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Nekurjene tlačne posode - 6. del: Zahteve za konstruiranje in proizvodnjo tlačnih posod in tlačnih delov posode iz nodularne litine

Unfired pressure vessels - Part 6: Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron

Unbefeuerte Druckbehälter - Teil 6: Anforderungen an die Konstruktion und Herstellung von Druckbehältern und Druckbehälterteilen aus Gusseisen mit Kugelgraphit

Récipients sous pression non soumis à la flamme - Partie 6: Exigences pour la conception et la fabrication des récipients sous pression et des parties sous pression moulés en fonte à graphite sphéroïdal

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EUROPEAN STANDARD

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English Version

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This European Standard was approved by CEN on 24 February 2021.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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

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European foreword

This document (EN 13445-6:2021) 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of an identical text or by endorsement, at the latest by November 2021, and conflicting national standards shall be withdrawn at the latest by November 2021.

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 given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 2014/68/EU.

For relationship with EU Directive 2014/68/EU, see informative Annex ZA, which is an integral part of this document.

list of all parts in the EN 13445 series can be found on the CEN website.

Although these Parts may be obtained separately, it should be recognised that the Parts are inter-dependent. As such the manufacture of unfired pressure vessels requires the application of all the relevant Parts in order for the requirements of the Standard to be satisfactorily fulfilled.

Corrections to the standard interpretations where several options seem possible are conducted through the Migration Help Desk (MHD). Information related to the Help Desk can be found at http://www.unm.fr (en13445@unm.fr). A form for submitting questions can be downloaded from the link to the MHD website. After subject experts have agreed an answer, the answer will be communicated to the questioner. Corrected pages will be given specific issue number and issued by CEN according to CEN Rules. Interpretation sheets will be posted on the website of the MHD.

This document supersedes EN 13445-6:2014. This new edition incorporates the Amendments which have been approved previously by CEN members, and the corrected pages up to Issue 5 without any further technical change. Annex Y provides details of significant technical changes between this European Standard and the previous edition.

Amendments to this new edition may be issued from time to time and then used immediately as alternatives to rules contained herein. It is intended to deliver a new Issue of EN 13445:2021 each year, starting with the precedent as Issue 1, consolidating these Amendments and including other identified corrections.

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

1 Scope

This document specifies requirements for the design, materials, manufacturing and testing of pressure vessels and pressure vessel parts intended for use with a maximum allowable pressure, PS, equal or less than:

— 100 bar when containing gases or liquids in group 1 or 2

— 1000 bar when containing liquids in group 2 only.

and shell wall thicknesses not exceeding 60 mm, which are constructed of ferritic or austenitic spheroidal graphite cast iron. The thickness limitation of the shell does not apply to thickness of flanges, reinforcements, bosses etc.

NOTE 1 Austenitic spheroidal graphite cast iron grades are principally used for high and low temperature applications and for their corrosion resistance properties.

NOTE 2 The allowable grades of spheroidal graphite cast iron are listed in Tables 5.1-1 and 5.1-2. Service conditions are given in Clause 4.

This document, EN 13445-6, does not include lamellar graphite cast iron grades for ferritic and austenitic grades, with an elongation after fracture equal or less than 15 % which are explicitly excluded. Requirements for the use of cast irons with an elongation after fracture equal or less than 15 % are given in EN 15776.

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 287-6:2018, *Qualification test of welders — Fusion Welding — Part 6: Cast iron*

EN 764-2:2012, *Pressure equipment — Part 2: Quantities, symbols and units*

EN 764-5:2014, *Pressure equipment — Part 5: Compliance and inspection documentation of materials*

EN 837-1:1996, *Pressure gauges — Part 1: Bourdon tube pressure gauges — Dimensions, metrology, requirements and testing*

EN 837-3:1996, *Pressure gauges — Part 3: Diaphragm and capsule pressure gauges — Dimensions, metrology, requirements and testing*

EN 1011-8:2004, *Welding — Recommendations for welding of metallic materials — Part 8: Welding of cast irons*

EN 1369:2012, *Founding — Magnetic particle testing*

EN 1370:2011, *Founding — Examination of surface condition*

EN 1371-1:2011, *Founding — Liquid penetrant testing — Part 1: Sand, gravity die and low pressure die castings*

EN 1559-1:2011, *Founding — Technical conditions of delivery — Part 1: General*

EN 1559-3:2011, *Founding — Technical conditions of delivery — Part 3: Additional requirements for iron castings*

EN 1563:2018, *Founding — Spheroidal graphite cast irons*

EN 12680-3:2011, *Founding — Ultrasonic testing — Part 3: Spheroidal graphite cast iron castings*

EN 12681:2003, *Founding — Radiographic examination*

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

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

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

EN 13835:2012, *Founding — Austenitic cast irons*

EN ISO 945-1:2008, *Microstructure of cast irons — Part 1: Graphite classification by visual analysis* (ISO 945-1:2008)

EN ISO 8062-1:2007, *Geometrical product specifications (GPS) — Dimensional and geometrical tolerances for moulded parts — Part 1: Vocabulary* (ISO 8062-1:2007)

EN ISO 8062-3:2007, *Geometrical product specifications (GPS) — Dimensional and geometrical tolerances for moulded parts — Part 3: General dimensional and geometrical tolerances and machining allowances for castings* (ISO 8062-3:2007)

EN ISO 15614-3:2008, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 3: Fusion welding of non-alloyed and low-alloyed cast irons* (ISO 15614-3:2008)

3 Terms, definitions units and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions 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.

3.1.1
critical zone
highly stressed area where a fracture is expected to occur in a burst test or where surface fatigue cracks are expected to be initiated due to fluctuating pressure loads

Note 1 to entry: Critical zones may occur, for example, by any of the following:

— sudden change in cross section;

— sharp edges;

— sharp radii;

— peak stresses;

— bending stresses;

— stresses due to other than membrane stress;

— changes in curvature.

Note 2 to entry: A critical zone is analysed by any appropriate method, e.g. holographic, interferometric, strain gauge methods, burst test, fatigue testing, FEM analysis etc.

Note 3 to entry: Additionally, thermal gradients and thermal stresses due to different operating wall temperatures need to be considered in defining critical zones.

3.1.2
purchaser
individual or organisation that buys pressure equipment, including assemblies or parts, for its own use or on behalf of the user and/or operator

3.1.3
manufacturer
individual or organisation responsible for the design, fabrication, testing, inspection, installation of pressure equipment and assemblies where relevant

Note 1 to entry: The manufacturer may subcontract one or more of the above mentioned tasks under its responsibility.

3.1.4
casting manufacturer
subcontractor that produces the castings used in the manufacture of pressure equipment

3.1.5
testing factor
A reduction factor applied to the nominal design stress to take account of possible manufacturing deficiencies

3.1.6
temperature factor
A reduction factor applied to the 0,2 % proof strength to take account of temperature influence

3.1.7
wall thickness factor
a reduction factor applied to the nominal design stress to take account of reduced mechanical properties

3.1.8
ferritic spheroidal graphite cast iron
cast material, iron and carbon based (carbon being present mainly in the form of spheroidal graphite particles) with a predominantly ferritic matrix

3.1.9
austenitic spheroidal graphite cast iron
cast material with an austenitic matrix which is iron and carbon based and alloyed with nickel and manganese, copper and/or chromium in order to stabilize the austenitic structure at room temperature

3.2 Units

For the purposes of this document, the units given in EN 764-2:2012 apply.

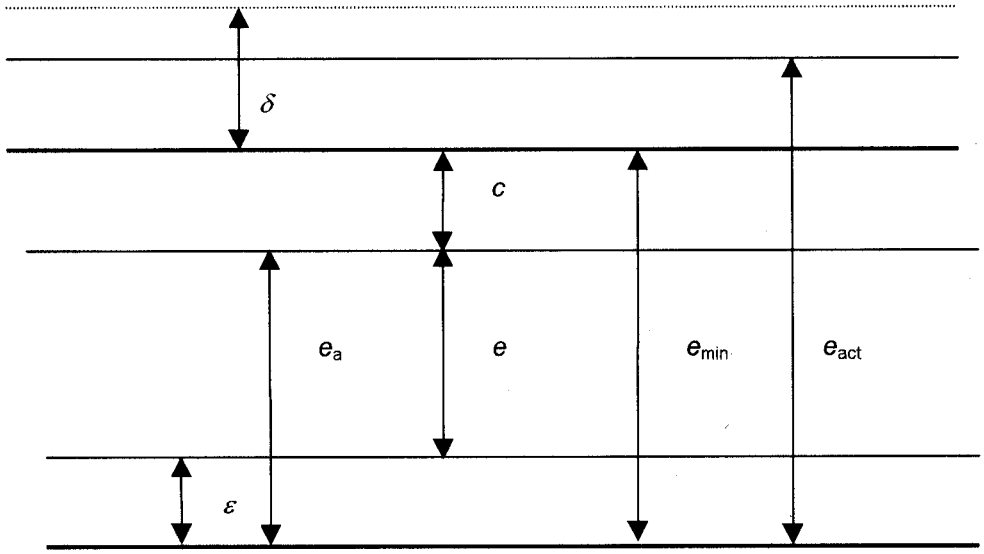
3.3 Symbols

Symbols used in this document are listed in Table 3.3-1.

Table 3.3-1 — Symbols

Symbol	Quantity	Unit
c	Corrosion allowance	mm
e	Required thickness	mm
e_a	Analysis thickness	mm
e_{act}	Actual thickness	mm
e_{min}	Minimum thickness as specified on drawing	mm
E	Modulus of elasticity	MPa
f	Nominal design stress	MPa
F	Fatigue factor related to 99,8 % survival	—
$P_{b,act}$	Actual burst test pressure	MPa[a]
P_b	Minimum required bursting pressure	MPa [a]
P_d	Design pressure	MPa [a]
PS, P_S	Maximum allowable pressure	MPa [a]
PT, P_t	Test pressure	MPa [a]
RM	Material strength parameter	MPa
$R_{p0,2}$	0,2 %-proof strength	MPa
R_m	Tensile strength	MPa
$RM3$	Average material strength from 3 test samples for DBE purposes	MPa
TS_{min} , TS_{max}	Minimum / maximum allowable temperature	°C
T	Calculation temperature	°C
V	Volume	L
C_e	Wall thickness factor	—
C_T	Temperature factor	—
C_Q	Testing factor	—
n	Factor depending on shape of shell	—
f_e	Thickness correction factor	—
f_m	Mean stress correction factor	—
f_s	Surface finish correction factor	—
S	Safety factor	—
γ_R	Partial safety factor	—
δ	Casting tolerance	mm
ε	Extra thickness due to casting process	mm
ν	Poisson's ratio	—
[a] MPa for calculation purpose only, otherwise the unit is bar (1 MPa = 10 bar)		

3.4 Inter-relation of thicknesses definitions



Key

e is the required thickness
e_a is the analysis thickness
e_{min} is the minimum thickness including corrosion allowance as indicated on drawings
e_{act} is the actual thickness
c is the corrosion allowance
ε is the extra thickness due to casting process
δ is the casting tolerance

Figure 3.4-1 — Inter-relation of thicknesses definitions

4 Service conditions

4.1 Cyclic loading

Spheroidal graphite cast iron pressure vessels and vessel parts can be used for cyclic operation if the stress factor is limited to 3. If the calculated number of cycles is close to a limit number of cycles mentioned in Table 4.1-1 below to determine the need for fatigue analysis, a worst-case model shall be implemented for this determination.

If it is expected that under service conditions the maximum number of full pressure cycles will exceed the limit number according to Table 4.1-1, or exceeds more than the equivalent number of cycles with smaller amplitude, then a fatigue analysis shall be performed according to Annex D.

Table 4.1-1 — Number of full pressure cycles for cyclic loading consideration

Testing factor	Maximum number of full pressure cycles without mandatory fatigue analysis according to Annex D	
$C_Q = 0,9$	1 000	
$C_Q = 0,8$	40 000	if 2,5 < stress factor ≤ 3
	200 000	If stress factor ≤ 2,5

NOTE 1 A testing factor of 0,9 implies the application of higher nominal design stresses and consequently results in a lower maximum number of full pressure cycles without mandatory fatigue analysis.

