection"** **Annex A: "Design requirements for pressure bearing parts"**
Comments [c] :
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B "Design by Analysis – Direct Route", Clause B.4: "Failure modes and limit states"**
Comments:
FABRICATION DETAILS [e]
References:
Comments:

MATERIAL REQUIREMENTS [f]
References:
Comments:
EXAMINATION REQUIREMENTS [g]
References:
Comments:
TESTING REQUIREMENTS [h]
References:
Comments:
USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Environmentally assisted cracking, e.g. stress corrosion cracking, hydrogen induced cracking, etc.
EXPLICIT DESIGN [d]
References [b] :
Comments [c] :
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B "Design by Analysis – Direct Route", Clause B.4 "Failure modes and limit states", Table B.4-1 "Classification of failure modes"**
Comments:
FABRICATION DETAILS [e]
References:
Comments:

MATERIAL REQUIREMENTS [f]
References:
Comments:
EXAMINATION REQUIREMENTS [g]
References:
Comments:
TESTING REQUIREMENTS [h]
References:
Comments:
USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Progressive plastic deformation
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Clauses 1 to 16.**
Comments [c] : **Design in the creep range** **Sub-Clause 19.4 applies for the design by formula in Clauses 7, 9, 11, 12, 15 and 16.** **For Clauses 8, 13, 16, and Annexes G and J the design in the creep range is only applicable if the modulus of elasticity is known in the creep range.**
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B "Design by Analysis – Direct Route", Clause B.4: "Failure modes and limit states", B.8 "Non-creep design checks", B.9 "Creep design checks"** **Annex C "Design by Analysis – Method based on stress categories"**
Comments: **Presently, Annex C is applicable below the creep range.**
FABRICATION DETAILS [e]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex A "Design requirements for pressure-bearing welds"** **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication** **Clause 5: "Manufacturing tolerances"**
Comments:

MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Clause 4: "Requirements for materials to be used for pressure-bearing parts"**
Comments:
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 6: "Inspection and testing during fabrication", 6.6 "Non-destructive testing of welded joints"**
Comments: **Acceptance criteria based on EN ISO 5817:2007 level C (level B for creep, Design by Analysis - Direct Route, critical zones under cyclic loadings).**
TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 10: "Final assessment", 10.2.3.3 "Standard hydrostatic test"**
Comments:

USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Alternating plasticity (see hereafter fatigue)
EXPLICIT DESIGN [d]
References [b] :
Comments [c] :
IMPLICIT DESIGN [d]
References:
Comments:
FABRICATION DETAILS [e]
References:
Comments:

MATERIAL REQUIREMENTS [f]
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EXAMINATION REQUIREMENTS [g]
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TESTING REQUIREMENTS [h]
References:
Comments:
USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Fatigue under elastic strains (medium and high cycle fatigue) or under elastic-plastic strains (low cycle fatigue)
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Clause 17: "Simplified assessment of fatigue life"** **Clause 18: "Detailed assessment of fatigue life"**
Comments [c] : **Operation is regarded as non-cyclic if the required number of full range or equivalent pressure cycles does not exceed 500. Vessels subject to non destructive examination (NDE) can be used for more than 500 full range or equivalent pressure cycles if a fatigue analysis is performed.** **Fatigue analysis of welded zones is based on design fatigue curves which are associated to weld details. For the same detail the design curve depends of the extent of NDE (full NDE or partial NDE).**
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B "Design by Analysis – Direct Route", Clause B.8.5: "Fatigue failure (F)" and fatigue analysis according to Clause 18** **Annex C "Design by Analysis – Method based on stress categories" and fatigue analysis according to Clause 17 or 18**
Comments: **Fatigue analysis according to Annex B and Annex C is limited to vessel or parts with full NDE.**

FABRICATION DETAILS [e]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex A: "Design requirements for pressure bearing parts"** **EN 13445-4:2009 Unfired pressure vessels – Part 4: Fabrication** **Clause 5: "Manufacturing tolerances"**
Comments: **Manufacturing tolerances of welded joints included in Part 4 "Fabrication" of EN 13445:2009 are acceptable for vessels subject to predominantly non cyclic loading, but shall be reduced for vessels subject to cyclic loading because the fatigue life given by the nominal design curves needs to be corrected to include the effect of large bending stresses due to axial or angular misalignment.**
MATERIAL REQUIREMENTS [f]
References: **EN 13445-2:2009 Unfired pressure vessels – Part 2: Materials** **Clause 4: "Requirements to be used for pressure-bearing parts".**
Comments:
EXAMINATION REQUIREMENTS [g]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Annex G "Inspection and testing of pressure vessels subject to cyclic loads"**
Comments: **For cyclic operation, more severe examination acceptance criteria are required (based on EN ISO 5817:2007 level B).**

