SLOVENSKI STANDARD
SIST EN 13445-11:2024

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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

Récipients sous pression non soumis à la flamme - Partie 11 : Exigences supplémentaires pour les récipients sous pression en titane et alliage de titane

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

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Contents

European foreword

This document (EN 13445-11:2024) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2025, and conflicting national standards shall be withdrawn at the latest by March 2025.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a standardization request addressed to CEN by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

For the relationship with EU Legislation, see informative Annex ZA, which is an integral part of this document.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

1 Scope

This document 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 13445-1:2021 to EN 13445-5:2021.

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 13445-1:2021, *Unfired pressure vessels - Part 1: General*

EN 13445-2:2021+A1:2023, *Unfired pressure vessels - Part 2: Materials*

EN 13445-3:2021, *Unfired pressure vessels - Part 3: Design*

EN 13445-4:2021+A1:2023, *Unfired pressure vessels - Part 4: Fabrication*

EN 13445-5:2021, *Unfired pressure vessels - Part 5: Inspection and testing*

EN ISO 148-1:2016, *Metallic materials - Charpy pendulum impact test - Part 1: Test method (ISO 148-1:2016)*

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

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 procedures for metallic materials - Welding procedure test - Part 8: 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)*

3 Terms, definitions, symbols and units

For the purposes of this document, the terms, definitions, symbols and units given in EN 13445-1:2021 to EN 13445-5:2021 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 13445-1:2021 shall apply.

5 Materials

5.1 General

The general requirements of EN 13445-2:2021+A1:2023 shall apply with the following additions/exclusions in 5.2 to 5.5.

There are presently no European Standards or European Approval of Materials (EAMs) specifically for titanium and titanium alloys for pressure purposes. This document is therefore limited to the use of Particular Materials 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. The specified minimum elongation after fracture shall be measured on a gauge length as defined in EN 13445-2:2021+A1:2023, 4.1.4.

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

5.3 Material grouping system

EN 13445-2:2021+A1:2023, Annex A, is not applicable to pressure vessels of titanium and titanium alloys and is replaced by Annex A of this document.

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

5.4 Material documentation

Materials for pressure bearing parts compliant with the requirements of this document 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 an affirmation 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 of a Charpy-V-notch test specimen (according to EN ISO 148-1:2016) at a temperature not higher than the minimum metal temperature T_M achieving a mean impact energy *KV* of 27 J in the base material, welds, and heat affected zones. The impact tests shall be carried out in accordance with the requirements of EN 13445-2:2021+A1:2023, B.3.

NOTE For practical reasons, a test temperature of −196 °C is commonly used for all impact testing of titanium and titanium alloys for any minimum metal temperature below −100 °C.

Alternatively, a fracture mechanics approach in line with EN 13445-2:2021+A1:2023, Annex B method 3 may be employed.

6 Design

6.1 General

All the requirements included in EN 13445-3:2021 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 of this document.

6.2 Corrosion, erosion and protection

Unalloyed 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 document.

Table 6.3–1 — Joint coefficient and corresponding testing group

z	1	0,8
Testing group	1	3

Testing groups 2 and 4 are not permitted for pressure vessels made of titanium and titanium alloys.

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 derived 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	Design stress for testing and exceptional load cases
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 derived 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.

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.

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 are available

Grade/group	Design stress for normal operating load cases
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 13445-3:2021, 19.3)	

Where creep data are not available, a safe design for a life of up to 100,000 h can be achieved by using the design stresses obtained from Table 6.4-1 but taking $R_{p0,2/T}$ in place of $R_{p\,1,0/T}$.

Unalloyed titanium and titanium alloys can exhibit time dependent deformation when loads are sustained for long periods near the proof stress value. Informative Annex E of this document 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, in order for the designer to consider the effect of those properties which influence time dependent deformation, it may be appropriate to take specialist metallurgical advice.

6.6 Shells under external pressure

The requirements in EN 13445-3:2021, Clause 8, 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	Elastic limit for stiffeners
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 document.

6.7 Flanges

The requirements of EN 13445-3:2021, Clause 11 or Annex G, 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 EN 13445-3:2021, Annex G, is preferred to EN 13445-3:2021, Clause 11.

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 EN 13445-3:2021, Clause 17, shall apply with the following modifications:

The application of Clause 17 (see EN 13445-3:2021, 17.4.4) 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 EN 13445-3:2021, 17.6.2.2) 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 EN 13445-3:2021, Clause 18, shall apply with the following modifications:

The application of Clause 18 (see EN 13445-3:2021, 18.4.3) 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 EN 13445-3:2021, 18.10.6.2) is given by: