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Neogrevane tlaļne posode - 6. del: Zahteve za konstruiranje in proizvodnjo tlaļnih posod in tlaļnih 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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23.020.30	Tlaļne posode, plinske jeklenke	Pressure vessels, gas cylinders

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EUROPEAN STANDARD

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English Version

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

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This European Standard was approved by CEN on 30 June 2009.

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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 Management Centre has the same status as the official versions.

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COMITÉ EUROPÉEN DE NORMALISATION
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Foreword

This document (EN 13445-6:2009) 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of an identical text or by endorsement, at the latest by *December 2009*, and conflicting national standards shall be withdrawn at the latest by *December 2009*.

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 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.

In this standard the Annexes A, D, E, G and H are normative and the Annexes B, C and F are informative.

This European Standard consists of the following Parts:

- Part 1: *General*
- Part 2: *Materials*

- Part 3: *Design*
- Part 4: *Fabrication*
- Part 5: *Testing and Inspection*
- Part 6: *Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron*
- CR 13445-7, *Unfired pressure vessels — Part 7: Guidance on the use of conformity assessment procedures*
- Part 8: *Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron*.
- CEN/TR 13445-9, *Unfired pressure vessels — Part 9: Conformance of EN 13445 series to ISO 16528*

This document supersedes EN 13445-6:2002. This new edition incorporates the Amendments which have been approved previously by CEN members and the corrected pages up to Issue 36 without any further technical change. Annex Y to EN 13445-1:2009 and Annex Y to this Part 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 13445:2009 each year, 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, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard 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 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.

The allowable grades do not include lamellar graphite cast iron grades for ferritic and austenitic grades, which are explicitly excluded from this European Standard because of low elongation and brittle material behaviour, which requires the use of different safety factors and a different approach.

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 3 and 4. Service conditions are given in Clause 4.

2 Normative references

The following referenced documents are indispensable for the application 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 764-2:2002, *Pressure equipment — Part 2: Quantities, symbols and units*.

EN 764-5:2002, *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 1369:1996, *Founding — Magnetic particle inspection*.

EN 1370:1996, *Founding — Surface roughness inspection by visual tactile comparators*.

EN 1371-1:1997, *Founding — Liquid penetrant inspection — Part 1: Sand, gravity die and low pressure die castings.*

EN 1559-1:1997, *Founding — Technical conditions of delivery — Part 1: General.*

EN 1559-3:1997, *Founding — Technical conditions of delivery — Part 3: Additional requirements for iron castings*.

EN 1563:1997, EN 1563:1997/A1:2002, EN 1563:1997/A2:2005, *Founding — Spheroidal graphite cast irons*.

EN 12680-3:2003, *Founding — Ultrasonic examination — Part 3: Spheroidal graphite cast iron castings.*

EN 12681:2003, *Founding — Radiographic examination*.

EN 13445-1:2009, *Unfired pressure vessels — Part 1: General*.

EN 13445-3:2009, *Unfired pressure vessels — Part 3: Design*.

EN 13445-5:2009, *Unfired pressure vessels — Part 5: Inspection and testing*.

EN 13835:2002, EN 13835/A1:2006, *Founding — Austenitic cast irons.*

EN ISO 945:1994, *Cast iron — Designation of microstructure of graphite (ISO 945:1975).*

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).*

3 Terms, definitions, units and symbols

3.1 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply.

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 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 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 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 The manufacturer may subcontract one or more of the above mentioned tasks under its responsibility.

NOTE 2 In EU member states the manufacturer is responsible for compliance with the Pressure Equipment Directive 97/23/EC. For those manufacturers outside of the EU their authorized representative inside the EU assumes this 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 European Standard, the units given in EN 764-2:2002 apply.

