

Non-destructive testing — Ultrasonic testing of steel bars

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British Standard

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National foreword

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en acier

Zerstörungsfreie Prüfung — Ultraschallprüfung von Stäben
aus Stahl

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

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Foreword

This European Standard has been prepared by Technical Committee ECISS/TC 2, Steel — Physico-chemical and non-destructive testing, the Secretariat of which is held by AFNOR.

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of an identical text or by endorsement, at the latest by May 2002, and conflicting national standards shall be withdrawn at the latest by May 2002.

Annex A is informative.

This standard includes a Bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard describes the techniques to be used for the manual, pulse-echo, ultrasonic testing of steel bars of diameter or equivalent thickness less or equal to 400 mm or equivalent section. Mechanized, semi-automatic or automatic techniques may be used but should be agreed between the purchaser and the supplier.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 473, *Non-destructive testing — Qualification and certification of NDT personnel — 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*.

3 Terms and definitions

Definitions for general terms of non-destructive testing can be found in other European Standards, e.g. EN 1330-1 and EN 1330-2. For the purposes of this European Standard, the following terms and definitions given in EN 1330-4 apply, together with the following.

3.1

manual testing

testing by an operator applying an ultrasonic probe, or probes, to the product surface, manually executing the appropriate scanning pattern on the product surface and assessing ultrasonic signal indications on the electronic equipment screen either by direct viewing or by built-in signal amplitude alarm devices

3.2

automatic and semi-automatic testing

testing using a mechanized means of applying the ultrasonic probe or probes to, and executing the appropriate scanning pattern on the flat product surface, together with ultrasonic signal indication evaluation by electronic means

NOTE Such testing can be either fully automatic with no operator involvement, or semi-automatic when the operator performs basic equipment operation functions.

A list of equivalent terms in several European languages is given in Annex A.

4 Items for agreements

The following aspects concerning ultrasonic testing shall be agreed between the purchaser and supplier at the time of the enquiry or order:

- a) the manufacturing stage(s) at which ultrasonic testing shall be performed (see clause 10);
- b) the volume(s) to be tested and whether grid scanning coverage or complete scanning coverage is required (see clause 13);
- c) the Quality Class required, or the Quality Classes and the zones to which they apply (see clause 15);
- d) the applicable evaluation level and acceptance criteria if different from those detailed in Tables 2 and 3;
- e) whether any special scanning coverage, equipment or couplant is required in addition to that detailed in clauses 8 and 13;
- f) the scanning technique to be used if not manual;
- g) the sizing techniques to be used for extended discontinuities (see clause 16);
- h) the technique(s) to be used for setting sensitivity (see clause 12);
- i) whether the test is to be conducted in the presence of the purchaser or his representative;
- j) whether a written procedure shall be submitted for approval by the purchaser (see clause 6).

5 Principle

The method used is based on the reflection of ultrasonic waves (generally longitudinal), the direction of which is approximately perpendicular to the surface of the product. The examination consists of:

- a) locating and evaluation of discontinuity by comparing the amplitude of the discontinuity echo with the amplitude of the echo of a flat-bottomed hole of a given diameter and located at the same depth as the discontinuity.

NOTE Only those discontinuities giving an echo in amplitude equal to or greater than that obtained with the reference flat-bottomed hole are taken into consideration.

- b) determining the area of the discontinuity according to the -6 dB beam width technique.

If areas with particular permeability are located, the testing conditions shall be adjusted in order to test these areas with the required sensitivity level.

The examination is carried out during the first ultrasonic scan (first back wall echo) for all the product thicknesses or diameter and from one side only.

6 Procedure

The inspection is normally carried out in the place of production or on the premises of the supplier. If specified on the order, the inspection may take place in the presence of the purchaser or his representative¹⁾.

Ultrasonic testing shall be performed in accordance with a written procedure. Where specified in the enquiry or order, the written procedure shall be submitted to the purchaser for approval prior to testing.

This written procedure shall be in the form of:

- a) a product specification or;
- b) a procedure written specifically for the application or;
- c) this European Standard may be used if it is accompanied by examination details specific to the application.

The procedure shall contain the following details as a minimum requirement:

- a) description of the item to be examined;
- b) reference documents;
- c) qualification and certification of examination personnel;
- d) stage of manufacture at which the examination is carried out;
- e) examination zones specified in terms of the applicable Quality Classes;
- f) any special preparation of scanning surfaces, if applicable;
- g) couplant;
- h) description of examination equipment;
- i) calibration;
- j) scanning plan;
- k) description and sequence of examination operations;
- l) recording level;
- m) characterization of discontinuities;
- n) acceptance criteria;
- o) examination report.

7 Personnel qualification

It is assumed that ultrasonic testing is performed by qualified and capable personnel. In order to prove this qualification, it is recommended to certify the personnel in accordance with EN 473 or equivalent.

¹⁾ In this case, all steps should be taken to ensure that the production process is not disturbed.

8 Ultrasonic test equipment

8.1 Instrument

Instrument for manual testing shall feature A-scan presentation and shall comply with the requirements of EN 12668-1.

8.2 Probe

8.2.1 General

Single transducer probes and double transducer probes shall conform to the requirements of EN 12668-2.

Additionally, other types of probes may be used. Such supplementary probes need not to comply with EN 12668-2 requirements.

8.2.2 Contouring

Probes shall be contoured when required according to EN 583-2.

8.2.3 Nominal frequency

Probes shall have a nominal frequency in the range from 1 MHz to 6 MHz.

8.2.4 Type of Probes

The greatest transducer dimension shall be in the range from 9 mm to 25 mm, unless otherwise agreed. Double transducer probes can be used for bars with sizes up to 150 mm diameters or thickness.

Single transducer probes shall be used for bars with diameter or thickness greater than 60 mm.

8.3 Calibration blocks

Calibration blocks shall conform to the requirements detailed in EN 12223.

8.4 Reference blocks

References blocks shall be made from a material having similar acoustic properties to the product to be examined. The surface condition of the reference block shall be representative of the surface condition of the bars to be examined. Unless otherwise specified the reference block shall contain at least three reflectors covering the entire depth range under examination.

The form of the reference block will depend upon the application.

The bottom of the holes shall be as flat as practicable, parallel to the ultrasound entry surface and free from pits or score marks that significantly degrade its ultrasonic reflectivity. The tolerance on the diameter of the flat-bottomed hole or width of recess shall be $\pm 5\%$.

8.5 Couplant

The couplant used shall be appropriate to the application. The same type of couplant shall be used for calibration, setting sensitivity, scanning and evaluation of discontinuities.

After examination, couplant shall be removed if its presence could adversely affect later manufacturing or inspection operations or the integrity of the component.

NOTE Water is normally used but other coupling media may be used at the discretion of the supplier.

9 Routine calibration and checking

The combined equipment (instrument and probes) shall be calibrated and checked in accordance with the requirements detailed in EN 12668-3.

10 Stage of manufacture

Ultrasonic testing shall be performed after the final quality heat treatment unless otherwise agreed at the time of enquiry and order.

11 Surface condition

Scanning surfaces shall be free from paint, non-adhering scale, dry couplant, surface irregularities or any other substance which could reduce coupling efficiency, hinder the free movement of the probe or cause errors in interpretation. The surface condition shall be considered acceptable providing the specified quality class can be achieved.

12 Sensitivity setting

Sensitivity shall be sufficient to ensure the detection of the smallest discontinuities required by the recording/evaluation levels (see Tables 2 and 3).

One of the following techniques shall be used to establish sensitivity for scanning with a particular probe. The procedure to be used in each case shall be as detailed in EN 583-5.

- a) Distance Amplitude Curve (DAC) technique, based upon the use of flat-bottomed holes (FBH);
- b) distance gain size (DGS) technique.

13 Scanning

13.1 General

Manual scanning shall be performed using the manual contact pulse-echo technique.

The minimum scanning coverage required is dictated by the type of bars and whether grid scanning coverage or complete scanning coverage has been specified in the enquiry or order.

Table 1 classifies two types of bars according to their shapes and specifies the requirements for normal scanning coverage for bars.

13.2 Grid scanning coverage

Grid scanning shall be performed with the probe or probes traversed along the grid lines defined in Table 1.

Where recordable indications are revealed by grid scanning, additional scanning shall be performed to determine the extent of the indications.

