BS ISO 4992-1:2020

BSI Standards Publication

Steel castings — Ultrasonic testing

Part 1: Steel castings for general purposes

bsi.

National foreword

This British Standard is the UK implementation of ISO 4992-1:2020. It supersedes BS ISO 4992-1:2006, which is withdrawn.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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Second edition
2020-03

Steel castings — Ultrasonic testing —

Part 1: **Steel castings for general purposes**

Pièces moulées en acier - Contrôle par ultrasons —

Partie 1: Pièces moulées en acier pour usages généraux

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 11, *Steel castings*.

This second edition cancels and replaces the first edition (ISO 4992-1:2006), which has been technically revised. The main changes compared to the previous edition are as follows:

— New definition added for “rim zone” (3.6) and “non-measurable dimension (3.8);

— New subclause 4.3.1;

— Figure 2 was redrawn;

— Subtitles added to Figures 2, 3, 4 and Figures in Annexes A and B

— Figure A.1 Key 8 was corrected;

— Table in Figure A.1 numbered as Table A.1.

A list of all parts in the ISO 4992 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Steel castings — Ultrasonic testing —

Part 1: Steel castings for general purposes

1 Scope

This document specifies the requirements for the ultrasonic testing of steel castings (with ferritic structure) for general purposes, and the methods for determining internal discontinuities by the pulse-echo technique.

This document applies to the ultrasonic testing 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 the test procedure and the acceptance levels.

This document does not apply to austenitic steels and to joint welds.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 2400, *Non-destructive testing — Ultrasonic testing — Specification for calibration block No. 1*

ISO 5577, *Non-destructive testing — Ultrasonic testing — Vocabulary*

ISO 7963, *Non-destructive testing — Ultrasonic testing — Specification for calibration block No. 2*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 11971, *Steel and iron castings — Visual testing of surface quality*

ISO 16810, *Non-destructive testing — Ultrasonic testing — General principles*

ISO 16811, *Non-destructive testing — Ultrasonic testing — Sensitivity and range setting*

ISO 16827, *Non-destructive testing — Ultrasonic testing — Characterization and sizing of discontinuities*

ISO 22232-1[1)], *Non-destructive testing — Characterization and verification of ultrasonic test equipment — Part 1: Instruments*

ISO 22232-2[2)], *Non-destructive testing — Characterization and verification of ultrasonic test equipment — Part 2: Probes*

ISO 22232-3[3)], *Non-destructive testing — Characterization and verification of ultrasonic test equipment — Part 3: Combined equipment*

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1) Under preparation. Stage at the time of publication: ISO/DIS 22322-1.

2) Under preparation. Stage at the time of publication: ISO/DIS 22322-2.

3) Under preparation. Stage at the time of publication: ISO/DIS 22322-3.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, ISO 16810, ISO 16811, ISO 16827 and the following, apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
equivalent reference discontinuity echo size
indication to be recorded during the assessment phase of an ultrasonic test, usually expressed as an equivalent diameter of a flat-bottomed hole (FBH)

3.2
point-like discontinuity
discontinuity, the dimensions of which are smaller than or equal to the sound-beam width

Note 1 to entry: Dimensions in this document relate to length, width and/or dimension in the through-wall direction.

3.3
extended discontinuity
discontinuity, the dimensions of which are larger than the sound-beam width

Note 1 to entry: Dimensions in this document relate to length, width and/or dimension in the through-wall direction.

3.4
planar discontinuity
discontinuity having two measurable dimensions

3.5
volumetric discontinuity
discontinuity having three measurable dimensions

3.6
rim zone
1/3 the through-wall thickness from the surface with a maximum of 30 mm

3.7
special rim zone
outer *rim zone* (3.6) of the test object with special requirements

Note 1 to entry: Examples of special requirements are machined surfaces, higher stresses and sealing surfaces.

3.8
non-measurable dimension
dimension of a discontinuity that is smaller than the beam width, which depends on the probe size and the frequency used

Note 1 to entry: Current state of the industry is <3 mm.

3.9
production welding
any welding on the test object carried out during manufacturing before final delivery to the purchaser

3.10
joint welding
production welding used to assemble components together to obtain an integral unit

3.11
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 ISO 16810):

a) the areas of the casting and the number or percentage of castings to which the requirements of ultrasonic testing apply (testing volume, extent of testing);

b) the acceptance levels to be applied to the various zones or areas of the casting;

c) requirements for a written test procedure;

d) whether there are any additional requirements for the test procedure, see also 5.5.1.

4.2 Extent of testing

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

For wall thicknesses greater than 600 mm, agreement shall be made between the purchaser and manufacturer on the acceptance levels, test procedure, and the recording of the test results.

4.3 Maximum acceptable size of discontinuities

4.3.1 General

Single discontinuities extending into the rim zone and core zone shall be evaluated as rim zone.

4.3.2 Acceptance levels for planar discontinuities mainly orientated perpendicular to the surface

The acceptance levels for planar discontinuities are given in Figure 1.

Discontinuities exceeding 3 mm FBH shall not be acceptable in class 1.

The largest dimension of a discontinuity in the through-wall direction shall not exceed 10 % of the wall thickness, except discontinuities with a length ≤10 mm. Discontinuities with a length ≤10 mm shall not exceed a dimension in the through-wall direction of 25 % of the wall thickness.

The greatest distance between discontinuities, as a criterion for evaluation as a single discontinuity or a discontinuity area perpendicular or lateral to the surface, shall be 10 mm.

For a discontinuity with more than 3 mm in length and non-measurable dimension in the through-wall direction, this non-measurable dimension shall be taken as 3 mm and the discontinuity area shall be calculated as follows:

$$A = 3L \tag{1}$$

where

A is the area of discontinuity, in square millimetres;

3 is the width taken, in millimetres;

L is the length, in millimetres.

4.3.3 Acceptance levels for volumetric discontinuities

The acceptance levels for volumetric discontinuities are given in Table 1. Any discontinuity exceeding one of the levels shall not be acceptable.

4.3.4 Maximum acceptable discontinuities when radiographic testing (RT) of the casting is carried out as a supplement to ultrasonic testing (UT)

Unless otherwise agreed at the time of enquiry and order, when conducting radiographic and ultrasonic testing in combination it was proven that if a discontinuity indicated by radiographic testing is situated in the core zone, the discontinuity is acceptable at one level lower, e.g. in class 3 instead of class 2 for radiographic testing. For further information, see EN 1559-2.

4.4 Qualification of personnel

Ultrasonic testing shall be performed by qualified personnel. Qualification of personnel may be according to ISO 9712 or other equivalent recognised standards.

4.5 Wall-section zones

The wall section shall be divided into core and rim zones as shown in Figure 2. These zones relate to the dimensions of the casting ready for assembly (finish-machined).

4.6 Classes

If the purchaser specifies different classes in different areas of the same casting, all of these areas shall be clearly identified and shall include:

a) all necessary dimensions for accurate location of zones;

b) the full extent of all weld preparations and the thickness of any special rim zone.

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

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

5 Testing

5.1 Principles

The principles of ultrasonic testing given in ISO 16810, ISO 16811 and ISO 16827 shall apply.

5.2 Material

The suitability of 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 level. This assessment shall be carried out on selected casting areas which are representative of the surface finish and of the total thickness range of the objects to be tested. The assessment areas shall have parallel surfaces.

The reference echo height according to Table 2 shall be at least 6 dB above the noise level.

If the echo height of the smallest detectable flat-bottomed or equivalent side-drilled hole at the far end of the test range to be assessed is less than 6 dB above the noise level, then ultrasonic testing has reduced performance. In this case, the diameter of the flat-bottomed or side-drilled hole 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 For the definition of an adequate diameter of a flat-bottomed hole, the distance-gain-size system (DGS) or a test block of identical material, heat treatment, and thickness containing flat-bottomed holes with a diameter according to Table 2 or equivalent side-drilled holes, can be used. The following formula can be used for converting a flat-bottomed hole diameter into an equivalent side-drilled hole diameter:

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

where

D_{SDH} is the side-drilled hole diameter, in millimetres;

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

λ is the wavelength, in millimetres;

s is the path length, in millimetres.

Formula (2) is applicable for $D_{SDH} \geq 2\lambda$ and $s \geq 5$ times the near-field length and is only defined for single-element probes.

5.3 Test equipment and coupling fluid

5.3.1 Ultrasonic instrument

The ultrasonic instrument shall meet the requirements given in ISO 22232-1 and shall have the following characteristics:

a) range setting capability, from at least 10 mm to 2 m, continuously selectable, for longitudinal and transverse waves in steel;

b) gain span, adjustable in 2 dB maximum steps over a range of at least 80 dB with an accuracy of 1 dB;

c) time-base and vertical linearities less than 5 % of the adjustment range of the screen;

d) operating in combined transmitter-receiver mode or in separate transmitter-receiver mode;

e) suitability, at least for nominal frequencies from 1 MHz up to and including 5 MHz, for the pulse-echo technique with single-element and dual-element probes.

5.3.2 Probes

The probes shall meet the requirements given in ISO 22232-2 and ISO 22232-3 with the following exceptions:

a) nominal frequencies shall be in the range 1 MHz to 5 MHz;

b) for oblique incidence, angle-beam probes with angles between 35° and 70° shall be used.

NOTE Normal-beam or angle-beam probes can be used for the testing of steel castings. The suited probe type depends on the geometry of the casting and the type of discontinuity to be detected.

For test zones close to the surface, dual-element probes (normal-beam or angle-beam) should be preferred.

5.3.3 Checking of the ultrasonic test equipment

The ultrasonic test equipment shall be checked regularly by the operator in accordance with ISO 22232-3.

5.3.4 Coupling fluid

A coupling fluid in accordance with ISO 16810 shall be used. The coupling fluid shall wet the test surface to ensure satisfactory sound transmission. The same coupling fluid shall be used for the calibration and all subsequent test operations.

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

5.4 Preparation of casting surfaces for testing

For the preparation of casting surfaces for ultrasonic testing, see ISO 16810.

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

With single-element probes, satisfactory coupling can be achieved if the surfaces correspond at least to the limit comparator 4 S1 or 4 S2 according to ISO 11971.

The roughness of any machined surface used for testing shall be $R_a \leq 12{,}5$ µm.

For special test techniques, higher surface qualities such as 2 S1 or 2 S2 (see ISO 11971) and $R_a \leq 6{,}3$ µm may be necessary.

5.5 Test 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 discontinuities in the casting or on the possible discontinuities from finishing welding, the applicable test procedure shall be specified by the manufacturer of the casting.

If possible, the areas to be tested shall be tested 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 dual-element 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, dual-element normal-beam and/or angle-beam probes shall be used to test the following areas up to a depth of 50 mm:

a) critical areas, e.g. fillets, changes in cross-section, areas with external chills;

b) finishing welds;

c) weld preparation areas, as specified in the order;

d) 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 testing with other suitable angle-beam probes.

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

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

The scanning speed shall not exceed 150 mm/s.

5.5.2 Range setting

Range setting on the ultrasonic instrument shall be carried out in accordance with ISO 16811, using normal-beam or angle-beam probes in accordance with one of the three options given below:

a) with the calibration block No. 1 in accordance with ISO 2400, or block No. 2 in accordance with ISO 7963;

b) with an alternative calibration block made of a material exhibiting similar acoustic properties to those of the material to be tested;

c) on the casting itself when using normal-beam probes. The casting to be tested shall have parallel surfaces, the distance between which shall be measured and recorded.

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 ISO 16811. One of the two following techniques shall be used:

a) 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 path.

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

b) Distance-gain-size technique (DGS)

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

5.5.3.2 Transfer correction

The transfer correction shall be determined in accordance with ISO 16811.

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 back-wall 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 ISO 11971, this surface has a quality which is sufficient for transfer correction measurements.

5.5.3.3 Detection of discontinuities

For detection of discontinuities, 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 full screen height (FSH) at the end of the thickness range to be tested.

If, during testing, suspicion arises that the reduction of back-wall echo signal exceeds the recordable value (see Table 3), testing shall be repeated using locally reduced test sensitivity and the reduction of back-wall echo signal shall be determined quantitatively in decibels.