TESTING REQUIREMENTS [h]
References: **EN 13445-5:2009 Unfired pressure vessels – Part 5: Inspection and testing** **Clause 10: "Final assessment", 10.2.3.3 "Standard hydrostatic test".**
Comments:
USE / FAILURE HISTORY [i]
References:
Comments:

STANDARD : Unfired pressure vessels EN 13445:2009
FAILURE MODE [a] : Environmentally assisted fatigue.
EXPLICIT DESIGN [d]
References [b] : **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Clause 18: "Detailed assessment of fatigue life", 18.4 "Limitations"** **Clause 17: "Simplified assessment of fatigue life", 17.4 "Conditions of applicability"**
Comments [c] :
IMPLICIT DESIGN [d]
References: **EN 13445-3:2009 Unfired pressure vessels – Part 3: Design** **Annex B "Design by Analysis – Direct Route", Clause B.4: "Failure modes and limit states", Table B.4-1: "Classification of failure modes and limit states".**
Comments:
FABRICATION DETAILS [e]
References:
Comments:

MATERIAL REQUIREMENTS [f]
References:
Comments:
EXAMINATION REQUIREMENTS [g]
References:
Comments:
TESTING REQUIREMENTS [h]
References:
Comments:
USE / FAILURE HISTORY [i]
References:
Comments:

4 Detailed technical requirements checklist

Table 3 — Detailed technical requirements checklist

ISO 16528-1 Clause	Description	Reference standard clause(s)	Description	Comments
7.2.1	Materials - General	EN 13445-2 Clause 4.1	General requirements	Pressure-bearing parts
7.2.2	Specification of materials	Clause 4.3	Technical delivery conditions	Materials and welding consumables
7.2.3	Material certification	Clause 4.3	Particular material appraisals	
7.3.1	Design – loadings and other design considerations	EN 13445-3 5.3	Load cases and failure modes	
7.3.2	Design methods	Clause 5.4	Design methods	Considers testing (examination) groups, cyclic nature of the loads
7.3.3	Design margins	Clause 6	Nominal design stresses for pressure parts	Rolled, forged and cast steels
7.3.4	Design factors	Clause 6 Clause 5	Nominal design stresses and weld joint factors	
7.3.5	Means for examination	EN 13445-5 Annex C	Access and inspection openings	
7.3.6	Draining and venting	EN 13445-5 Annex C		
7.3.7	Corrosion and erosion	EN 13445-3 Clause 5.2		
7.4.1	Manufacture - methods	EN 13445-4 Clauses 6, 9	Weld details, Forming	

ISO 16528-1 Clause	Description	Reference standard clause(s)	Description	Comments
7.4.2	Identification of materials	EN 13445-4 Clause 4.2	Material traceability	
7.4.3	Preparation of parts	EN 13445-4 Clauses 7.6	Joint preparation	
7.4.4	Welding	EN 13445-4 Clauses 7.1, 7.7, 7.8, 8	General, Execution of welded joints, Attachments, supports, stiffeners, Production test	
7.4.5	Welding procedure qualifications	EN 13445-4 Clauses 7.2 and 7.3	Welding procedure specification, Welding procedure qualification	
7.4.6	Welder qualifications	EN 13445-4 Clause 7.4	Qualification of welders and welding operators	
7.4.7	Welder identification	EN 13445-4 Clauses 7.7	Execution of welded joints	
7.4.8	Heat treatment	EN 13445-4 Clauses 9.4, 10	Heat treatment after forming, PWHT	
7.4.9	Tolerances	EN 13445-4 Clause 5	Manufacture tolerances	
7.5.1	Inspection and examination (I&E) – General	EN 13445-5 Clause 4	Performance of inspection and testing	
7.5.2	I and E methods	EN 13445-5 Clause 6.6.3	Performing non-destructive testing	
7.5.3	I and E procedures	EN 13445-5 Clause 6.6.3	Performing non-destructive testing	
7.4.4	I and E personnel qualification	EN 13445-5 Clause 6.6.3.7	Qualification of non-destructive testing personnel	

ISO 16528-1 Clause	Description	Reference standard clause(s)	Description	Comments
7.5.5	Evaluation of indications and acceptance criteria	EN 13445-5 Clause 6.6.3, Table 6.6.3-1	NDT methods, techniques, characterisation, acceptance criteria	
7.5.6	Disposition of unacceptable imperfections	EN 13445-5 Clause 6.6.6	Procedure for non-destructive retesting	
7.6.1	Final inspection	EN 13445-5 Clauses 10.1, 10.2	General, extent of final assessment	
7.6.2	Final pressure test	EN 13445-5 Clause 10.2.3	Standard hydrostatic test, Pneumatic test	Higher test pressure for testing group 4 vessels, with just visual inspection
7.7	Marking/labelling	EN 13445-5 Clause 11		
8	Conformity assessment	CR 13445-7	Guidance on the use of conformity assessment procedures	

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