



BSI Standards Publication

Founding — Ultrasonic testing

Part 3: Spheroidal graphite cast iron castings

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National foreword

This British Standard is the UK implementation of EN 12680-3:2011. It supersedes BS EN 12680-3:2003 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/111, Steel Castings and Forgings.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Founding - Ultrasonic testing - Part 3: Spheroidal graphite cast iron castings

Fonderie - Contrôle par ultrasons - Partie 3: Pièces moulées en fonte à graphite sphéroïdal

Gießereiwesen - Ultraschallprüfung - Teil 3: Gussstücke aus Gusseisen mit Kugelgraphit

This European Standard was approved by CEN on 15 October 2011.

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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

Management Centre: Avenue Marnix 17, B-1000 Brussels

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Foreword

This document (EN 12680-3:2011) has been prepared by Technical Committee CEN/TC 190 "Foundry Technology", the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by May 2012, and conflicting national standards shall be withdrawn at the latest by May 2012.

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 supersedes EN 12680-3:2003.

Within its programme of work, Technical Committee CEN/TC 190 requested CEN/TC 190/WG 10 "Inner defects" to revise the following standard:

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

This is one of three European Standards for ultrasonic testing. The other standards are:

EN 12680-1, *Founding — Ultrasonic examination — Part 1: Steel castings for general purposes*;

EN 12680-2, *Founding — Ultrasonic examination — Part 2: Steel castings for highly stressed components*.

Annex A provides details of significant technical changes between this European Standard and the previous edition.

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, 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 the requirements for the ultrasonic testing of spheroidal graphite cast iron castings and the techniques for determining internal discontinuities by the pulse-echo technique.

This European Standard does not apply to ultrasonic testing of the nodularity of spheroidal graphite cast irons.

This European Standard does not apply to transmission technique.

NOTE The transmission technique has insufficient sensitivity to detect the discontinuities found in spheroidal graphite cast iron castings and is used in exceptional cases only.

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 473, *Non-destructive testing — Qualification and certification of NDT personnel — General principles*

EN 583-1, *Non-destructive testing — Ultrasonic examination — Part 1: General principles*

EN 583-2, *Non-destructive testing — Ultrasonic examination — Part 2: Sensitivity and range setting*

EN 583-5, *Non-destructive testing — Ultrasonic examination — Part 5: Characterization and sizing of discontinuities*

EN 1330-4, *Non-destructive testing — Terminology — Part 4: Terms used in ultrasonic testing*

EN 12223, *Non-destructive testing — Ultrasonic examination — Specification for calibration block No. 1*

EN 12668-1, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 1: Instruments*

EN 12668-2, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 2: Probes*

EN 12668-3, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 3: Combined equipment*

EN ISO 7963, *Non-destructive testing — Ultrasonic testing — Specification for calibration block No. 2 (ISO 7963:2006)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-4 and the following apply.

3.1

dross

accumulation of fine slag particles (oxides, sulphides, etc.) in the rim zone of castings

NOTE In smaller castings, dross is usually not detected by ultrasonic testing.

4 Requirements

4.1 Order information

The following information shall be available at the time of enquiry and order (see also EN 583-1):

- the areas of the casting and the number or percentage of castings to which the ultrasonic testing requirements apply;
- the severity levels for small castings in accordance with Table 1 and if applicable Table 3, or for large castings Table 2 and if applicable Table 4, to be applied to the various areas of the casting;
- requirements for a written test procedure.

NOTE 1 Severity levels in Tables 1 and 3 as well as 2 and 4 can be chosen differently.

NOTE 2 Small castings are typically produced under serial conditions, e.g. automatic moulding lines, with a mass up to 500 kg.

NOTE 3 Large castings are typically hand moulded, with a mass higher than 500 kg.

4.2 Extent of testing

The areas of the casting to be tested shall be agreed. This agreement shall state how these areas are to be tested, i.e. point testing or scanning, and in which directions.

NOTE These areas should be preferably indicated on the casting drawing.

For wall thicknesses outside of the range 10 mm to 500 mm, agreement shall be made between the parties concerned on the test procedure and also on the recording and acceptance levels.

4.3 Maximum permissible size of discontinuities

Unless otherwise agreed between the parties concerned, the maximum permissible sizes of discontinuities shall not exceed those of the severity level given in either Table 1 resp. 2 and/or Table 3 resp. 4.