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

It is recommended that the sensitivity setting of angle-beam probes is verified on real (not artificial) planar discontinuities (cracks with dimensions in the through-wall direction) or on walls perpendicular to the surface and infinite compared to the width of the sound beam.

Under these circumstances, the probe shoe should be contoured to fit to the contour of the casting (see ISO 16811).

5.5.4 Consideration of various types of indications

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

a) reductions of back-wall echo which is not due to the shape of the casting or the coupling;

b) echoes from discontinuities.

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

5.5.5 Recording limits

Unless otherwise specified, all back-wall echo reductions and all echo heights reaching or exceeding the levels given in Table 3 shall be recorded.

When using transverse-wave probes, irrespective of their amplitude, all indications which display travelling characteristics or come from discontinuities which have an apparent dimension in the through-wall direction shall be recorded for subsequent assessment in accordance with 5.5.7.2.

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

5.5.6 Assessment of discontinuities to be recorded

The locations where discontinuities 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. by changing the angle of incidence) or by additionally carrying out radiographic testing.

5.5.7 Characterization and sizing of discontinuities

5.5.7.1 General

For characterization and sizing of discontinuities, see ISO 16827.

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 discontinuity type, 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 characterizations of discontinuities can be made:

a) discontinuities without measurable dimensions (point-like discontinuities);

b) discontinuities with measurable dimensions (extended discontinuities).

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

NOTE 2 Annex B gives information on types of discontinuities 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).

For the determination of the dimensions of discontinuities, it is recommended to use probes with a sound-beam diameter as small as possible at the location of the discontinuity.

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 back-wall echo reduction, the echo is reduced by 6 dB (2 MHz probe) below the height of the undisturbed back-wall echo.

The dimension in the through-wall direction of the discontinuity should be measured according to Figure 4.

5.5.7.3 Sizing of discontinuities in the through-wall direction

The sizing of planar discontinuities and their assessment, in relation to specified classes, shall be carried out by probe movement in accordance with 5.5.7.1, but in this case, the echo is reduced by 20 dB (see Figure 3).

5.6 Test report

The test report shall contain at least the following information:

a) a reference to this document, i.e. ISO 4992-1:2020;

b) characteristic data of the tested casting;

c) extent of testing;

d) type of test equipment used;

e) probes used;

f) the test technique, with reference to the tested area (range setting);

g) all data necessary for sensitivity setting (calibration blocks);

h) information on all characteristic features of discontinuities to be recorded (e.g. back-wall echo reduction, position and dimension in the through-wall direction, length, area and equivalent flat-bottomed hole diameter) and the descriptions of their position (sketch or photograph);

i) date of testing and name and signature of the responsible person.

Table 1 — Acceptance levels for volumetric discontinuities

Feature	Unit	Zone (see Figure 2)		Class												
				1	2			3			4			5		
Casting wall thickness at the tested area	mm			—	≤50	>50 ≤100	>100 ≤600	≤50	>50 ≤100	>100 ≤600	≤50	>50 ≤100	>100 ≤600	≤50	>50 ≤100	>100 ≤600
Discontinuities without measurable dimension																
Largest diameter of equivalent flat-bottomed hole	mm	rim zone		3	[a]									not used as criterion		
		core zone														
Number of discontinuities to be recorded in a frame 100 mm × 100 mm	—	rim zone		3[b]	3	5		6		6	not used as criterion					
		core zone			not used as criterion											
Discontinuities with measurable dimension																
Largest diameter of equivalent flat-bottomed hole	mm	rim zone		3	[a]									not used as criterion		
		core zone														
Maximum values of dimension of discontinuities in the through-wall direction	—	rim zone		not permitted	15 % of zone thickness									20 % of zone thickness		
		core zone			15 % of wall thickness									20 % of wall thickness		
Maximum length without measurable width	mm	rim zone			75	75	75	75	75	75	75	75	75	75	75	75
		core zone			75	75	100	75	75	120	100	100	150	100	100	150
Largest individual area[c, d]	mm^2	rim zone			600	1 000	1 000	600	2 000	2 000	2 000	2 000	2 000	3 000	4 000	4 000
		core zone			10 000	10 000	15 000	15 000	15 000	20 000	15 000	15 000	20 000	20 000	30 000	40 000
Largest total area for a reference area [c]	mm^2	rim zone			10 000	10 000	10 000	10 000	10 000	10 000	10 000	15 000	15 000	15 000	20 000	20 000
		core zone			10 000	15 000	15 000	15 000	20 000	20 000	15 000	20 000	20 000	30 000	40 000	40 000
Reference area	mm^2	—			150 000 ≈ (390 mm × 390 mm)			100 000 ≈ (320 mm × 320 mm)								

[a] For wall thicknesses not greater than 50 mm, flat-bottomed holes exceeding 8 mm diameter are not acceptable.

For wall thicknesses greater than 50 mm, the acceptability of flat-bottomed holes exceeding 8 mm diameter in the rim zone shall be agreed between the manufacturer and the purchaser.

[b] Accumulated in core zone and rim zone.

[c] Discontinuities less than 25 mm apart shall be considered as one discontinuity.

[d] If the indication in the core zone is caused by an individual discontinuity, the thickness of which does not exceed 10 % of the wall thickness, (e.g. centreline shrinkage), then, in the case of classes 2 to 4, values 50 % higher than those specified in this table are acceptable, and in the case of class 5, no acceptance level is specified.

Table 2 — Requirements for ultrasonic testability

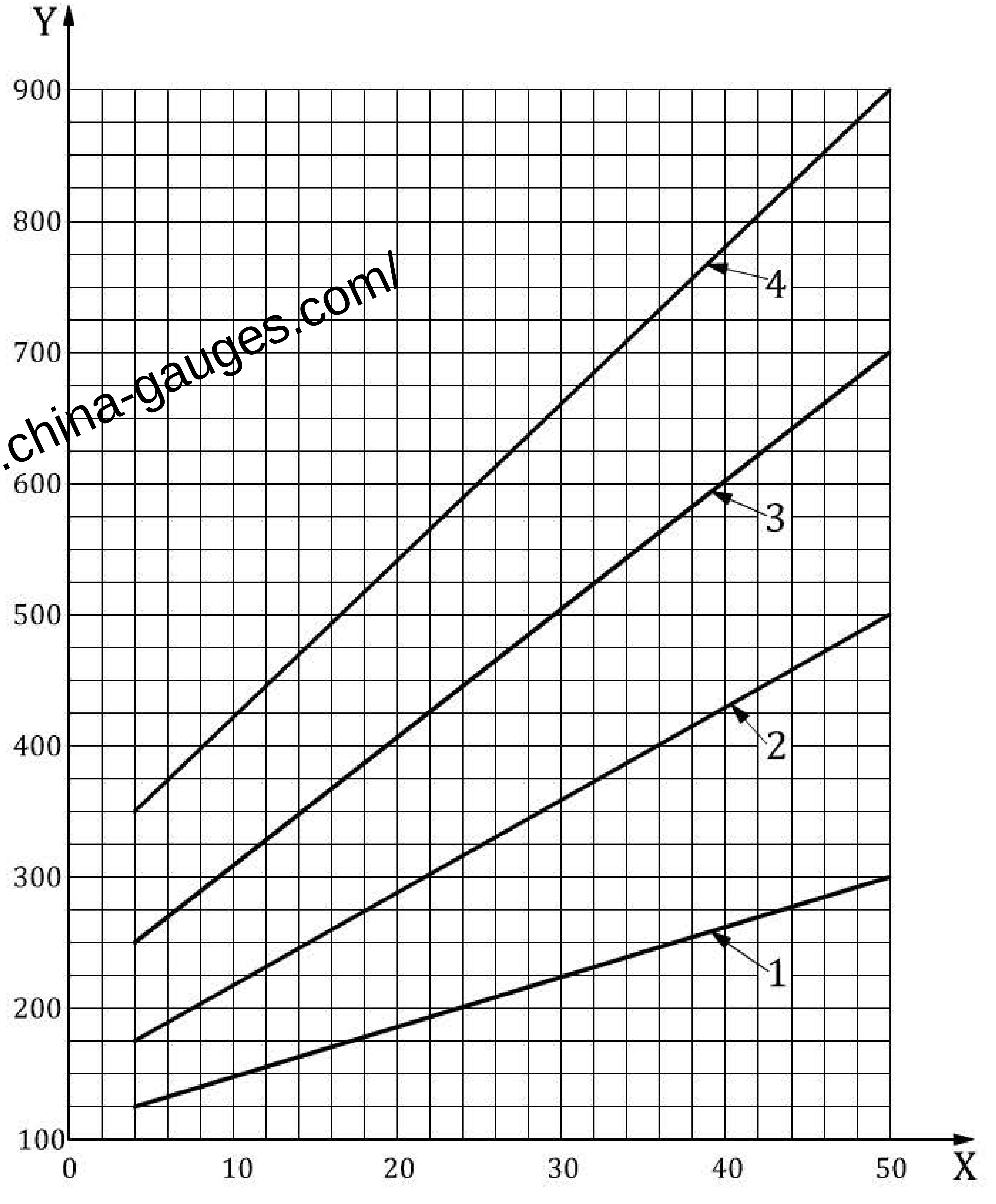
Dimensions in millimetres

Wall thickness	Smallest flat-bottomed hole diameter detectable according to 5.2
≤300	3
>300 to ≤400	4
>400 to ≤600	6

Table 3 — Recording levels

Wall thickness mm	Tested area	Discontinuities without measurable dimension Diameter of the equivalent flat-bottomed hole[a] min. mm	Discontinuities with measurable dimension Diameter of the equivalent flat-bottomed hole[a] min. mm	Reduction of back-wall echo min. dB
≤300	—	4	3	
>300 to ≤400	—	6	4	12
>400 to ≤600	—	6	6	
—	Areas with class 1	3	3	6
—	Special rim zone	3	3	—

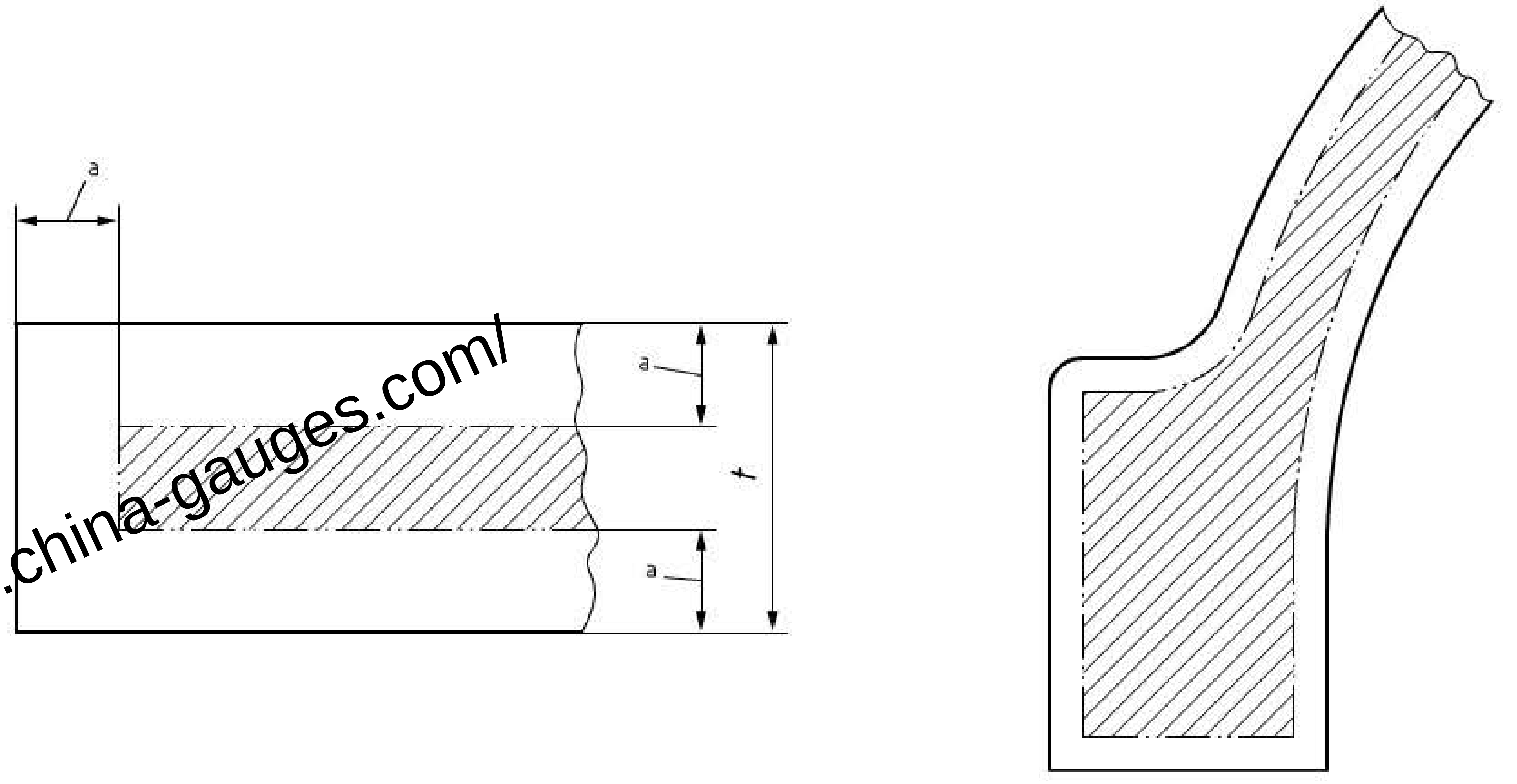
[a] For the formula for converting the flat-bottomed hole diameter into the side-drilled hole diameter, see the note to 5.2.



