SLOVENSKI STANDARD
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Neogrevane (nekurjene) tlačne posode - 11. del: Dodatne zahteve za tlačne posode iz titana in titanovih zlitin

Unfired pressure vessels - Part 11: Additional requirements for pressure vessels of titanium and titanium alloys

Unbefeuerte Druckbehälter - Teil 11: Zusätzliche Anforderungen an Druckbehälter aus Titan und Titanlegierungen

Récipients sous pression non soumis à la flamme - Partie 11 : Exigences complémentaires pour les récipients sous pression en titan et alliages de titan

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Unfired pressure vessels - Part 11: Additional requirements for pressure vessels of titanium and titanium alloys

Unbefeuerte Druckbehälter - Teil 11: Zusätzliche Anforderungen an Druckbehälter aus Titan und Titanlegierungen

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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European foreword

This document (prEN 13445-11:2018) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

This document is currently submitted to the CEN Enquiry.

This document has been prepared under a mandate 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.

1 Scope

This Part 11 of this European Standard specifies requirements for unfired pressure vessels and their parts made of titanium and titanium alloys in addition to the general requirements for unfired pressure vessels under EN 13445:2014 Parts 1 to 5.

NOTE 1 Cast materials, HIP and additive manufacturing are not included in this version. Details regarding such materials will be subject to an amendment to or a revision of this European Standard.

NOTE 2 Materials in Groups 51.4 and 54 are not included in this version.

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 764-5:2014, *Pressure equipment - Part 5: Inspection documentation of metallic materials and compliance with the material specification*

EN 10204:2004, *Metallic products - Types of inspection documents*

EN 13445-1:2014, *Unfired pressure vessels - Part 1: General*

EN 13445-2:2014, *Unfired pressure vessels - Part 2: Materials*

EN 13445-3:2014, *Unfired pressure vessels - Part 3: Design*

EN 13445-4:2014, *Unfired pressure vessels - Part 4: Fabrication*

EN 13445-5:2014, *Unfired pressure vessels - Part 5: Inspection and testing*

EN ISO 9606-5:2000, *Approval testing of welders - Fusion welding - Part 5: Titanium and titanium alloys, zirconium and zirconium alloys (ISO 9606-5)*

EN ISO 15614-5:2004, *Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 5: Arc welding of titanium, zirconium and their alloys (ISO 15614-5:2004)*

EN ISO 15614-8:2016, *Specification and qualification of welding procedure for metallic materials - Welding procedure test - Welding of tubes to tube-plate joints (ISO 15614-8:2016)*

CEN ISO/TR 15608:2017, *Welding - Guidelines for a metallic materials grouping system (ISO/TR 15608:2017)*

ASME Section II Part D – 2017, *ASME Boiler and Pressure Vessel Code, Section II – Materials, Part D – Properties 2017 edition*

ASME SB-265 / *ASTM B265, Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate*

ASME SB-338 / *ASTM B338, Standard Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers*

ASME SB-348 / *ASTM B348, Standard Specification for Titanium and Titanium Alloy Bars and Billets*

ASME SB-363 / *ASTM B363, Standard Specification for Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings*

ASME SB-381 / *ASTM B381, Standard Specification for Titanium and Titanium Alloy Forgings*

ASME SB-861 / *ASTM B861, Standard Specification for Titanium and Titanium Alloy Seamless Pipe*

DIN 17850, *Titanium; chemical composition*

DIN 17851, *Titanium alloys; chemical composition*

DIN 17860, *Titanium and titanium alloy strip, sheet and plate - Technical conditions of delivery*

DIN 17861, *Seamless circular titanium and titanium alloy tubes; Technical delivery conditions*

DIN 17862, *Titanium and titanium alloy bars - Technical delivery conditions*

DIN 17864, *Titanium and titanium wrought alloys forgings (hammer and drop forgings) - Technical delivery conditions*

3 Terms, definitions, symbols and units

For the purposes of this European Standard, the terms, definitions, symbols and units given in EN 13445:2014 Parts 1 to 5 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

4 General requirements

The general requirements of EN 13445-1:2014 shall apply.

5 Materials

5.1 General

The general requirements of EN 13445-2:2014 shall apply with the following additions/exclusions in 5.2 to 5.6.

The base materials, listed in Annex C, additionally specified with the extra requirements given in the main body of this European Standard, are suitable for and may be employed in the manufacture of pressure vessels conforming to EN 13445-11.