4.4 Personnel qualification

Unless otherwise agreed, testing shall be performed by personal, qualified in accordance with EN 473 or by a certification scheme which is considered to be equivalent.

4.5 Wall section zones

The wall section shall be divided into zones as shown in Figure 1. For wall thickness equal to or less than 10 mm the total wall thickness shall be considered as rim zone.

Unless otherwise agreed these wall sections shall relate to the dimensions of the casting in the "as delivered" condition.

When a discontinuity is located simultaneously in both, the rim zone and the core zone, the following applies:

- $\geq 50\%$ in the rim zone, the specified area of the largest discontinuity for the rim zone shall be doubled;
- $< 50\%$ in the rim zone, the specified area of the largest discontinuity for the core zone shall be halved.

5 Testing

5.1 Principles

The principles given in EN 583-1 and EN 583-2 shall apply.

5.2 Material

The suitability of a material for ultrasonic testing is assessed by comparison with the echo height of a reference reflector (usually the first back-wall echo) and the noise signal. This assessment shall be carried out on selected casting areas which are representative of the surface finish and of the total thickness range. The assessment areas shall have parallel surfaces.

The reference echo height shall be at least 6 dB above the noise level. If the echo height of this smallest detectable flat-bottomed or equivalent side-drilled hole diameter at the end of the test range to be assessed is less than 6 dB above the noise level, then the ultrasonic testability is reduced. In this case, the flat-bottomed or side-drilled hole diameter which can be detected with a signal-to-noise ratio of at least 6 dB shall be noted in the test report and the additional procedure shall be agreed between the manufacturer and the purchaser.

NOTE If a distance-gain-size diagram (DGS) is available, the suitability of castings for ultrasonic testing with normal probes can be determined for example as follows: with the suppression switched off, the back-wall echo is brought to any reference level desired. The amplification according to the DGS diagram is then increased so that the echo signal height from the reference reflector according to 5.3.5.3 reaches the reference level. If the amplification is further increased by 6 dB the background noise level should not exceed the reference height. If necessary, a reference reflector can be used to determine the testing suitability in areas without the back-wall echo.

5.3 Equipment, coupling medium, time base range and sensitivity setting

5.3.1 Ultrasonic instrument

The ultrasonic instrument shall meet the requirements given in EN 12668-1 and shall have the following characteristics:

- range setting, from at least 10 mm to 2 m continuously selectable, for longitudinal and transverse waves transmitted in steel;
- gain, adjustable in 2 dB maximum steps over a range of at least 80 dB with a measuring accuracy of 1 dB;
- time base and vertical linearities less than 5 % of the adjustment range of the screen;
- suitability at least for nominal frequencies from 0,5 MHz up to and including 5 MHz in pulse-echo technique with dual-element probe and single-element probe.

5.3.2 Probes and transducer frequencies

The probes and transducer frequencies shall be as given in EN 12668-2 and EN 12668-3 with the following exceptions:

- to cover the range of discontinuity types to be detected, the casting can be tested using compression-wave dual-element probe or single-element probe.

NOTE 1 Dual-element probe should be used for the testing of areas close to the test surface.

- for special geometrical conditions, angle-beam probes can be used up to a sound path length of about 100 mm, preferably with nominal angles between 45° and 70°. The frequency value shall be selected to suit the test and shall be within the range 0,5 MHz to 5 MHz. Higher frequencies can be used for testing wall thicknesses of less than 20 mm or areas close to the surface.

NOTE 2 For the detection of near-surface discontinuities, the use of dual-element and/or angle probes is recommended.

NOTE 3 Since sound travels at different velocities in steel and spheroidal graphite cast iron, the actual angle of refraction deviates from the nominal angle of the probe for steel.

If the sound velocity of spheroidal graphite cast iron is known, the angle of refraction of the probe can be determined from the sound velocity according to Figure 2.

Figure 3 shows how the angle of refraction can be determined to an accuracy sufficient for practical purposes using two probes of the same type. The sound velocity of spheroidal graphite cast iron can also be determined from the angle of refraction α as follows:

$$C_c = 3\ 255 \times \frac{\sin \alpha_c}{\sin \alpha_s} \quad (1)$$

where

C_c is the sound velocity of transverse waves in the casting in metres per second;

3 255 is the sound velocity of transverse waves for steel in metres per second,

α_c is the angle of refraction in the casting in degrees;

α_s is the angle of refraction in steel in degrees.

NOTE 4 For special cases, longitudinal wave angle beam probes can be used.

NOTE 5 The longitudinal wave velocity for spheroidal graphite cast iron is equal to or above 5 500 m/s.

5.3.3 Checking the ultrasonic testing equipment

The ultrasonic testing equipment shall be checked regularly by the operator according to EN 12668-3.

5.3.4 Coupling medium

A coupling medium in accordance with EN 583-1 shall be used. The coupling medium shall wet the test area to ensure satisfactory sound transmission. The same coupling medium shall be used for range and sensitivity setting and all subsequent testing operations.

NOTE The sound transmission can be checked by ensuring one or more stable back-wall echoes in areas with parallel surfaces.

5.3.5 Time base range and sensitivity setting of the ultrasonic equipment

5.3.5.1 General

A spheroidal graphite cast iron reference block shall be used for range and sensitivity setting. The thickness of the reference block shall be comparable to the wall thickness range of the casting to be tested and shall be agreed at the time of enquiry and order. The reference block shall have the same ultrasonic properties as the casting to be tested and shall have the same surface finish. The reference block shall contain flat-bottomed holes according to Table 5 or equivalent side-drilled holes as reference reflectors.

NOTE The following equation is used for converting the flat-bottomed hole diameter into the side-drilled hole diameter:

$$D_Q = \frac{4,935 \times D_{FBH}^4}{\lambda^2 \times s} \quad (2)$$

where

D_Q is the side-drilled hole diameter in millimetres;

D_{FBH} is the flat-bottomed hole diameter in millimetres;

λ is the wave length in millimetres;

s is the path length in millimetres.

The equation is applicable for $D_Q \geq 2 \lambda$ and $s \geq 5 \times$ nearfield length and is only defined for single element probes.

Other reference reflector sizes or reflector types may be agreed at the time of enquiry and order. All sides of the reference block shall be flat and parallel. If standard steel calibration blocks are used, differences in sound velocity, sound attenuation and surface quality between the casting and the calibration blocks shall be taken into consideration.

The equipment can also be set using a DGS diagram, see bibliography [1] and [2] calculated for spheroidal graphite cast iron. In this case, the reference block is not necessary and range and sensitivity setting can be done on the casting itself.

5.3.5.2 Time base range setting

Range shall be set either on the reference block or calibration block and checked on the casting itself or directly on the casting, if its thickness is known and if it has parallel surfaces.

5.3.5.3 Sensitivity setting

The sensitivity shall be set by reflecting sound from a suitable reflector, e.g. the opposite surface of a casting, a flat-bottomed or side-drilled hole of the reference block or the circular segments of the calibration blocks K1 according to EN 12223 or K2 according to EN ISO 7963. Account shall be taken of the sound attenuation, surface quality and velocity of sound through the casting. The transfer correction shall be determined. When determining the transfer correction, not only the quality of the coupling areas but also the surface quality of the opposite surface shall be taken into consideration. The signal level in the thickness range to be assessed is given by the diameter in millimetres of any suitable reflector (see 5.3.5.1)

NOTE A reference curve can be taken on the reference reflectors of the reference block and transferred to the instrument screen. In order to prevent incorrect evaluation of the signals for different path lengths, the reference curve should be corrected to take into account different sound attenuations between the reference block and the casting.

5.3.6 Detection sensitivity

The detection sensitivity of the equipment shall ensure at least the setting of the sensitivity in accordance with the requirements of 5.5.3.

5.4 Preparation of casting surfaces for testing

For the preparation of casting surfaces for testing, see EN 583-1.

The casting surfaces to be tested shall be such that satisfactory coupling with the probe can be achieved.

NOTE It is recommended that surface condition requirements according to EN 1370 (see bibliography [3]) are agreed at the time of enquiry and order (e.g. as-cast, shot-blasted, fettled or machined surfaces).

5.5 Test procedure

5.5.1 General

The selection of the incidence direction and of the most suitable probes depends largely on the casting shape and the nature and position of the casting discontinuities. Therefore, the applicable test procedure shall be specified by the manufacturer of the casting and the operator as applicable. The method most widely used is vertical incidence with compression wave probes having frequencies within the range 0,5 MHz up to and including 5 MHz. Single-element or dual-element probes can be used. Oblique incidence (angle-beam probes) can be used for special geometrical conditions, where compression wave probes are not satisfactory. If the intended application of the casting needs special requirements regarding the test procedure, the purchaser shall inform the manufacturer accordingly.

NOTE Higher frequencies are normally used to test castings with small wall thicknesses and high quality requirements.

Complete coverage of all areas specified for scanning shall be conducted by carrying out systematically over-lapping scans.

If scanning is agreed (see 4.2), the scanning speed shall not exceed 150 mm/s.

5.5.2 Sensitivity setting

5.5.2.1 Minimum sensitivity (detection sensitivity)

The sensitivity of the system shall be set in such a way that the echo heights of the flat-bottomed holes given in Table 5 or of the equivalent side-drilled holes shall be at least 40 % of the screen height at the end of the thickness range to be tested. If it is not possible to set this minimum sensitivity, the smallest flat-bottomed hole which can be detected shall be recorded in the test report. In this case, the purchaser and the manufacturer shall agree on further action.

5.5.2.2 Search sensitivity

When searching for discontinuities, the amplification shall be set in such a way that the noise level is visible on the screen.

If there are local variations in surface quality, the sensitivity can fluctuate widely. In such cases, the search sensitivity shall not fall below the minimum sensitivity.

NOTE For discontinuity, searching with simultaneous observation of the back-wall echo (see Table 6), the use of devices with adjustable back-wall echo reduction is advantageous.

5.5.3 Consideration of various types of indications

The following types of indications, which are proven not to be due to the casting shape or the coupling, shall be taken into consideration and evaluated in the testing of castings:

- reduction of the back-wall echo;
- intermediate echoes.

NOTE All types of indications can occur alone or together. Back-wall echo reduction is expressed as a decrease in back echo in decibels; the height of an echo indication is given as a flat-bottomed hole or side-drilled hole diameter (see EN 583-2).

5.5.4 Evaluation and recording of indications

Unless otherwise agreed, all back-wall echo reductions or echo heights reaching or exceeding the limits given in Table 6 shall be evaluated and shall be recorded if their values exceed 75 % of the limits given in Tables 1 resp. 2 and 3 resp. 4. Whenever such indications are found, their location shall be indicated and included in the test report (see 5.6). The location of the indications to be recorded can be described using grids, sketches or photographs.

In case of simultaneous indications according to Tables 1 and 3 resp. 2 and 4, the procedure shall be agreed between the contracting parties.

5.5.5 Investigation of indications to be recorded

The locations where indications to be recorded have been found (see 5.5.4) shall be investigated more closely with respect to their type, shape, size and position. This can be achieved by altering the transducer frequency or by altering the test procedure or by using other test methods such as radiography.

5.5.6 Sizing of discontinuities

5.5.6.1 General

The techniques of sizing of the dimensions of discontinuities given in 5.5.6.2 and 5.5.6.3 shall be used according to EN 583-5.

Adjacent discontinuities have to be considered as one discontinuity, if the distance between these discontinuities is smaller than the length of the largest discontinuity.

NOTE The dimensions of a discontinuity determined by ultrasonic testing can only be measured to an accuracy sufficient for technical applications under certain preconditions (e.g. knowledge of the type of the discontinuity, simple geometry of the discontinuity, optimum impact of the sound beam on the discontinuity). These preconditions are often not present in spheroidal graphite cast iron.

5.5.6.2 Determination of the dimensions of discontinuities projected on the surface

In order to determine the dimensions of discontinuities projected on the surface, it is recommended that probes with the smallest possible sound beam diameter at the discontinuity location are used.

For the determination of the dimensions of discontinuities which shall be recorded according to Table 1 resp. 2 on account of their echo height (see Table 6), the probe shall be moved over the test area to identify those points where the signal amplitude falls to 6 dB below the last maximum.

For back-wall echo reduction the probe shall be moved over the test surface to identify those points where the back-wall echo is reduced by 12 dB or 20 dB according to Table 6.

In both cases, the points shall be marked as accurately as possible (e.g. probe centre for normal probes, probe index point for angle-beam probes).

The measurable dimensions of the discontinuity are given by a connecting line between the marked points. With angle-beam probes, the edge points of the discontinuities shall be projected onto the test surface as far as the casting geometry allows.

5.5.6.3 Determination of the dimensions of discontinuities in through-wall direction

As far as possible, dimensions of discontinuities in through-wall direction to the test area are measured using normal probes from opposite sides (see Figure 4).

