

Founding — Ultrasonic examination —

Part 2: Steel castings for highly stressed components

The European Standard EN 12680-2:2003 has the status of a
British Standard

ICS 77.040.20

National foreword

This British Standard is the official English language version of EN 12680-2:2003.

The UK participation in its preparation was entrusted to Technical Committee ISE/NFE/9, Foundry technology, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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Foreword

This document (EN 12680-2:2003) 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of an identical text or by endorsement, at the latest by July 2003, and conflicting national standards shall be withdrawn at the latest by July 2003.

Within its programme of work, Technical Committee CEN/TC 190 requested CEN/TC 190/WG 4.10 "Inner defects" to prepare the following standard:

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

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

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

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

Annex A is normative. Annexes B and C are informative.

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, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies the requirements for the ultrasonic examination of steel castings (with ferritic structure) for highly stressed components and the methods for determining internal discontinuities by the pulse echo technique.

This European Standard applies to the ultrasonic examination of steel castings which have usually received a grain refining heat treatment and which have wall thicknesses up to and including 600 mm.

For greater wall thicknesses, special agreements apply with respect to test procedure and recording levels.

This European Standard does not apply to austenitic steels and joint welds.

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 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 583-5:2000, *Non-destructive testing — Ultrasonic examination — Part 5: Characterization and sizing of discontinuities.*

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 27963, *Welds in steel — Calibration block No. 2 for ultrasonic examination of welds (ISO 7963:1985).*

3 Terms and definitions

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

NOTE Other terms and definitions used in this European Standard are given in EN 583-1, EN 583-2, EN 583-5 and EN 1330-4.

3.1 reference discontinuity echo size

smallest indication to be recorded during the assessment phase of an ultrasonic examination, usually expressed as an equivalent flat-bottomed hole diameter

3.2 point discontinuity

discontinuity, the dimensions of which are smaller than or equal to the sound-beam diameter

4

NOTE Dimensions in this standard relate to length, width and/or dimension in through-wall direction.

3.3

complex discontinuity

discontinuity, the dimensions of which are larger than the sound-beam diameter

NOTE Dimensions in this standard relate to length, width and/or dimension in through-wall direction.

3.4

planar discontinuity

discontinuity having two measurable dimensions

3.5

volumetric discontinuity

discontinuity having three measurable dimensions

3.6

special rim zone

outer rim zone part with special requirements (for e.g. machined surfaces, higher stresses, sealing surfaces)

3.7

production welding

any welding carried out during manufacturing before final delivery to the purchaser

3.7.1

joint welding

production welding used to assemble components together to obtain an integral unit

3.7.2

finishing welding

production welding carried out in order to ensure the agreed quality of the casting

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 examination requirements apply;
- the severity level to be applied to the various zones or areas of the casting;
- requirements for a written examination procedure;
- whether there are any additional requirements for the examination procedure, see also 5.5.1.

4.2 Extent of examination

The casting shall be examined so that the agreed areas are totally covered (insofar as this is possible from the shape of the casting) by the use of the best applicable examination technique.

For wall thicknesses greater than 600 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

4.3.1 General

The purchaser shall specify the acceptance level according to the required severity level for planar and volumetric discontinuities within each zone and in each specified area of the casting.

The wall section shall be divided into zones as shown in Figure 1. These sections relate to the sizes of castings ready for assembly (finish machined).

4.3.2 Indications without measurable dimensions

In special rim zones and at weld preparation ends, indications without measurable dimensions are limited to a maximum number of indications.

These indications shall not exceed the limits given in Table 1.

4.3.3 Indications with measurable dimensions

4.3.3.1 Planar discontinuities

Planar discontinuities shall not exceed the limits given in Figure 2.

The area of indication with measurable length but with non-measurable dimension in through-wall direction shall be calculated according to the formula given in Figure 2.

The sizing of small planar discontinuities, as given in Figure 2, becomes more difficult with increasing beam-path length and sound-beam diameter. As a guide, these sizings are normally applied to a rim zone of 30 mm. It makes the use of probes with focussed beams such as twin-crystal probes necessary.

4.3.3.2 Volumetric discontinuities

Volumetric discontinuities shall not exceed the sizes given in Figure 3 for rim zone and Figure 4 for core zone. Indications with measurable dimensions are not permissible in severity level 1. The area of an indication with measurable length but non-measurable width shall be calculated in accordance with the formula given in Figures 3 and 4.

4.4 Personnel qualification

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

4.5 Wall section zones

The wall section shall be divided into zones as shown in Figure 1. These sections relate to the dimensions of the casting ready for assembly (finish machined).

4.6 Severity levels

If the purchaser specifies different severity levels in different areas of the same casting, all of these areas shall be clearly identified on the purchaser's drawing and shall include:

- all necessary dimensions for accurate location of zones;
- the full extent of all weld preparations and the thickness of any special rim zone.

Severity level 1 is only applied to weld preparations and special rim zones.

Unless other requirements have been agreed by the time of acceptance of the order, for finishing welds, the requirements for the parent metal shall apply.

5 Examination

5.1 Principles

The principles of ultrasonic examination given in EN 583-1, EN 583-2 and EN 583-5 shall apply.

5.2 Material

The suitability of material for ultrasonic examination is assessed by comparison with the echo height of a reference reflector (usually the first backwall 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 according to Table 2 shall be at least 6 dB above the noise signal.

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 grass 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-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 For the definition of an adequate flat-bottomed hole size, the distance gain size system (DGS) or a test block of identical material, heat treatment condition and section thickness containing flat-bottomed holes with a diameter according to Table 2 or equivalent side-drilled holes, can be used. The following formula is used for converting the flat-bottomed hole diameter into the side-drilled hole diameter:

$$D_Q = \frac{4,935 \times D_{FBH}^4}{\lambda^2 \times s} \quad (1)$$

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 formula is applicable for $D_Q \geq 2 \lambda$ and $s \geq 5 \times$ near-field length and is only defined for single element probes.

5.3 Equipment, coupling medium, sensitivity and resolution of detection

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 1 MHz up to and including 6 MHz in pulse-echo technique with single-crystal and twin-crystal probes.

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:

- nominal frequencies shall be in the range 1 MHz to 6 MHz;
- for oblique incidence, angle probes with angles between 35° and 70° shall be used.

NOTE Normal or angle probes can be used for the examination of steel castings for highly stressed components. The type of probe used depends on the geometry of the casting and the type of discontinuity to be detected.

For examining zones close to the surface, twin-crystal probes (normal or angle) should be preferred.

5.3.3 Checking the ultrasonic examination equipment

The ultrasonic examination 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 examination area to ensure satisfactory sound transmission. The same coupling medium shall be used for calibration and all subsequent examination operations.

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

5.3.5 Sensitivity and resolution of detection

The detection sensitivity of the instrument shall allow at least the setting of the sensitivity in accordance with the requirements of 5.5.2.

The resolution of detection of the instrument/probe combination shall meet the requirements of annex A.

5.4 Preparation of casting surfaces for testing

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

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

In the case of single-crystal probes, satisfactory coupling can be achieved if the condition of the surfaces to be examined corresponds at least to the limit comparator 4 S1 or 4 S2 according to EN 1370.

The roughness of any machined surface to be examined shall be $R_a \leq 12,5 \mu\text{m}$.

For special techniques, higher surface qualities such as 2 S1, 2 S2 (see EN 1370) and $R_a \leq 6,3 \mu\text{m}$ can be necessary.

5.5 Examination procedure

5.5.1 General

Because the choice of both the direction of incidence and suitable probes largely depends on the shape of the casting or on the possible casting discontinuities or on the possible discontinuities from finishing welding, the applicable examination procedure shall be specified by the manufacturer of the casting. In special cases, specific agreements can be made.

If possible, the areas to be tested shall be examined from both sides. When testing from one side only, short-range resolving probes shall be used additionally for the detection of discontinuities close to the surface. Testing with twin-crystal probes is only adequate for wall thicknesses up to 50 mm.

Additionally, when not otherwise agreed between the purchaser and the manufacturer, for all castings, twin-crystal normal and/or angle probes shall be used to examine the following areas up to a depth of 50 mm:

- critical areas, e.g. fillets, changes in cross-section, areas with external chills;
- finishing welds;
- weld preparation areas as specified in the order;
- special rim zones, as specified in the order, critical for the performance of the casting.

Finishing welds which are deeper than 50 mm shall be subject to supplementary examination with other suitable angle probes.

For angle probes with angles over 60° , the sound beam path shall not exceed 150 mm.

Complete coverage of all areas specified for examination shall be conducted by carrying out systematically overlapping scans.

The scanning rate shall not exceed 150 mm/s.

5.5.2 Range setting

Range setting shall be carried out in accordance with EN 583-2 on the screen of the test instrument using normal or angle probes in accordance with one of the three options given below:

- with the calibration block in accordance with No. 1 EN 12223 or No. 2 in accordance with EN 27963;
- with an alternative calibration block made in a material exhibiting similar acoustic properties to those of the material to be examined;
- on the casting itself when using normal probes. In this case, the casting to be tested shall have parallel surfaces, the distance between which shall be measured.

5.5.3 Sensitivity setting

5.5.3.1 General

Sensitivity setting shall be carried out after range setting (see 5.5.2) in accordance with EN 583-2. One of the following two techniques shall be used:

- Distance-amplitude correction curve technique (DAC)

The distance-amplitude correction curve technique makes use of the echo-heights of a series of identical reflectors (flat-bottomed holes FBH or side-drilled holes SDH), each reflector having a different sound-beam path.

NOTE A frequency of 2 MHz and a diameter of 6 mm for the flat-bottomed holes are most commonly used.

- Distance gain size technique (DGS)

The distance gain size technique makes use of a series of theoretically derived curves which link the sound-beam path, the apparatus gain and the diameter of a disc-shaped reflector which is perpendicular to the beam axis.

5.5.3.2 Transfer correction

Transfer correction shall be determined according to EN 583-2.

When calibration blocks are used, transfer correction can be necessary. When determining the transfer correction, consideration shall be given not only to the quality of the coupling surface but also to that of the opposite surface because the opposite surface also influences the height of the backwall echo (used for calibration). If the opposite surface is machined or complies at least to the limit comparator 4 S1 or 4 S2 according to EN 1370, this surface has a quality which is sufficient for transfer correction measurements.

5.5.3.3 Detection of discontinuities

For discontinuity detection, the gain shall be increased until the noise level becomes visible on the screen (search sensitivity).

The echo heights of the flat-bottomed holes given in Table 2 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, during testing, suspicion arises that the reduction of backwall echo indication exceeds the recordable value (see Table 3), testing shall be repeated using locally reduced test sensitivity and the reduction of backwall echo indication shall be determined quantitatively in decibels.

The sensitivity setting of angle -beam probes shall be such that the typical dynamic echo pattern of these reflectors (see Figure 3) is clearly visible on the screen.

NOTE It is recommended that the sensitivity setting of angle-beam probes is verified on real (not artificial) planar discontinuities (cracks with dimensions in through-wall direction) or on walls perpendicular to the surface and infinite to the sound beam. In these circumstances, the probe shoe should be contoured to fit the casting shape (see EN 583-2).

5.5.4 Consideration of various types of indications

The following types of indications can occur separately or jointly during the examination of castings and shall be observed and evaluated:

- reductions of backwall echo which are not due to the casting shape or the coupling;
- echo indications of discontinuities.

The reduction of backwall echo is expressed in decibels as the drop of the backwall echo height. The height of the echo indication is given as flat-bottomed or side-drilled hole diameter.

5.5.5 Recording and recording limits

5.5.5.1 Reduction of backwall echo

All backwall echo reductions in excess of 12 dB (for a nominal test frequency of 2 MHz) shall be recorded. The backwall echo reductions to be recorded shall be marked and measured as indication areas.

5.5.5.2 Echo indications from discontinuities

The recording limit of an echo indication is defined by its signal amplitude according to a reference discontinuity echo size.

All echo indications from discontinuities with measurable dimensions shall be recorded, when the signal amplitude exceeds both the levels given in Table 3 and the criteria given in Figures 3 and 4.

Distinction shall be made between the different types of indications given in Table 4.

To identify the type of indication, the test sensitivity can be changed according to the distance from the test surface, the geometrical shape and the surface finish of the test surface.

When using transverse wave probes, irrespective of amplitude, all indications which display travelling characteristics or have an apparent dimension in through-wall direction shall be recorded for subsequent assessment according to 5.5.7.3.

Each location where indications to be recorded have been found, shall be marked and indicated in the test report. The location of reflection points shall be documented, e.g. by sketch or by photograph.

5.5.6 Investigation of indications to be recorded

The locations where indications to be recorded have been found (see 5.5.5) shall be investigated more closely with respect to their type, shape, size and position. This investigation can be achieved by altering the ultrasonic test technique (e.g. changing the angle of incidence) or by additionally carrying out radiographic examination.

5.5.7 Characterization and sizing of discontinuities

5.5.7.1 General

For characterization and sizing of discontinuities see EN 583-5.

The ultrasonic determination of the dimensions of a discontinuity with an accuracy sufficient for engineering applications is only possible under certain preconditions (e.g. knowledge of the type of discontinuity, simple geometry of the discontinuity and optimum impact of the sound beam on the discontinuity).

The characterization of the type of discontinuities can be improved by using additional sound directions and angles of incidence. For simplification of the procedure, the following categorizations of discontinuities are made:

- discontinuities without measurable dimensions (point discontinuities);
- discontinuities with measurable dimensions (complex discontinuities).

NOTE 1 Annex B gives information on sound-beam diameters in order to distinguish between discontinuities with or without measurable dimensions.

NOTE 2 Annex C gives information on types of indications and on the determination of their dimensions. It also gives information on range setting (see 5.5.2) and on sensitivity setting (see 5.5.3).

NOTE 3 For the determination of the dimensions of discontinuities, it is recommended that probes having a sound-beam diameter as small as possible at the location of the discontinuity are used.

5.5.7.2 Sizing of discontinuities mainly parallel to the test surface

The boundaries of any discontinuity shall be defined by the perimeter line at which the signal amplitude falls to 6 dB below the last maximum or at which, in the case of backwall echo reduction, the echo is reduced by 6 dB (2 MHz probe) below the height of the undisturbed backwall echo.

The dimension in through-wall direction of the discontinuity should be measured according to Figure 5.

5.5.7.3 Sizing of discontinuities in through-wall direction

The sizing of planar discontinuities and their assessment in relation to specified severity levels shall be carried out by the probe movement according to 5.5.7.1, but in this case, the echo is reduced by 20 dB (see Figures C.7 and C.9).

5.6 Examination report

The examination report shall contain at least the following information:

- reference to this European Standard (EN 12680-2);
- characteristic data of the examined casting;
- extent of examination;
- type of examination equipment used;
- probes used;
- the examination technique with reference to the examination area;
- all data necessary for sensitivity setting;
- information on all characteristic features of discontinuities to be recorded (e.g. backwall echo reduction, position and dimension in through-wall direction, length, area and flat-bottomed hole diameter) and the description of their position (sketch or photograph);
- date of the examination and name of the responsible person.

Table 1 — Acceptance limits for discontinuities without measurable dimensions in special rim zones and weld preparation ends (scanned by normal or angle probes)

| Severity level ^a | Smallest equivalent flat-bottomed or side-drilled hole diameter to be considered | | Acceptance limits ^c for discontinuities in a frame 100 mm × 100 mm | |
|-----------------------------|--|--|---|------------------------|
| | FBH ^b mm | SDH ^b mm | number max. | distance min. mm |
| 1 | 1,5 | 3 ^{d, e} (with -6 db on DAC) | 6 | 12 |
| 2 | 1,5 | 3 ^{d, e} (with -6 db on DAC) | 12 | 10 |
| 3 | 2 | 3 ^d | 12 | 8 |

^a Severity level 1 generally applies to the complete wall thickness of weld preparation ends. The severity level for special rim zones shall be specified by the purchaser.

^b FBH = flat-bottomed hole, SDH = side-drilled hole.

^c If the indications are more than 15 mm apart they are acceptable irrespective of their number.

^d Applicable to angle probes (4 MHz, crystal diameter approx. 10 mm).

^e A 0,75 mm diameter SDH can be represented by a 3 mm diameter SDH, if the distance-amplitude correction curve of a 3 mm diameter SDH is reduced by 50 %.

Table 2 — Ultrasonic testability requirements

Dimensions in millimetres

| Wall thickness | Tested area | Smallest flat-bottomed hole diameter detectable according to 5.2 |
|----------------|---|--|
| ≤ 100 | — | 2 |
| > 100 to ≤ 300 | — | 3 |
| > 300 to ≤ 600 | — | 4 |
| — | Special rim zone, weld preparation ends | 1,5 |

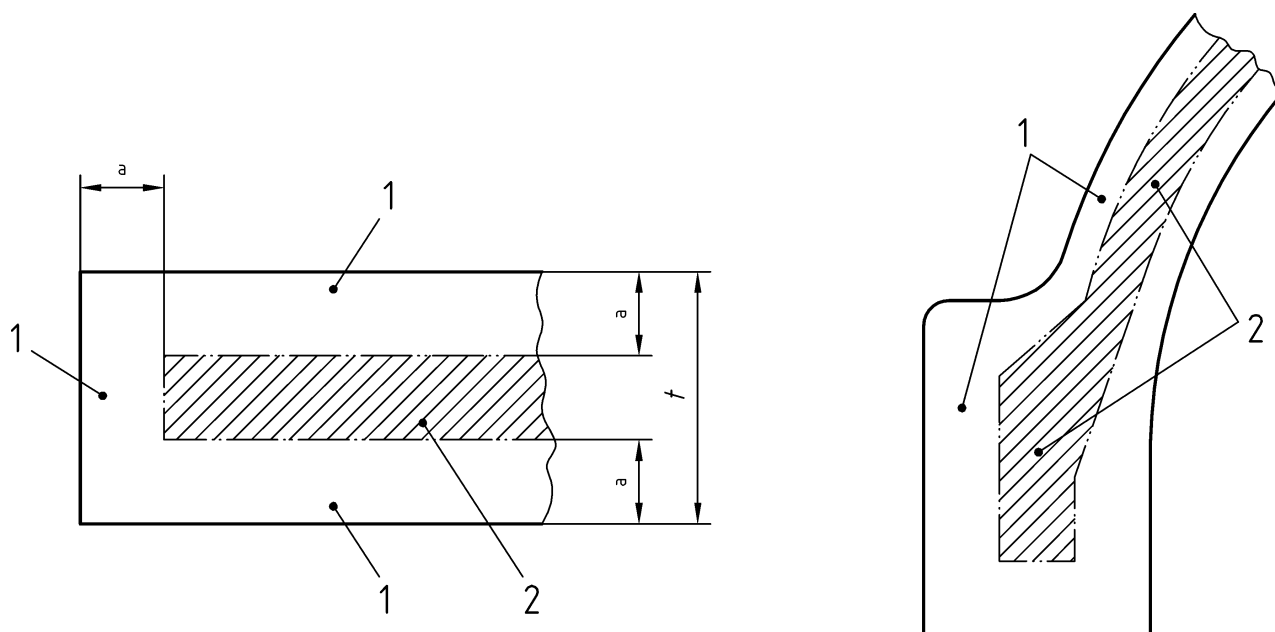
Table 3 — Recording levels

| Wall thickness mm | Smallest equivalent flat-bottomed hole diameter mm | Reduction of backwall echo min. dB |
|----------------------|---|--|
| ≤ 100 | 2 | 12 |
| > 100 to ≤ 300 | 3 | |
| > 300 to ≤ 600 | 4 | |

Table 4 — Reference codes for types of indications

| Reference code ^a | Type of indication | Figure |
|-----------------------------|--|------------|
| SDB | Reduction of backwall echo | C.2 |
| II | Individual indication without measurable dimension | C.3, C.4 |
| IIL | Individual indication with one measurable dimension | C.4, C.5 |
| GIR | Group of resolvable indications | C.6 |
| IIP/IID | Individual indication with two dimensions | C.5, C.7 |
| NII | Numerous indications without measurable dimensions | C.8 |
| NIP | Numerous indications with dimensions in through-wall direction | C.9 |
| GIN | Group of non-resolvable indications | C.10, C.11 |

^a For characterization of indications see EN 583-5:2000, annex B.

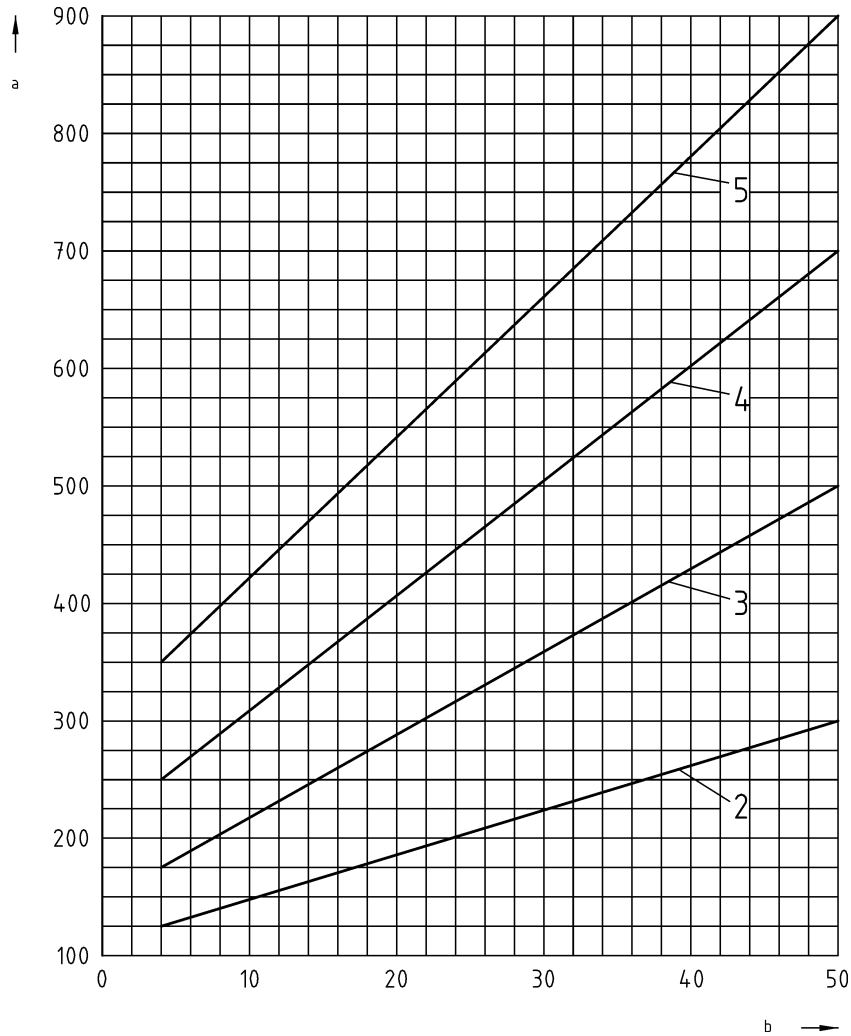
**Key**

- 1 Rim zone
- 2 Core zone

t Wall thickness

a $t/3 \times t$ (max. 30 mm)

Figure 1 — Division of wall section into zones



- Key**
- 2 Severity level 2
 - 3 Severity level 3
 - 4 Severity level 4
 - 5 Severity level 5

- a Largest acceptable individual indication area in square millimetres
- b Distance from test surface in millimetres

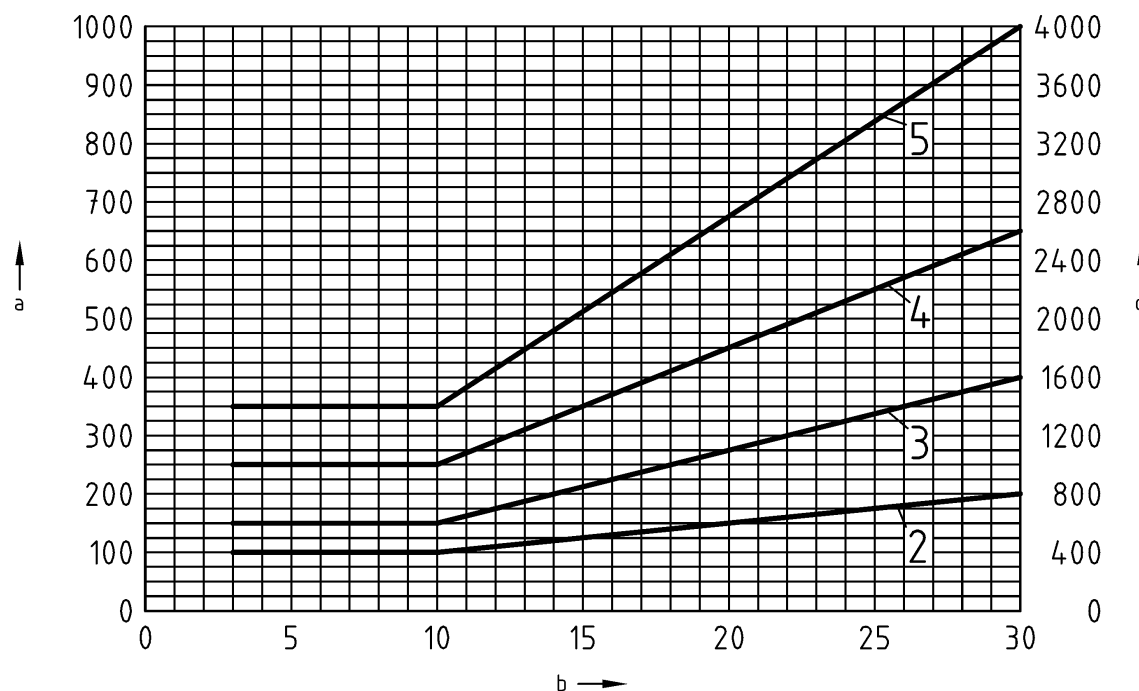
Indications with measurable dimensions are not permissible as severity level 1.

The maximum dimension in through-wall direction shall not exceed 10 % of the wall thickness, except indications with a measurable length ≤ 10 mm. Such indications shall not exceed a dimension in through-wall direction of 25 % of the wall thickness or 20 mm, whichever is the least.

The maximum distance between indications as criterion for evaluation as an individual indication or indication area in through-wall direction or lateral to the surface, shall be 10 mm.

For an area with measurable length and non-measurable dimension in through-wall direction, this non-measurable dimension shall be taken as 3 mm and the area be calculated: $A = 3 \times L$, where A is the area of indication expressed in square millimetres; 3 is the defined width in millimetres; L is the measurable length expressed in millimetres.

Figure 2 — Acceptance limits for individual planar indications mainly orientated in through-wall direction (see also Figures C.8, C.9 and C.11) detected with angle probes



Key

- 2 Severity level 2
- 3 Severity level 3
- 4 Severity level 4
- 5 Severity level 5

- a Smallest indication area to be recorded in square millimetres
- b Shortest distance from test surface or from backwall in millimetres
- c Largest acceptable individual indication area in square millimetres

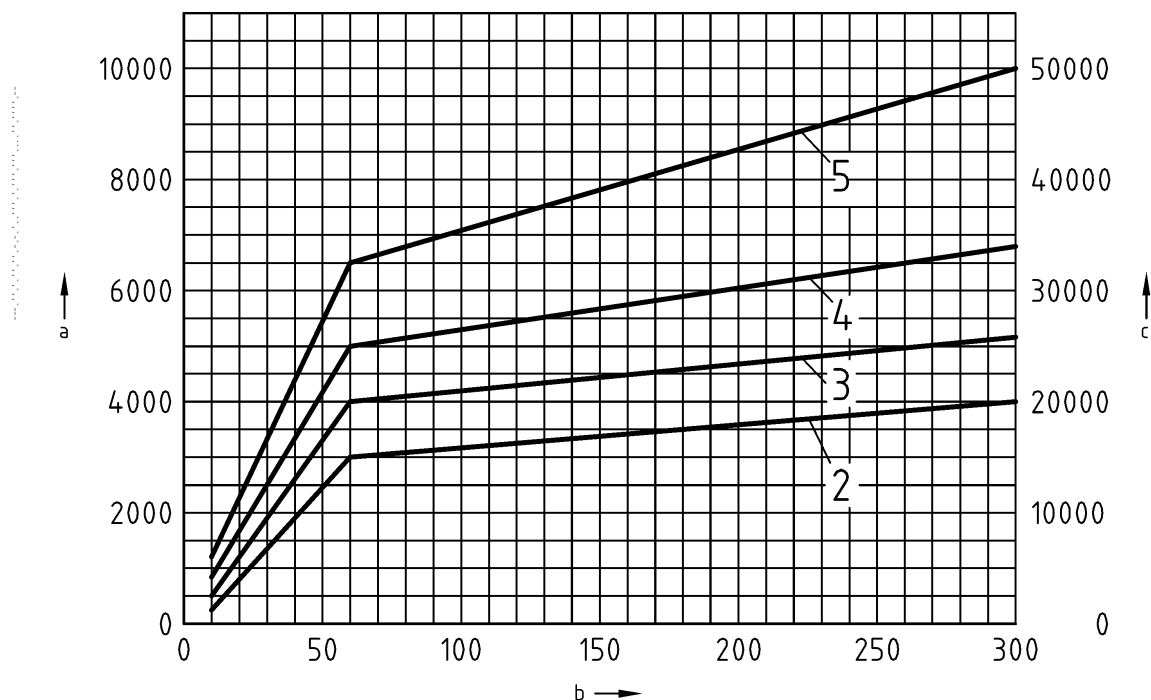
Indications with measurable dimensions are not permissible as severity level 1.

The maximum acceptable dimensions of discontinuities or indication areas in through-wall direction shall be 15 % of the rim zone thickness.

The maximum distance between discontinuities as criterion for evaluation as an individual indication in through-wall direction or lateral to the surface, shall be 10 mm.

For an area with measurable length and non-measurable dimension in through-wall direction, this non-measurable dimension shall be taken as 3 mm and the area be calculated: $A = 3 \times L$, where A is the area of indication expressed in square millimetres; 3 is the defined width in millimetres; L is the measurable length expressed in millimetres.

Figure 3 — Recording and acceptance limits for volumetric indications with measurable dimensions in the rim zone (see also Figures C.2, C.5 and C.10) detected with normal probes



Key

- 2 Severity level 2
- 3 Severity level 3
- 4 Severity level 4
- 5 Severity level 5

- a Smallest indication area to be recorded in square millimetres
- b Shortest distance from test surface or from backwall in millimetres
- c Largest acceptable individual indication area in square millimetres

Indications with measurable dimensions are not permissible in severity level 1.

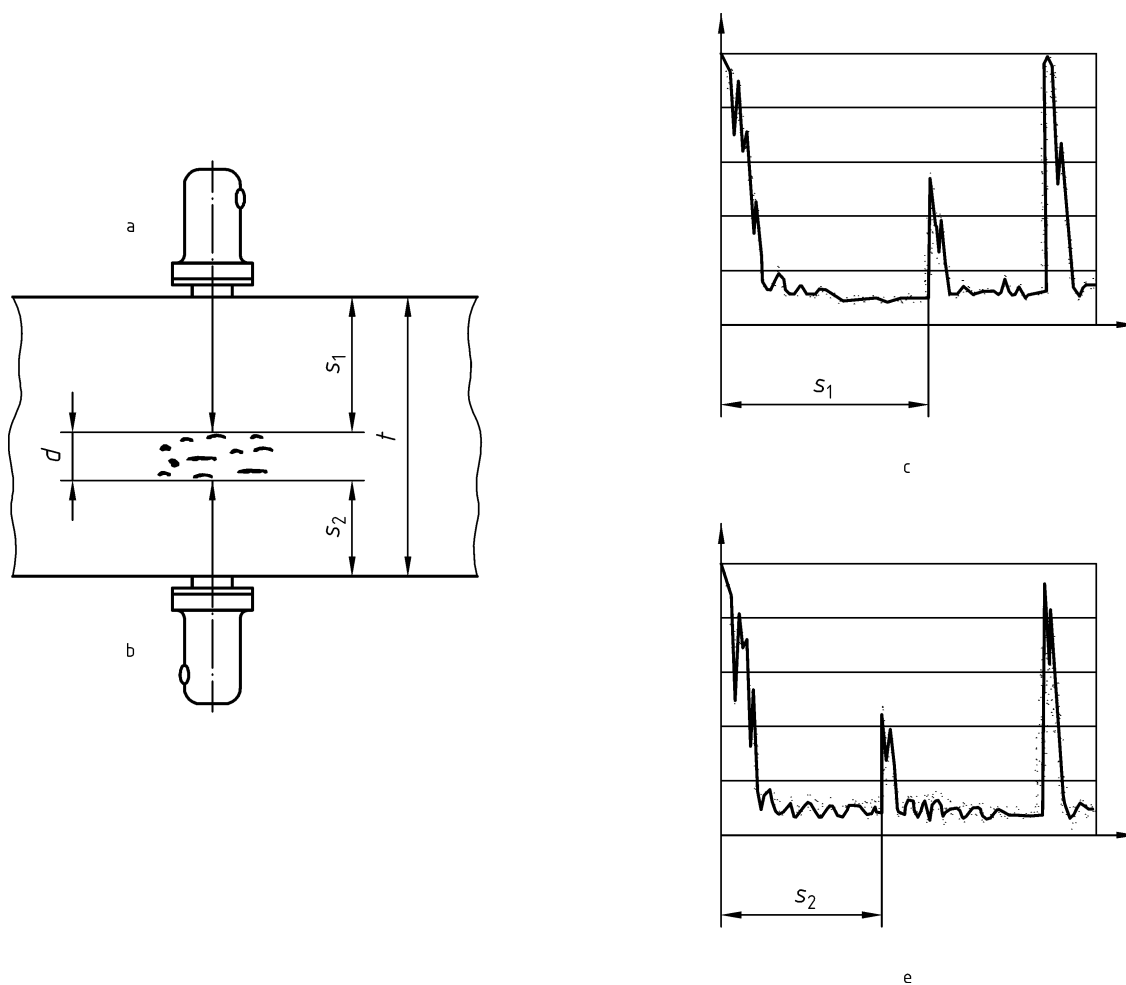
The maximum acceptable dimensions of discontinuities or indication areas in through-wall direction shall be 15 % of the wall thickness.

The maximum distance between discontinuities as criterion for evaluation as an individual indication in through-wall direction or lateral to the surface, shall be 20 mm.

For an area with measurable length and non-measurable dimension in through-wall direction, this non-measurable dimension shall be taken as 3 mm and the area be calculated: $A = 3 \times L$, where A is the area of indication expressed in square millimetres; 3 is the defined width in millimetres; L is the measurable length expressed in millimetres.

Unless otherwise agreed by the time of enquiry and order, when, after conducting the radiographic and the ultrasonic examination in combination, it has been demonstrated that a discontinuity is situated in the core zone, this additional information shall make the discontinuity acceptable at one level less severe, e.g. severity level 3 instead of severity level 2 for radiographic examination, see EN 1559-2.

Figure 4 — Recording and acceptance limits for volumetric indications with measurable dimensions in the core zone (see also Figures C.2, C.5 and C.10) detected with normal probes



Key

- a Scanning position "A"
- b Scanning position "B"
- c A-scan from scanning position "A"
- e A-scan from scanning position "B"

Depth extension $d = t - (s_1 + s_2)$

where

t is the wall thickness;
 s_1, s_2 are the lengths of the sound-beam paths.

Figure 5 — Measurement of the dimension of discontinuities in through-wall direction with normal probes

Annex A (normative)

Resolution of detection of the instrument/probe combination

Resolution of detection of the instrument/probe combination shall be assessed by measuring the width of the first backwall echo using the 25 mm thick section of the IIW A 2 steel reference block in accordance with EN 12223. The echo amplitude shall be set at 80 % to 100 % full screen height and the width of the echo measured in millimetres of steel at a level of 10 % of the echo height. Typical values are given in Table A.1.

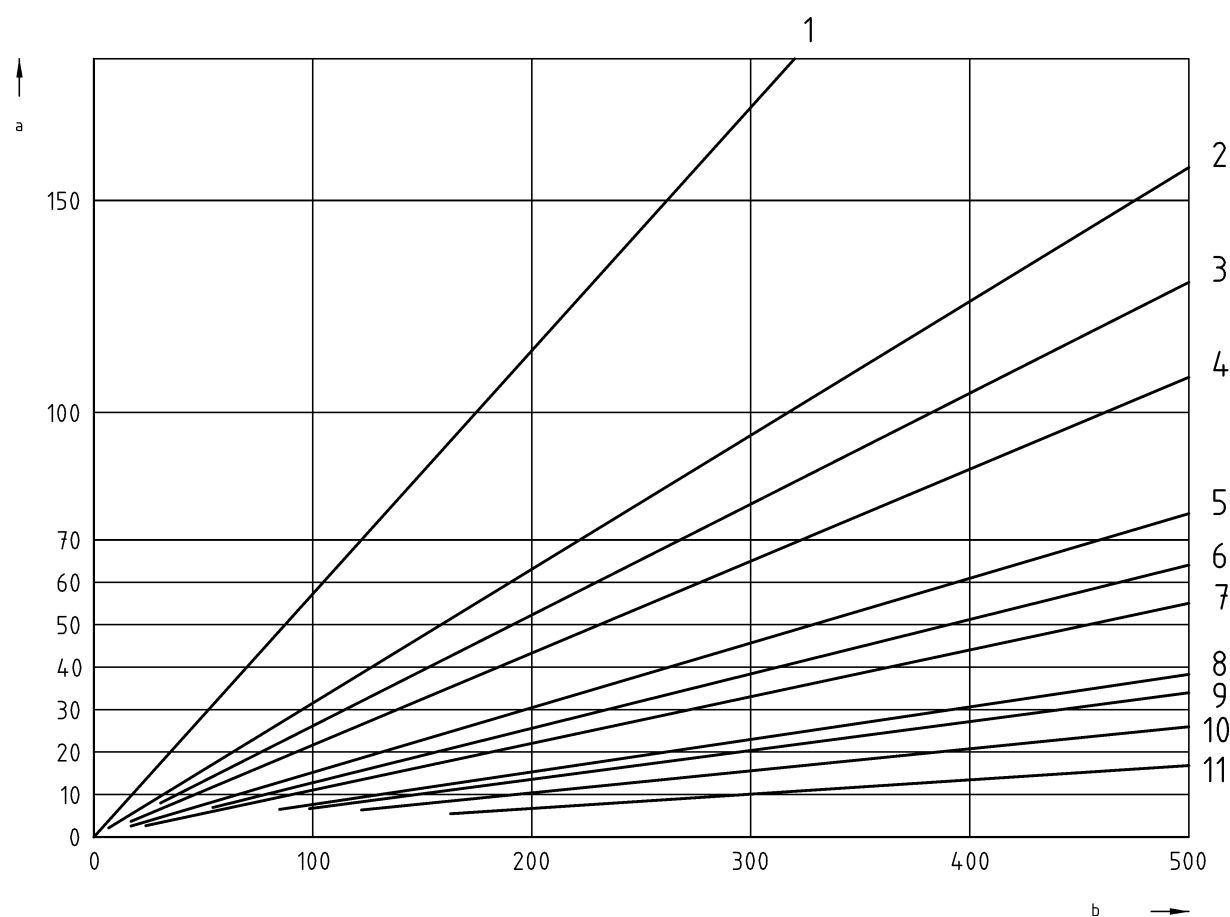
Table A.1 — Typical values of echo widths

| Frequency MHz | Echo width | |
|------------------|------------------------------|----------------------------|
| | longitudinal waves (L) mm | transverse waves (T) mm |
| 1 | 15 | — |
| 2 or 2,25 | 9 | 5 |
| 4 | 5 | 3 |
| 5 | 4 | 2,5 |

Annex B (informative)

Sound-beam diameters

Annex B gives information on sound-beam diameters in order to distinguish between discontinuities with or without measurable dimensions.



Key

- 1 1 MHz, L, \varnothing 10
- 2 2 MHz, L, \varnothing 10
- 3 1 MHz, L, \varnothing 24
- 4 2 MHz, T, 8 \times 9
- 5 4 MHz, L, \varnothing 10
- 6 2 MHz, L, \varnothing 24
- 7 4 MHz, T, 8 \times 9
- 8 2 MHz, T, 8 \times 9
- 9 4 MHz, L, \varnothing 24
- 10 5 MHz, L, \varnothing 24
- 11 4 MHz, T, 20 \times 22

Near-field lengths

| Probe crystal dimension | Near-field length in millimetres (approximate values) | | | | | |
|-------------------------|---|-------|-------|-------|----------------------|-------|
| | longitudinal waves (L) | | | | transverse waves (T) | |
| | mm | 1 MHz | 2 MHz | 4 MHz | 5 MHz | 2 MHz |
| \varnothing 10 | 4,2 | 8,0 | 15,6 | — | — | — |
| \varnothing 24 | 22,7 | 45 | 88 | 115 | — | — |
| 8 \times 9 | — | — | — | — | 14 | 28 |
| 20 \times 22 | — | — | — | — | 75 | 150 |

- a Sound-beam diameter (- 6 dB) in millimetres
- b Sound-beam path in millimetres

Figure B.1 — Sound-beam diameters according to sound-beam path and near-field length for various probes

The near-field length and the sound-beam diameter can be calculated using the following formulae:

$$N = \frac{D_c^2}{4 \times \lambda} \quad (\text{B.1})$$

$$D_F = \frac{2 \times s}{D_c} \quad (\text{B.2})$$

where

N is the near-field length in millimetres;

D_c is the crystal diameter in millimetres;

λ is the wave length in millimetres;

s is the sound-beam path in millimetres;

D_F is the sound-beam diameter, in millimetres, along the sound-beam path, where the decrease of the sound pressure perpendicular to the central beam is 6 dB.

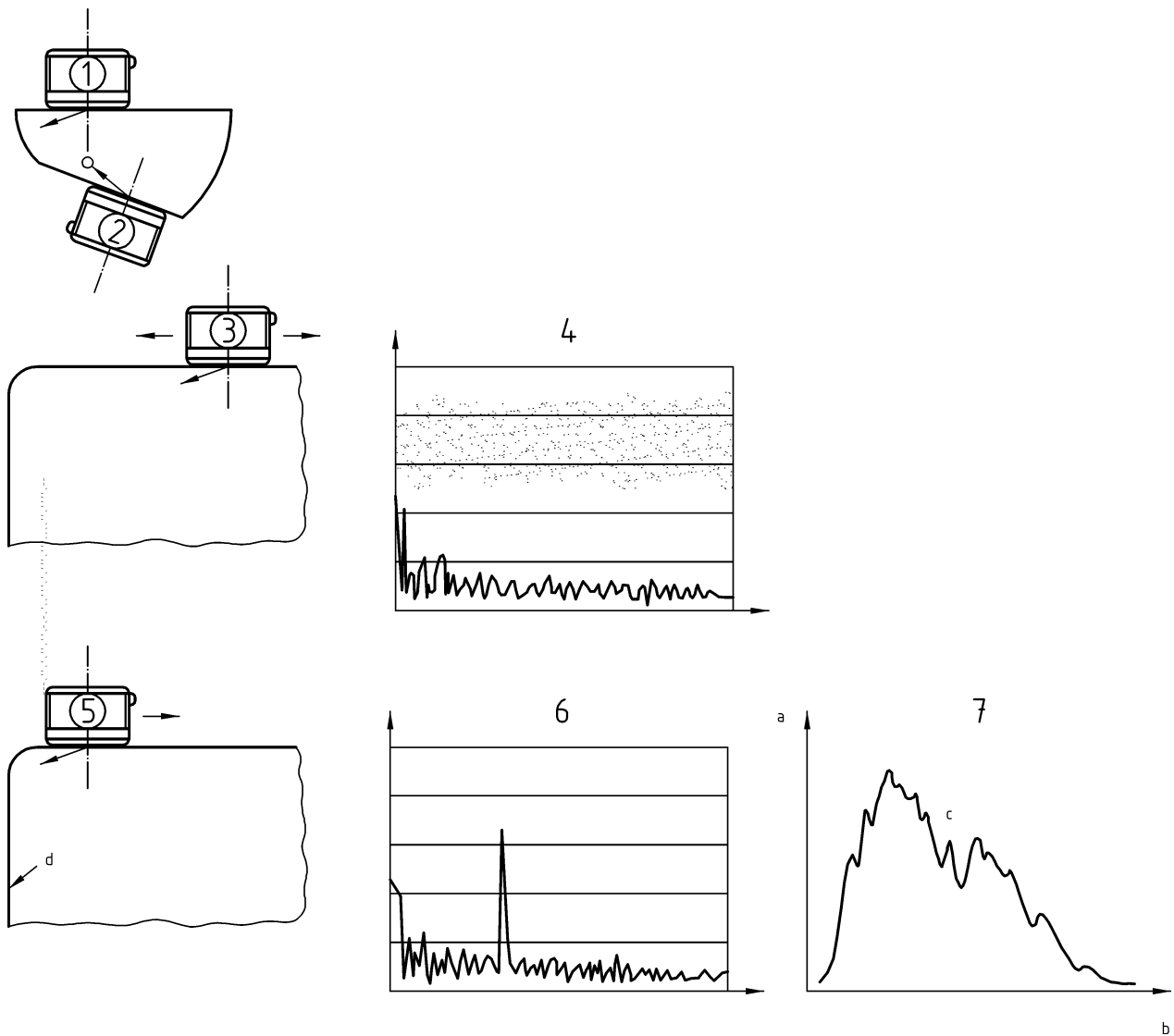
Annex C (informative)