NOTE 2 A stress factor (ratio of peak stress to fatigue stress) of more than 3, determined by any of the design methods given in 5.2 can be the result of inappropriate design. By enlarging radii or other small changes, an acceptable design may be generated.

For pressure cycles at a pressure difference ΔP_i less than the full pressure, the number of equivalent full cycles is given by Formula (4.1-1):

$$n_{eq} = \sum_{i=1}^{i=N} n_i \cdot \left(\frac{\Delta P_i}{P_{max}} \right)^{8,6} \quad (4.1\text{-}1)$$

where

N is the total number of envisaged types of pressure cycles with different amplitude;

n_i is the number of cycles of amplitude ΔP;

ΔP_i is the pressure cycle amplitude;

P_{max} is the maximum permissible pressure, as defined in EN 13445-3:2021, 3.15.

4.2 Limitations on temperature and energy content

The minimum and maximum allowable temperatures TS_{min} and TS_{max} shall be in accordance with the limits given in Tables 5.1-1 and 5.1-2.

The product $PS \cdot V$ for a single casting shall not exceed 100 000 bar·L.

5 Requirements

5.1 Materials

All cast iron grades subject to internal or external pressure shall comply with EN 1563 for ferritic spheroidal graphite cast iron and EN 13835 for austenitic spheroidal graphite cast iron.

The material grades listed in Table 5.1-1 and Table 5.1-2 may be produced in the as-cast or heat-treated condition (see EN 1563:2018, Clause 6).

The ferritic material grades given in Table 5.1-1 shall be used for applications where the minimum allowable temperature is higher or equal to –10 °C.

The material grades listed in Table 5.1-2 are intended for low temperature or high temperature design conditions.

Table 5.1-1 — Allowable material grades for usual design temperatures (-10 °C up to 300 °C)

Material standard	Material designation[a]		Design temperature limits °C
	Symbol	Number	
EN 1563:2018	EN-GJS-350-22-RT	5.3101	-10 ≤ TS ≤ 300
	EN-GJS-350-22	5.3102	-10 ≤ TS ≤ 300
	EN-GJS-400-18-RT	5.3104	-10 ≤ TS ≤ 300
	EN-GJS-400-18	5.3105	-10 ≤ TS ≤ 300
	EN-GJS-450-18	5.3108	-10 ≤ TS ≤ 300
[a] When materials specified in these tables are not available, other suitable materials may be used when the technical documentation defining the characteristics of the materials has been accepted in accordance with the requirements for European approval for materials (EAM) or particular material appraisal (PMA).			

Table 5.1-2 — Allowable material grades for low or high temperature design conditions

Material standard	Material designation[a]		Design temperature limits °C
	Symbol	Number	
EN 1563:2018	EN-GJS-350-22-LT	5.3100	-40 ≤ TS ≤ 300
	EN-GJS-400-18-LT	5.3103	-20 ≤ TS ≤ 300
EN 13835:2012	EN-GJSA-XNiMn23-4	5.3501	-196 ≤ TS ≤ 300
	EN-GJSA-XNi22	5.3503	-40 ≤ TS ≤ 540
	EN-GJSA-XNiMn13-7	5.3506	-40 ≤ TS ≤ 300
[a] When materials specified in these tables are not available, other suitable materials may be used when the technical documentation defining the characteristics of the materials has been accepted in accordance with the requirements for European approval for materials (EAM) or particular material appraisal (PMA).			

Material grades EN-GJS-350-22-LT or EN-GJS-350-22U-LT can be used at design temperatures down to –60 °C. When used between (–40 ± 2) °C and (–60 ± 2) °C, impact testing at the minimum design temperature shall be:

— mean value from 3 tests 12 J for e_{act} ≤ 60 mm;

— 10 J for 60 mm ≤ e_{act} ≤ 200 mm;

— individual value 9 J for e_{act} ≤ 60 mm and 7 J for 60 mm ≤ e_{act} ≤ 200 mm.

The applicable requirements for the delivery conditions given in EN 1559-1:2011 and EN 1559-3:2011 shall also apply.

NOTE The use of materials working in the creep domain is not applicable to this standard since stress ranges are limited to elastic behaviour.