5.5.6.4 Determination of the thickness of the dross layer in through-wall direction

As far as possible, the thickness of the dross layer in through-wall direction to the testing area is measured using normal probes from only the opposite side (see Figure 5).

5.6 Test report

The test report shall contain at least the following information:

- reference to this European Standard (EN 12680-3);
- characteristic data of the tested casting;
- extent of testing;
- type of test equipment used;
- probes used
- test techniques with reference to the tested area;
- all data necessary for the sensitivity setting;
- details of ultrasonic testing suitability;
- information on all characteristic features of discontinuities to be recorded (e.g. back-wall echo reduction, position and dimension in through-wall direction, length, area and equivalent flat-bottomed hole diameter) and the description of their position (sketch or photograph);
- date of the test and name and signature of the responsible person.

Table 1 — Maximum permissible indicated dimensions of discontinuities – Small castings

Mark	Unit	Severity level									
		VU1.1	VU2.1		VU3.1		VU4.1		VU5.1		
Wall thickness in investigated area	mm	—	< 50	≥ 50	< 50	≥ 50	< 50	≥ 50	< 50	≥ 50	
Maximum thickness of discontinuity as % of wall thickness	%	—	15		20		25		30		
Maximum length of discontinuity in the rim zone ^{a, b}	mm	c	4	6	6	10	10	16	16	25	
Maximum area of discontinuities in the rim zone ^{a, b, d}	mm ²	c	35	70	70	200	200	500	500	1 250	
Maximum length of discontinuity in the core zone ^{a, b}	mm	c	8	12	12	20	20	32	32	45	
Maximum area of discontinuities in the core zone ^{a, b, d}	mm ²	c	125	300	300	800	800	2 000	2 000	4 000	

^a For dross see Table 3.

^b Rim zone, see Figure 1.

^c No indications exceeding the limits given in Table 6.

^d A maximum number of 2 indications of the designated maximum dimensions are permitted.

Table 2 — Maximum permissible indicated dimension of discontinuities – Large castings

Mark	Unit	01	Severity level											
			1			2			3			4		
Wall thickness in the test area	mm	—	< 50	50 to 200	> 200	< 50	50 to 200	> 200	< 50	50 to 200	> 200	< 50	50 to 200	> 200
Percent of wall area	%	—	15			20			25			30		
Largest discontinuity in the rim zone ^{a,b}	cm ²	c	3	5	8	6	10	10	10	20	20	—	—	—
Largest discontinuity in the core zone	cm ²	c	25	50	100	100	150	200	150	200	300	200	—	—
Total area of discontinuities as percentage of tested surface	%	c	10	10	10	10	15	15	15	20	20	15	20	30

^a For dross see Table 4.
^b Rim zone, see Figure 1.
^c No indications exceeding the limits given in Table 6.

Table 3 — Maximum permissible indicated thickness of dross layer for areas to be left un-machined – Small castings

Mark	Severity level				
	VU1.2	VU2.2	VU3.2	VU4.2	VU5.2
Percentage of wall thickness	a	5	10	15	20
a No indications exceeding the limits given in Table 6.					

Table 4 — Maximum permissible indicated thickness of dross layer for areas to be left un-machined – Large castings

Mark	Severity level				
	01	1	2	3	4
Percentage of wall thickness	a	10	15	20	25
a No indications exceeding the limits given in Table 6.					

