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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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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 flame - 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 draft amendment is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 54.

This draft amendment A2, if approved, will modify the European Standard EN 13445-6:2002. If this draft becomes an amendment, 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.

This draft amendment was established by CEN 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 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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Foreword

This document (EN 13445-6:2002/prA2:2005) 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, B, C or D, which is an integral part of this document.

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 the thickness of flanges, reinforcements, bosses, etc.

NOTE1 Austenitic spheroidal graphite cast iron grades are principally used for high and low temperature applications and their corrosion resistance properties.

NOTE2 The allowable grades of spheroidal graphite cast iron are listed in Tables 3 and 4Service conditions are given in clause 4.

NOTE3 The allowable grades do not include lamellar graphite cast iron grades, which are explicitly excluded from this standard because of low elongation and brittle material behaviour, which requires the use of different safety factors and a different approach.

2 Normative references

Insert the following Normative reference:

EN 13835, *Founding-Austenitic cast irons*

3 Terms, definitions, unit and symbols

3.1 Terms and definitions

Replace clause 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 initiate 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 are to be considered in defining critical zones.

Add new clauses 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

Insert 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_{min}	minimum thickness including corrosion allowance as specified on drawing	Mm
F	nominal design stress	Mpa or N/mm²
P_{d}	design pressure	Mpa, N/mm^2
PS, P_{S}	maximum allowable pressure	bar, MPa, N/mm^2
RM	Material strength parameter	N/mm² or MPa
γ_R	Partial safety factor	dimensionless
E	Modulus of elasticity	N/mm² or MPa
ν	Poisson's ratio	dimensionless
$R_{p0,2}$	minimum 0,2 % - proof strength at room temperature	N/mm² or MPa
V	internal volume	L
TS_{min} , TS_{max}	Minimum / maximum allowable temperature	°C
t	Calculation temperature	°C
C_e	wall thickness factor	dimensionless
C_t	temperature factor	dimensionless
C_Q	testing factor	dimensionless
e_{act}	actual thickness	Mm
$P_{b,act}$	Actual burst test pressure	N/mm² or MPa
n	factor depending on shape of shell	dimensionless
P_b	bursting test pressure	N/mm² or MPa
$R_{m(3)}$	average tensile strength of 3 test bars taken from the same lot	N/mm² or MPa
ε	extra thickness due to casting process	Mm
δ	casting tolerance	Mm
SF	Safety factor	dimensionless
f_e	Thickness correction factor	dimensionless
f_m	Mean stress correction factor	dimensionless
f_s	Surface finnish correction factor	dimensionless
F_{t^*}	Temperature correction factor	dimensionless

4 Service conditions

Replace the whole of clause 4 with the following text:

4.1 Cyclic loading

Spheroidal graphite cast iron pressure vessels and vessel parts can be used for non-cyclic or cyclic operation if the stress concentration factor is limited to 3.

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

If the service conditions require more than the maximum number of full pressure cycles according to Table 4.1-1, or more than an 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

<table>
<tr><td>Testing factor</td><td colspan="2">Maximum number of full pressure cycles without mandatory fatigue analysis according to Annex D</td></tr>
<tr><td>C_Q=0,9</td><td colspan="2">1000</td></tr>
<tr><td rowspan="2">C_Q =0,8</td><td>40000</td><td>Max. stress concentration factor 3</td></tr>
<tr><td>200.000</td><td>Max.stress concentration factor 2,5</td></tr>
</table>

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: If the calculated number of cycles is close to an above limit to determine the need for fatigue analysis, a worst-case model shall be implemented for this determination.

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):

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

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 paragraph 3.15 of EN 13445-3

4.2 Limitations on temperature and energy content

The minimum and maximum allowable temperature *TS* shall be in accordance with the limits given in Tables 5.1-1 and 5.1-2.

The product *PSxV* for a single casting shall not exceed 10. 000 MPa·l (100 000 bar·l).

5 Requirements

5.1 Materials

Replace clause 5.1 with the following text:

All spheroidal graphite 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.

For all material grades, mechanical properties shall be guaranteed by the foundry at specified locations on the castings.