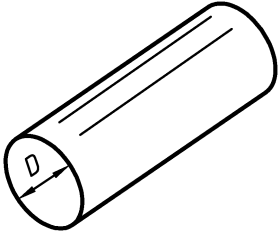
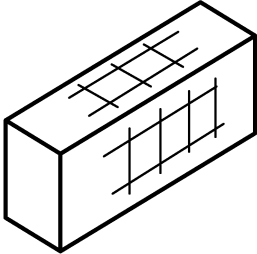
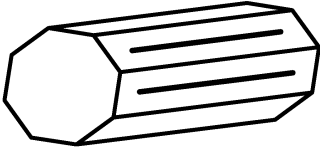
13.3 Complete scanning coverage

Complete scanning coverage shall be performed over the surfaces specified in Table 1, by overlapping consecutive probe traverses by at least 10 % of the transducer diameter.

13.4 Scanning speed

Manual scanning speed shall not exceed 150 mm/s.

Table 1 — Scanning coverage with normal probes

Type	Grid scanning ^{a b}		Complete scanning ^{a b}
1a 	Diameter, <i>D</i> or thickness, <i>t</i> mm	Scan lines ^c	Scan completely around at least 180° of cylindrical surface
	<i>D</i> ≤ 200 200 < <i>D</i> ≤ 400	2 at 90° 3 at 60° or 120°	
1b 	<i>t</i> ≤ 150 150 < <i>t</i> ≤ 400	1 line on 2 faces 3 lines on 2 faces ^d	Scan completely on two perpendicular surfaces
1c 	<i>t</i> ≤ 150 150 < <i>t</i> ≤ 400	1 line on 2 faces 1 line on at least half number of faces	Scan completely on at least half adjacent faces
<p>^a Additional scanning may be carried out if specified in the enquiry or order.</p> <p>^b A scanning may be carried out following a sinusoidal pattern or zigzag line over the complete length of the area giving the same degree of control.</p> <p>^c For type 1a or 1b, if the presence of a bore prevents the opposite surface being reached, the number of scan line shall be doubled symmetrically.</p> <p>^d The grid line separation shall be equal to the part thickness up to a maximum of 200 mm.</p>			

14 Classification

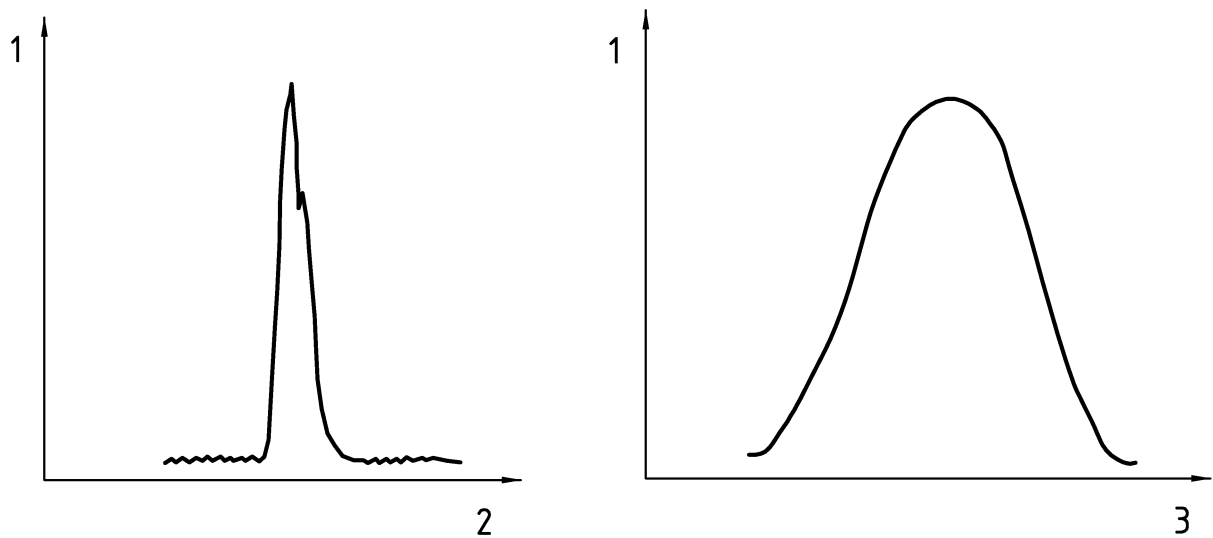
14.1 Classification of indications

Indications shall be classified according to their echodynamic patterns, as follow:

a) Pattern 1

As the probe is moved, the A-scan display shows a single sharp indication rising smoothly in amplitude to a maximum and then falling smoothly to zero (see Figure 1).