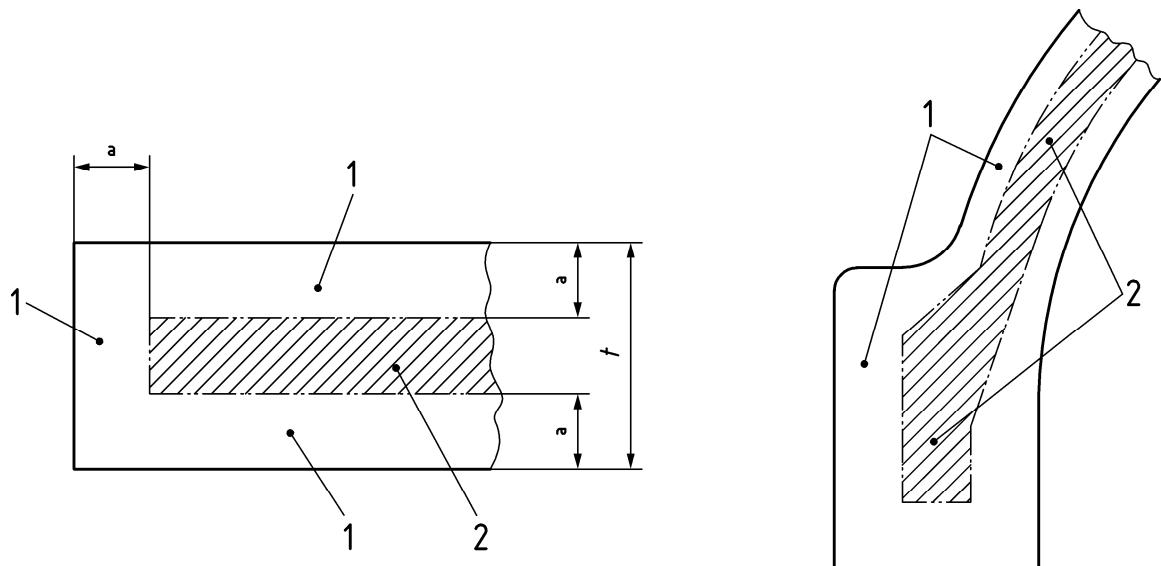
Table 5 — Requirements for ultrasonic testing suitability

Wall thickness of the casting in the tested area mm	Smallest flat-bottomed hole diameter detectable according to 5.2 mm
> 10 to 20	3
> 20 to 100	5
> 100 to 250	8
> 250 to 500	10

Table 6 — Ultrasonic indications to be evaluated

Wall thickness of the casting in the tested area mm	Reduction of back-wall echo min. dB	Evaluation limits Smallest flat-bottomed hole diameter detectable according to 5.2 mm	Echo height above noise level ^a min. dB
> 10 to 20	12	3	6
> 20 to 100		5	
> 100 to 250	20	8	12
> 250 to 500		10	

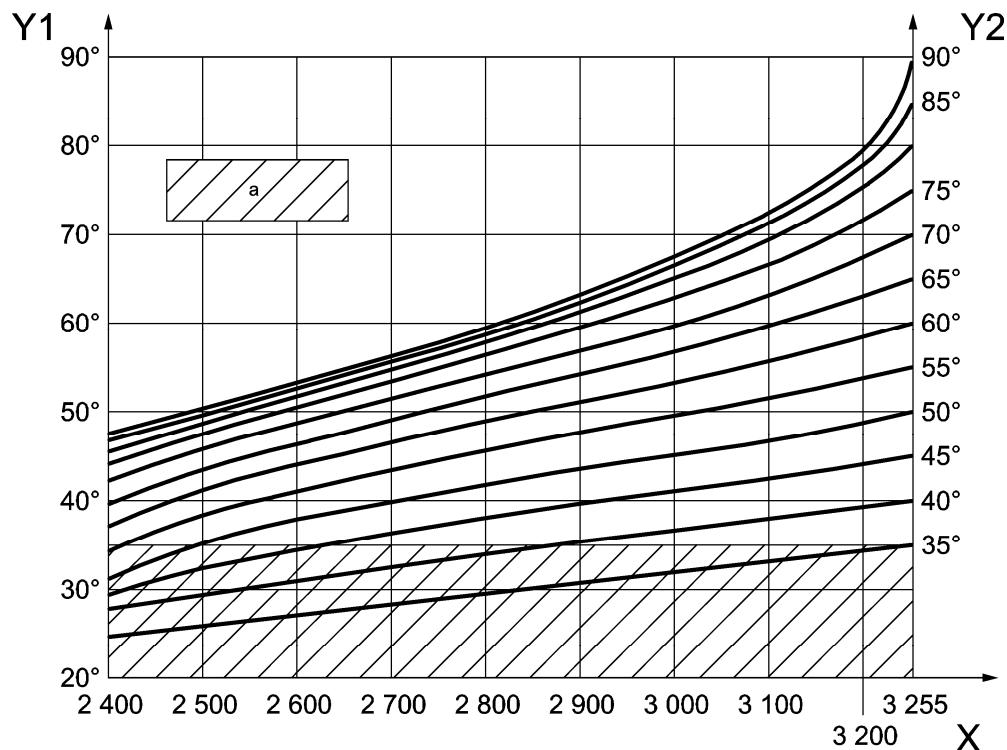
^a Only for areas where no back-wall echo is obtained due to the casting geometry.



Key

- 1 rim zone
- 2 core zone
- t wall thickness
- a $t/5$ (min. 5 mm, max. 30 mm)

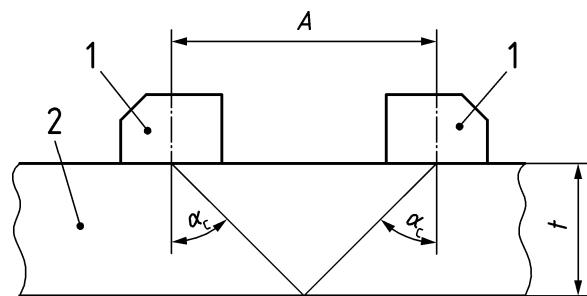
Figure 1 — Division of wall section into zones



Key

Y1 angle of refraction α_c in spheroidal graphite cast iron
X sound velocity of transverse wave c_{trans} in metres per second
Y2 nominal angle of refraction in steel
^a longitudinal and transverse wave simultaneously

Figure 2 — Determination of the nominal angle of refraction in spheroidal graphite cast iron for an angle-beam probe with known angle of refraction in steel



$$\alpha_c = \text{arc tan} \frac{A}{2 \times t}$$

where

α_c is the angle of refraction in the casting;

A is the distance between the probe indexes of the angle-beam probes at maximum signal;

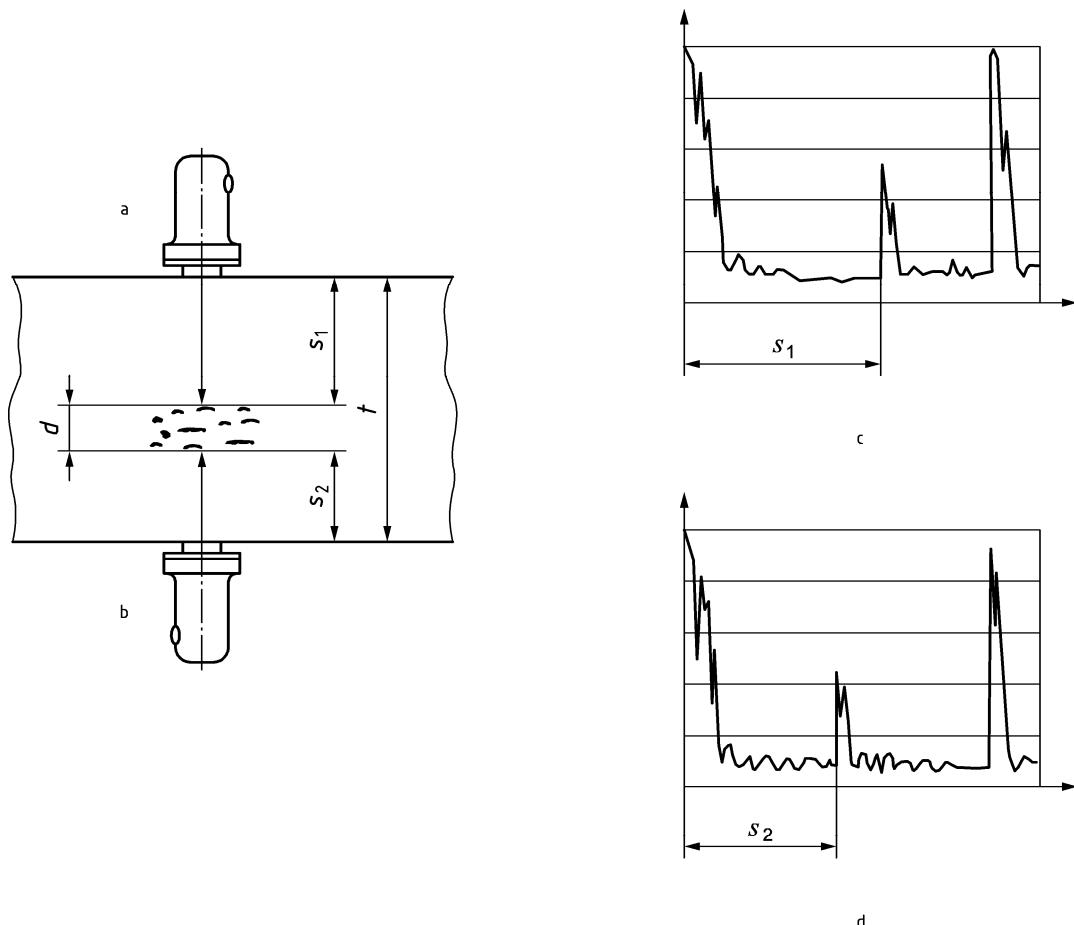
t is the wall thickness.