Types of indications

Figures C.1 to C.11 show possible distinctions between the different types of indications by echo-dynamics.

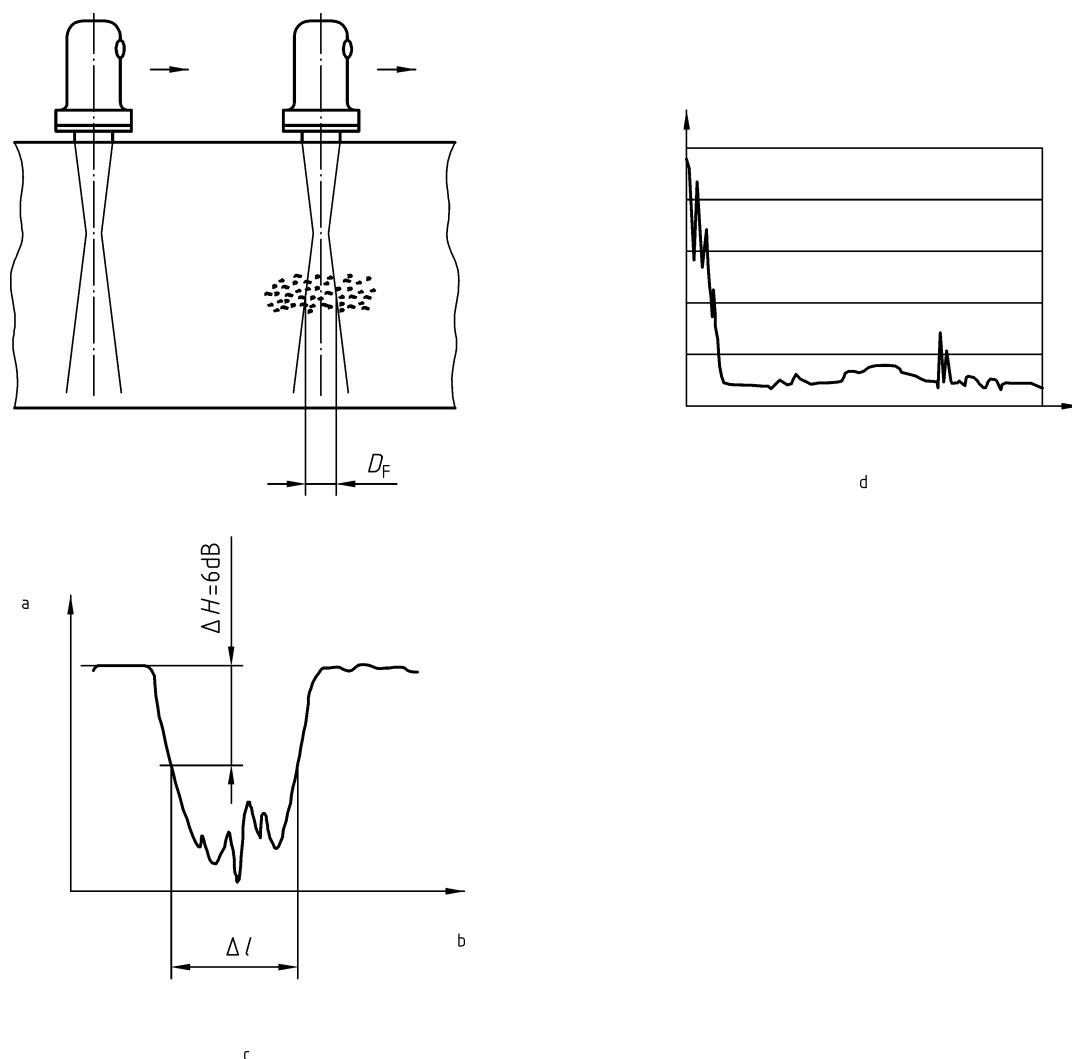
For the identification of the type of indication, the test sensitivities can be changed according to:

- the distance from the surface to be examined;
- the geometrical shape;
- the surface finish of the surface to be examined.



- Key**
- 1 Range setting, e.g. with calibration block in accordance with EN 12223 or EN 27963
 - 2 Check of test equipment on side-drilled hole of calibration block, echo height of side-drilled hole 100 % of screen height
 - 3 Sensitivity setting in an area of the casting to be examined, free from discontinuities without reference reflector
 - 4 Average height of noise level approximately 5 % to 10 % of screen height
 - 5 Check of test sensitivity and test equipment by observation of the echo-dynamics of an as-cast surface in through-wall direction
 - 6 A-scan
 - 7 Typical echo dynamic
- a Echo height
 - b Probe movement
 - c Echo dynamics
 - d As-cast surface

Figure C.1 — Range setting and sensitivity setting of ultrasonic instrument with a twin-crystal angle probe scan (4 MHz, 60° angle) to detect discontinuities mainly orientated in through-wall direction with measurable dimension in the region of the rim zone



Typical indication:

Reduction of backwall echo by more than 12 dB. Indications from discontinuities frequently invisible.

Reason: spongy shrinkage, gas holes, inclusions or large inclined discontinuity.

$$\Delta l > D_F$$

where

D_F is the sound-beam diameter;

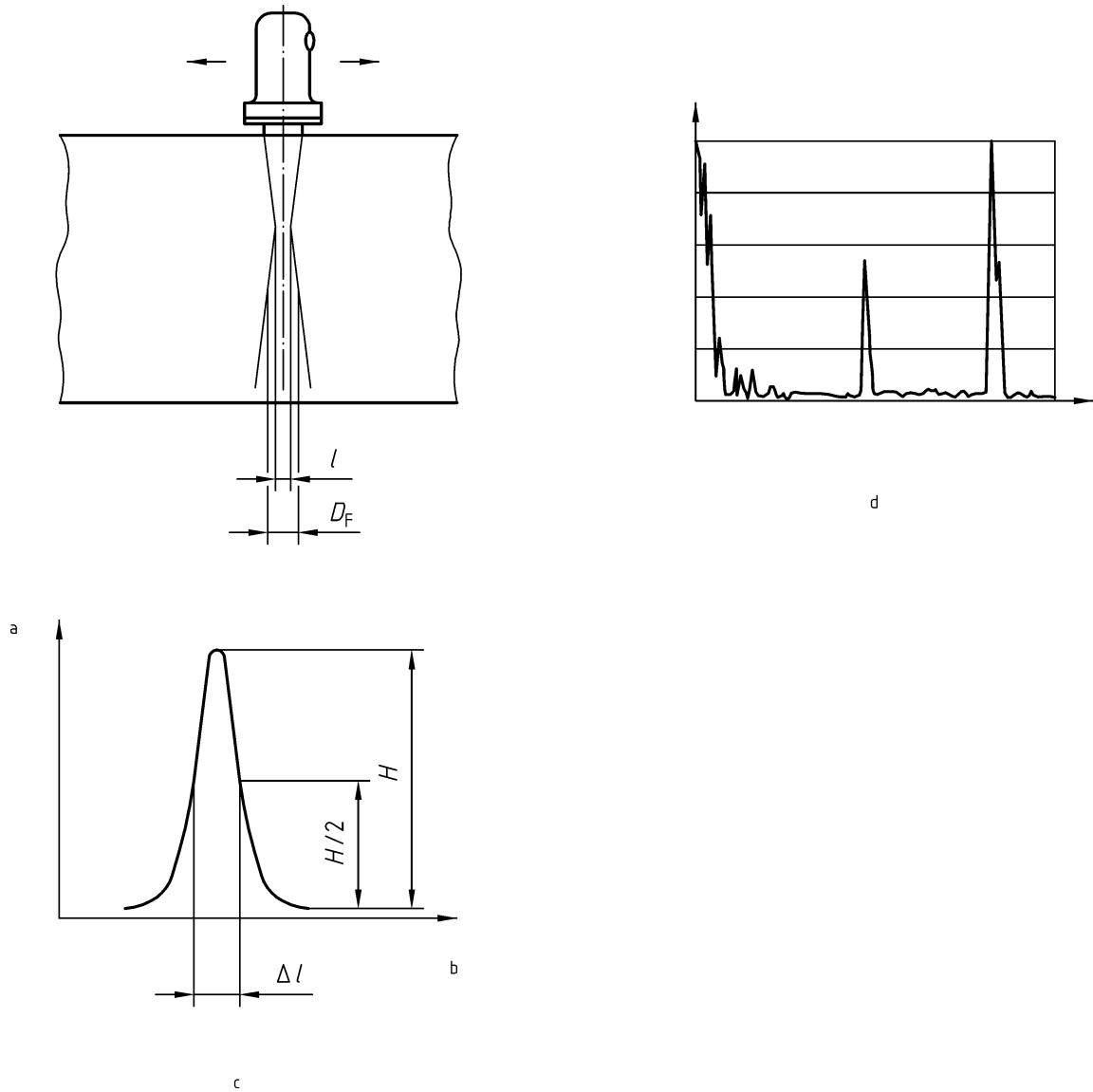
Δl is the dimension of the discontinuity.

Key

ΔH Reduction of backwall echo

- a Echo height
- b Probe movement
- c Echo dynamics
- d A-scan

Figure C.2 — Reduction of backwall echo by more than 12 dB, measurable dimension of indication range



Typical indication:

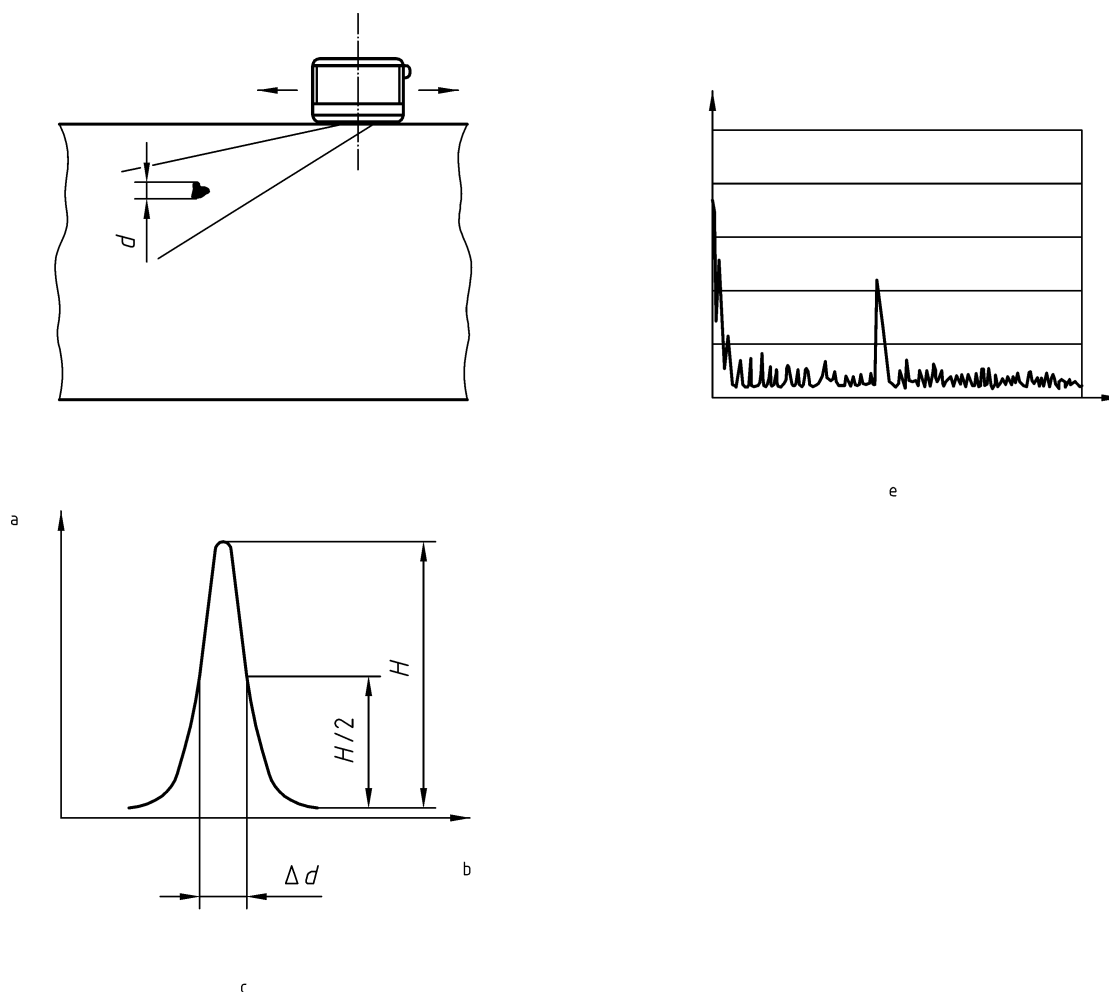
Individual indication, half-value dimension Δl smaller than or equal to the sound-beam diameter D_F .

Key

- l Lateral extension of indication
- H Maximum echo height of individual indication

- a Echo height
- b Probe movement
- c Echo dynamics
- d A-scan

Figure C.3 — Individual indication without measurable dimensions



Typical indication:

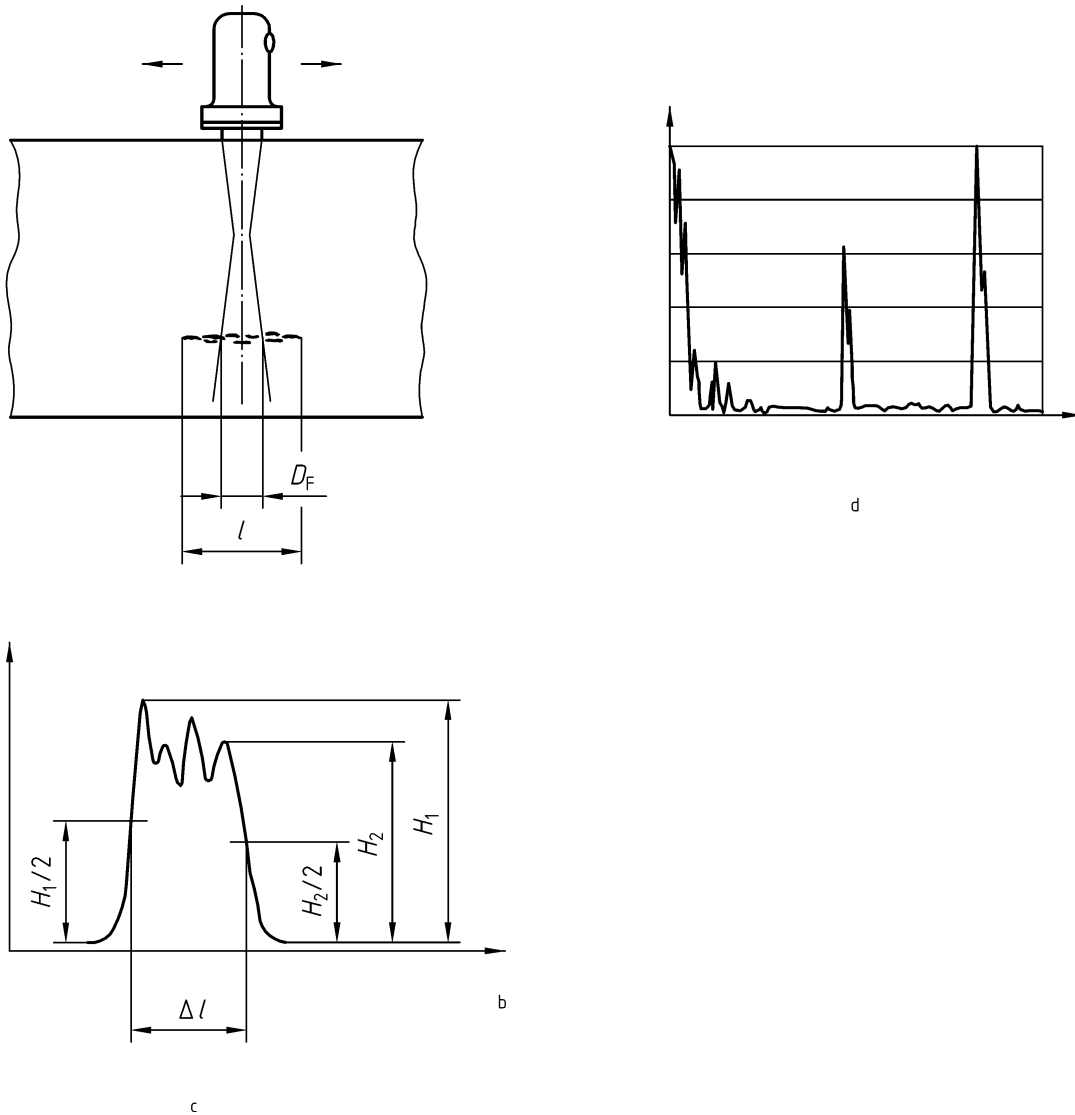
Individual indication, half-value dimension Δd equal to or less than sound-beam diameter D_F at reflection point.

Key

d Dimension of indication in through-wall direction
 H Maximum echo height of individual indication

- a Echo height
- b Probe movement
- c Echo dynamics
- e A-scan

Figure C.4 — Individual indication without measurable dimensions; individual indication with one measurable dimension parallel to the test surface and without measurable dimension in through-wall direction



Typical indication:

Individual indication(s), mainly in the same position in through-wall direction.

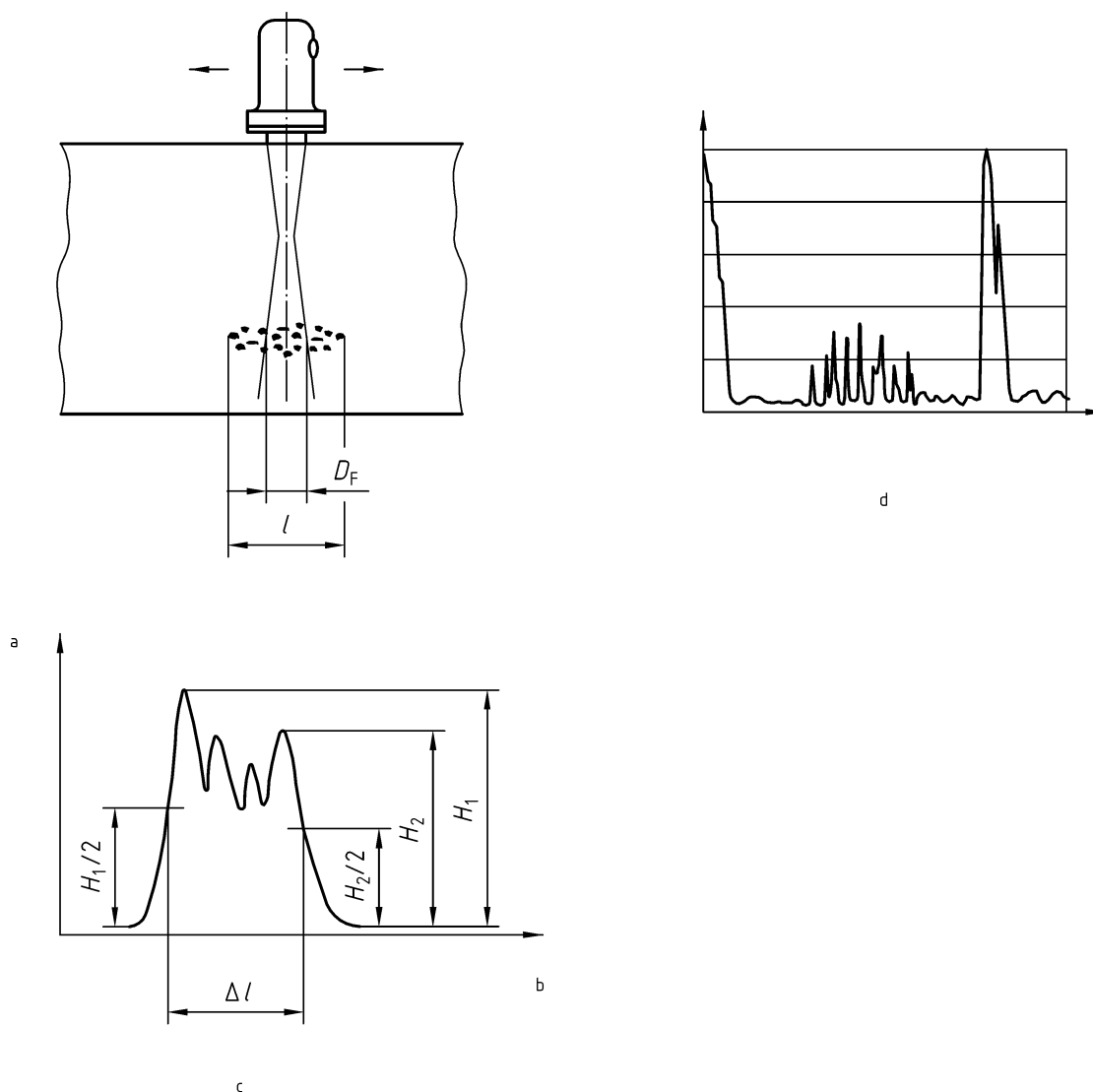
Dimension of indication range larger than the sound-beam diameter D_F .

Key

- l Lateral extension of indication
- Δl Half-value dimension of indication
- H_1, H_2 Last maximum echo heights on opposite sides of indication

- a Echo height
- b Probe movement
- c Echo dynamics
- d A-scan

Figure C.5 — Individual indication with measurable dimensions: Measurable length, non-measurable width; measurable length, measurable width



Typical indication:

Clustering of indications, mainly resolvable with non-measurable dimensions.

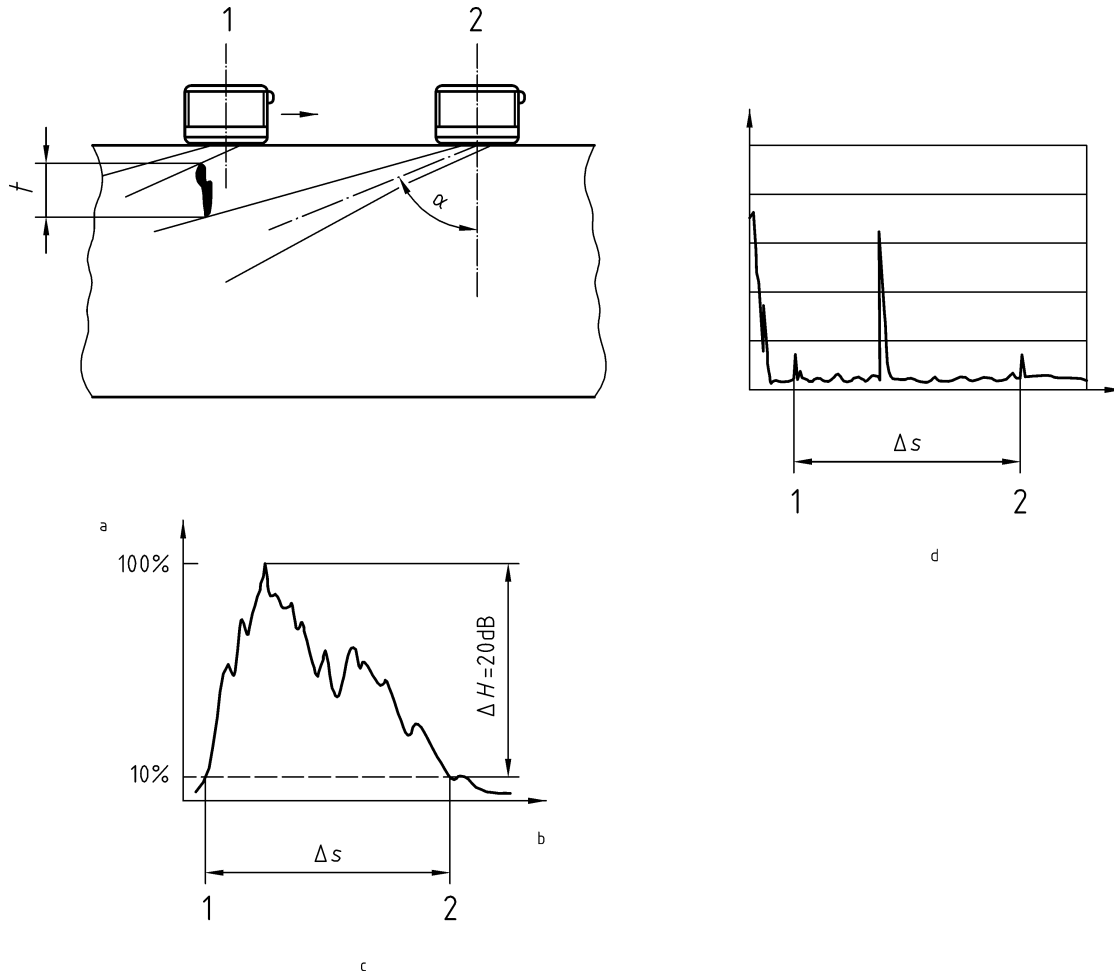
Dimension of indication range equal to or larger than the sound-beam diameter D_F .

Key

- l Lateral extension of indication
- Δl Half-value dimension of indication
- H_1, H_2 Last maximum echo heights on opposite sides of indication

- a Echo height
- b Probe movement
- c Echo dynamics
- d A-scan

Figure C.6 — Group of resolvable indications with measurable dimensions of the indication range



Typical indication:

Individual echo with pronounced echo dynamics only in through-wall direction (travelling indication), or both in through-wall direction and parallel to the test surface:

$$t = \Delta s \times \cos \alpha$$

where

t is the dimension in through-wall direction;

Δs is the difference of sound paths from position 2 to position 1;

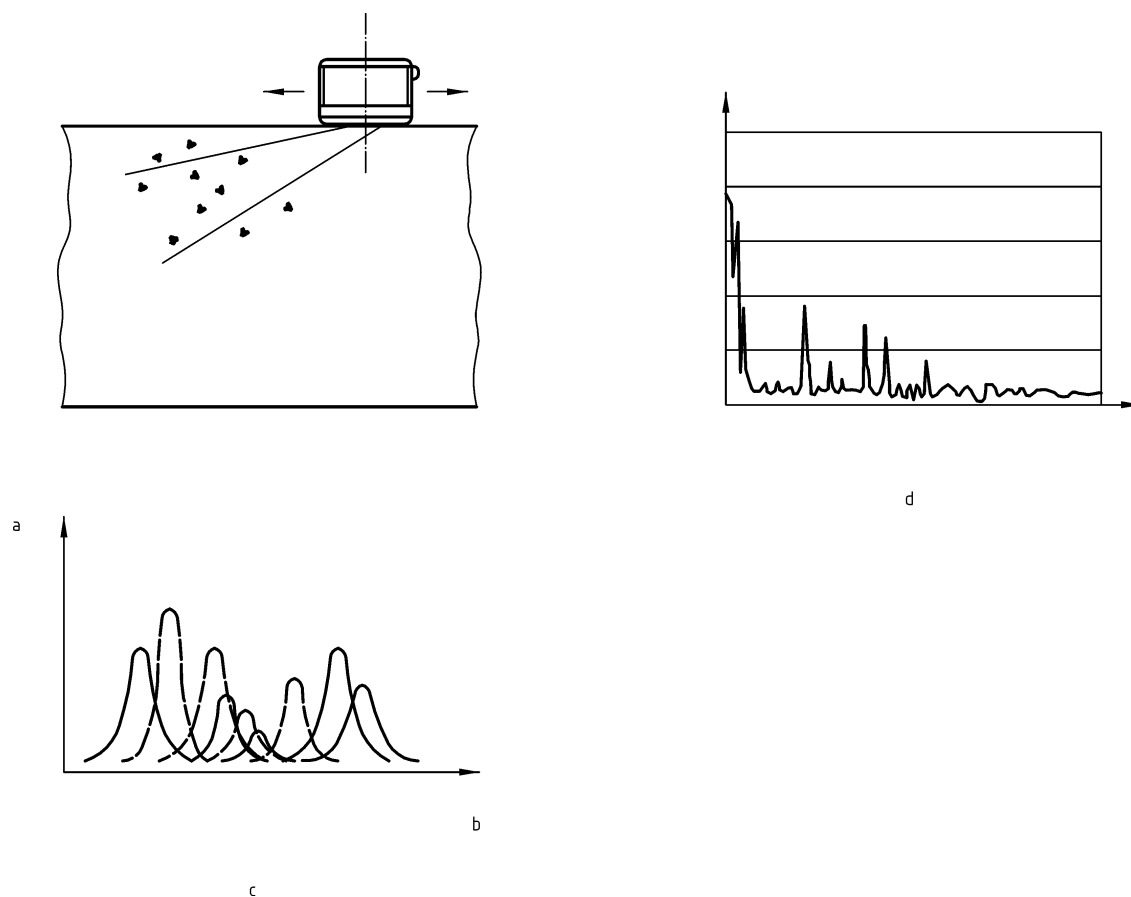
α is the angle of incidence.

Key

- 1 Probe position 1
- 2 Probe position 2
- ΔH Reduction of maximum echo height of indication

- a Echo height
- b Probe movement
- c Echo dynamics
- d A-scan

Figure C.7 — Individual indication with measurable dimensions in through-wall direction



Typical indication:

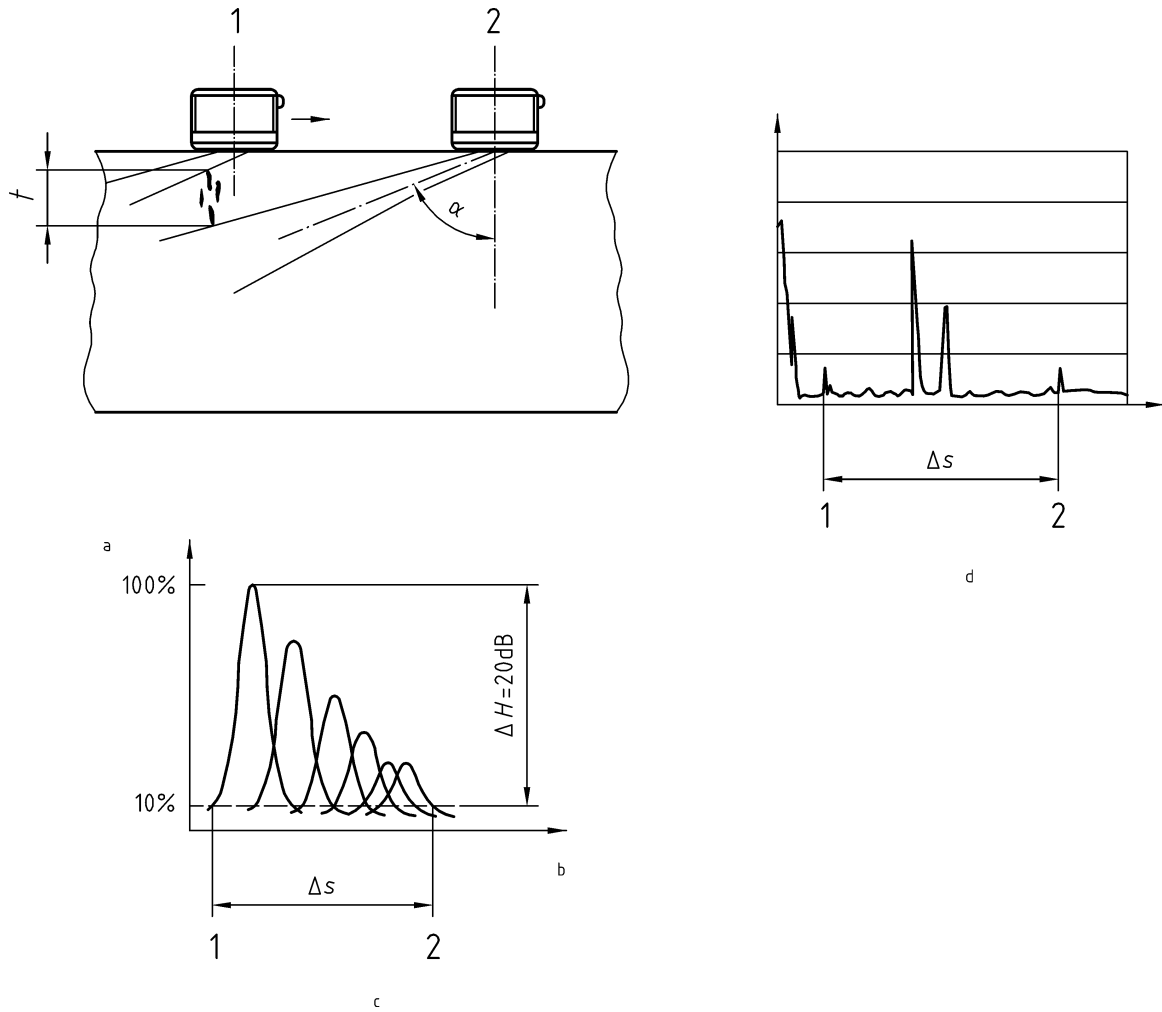
Numerous individual indications.

During probe movement the sound paths change, but all indications remain without measurable dimensions.

Key

- a Echo height
- b Probe movement
- c Echo dynamics
- d A-scan

Figure C.8 — Numerous individual indications without measurable dimensions but with measurable dimensions of the indication range



Typical indication:

Individual indications with measurable dimensions mainly in the through-wall direction:

$$t = \Delta s \times \cos \alpha$$

where

t is the dimension of the indication range in through-wall direction;

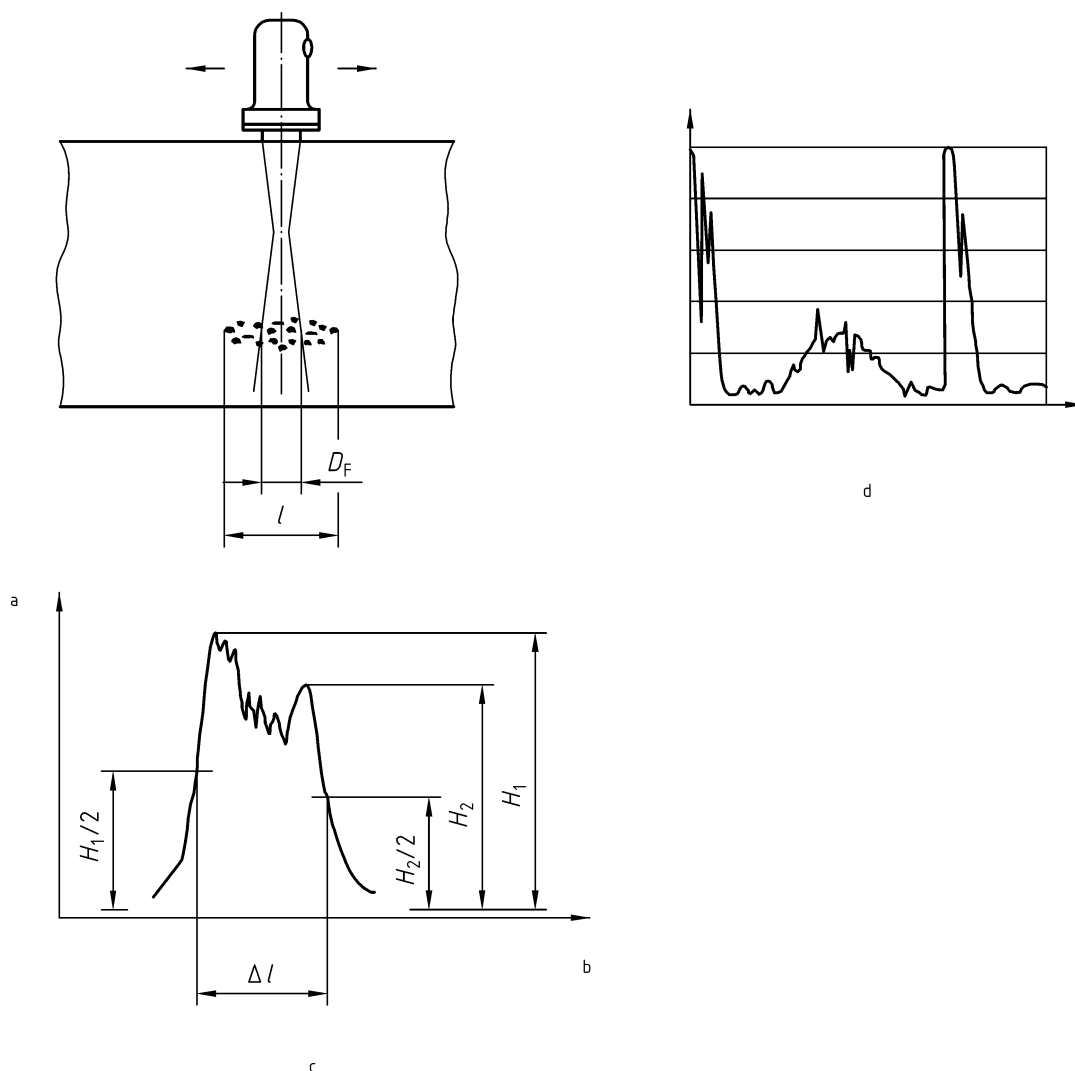
Δs is the difference of sound paths from position 2 and position 1;

α is the angle of incidence.

Key

- 1 Probe position 1
- 2 Probe position 2
- ΔH Reduction of maximum echo height of indication
- a Echo height
- b Probe movement
- c Echo dynamics
- d A-scan

Figure C.9 — Numerous planar indications with measurable dimensions in through-wall direction



Typical indication:

Group of indications, mainly non-resolvable individual indication. Dimension of indication range equal to or larger than sound-beam diameter D_F .

This type of indication should only be evaluated if, due to geometrical reasons, a back-wall echo cannot be obtained.

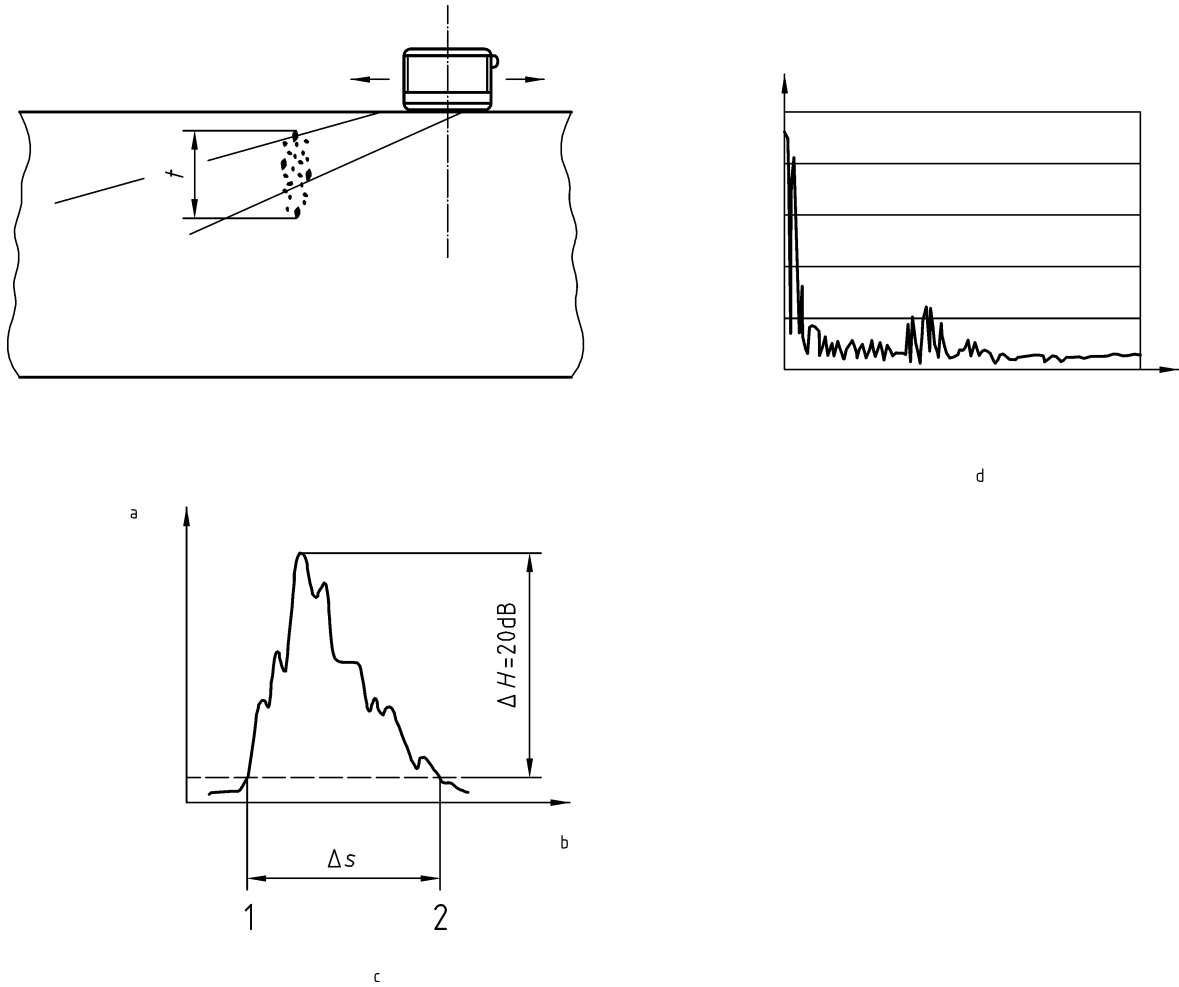
A simultaneous reduction of backwall echo should be evaluated in accordance with Figure C.2.

Key

- l Lateral extension of indication
- Δl Half-value dimension of indication
- H_1, H_2 Last maximum echo heights on opposite sides of indication

- a Echo height
- b Probe movement
- c Echo dynamics
- d A-scan

Figure C.10 — Group of non-resolvable indications with measurable dimensions of indication range (normal probe)



Typical indication:

Group of mainly non-resolvable indications:

$$t = \Delta s \times \cos \alpha$$

where

t is the dimension of the indication range in through-wall direction;

Δs is the difference of sound paths from position 2 and position 1;

α is the angle of incidence.

Key

1 Probe position 1

2 Probe position 2

ΔH Reduction of maximum echo height of indication

a Echo height

b Probe movement

c Echo dynamics

d A-scan

Figure C.11 — Group of non-resolvable indications with measurable dimensions of indication range (angle probe)

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- [3] EN 1370, *Founding — Surface roughness inspection by visualtactile comparators.*
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