This pattern corresponds to discontinuity dimensions smaller than or equal to the –6 dB beam profile, such as the echodynamic pattern obtained from the side-drilled holes used to plot the beam profile.



Key

- 1 Amplitude
- 2 Range
- 3 Probe position

A-scan presentation (at typical probe position)

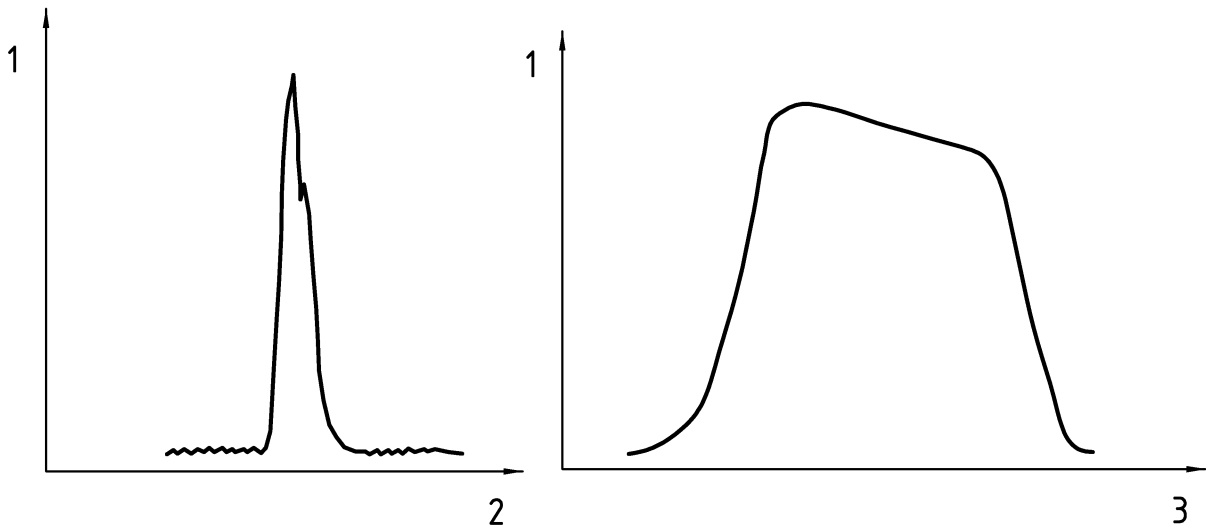
Echodynamic pattern (variation in signal amplitude as probe is moved)

Figure 1 — Pattern 1 A-scan presentation and echo envelope presentation

b) Pattern 2

As the probe is moved, the A-scan display shows a single sharp indication rising smoothly in amplitude to a maximum which is maintained with or without amplitude variation, and then falling smoothly to zero (see Figure 2).

This pattern corresponds to discontinuity dimensions greater than the -6 dB profile.



Key

- 1 Amplitude
- 2 Range
- 3 Probe position

A-scan presentation (at typical probe position)

Echodynamic pattern (variation in signal amplitude as probe is moved)

Figure 2 — Pattern 2 A-scan presentation and echodynamic pattern

14.2 Classification of discontinuities

Discontinuities shall be classified according to their echodynamic patterns as follows:

- a) point discontinuity;

Echodynamic pattern 1 and/or dimension equal to or less than the -6 dB beam width (see Figure 3a).

- b) extended discontinuity;

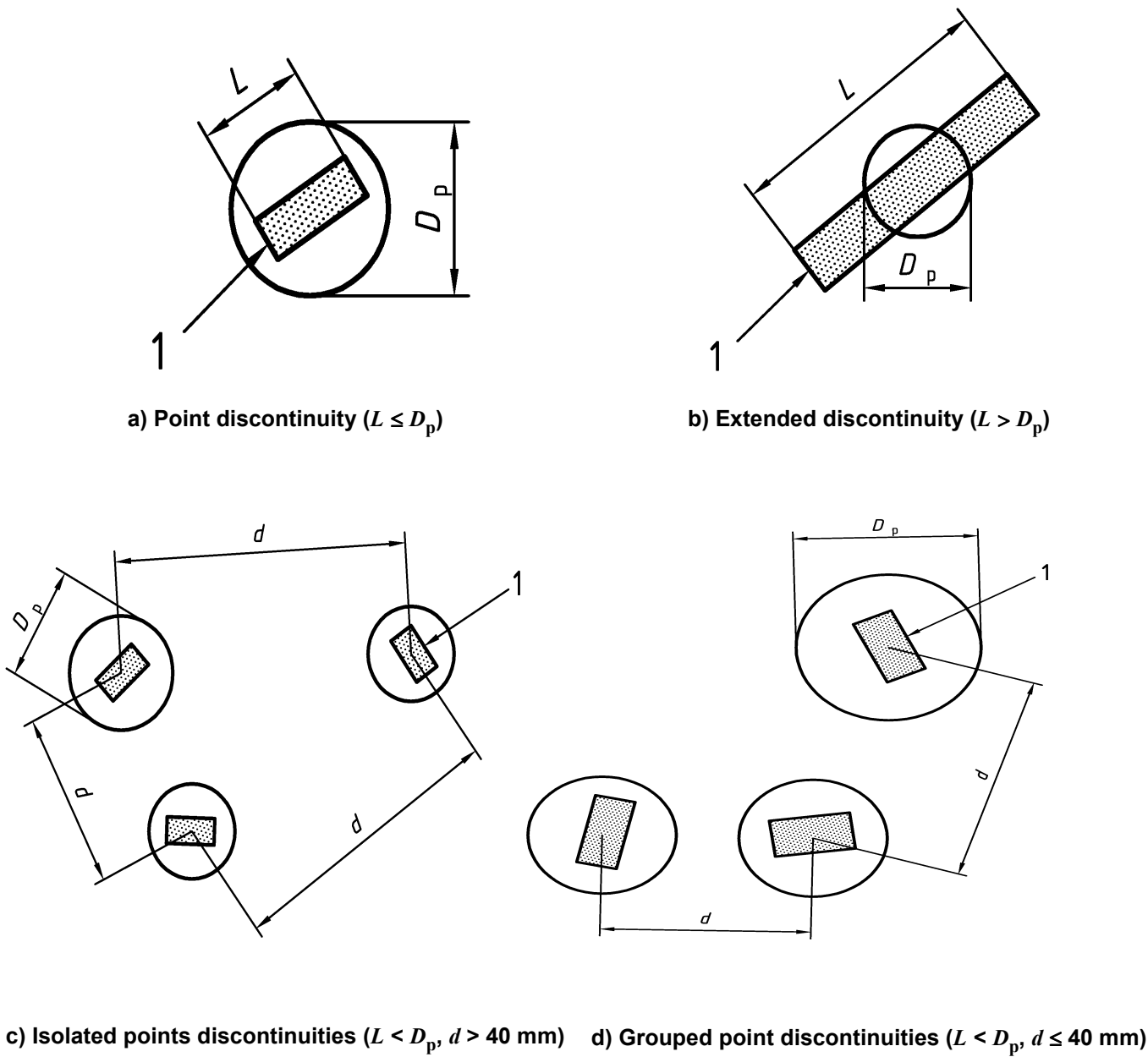
Echodynamic pattern 2 and/or dimension greater than the -6 dB width (see Figure 3b).

- c) isolated discontinuities;

The distance d , between points corresponding to the maxima of the indications of adjacent discontinuities exceeds 40 mm (see Figure 3c).

- d) grouped discontinuities.

The distance d , between points corresponding to the maxima of the indications of adjacent discontinuities is less than or equal to 40 mm (see Figure 3d).



Key

1 Conventional outline of -6 dB discontinuity

Symbols used

D_p Width of beam at depth of discontinuity

d Distance between two discontinuities

L Conventional length of -6 dB discontinuity

Figure 3 — Classification of discontinuities

15 Recording level and acceptance criteria

Several Quality Classes may be applied to bars. The applicable Quality Class(es) shall be agreed between the purchaser and supplier. Tables 2 and 3 details recording level and acceptance criteria, which shall be applied to three Quality classes for normal probes.