3.3 Symbols

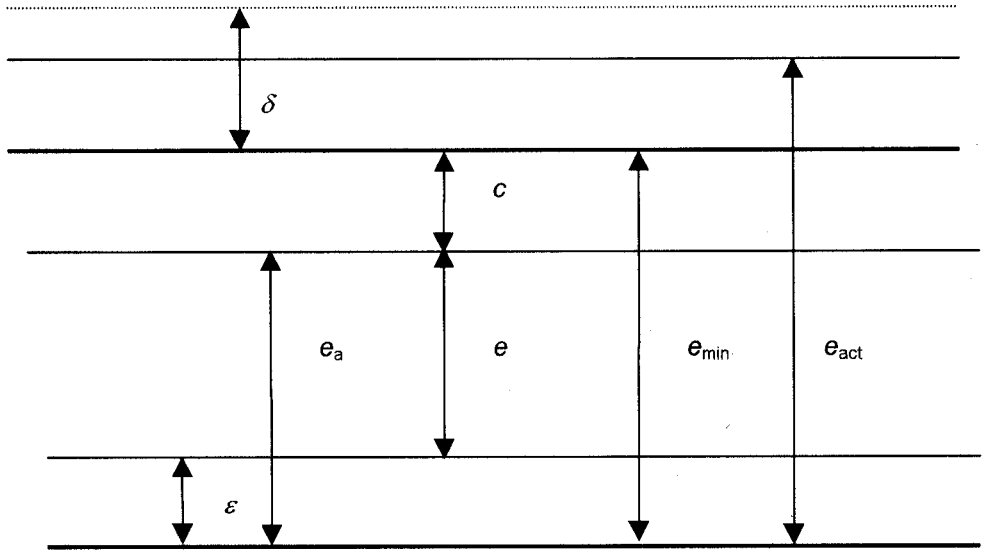
Symbols used in this European Standard are listed in Table 3.3-1.

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
$R_{m(3)}$	Average tensile strength of 3 test bars taken from the same lot or heat	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 be 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 Equation (4.1-1):

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

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_i;

ΔP_i is the pressure cycle amplitude;

P_{max} is the maximum permissible pressure, as defined in 3.15 of EN 13445-3:2009.

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 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 [b]		Design temperature limits °C
	Symbol	Number	
EN 1563	EN-GJS-350-22	EN-JS1010	$-10 \leq TS \leq 300$
	EN-GJS-350-22-RT	EN-JS1014	$-10 \leq TS \leq 300$
	EN-GJS-350-22 U [a]	EN-JS1032	$-10 \leq TS \leq 300$
	EN-GJS-350-22U-RT [a]	EN-JS1029	$-10 \leq TS \leq 300$
	EN-GJS-400-18	EN-JS1020	$-10 \leq TS \leq 300$
	EN-GJS-400-18-RT	EN-JS1024	$-10 \leq TS \leq 300$
	EN-GJS-400-18U [a]	EN-JS1062	$-10 \leq TS \leq 300$
	EN-GJS-400-18U-RT [a]	EN-JS1059	$-10 \leq TS \leq 300$

[a] Mechanical properties verified on test pieces from cast-on samples. These grades should be chosen in preference to the material grades with the separately cast samples when the unit mass of the casting is equal to or greater than 2 000 kg or when the relevant wall thickness varies between 30 mm and 200 mm.

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 1563:1997, Clause 6).

[b] 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 [b]		Design temperature limits °C
	Symbol	Number	
EN 1563	EN-GJS-350-22-LT	EN-JS1015	$-40 \leq TS \leq 300$
	EN-GJS-350-22U-LT [a]	EN-JS1019	$-40 \leq TS \leq 300$
	EN-GJS-400-18-LT	EN-JS1025	$-20 \leq TS \leq 300$
	EN-GJS-400-18U-LT [a]	EN-JS1049	$-20 \leq TS \leq 300$
EN 13835	EN-GJSA-XNiMn23-4	EN-JS3021	$-196 \leq TS \leq 300$
	EN-GJSA-XNi22	EN-JS3041	$-40 \leq TS \leq 540$
	EN-GJSA-XNiMn13-7	EN-JS3071	$-40 \leq TS \leq 300$

[a] Mechanical properties verified on test pieces from cast-on samples. These grades should be chosen in preference to the material grades with the separately cast samples when the unit mass of the casting is equal to or greater than 2 000 kg or when the relevant wall thickness varies between 30 mm and 200 mm.

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 1563:1997, Clause 6 and EN 13835:2002, Clause 6).

[b] 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 1559-1:1997 and EN 1559-3:1997 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.

5.2 Design

5.2.1 Technical documentation

The manufacturer shall document those items listed in Clause 5 of EN 13445-5:2009 prior to fabrication.

5.2.2 Design methods

5.2.2.1.1 Principle

The loadings to be accounted for shall be in accordance with EN 13445-3:2009, Clause 5.

The service conditions of Clause 4 shall be accounted for.

Design methods shall be in accordance with this European Standard and, when applicable, with the relevant clauses of EN 13445-3:2009.

If the geometry of the component or the loading case do not allow calculation by the formulas given in EN 13445-3:2009 and Annex G, design by analysis (DBA) (see Annex E) or design by experiment (DBE) shall be applied.

Depending on the complexity of the component, the loading conditions and the level of NDT testing, the designer may choose one of the following available design methods mentioned below. Guidance is given on the correlation between safety factor, testing factor and the method to assess dynamic loading (see Table 5.2-1).

5.2.2.1.2 Static loading

In order to design the part for static loading, the following options can be considered by the designer.

5.2.2.1.3 Design by formula (DBF)

Equations for the calculation of the various components of the pressure part are given in EN 13445-3:2009 and Annex G. Annex G gives additional equations for non-standard shaped parts often used in casting design.

5.2.2.1.4 Design by analysis (DBA)

The following applies:

1) decide whether the direct route (limit load – EN 13445-3:2009, Annex B) or the stress categorisation method (EN 13445-3:2009, Annex C) will be followed. Decide whether linear or non-linear approach will be used;

2) base modelling and interpretation of calculation results shall be based on analysis thicknesses (e_a) and material characteristics at operation temperature;

3) for interpretation of calculation results, follow the evaluation procedures and assessment criteria in order to evaluate the fitness for purpose of the real structure. These design checks and related procedures are typical for the failure mode to be dealt with. For the different failure modes see EN 13445-3:2009.

5.2.2.1.5 Design by experiment (DBE)

Where design by equations according to EN 13445-3:2009 is not considered appropriate due to complex shape of the component, then a hydraulic burst test to determine the analysis thickness ea and the minimum thickness e_{min} shall be performed according to the procedure in 5.2.2.1.6. This test is also a part of the technical documentation.

This design method may be used without additional calculations if $P_d \cdot V < 6000$ bar·L.

If $P_d \cdot V > 6000$ bar·L for the complete vessel, this method can be used in addition to DBA or DBF.

The minimum required thickness at a specific location is given by:

$$e_a = e_{act} \cdot \left(\frac{S \cdot PS \cdot R_{m(3)}}{P_{b,act} \cdot R_{p0,2} \cdot C_Q \cdot C_T \cdot C_e} \right)^{1/n} \quad (5\text{-}1)$$

$$e_{min} \geq e_a + c \quad (5\text{-}2)$$

where

$e_{act.}$ is the minimum measured wall thickness at the specific location;

$R_{p0,2}$ is in accordance with Annex A;

$P_{b,act}$ is the actual obtained value of burst pressure or the highest pressure during the test;

$n = 1$ for curved surfaces (cylinders, spheres) or cones with angles $\alpha \leq 60°$, stayed surfaces and stressed parts if bending stress is less than 2/3 of the total stress;

$n = 2$ for all other surfaces.

5.2.2.1.6 Determination of the hydraulic burst pressure and maximum allowable pressure for static loading

A random sample from the production of the vessel or vessel part shall be taken for the burst test or to determine the maximum allowable working conditions. The procedure shall be as follows: