SLOVENSKI STANDARD
SIST EN 13445-6:2002/A2:2007

01-april-2007

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 a la flamme - Partie 6: Exigences pour la conception et la fabrication des récipients sous pression et des parties sous pression moulés en fonte a graphite sphéroidal

Ta slovenski standard je istoveten z: **EN 13445-6:2002/A2:2006**

ICS:

23.020.30	Tlaļne posode, plinske jeklenke	Pressure vessels, gas cylinders

SIST EN 13445-6:2002/A2:2007 **en**

SLOVENSKI STANDARD
SIST EN 13445-6:2002/A2:2007

01-april-2007

Neogrevane tlaļne posode - 6. del: Zahteve za konstruiranje in proizvodnjo tlaļnih posod in tlaļnih delov posode iz sive litine s kroglastim grafitom

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 a la flamme - Partie 6: Exigences pour la conception et la fabrication des récipients sous pression et des parties sous pression moulés en fonte a graphite sphéroidal

Ta slovenski standard je istoveten z: **EN 13445-6:2002/A2:2006**

ICS:

23.020.30	Tlacne posode, plinske jeklenke	Pressure vessels, gas cylinders

SIST EN 13445-6:2002/A2:2007 **English language**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13445-6:2002/A2

December 2006

ICS 23.020.30

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

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

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

This amendment A2 modifies the European Standard EN 13445-6:2002; it was approved by CEN on 11 October 2006.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for inclusion of this amendment into the relevant national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This amendment 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 Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, 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 United Kingdom.

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

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 13445-6:2002/A2:2006: E

Contents

Page

Foreword 4

1 Scope 5

2 Normative references 5

3 Terms, definitions, units and symbols 5
3.1 Terms and definitions 5
3.3 Symbols 6

4 Service conditions 7
4.1 Cyclic loading 8
4.2 Limitations on temperature and energy content 8

5 Requirements 9
5.1 Materials 9
5.2 Design 11
5.3 Founding 15

6 Material testing 16
6.1 General 16
6.2 Frequency and number of tests 16
6.3 Chemical analysis 16
6.4 Graphite structure 16
6.5 Inspection documents 17

7 Testing and final assessment 17
7.1 Testing 17
7.2 Final assessment 20

8 Pressure vessels constructed of a combination of parts in different materials 21

9 Marking and documentation 21
9.1 Marking of castings 21

Annex A (normative) Technical data for the design calculations 22
A.1 Purpose 22
A.2 Technical data 22

Annex B (informative) Ductility 24

Annex C (informative) Determination of the minimum local wall thickness and maximum allowable working pressure 25

Annex D (normative) Assessment of fatigue life 27
D.1 Purpose 27
D.3 Specific symbols and abbreviations 27
D.5 General 27
D.6 Simplified fatigue assessment 28
D.7 Detailed fatigue assessment 31
D.8 Assessment rule for total fatigue damage 35
D.9 Repairs of surface imperfections 35

Annex E (normative) Design by analysis for castings 36
E.1 Introduction 36
E.2 Special requirements to EN 13445-3:2002, Annex B 36
E.3 Additions to EN13445-3:2002, Annex C 37
E.4 Requirements 37

Annex F (informative) Recommendations for in-service validation and inspection 38
F.1 Purpose 38
F.2 Tests during operation 38
F.3 Measures to be taken when the calculated allowable fatigue lifetime has been reached 39

Annex G (normative) Specific design requirements 40
G.1 Scope 40
G.2 Design 40

Annex H (normative) Experimental cyclic pressure testing procedure 42
H.1 Purpose 42
H.2 Validity 42
H.3 Tests requirements 42
H.4 Allowable number of cycles 44

Annex ZA (informative) Relationship between this European Standard and the essential requirements of the EU Directive 97/23/EC 46

Bibliography 47

Foreword

This document (EN 13445-6:2002/A2:2006) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

This Amendment to the European Standard EN 13445-6:2002 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2007, and conflicting national standards shall be withdrawn at the latest by June 2007.

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.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, 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.

This document includes the text of the amendment itself. The corrected pages of EN 13445-6 will be delivered as issue 23 of the standard.

1 Scope

Replace the Scope with the following text:

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

Replace the standard paragraph with the following text:

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.

Insert the following normative references:

EN 13835:2002, *Founding — Austenitic cast irons*

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

Delete the following normative reference:

EN 10204:1991, *Metallic products — Types of inspection documents*

3 Terms, definitions, units and symbols

3.1 Terms and definitions

Replace 3.1.1 with the following text:

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.

Add 3.1.8 and 3.1.9:

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, iron and carbon based (carbon being present mainly in the form of spheroidal graphite particles) with an austenitic matrix and alloyed with nickel and where appropriate, manganese, copper and/or chromium

3.3 Symbols

Replace the old Table 3.3-1 with new Table 3.3-1:

Table 3.3-1 — Symbols

Symbol	Quantity	Unit
C	Corrosion allowance	mm
e	Required thickness	mm
e_a	Analysis thickness (without corrosion allowance)	mm
e_{act}	Actual thickness	mm
e_{min}	Minimum thickness including corrosion allowance as specified on drawing	mm
E	Modulus of elasticity	N/mm² or MPa
F	Nominal design stress	MPa or N/mm²
F	Fatigue factor related to 99,8 % survival	dimensionless
$P_{b,act}$	Actual burst test pressure	N/mm² or MPa
P_b	Minimum required bursting pressure	N/mm² or MPa
P_d	Design pressure	MPa, N/mm²
PS, P_S	Maximum allowable pressure	bar, MPa, N/mm²
RM	Material strength parameter	N/mm² or MPa
$R_{p0,2}$	Minimum 0,2 %-proof strength at room temperature	N/mm² or MPa
$R_{m(3)}$	Average tensile strength of 3 test bars taken from the same lot or heat	N/mm² or MPa
TS_{min} , TS_{max}	Minimum / maximum allowable temperature	°C
T	Calculation temperature	°C
V	Internal volume of the vessel	l
C_e	Wall thickness factor	dimensionless
C_t	Temperature factor	dimensionless
C_Q	Testing factor	dimensionless
N	Factor depending on shape of shell	dimensionless
f_e	Thickness correction factor	dimensionless
f_m	Mean stress correction factor	dimensionless
f_s	Surface finish correction factor	dimensionless
SF	Safety factor	dimensionless
γ_R	Partial safety factor	dimensionless
δ	Casting tolerance	mm
E	Extra thickness due to casting process	mm
ν	Poisson's ratio	dimensionless

4 Service conditions

Replace Clause 4 with the following text:

4.1 Cyclic loading

Spheroidal graphite cast iron pressure vessels and vessel parts can be used for cyclic operation if the stress concentration 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 stress concentration factor ≤ 3
	200 000	If stress concentration 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 concentration 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):

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

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 3.15 of EN 13445-3:2002.

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 10 000 MPa·l (100 000 bar·l).

5 Requirements

5.1 Materials

Replace 5.1 with the following text:

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 t ≤ 60 mm;
- 10 J for 60 mm ≤ t ≤ 200 mm;
- individual value 9 J for t ≤ 60 mm and 7 J for 60 mm ≤ t ≤ 200 mm.

The applicable requirements for the delivery conditions given in EN 1559-1 and EN 1559-3 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

Replace 5.2.1 with the following text:

5.2.1 Technical documentation

The manufacturer shall document those items listed in Clause 5 of EN 13445-5:2002 prior to fabrication.

5.2.2 Design methods

Replace 5.2.2.1 with the following text:

5.2.2.1 General

5.2.2.1.1 Principle

The loadings to be accounted for shall be in accordance with EN 13445-3:2002, 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.

If the geometry of the component or the loading case do not allow calculation by the formulas given in EN 13445-3 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 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 13445-3:2002, Annex B) or the stress categorisation method (EN 13445-3:2002, 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.

5.2.2.1.5 Design by experiment (DBE)

Where design by equations according to EN 13445-3 is not considered appropriate due to complex shape of the component, then a hydraulic burst test to determine the analysis thickness e_a and the minimum thickness e_{min} shall be performed according to the procedure in 5.2.3. This test is also a part of the technical documentation.

This design method may be used without additional calculations if $P_d \cdot V < 600$ MPa·l (6 000 bar·l).

If $P_d \cdot V > 600$ MPa·l (6 000 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:

$$e_a = e_{act} \cdot \left(\frac{SF \cdot PS \cdot R_{m(3)}}{P_{b,act} \cdot R_{p0,2} \cdot C_Q \cdot C_t \cdot C_e} \right)^{1/n} \quad (5.2\text{-}1)$$

$$e_{min} \geq e_a + c \quad (5.2\text{-}2)$$

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:

1) verify that the part or vessel to be tested is cast according to the specified drawing and any revision thereof. The material used shall be the same type and grade as for the production part;

2) verify that the part or vessel is machined to the same dimensions as the production part;

3) verify that the material properties meet the requirements of 5.1. For each casting used for the burst test, 3 test pieces for tensile testing, and, if applicable, for impact testing, shall be separately cast