The ferritic material grades are given in Table 5.1-1 and 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		Design temperature limits °C
	Symbol	Number	
EN 1563	EN-GJS-350-22	EN-JS1010	-10 ≤ *T*S ≤ 300
	EN-GJS-350-22-RT	EN-JS1014	-10 ≤ TS ≤ 300
	EN-GJS-350-22 U [a]	EN-JS1032	-10 ≤ TS ≤ 300
	EN-GJS-350-22U-RT [a]	EN-JS1029	-10 ≤ TS ≤ 300
	EN-GJS-400-18	EN-JS1020	-10 ≤ TS ≤ 300
	EN-GJS-400-18-RT	EN-JS1024	-10 ≤ TS ≤ 300
	EN-GJS-400-18U [a]	EN-JS1062	-10 ≤ TS ≤ 300
	EN-GJS-400-18U-RT [a]	EN-JS1059	-10 ≤ TS ≤ 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 3 and Table 4 may be produced in the as-cast or heat treated condition (See EN 1563 Clause 6 and EN 13835 Clause 6).

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

Material standard	Material designation		Design temperature limits °C
	Symbol	Number	
EN 1563	EN-GJS-350-22-LT	EN-JS1015	-40 ≤ TS ≤ 300
	EN-GJS-350-22U-LT [a]	EN-JS1019	-40 ≤ TS ≤ 300
	EN-GJS-400-18-LT	EN-JS1025	-20 ≤ TS ≤ 300
	EN-GJS-400-18U-LT [a]	EN-JS1049	-20 ≤ TS ≤ 300
EN 13835	EN-GJSA-XNiMn23-4	EN-JS3021	-196 ≤ TS ≤ 300
	EN-GJSA-XNi22	EN-JS3041	-40 ≤ TS ≤ 540
	EN-GJSA-XNiMn13-7	EN-JS3071	-40 ≤ TS ≤ 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 3 and Table 4 may be produced in the as-cast or heat treated condition (See EN 1563 Clause 6 and EN 13835 Clause 6).

The material grades EN-GJS-350-22-LT or EN-GJS-350-22U-LT can be used for design temperatures down to – 60 °C, provided that impact testing at the minimum allowable temperature is carried out on specimens representative of the production and the results meet the requirements given in EN 1563 for these grades.

The material grade EN-GJSA-XNiMn23-4 can be used for design temperatures down to – 254 °C, provided that impact testing at the minimum allowable temperature, but not lower than -196 °C, is carried out on specimens representative of the production and the results meets the requirements given in EN 13835 for this grade.

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

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).

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

5.2 Design

Replace clause 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 prior to fabrication.

5.2.2 Design methods

Replace clause 5.2.2.1 with the following text:

5.2.2.1 General

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

Design methods shall be in accordance with this part of the standard and, when applicable, with the relevant clauses of EN 13445-3.

If the geometry of all components or the loadings do not allow accurate calculation by the formulas given in EN 13445-3 and Annex G of this standard, design by analysis (DBA) or design by experiment (DBE) shall be applied.

The designer has a number of options to choose from; depending on the complexity of the pressure part, the loading conditions and the level of non destructive testing the designer may choose one of the available design methods mentioned below. Guidance is given on the correlation between safety factor, testing factor and the method how to assess for dynamic loading.

5.2.2.1.1 Static loading

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

5.2.2.1.2 Design by formula (DBF)

Formulas for the calculation of the various components of the pressure part are given in EN 13445-3 and Annex G of this standard. Annex G gives additional formulas for non-standard shaped parts often used in casting designs.

5.2.2.1.3 Design by analysis (DBA)

The following applies:

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

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

3. Interpretation of calculation results following 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 EN13445-3.

5.2.2.1.4 Design by experiment (DBE)

Where design by formulae according to EN 13445-3 is not considered reliable 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 clause 5.2.3. This test is also a part of the technical documentation.

This design method may be used without additional calculations if the P$d.V$ < 600 MPa.l (6000 bar.liter).

If P$d.V$ > 600 MPa.l (6000 bar.liter).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 :