NOTE Materials not listed in Annex C cannot be used without European approval of pressure equipment materials (EAMs) or Particular material appraisal (PMA).

5.2 Material specification

The material specification shall specify the composition limits for all constituents, heat treatment and the appropriate mechanical properties for acceptance and other purposes.

Only material having a minimum elongation after fracture of not less than 10 %, in its final fabricated state, shall be used for construction of pressure vessels.

NOTE To achieve this it may be necessary to start with a higher elongation, e.g. 14 %, prior to cold forming.

5.3 Material grouping system

Annex A of EN 13445-2:2014 is not applicable to pressure vessels of titanium and titanium alloys and is replaced by Annex A of this part 11 of EN 13445.

The grouping system for titanium and its alloys shown in Table A.1 of this part 11 of EN 13445 is based on ISO/TR 15608:2017. However, only the grades included in Annex C are considered suitable for welded pressure vessel construction.

5.4 Material documentation

Materials for pressure bearing parts compliant with the requirements of this European Standard shall be accompanied by inspection documentation in accordance with EN 10204:2004.

The type of inspection document shall be in accordance with EN 764-5:2014 and include a declaration of compliance to the material specification.

5.5 Prevention of brittle fracture

There are no general requirements for titanium and titanium alloys at temperatures down to

— −100 °C for group 51.1 and 51.2, and

— −60 °C for all other Groups.

Below these temperatures adequate toughness shall be demonstrated by impact testing achieving an average of 27 Joules in the base material, welds, and heat affected zones. Alternatively a fracture mechanics approach in line with EN 13445-2:2014, Annex B method 3 may be employed.

5.6 Lamellar tearing

Specific requirements of lamellar tearing for pressure vessels of titanium and its alloys are not applicable.

6 Design

6.1 General

All the requirements included in EN 13445-3:2014 shall apply, with the following amendments, given in 6.2 to 6.7.

Physical properties of titanium and titanium alloys are given in Annex D.

6.2 Corrosion, erosion and protection

Commercially pure titanium and titanium alloys have outstanding resistance to a wide range of reducing, neutral and oxidizing corrosive media. As a general rule no allowance is required for pitting or general corrosion.

Caution is required in the design of joints and the selection of gasket materials where crevice corrosion could occur.

6.3 Joint coefficient

For normal operating load cases the value of joint coefficient z is given in Table 6.3-1. It is related to the testing group of the governing welded joints.

Testing groups are specified in 8.2 of this part 11 of EN 13445.

Table 6.3–1 — Joint coefficient and corresponding testing group

z	1	0,8
Testing group	1	3

6.4 Time-independent nominal design stress

The design stress for titanium and titanium alloy materials entering service in the annealed condition following removal of test coupons at the material manufacturer's works, shall be evaluated in accordance with Table 6.4-1.

Table 6.4–1 — Maximum allowed values of the nominal design stress for titanium and titanium alloy materials for pressure parts

Grade/group	Design stress for normal operating load cases (MPa)	Design stress for testing and exceptional load cases (MPa)
51.1 and 51.2	$f_d = \min\left(\frac{R_{p1,0/T}}{1,5}; \frac{R_{m/T}}{3}\right)$	$f_{test} = \left(\frac{R_{p1,0/T_{test}}}{1,05}\right)$
All others	$f_d = \min\left(\frac{R_{p0,2/T}}{1,5}; \frac{R_{m/T}}{3}\right)$	$f_{test} = \left(\frac{R_{p0,2/T_{test}}}{1,05}\right)$

For design temperatures not exceeding 50 °C, the value of the design stress evaluated at 20 °C may be used.

Note In case values of $R_{p\,1.0/T}$ are not available, $R_{p\,0,2/T}$ values can be used.

Tensile and other strength values at room temperature may be used at temperatures below 20 °C. However, the specific requirements of individual PMAs or Annex C shall be taken into account.

6.5 Creep design

Where guaranteed creep rupture data are available for the intended life of the vessel from the material specification or the material manufacturer, design stresses for normal operating load cases shall be obtained from Table 6.5-1.

Where creep data are not available, a safe design can be achieved by using the design stresses in Table 6.4-1 but taking $R_{p0,2/T}$ in place of $R_{p\,1,0/T}$.

Table 6.5-1 — Maximum allowed values of the nominal design stress for titanium and titanium alloy materials for pressure parts for creep design when guaranteed creep rupture data is available

Grade/group	Design stress for normal operating load cases (MPa)
All	$f_d = \min\left(\frac{R_{p0,2/T}}{1,5}; \frac{R_{m/T/t}}{1,5}\right)$
$R_{m/T/t}$ is the mean creep rupture strength at calculation temperature T and lifetime t (EN 13445-3:2014, 19.3)	

Commercially pure titanium and titanium alloys can exhibit time dependent deformation when loads are sustained for long periods near the proof stress value. Informative Annex E gives typical properties.

NOTE Time-dependent deformation is particularly relevant where the design conditions result in $R_{m/T/t}/3$ exceeding 70 % of $R_{p0,2/T}$. In such circumstances the designer should consider the effect of those properties which influence time dependent deformation, and take specialist metallurgical advice as appropriate.

6.6 Shells under external pressure

The requirements in Clause 8 of EN 13445-3:2014 shall apply with the following modifications as shown in Table 6.6-1:

Table 6.6–1 — Nominal elastic limit

Grade/group	Elastic limit for shells (MPa)	Elastic limit for stiffeners (MPa)
51.1 and 51.2	$\sigma_e = \left(\frac{R_{p1,0/T}}{1,25}\right)$	$\sigma_{es} = \left(\frac{R_{p1,0/T,s}}{1,25}\right)$
All others	$\sigma_e = \left(\frac{R_{p0,2/T}}{1,25}\right)$	$\sigma_{es} = \left(\frac{R_{p0,2/T,s}}{1,25}\right)$

NOTE In case values of $R_{p\,1,0/T}$ are not available, $R_{p\,0,2/T}$ values can be used.

Values of the modulus of elasticity E as a function of the temperature can be found in Annex D of this part 11 of EN 13445.

6.7 Flanges

The requirements in Clause 11 or Annex G of EN 13445-3:2014 shall apply with the following modifications:

Gaskets made from or containing polymers which could release fluoride on thermal or acid decomposition shall not be used.

NOTE 1 Due to the high elastic deformations of Titanium and Titanium Alloys, to ensure leak tightness of flanges made of such materials the use of Annex G of EN 13445-3:2014 is preferred to Clause 11 of EN 13445-3:2014.

NOTE 2 Current European Standards for pipework flanges do not contain rating tables for titanium and titanium alloys and therefore the use of standard flanges without calculation is not possible.

6.8 Fatigue design

For loads up to 500 equivalent full pressure cycles no fatigue analysis is required. Above 500 cycles the requirements of Clause 17 of EN 13445-3:2014 shall apply with the following modifications:

The application of Clause 17 (see 17.4.4 of EN 13445-3:2014) to titanium and titanium alloys shall be limited to temperatures not exceeding 150 °C.

The correction factor to account for the influence of temperature on fatigue resistance (see 17.6.2.2 of EN 13445-3:2014) is:

For $T^* \geq 100$ °C:

$$C_T = 0{,}518 - 9{,}41 \times 10^{-5} T^* - 8{,}46 \times 10^{-7} (T^*)^2 \qquad (6.7\text{-}1)$$

For $T^* < 100$ °C, $C_T = 0{,}5$.

The requirements of Clause 18 of EN 13445-3:2014 shall apply with the following modifications:

The application of Clause 18 (see 18.4.3 of EN 13445-3:2014) to titanium and titanium alloys shall be limited to temperatures not exceeding 150 °C.

The correction factor to account for the influence of temperature on fatigue resistance, f_{T^*} (see 18.10.6.2 of EN 13445-3:2014) is given by:

For $T^* \geq 100$ °C:

$$f_{T^*} = 0{,}518 - 9{,}41 \times 10^{-5} T^* - 8{,}46 \times 10^{-7} (T^*)^2 \qquad (6.7\text{-}2)$$

For $T^* < 100$ °C, $f_{T^*} = 0{,}5$.

7 Manufacture

7.1 General

EN 13445-4:2014 shall apply, with the following amendments, given in 7.2 to 7.18.

NOTE Not all welding processes are suitable for all titanium alloys.

7.2 Filler metals

In all cases where the filler metals do not match parent metal combinations the filler metal used shall be suitable for the service conditions.

NOTE Welding consumables may be selected from EN ISO 24034:2010.