Key

1 angle beam probes of same type

2 test piece or reference block

Figure 3 — Determination of the angle of refraction in spheroidal graphite cast iron using angle-beam probes



Key

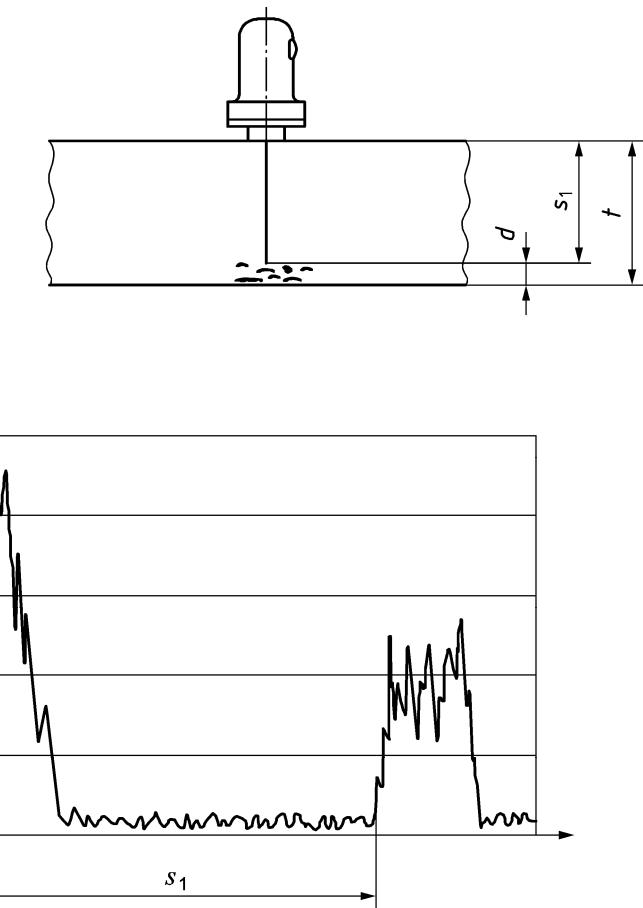
- a scanning position A
- b scanning position B
- c A scan from scanning position A
- d A scan from scanning position B

Dimension in through-wall direction $d = t - (s_1 + s_2)$

where

s_1, s_2 are the sound path lengths;
 t is the wall thickness.

Figure 4 — Determination of the dimensions of discontinuities in through-wall direction using normal probes



Key

t wall thickness
 s_1 sound path length
 d thickness of the dross layer

Figure 5 — Determination of the thickness of the dross layer in through-wall direction using normal probes

Annex A (informative)

Significant technical changes between this European Standard and the previous edition

Table A.1 — Significant technical changes between this European Standard and the previous edition

Clause/Paragraph/Table/Figure	Change
3.1	Term and definition of "dross" added
4.1	Notes 1 and 2, description of typical differences between small and large castings added
4.5	New definition of core and rim zone added
5.5.6.4	Added
Tables 1 and 3	New tables for small castings added
Tables 2 and 4	Table 2 for large castings based on the previous Table 1 of EN 12680-3:2003: new severity level 01, new values for severity level 1, no changes in severity level 2, 3 and 4, deletion of severity level 5; Table 4 for dross based on the previous Table 2 of EN 12680-3:2003: new severity level 01, new values for severity level 1, 2, 3 and 4, deletion of severity level 5
Figure 5	Added

NOTE The technical changes referred include the significant technical changes from the revised EN but this is not an exhaustive list of all modifications from the previous version.

Bibliography

- [1] Krautkramer J., Krautkramer H.: Ultrasonic testing of materials, 4th edition (1990), Springer, Berlin, New York
- [2] Krautkrämer, J. und Krautkrämer, H., Werkstoffprüfung mit Ultraschall, Springer Verlag — Berlin, Heidelberg, New York, London, Paris, Tokyo, 1986
- [3] EN 1370, *Founding — Examination of surface condition*

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