Table 2 — Quality classes, recording level and acceptance criteria for ferritic and martensitic steel bars

Parameter	Quality Class			
	1	2	3	4
Recording level				
Equivalent flat-bottomed holes (EFBH) d_{eq} mm ^a	> 8	> 5	> 3	> 2
Ratio R for rapid backwall echo reduction ^{b c}	≤ 0,1	≤ 0,3	≤ 0,5	≤ 0,5
Acceptance criteria				
EFBH (Isolated point type discontinuities) d_{eq} mm ^a	≤ 12	≤ 8	≤ 5	≤ 3
EFBH (Extended or grouped point type discontinuities) d_{eq} mm ^a	≤ 8	≤ 5	≤ 3	≤ 2
^a d_{eq} = Equivalent diameter of flat-bottomed hole.				
^b $R = \frac{F_n}{F_{o,n}}$				
where				
$n = 1$ for $t \geq 60$ mm;				
$n = 2$ for $t < 60$ mm;				
F_n = amplitude (screen height) of the n^{th} reduced backwall echo;				
$F_{o,n}$ = amplitude (screen height) of the n^{th} backwall echo in the nearest discontinuity-free area at the same range as F_n .				
^c If the reduction in backwall echo exceeds the recording level, this shall be further investigated. Ratio R applies only to rapid reduction of backwall echo caused by the presence of a discontinuity.				

Table 3 — Quality class, recording level and acceptance criteria for austenitic and austenoferritic steel bars

Bars thickness	Recording level d_{eq} ^a	Acceptance criteria for isolated discontinuities d_{eq} ^a	Acceptance criteria for extended and grouped discontinuities d_{eq} ^a
mm	mm	mm	mm
Quality class 1			
$t \leq 75$	> 5	≤ 8	≤ 5
$75 < t \leq 250$	> 8	≤ 11	≤ 8
$250 < t \leq 400$	> 14	≤ 19	≤ 14
Quality class 2			
$t \leq 75$	> 3	≤ 5	≤ 3
$75 < t \leq 250$	> 5	≤ 8	≤ 5
$250 < t \leq 400$	> 8	≤ 11	≤ 8
Quality class 3			
$t \leq 75$	> 2	≤ 3	≤ 2
$75 < t \leq 250$	> 3	≤ 5	≤ 3
$250 < t \leq 400$	> 5	≤ 8	≤ 5
^a d_{eq} = Equivalent diameter of flat-bottomed hole.			

16 Sizing

Where the extent of a discontinuity is required to be evaluated, one or more of the following techniques, as agreed between the purchaser and the supplier, shall be used. These techniques shall be carried out in accordance with the requirements detailed in EN 583-5:

- a) -6 dB-drop technique;
- b) 20 dB-drop technique;
- c) maximum amplitude technique.

17 Test report

The test report shall include the following information as a minimum requirement:

- a) name of supplier;
- b) order number;
- c) identification of product(s) under examination;
- d) scope of examination: examination zones and applicable Quality Classes;
- e) stage of manufacture at which ultrasonic testing was performed;
- f) surface condition;
- g) equipment used (instrument, probes, calibration and reference blocks);
- h) technique(s) used to set sensitivity;
- i) reference to this standard or reference to the written procedure used (where applicable);
- j) results of examination: location, classification of all discontinuities exceeding the appropriate recording level;
- k) details of any restrictions to the scanning coverage;
- l) date of examination;
- m) name, qualification and signature of operator.

Annex A
(informative)

List of equivalent terms in several European languages

English	French	German	Italian	Dutch
Time base	Base de temps	Zeitbasis	Base dei tempi	Tijdbasis
Noise signal	Bruit de fond	Rauschanzeige	Rumore di fondo	Ruis
Discontinuity echo	Echo de défaut	Fehlerecho	Eco del difetto	Foutecho
Back-wall echo	Echo de fond	Rückwandecho	Eco di fondo	Bodemecho
Probe	Traducteur	Prüfkopf	Sonda	Taster
Double transducer probe	Traducteur émetteur récepteur séparés	SE-Prüfkopf	Sonda ed emettitore e ricevitore separati (sonda doppia)	Dubbel-Kristaltaster
Single transducer probe	Traducteur droit	Einschwinger - Prüfkopf	Sonda normale	Rechtetaster
Transducer	Transducteur	Schwinger	Transduttore	Kristal
Flat-bottomed hole	Trou à fond plat	Flachbodenbohrung	Foro a fondo piatto	Vlakbodemgat

Bibliography

- [1] EN 1330-1, *Non-destructive testing — Terminology — Part 1: List of general terms.*
- [2] EN 1330-2, *Non-destructive testing — Terminology — Part 2: Terms common to the non-destructive testing methods.*

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