Key

1 class 2
2 class 3
3 class 4
4 class 5
X distance from test surface, in millimetres
Y largest acceptable area of an individual discontinuity, in square millimetres

Figure 1 — Acceptance levels for individual planar discontinuities mainly orientated in the through-wall direction, detected with angle-beam probes

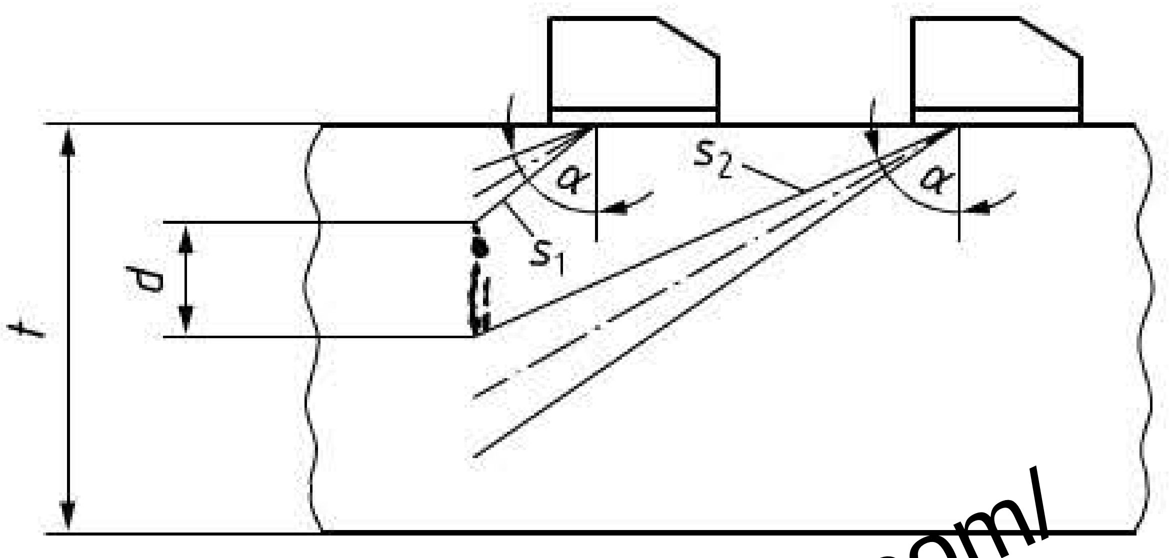


a) Flat casting **b) Curved casting**

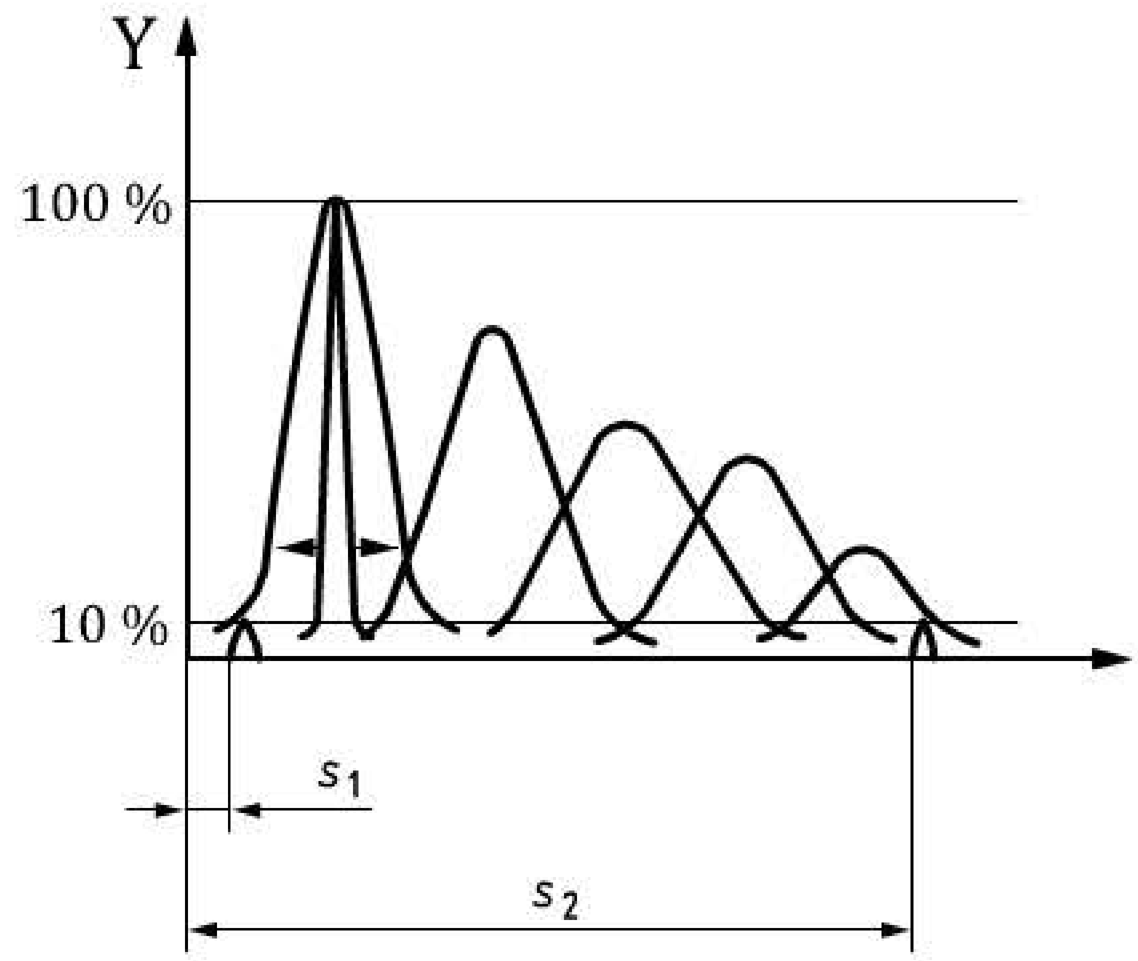
Key

rim zone (blank box)
core zone (hatched box)
t wall thickness
a *t*/3 (max. 30 mm)

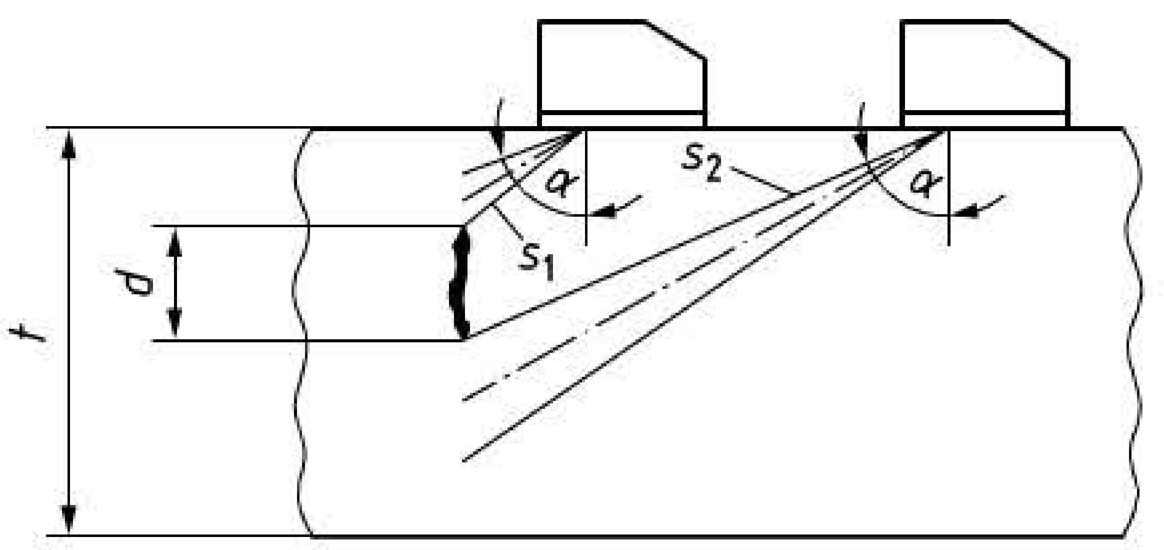
Figure 2 — Division of wall section into zones



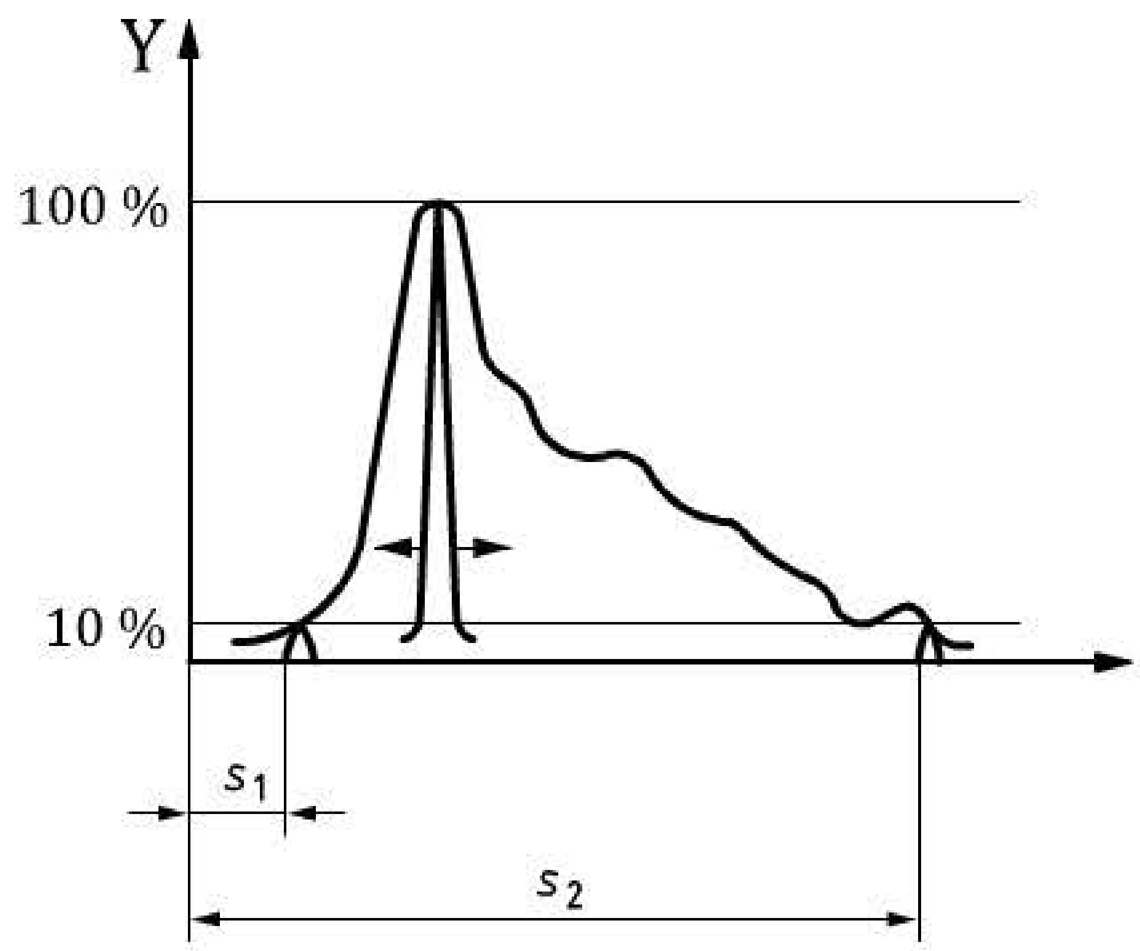
a) Wall section with broken discontinuity



b) Display for Figure 3 a)



c) Wall section with continuous discontinuity



d) Display for Figure 3 c)

Key

Y echo height

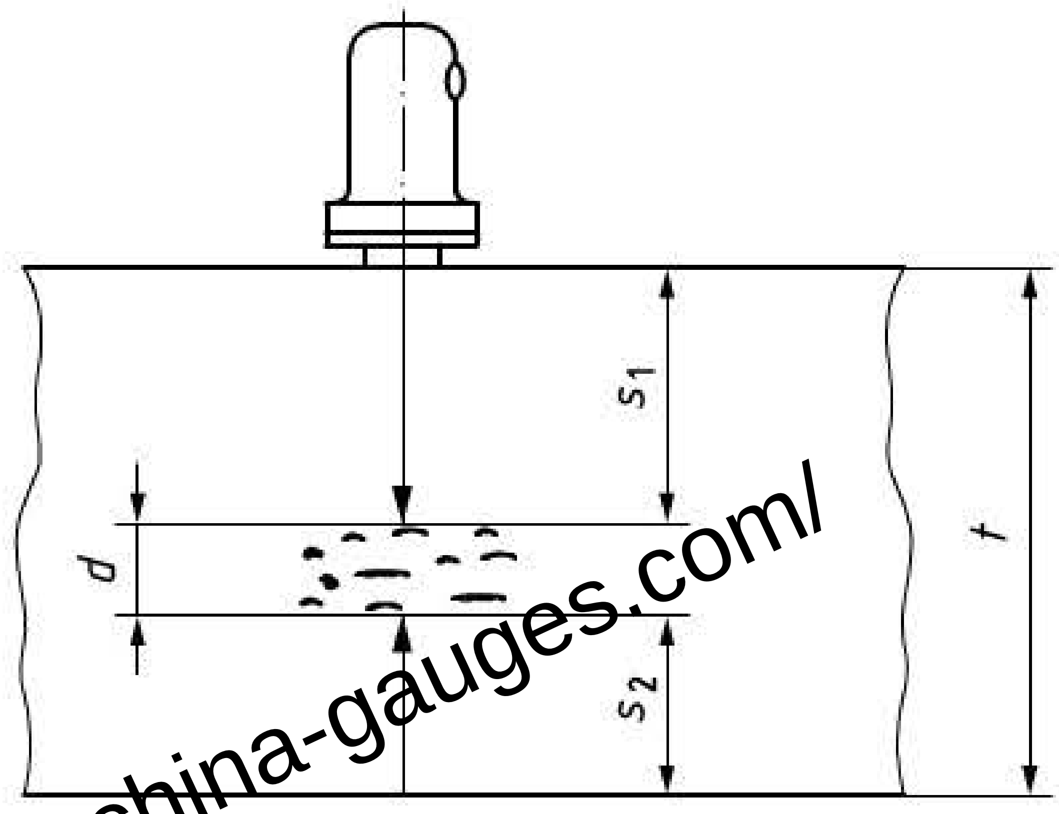
d dimension in the through-wall direction $d = (s_2 - s_1) \cos \alpha$

s_1, s_2 length of the sound path

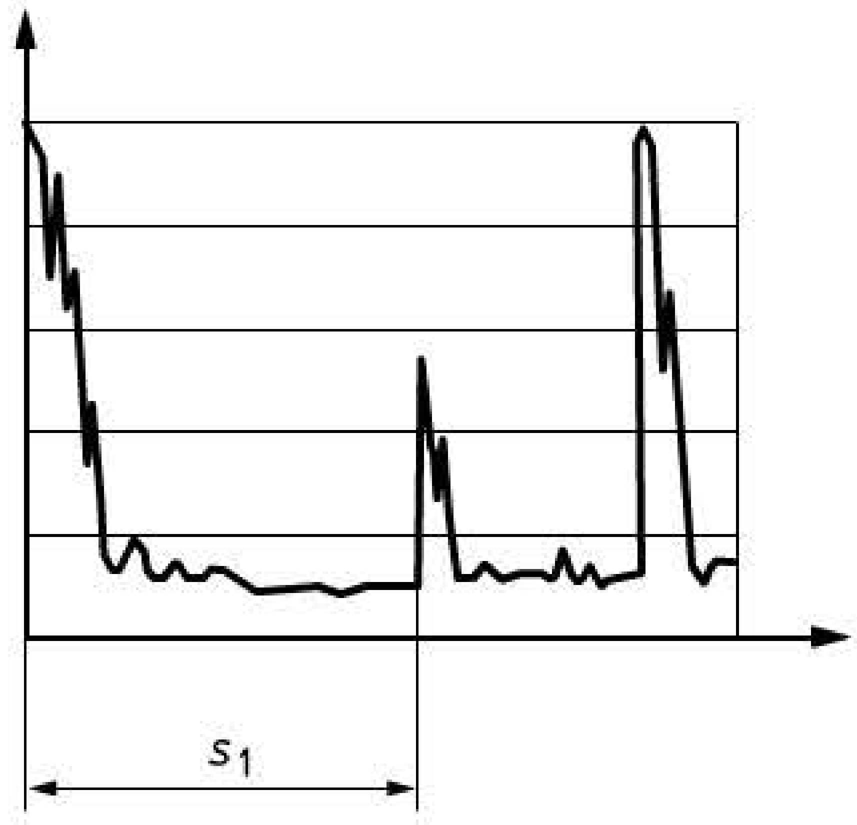
t thickness

α angle of incidence

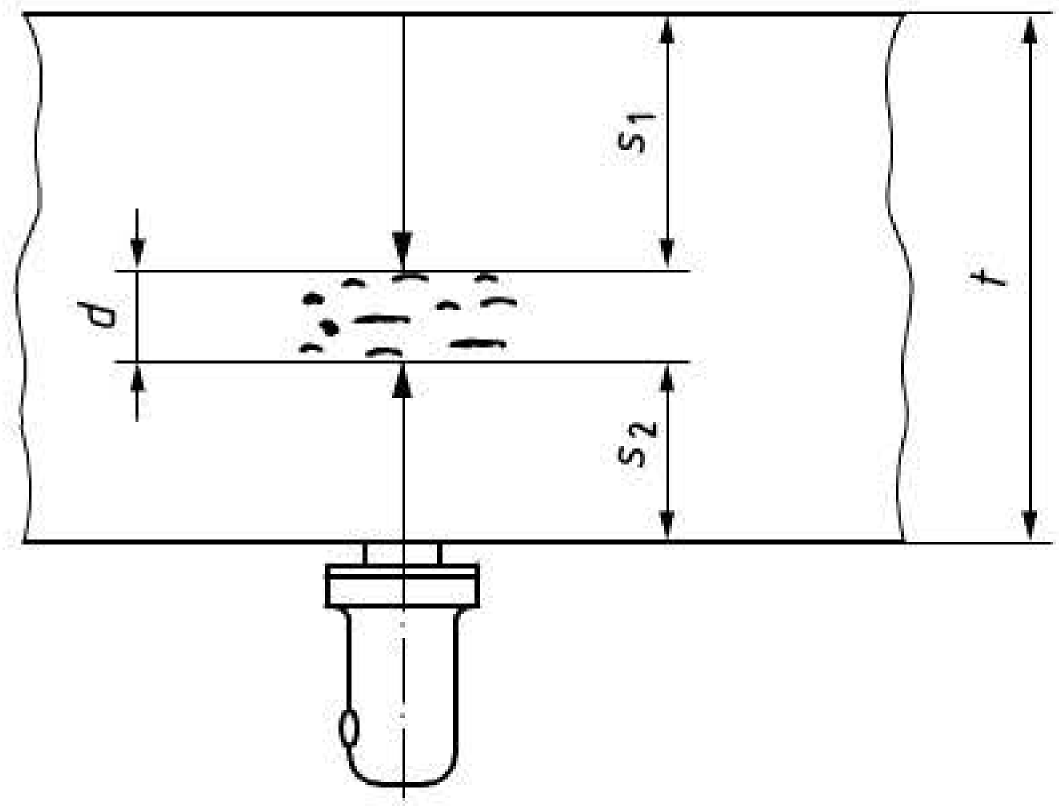
Figure 3 — Measurement of the dimension of discontinuities in the through-wall direction



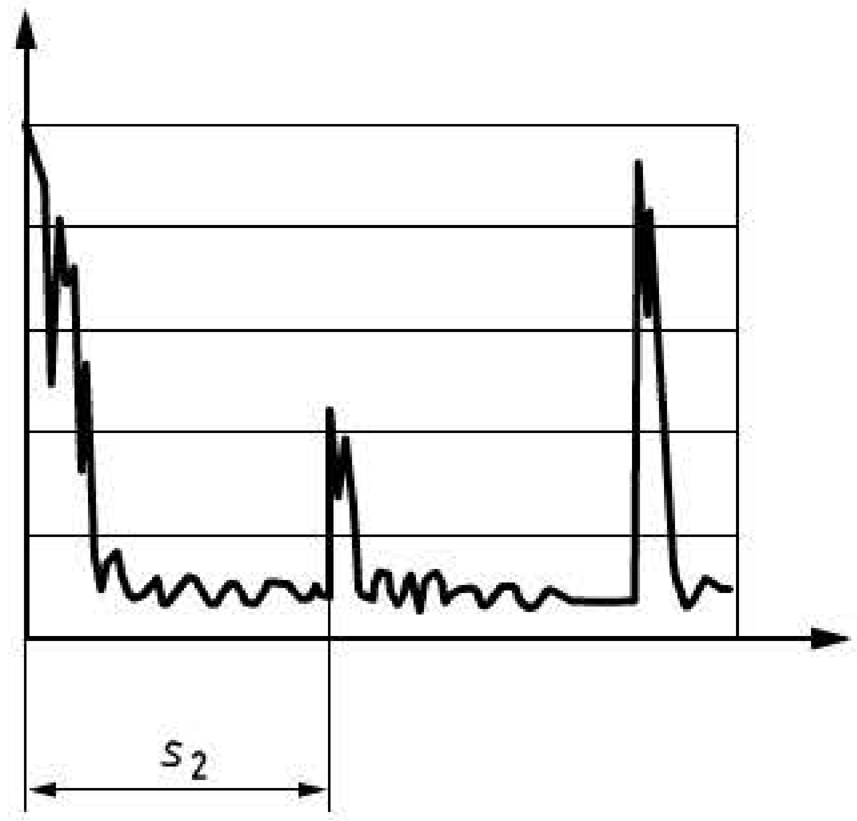
a) Scanning position "A"



b) A-scan from scanning position "A" in Figure 4 a)



c) Scanning position "B"



d) A-scan from scanning position "B" in Figure 4 c)

Key

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

t wall thickness

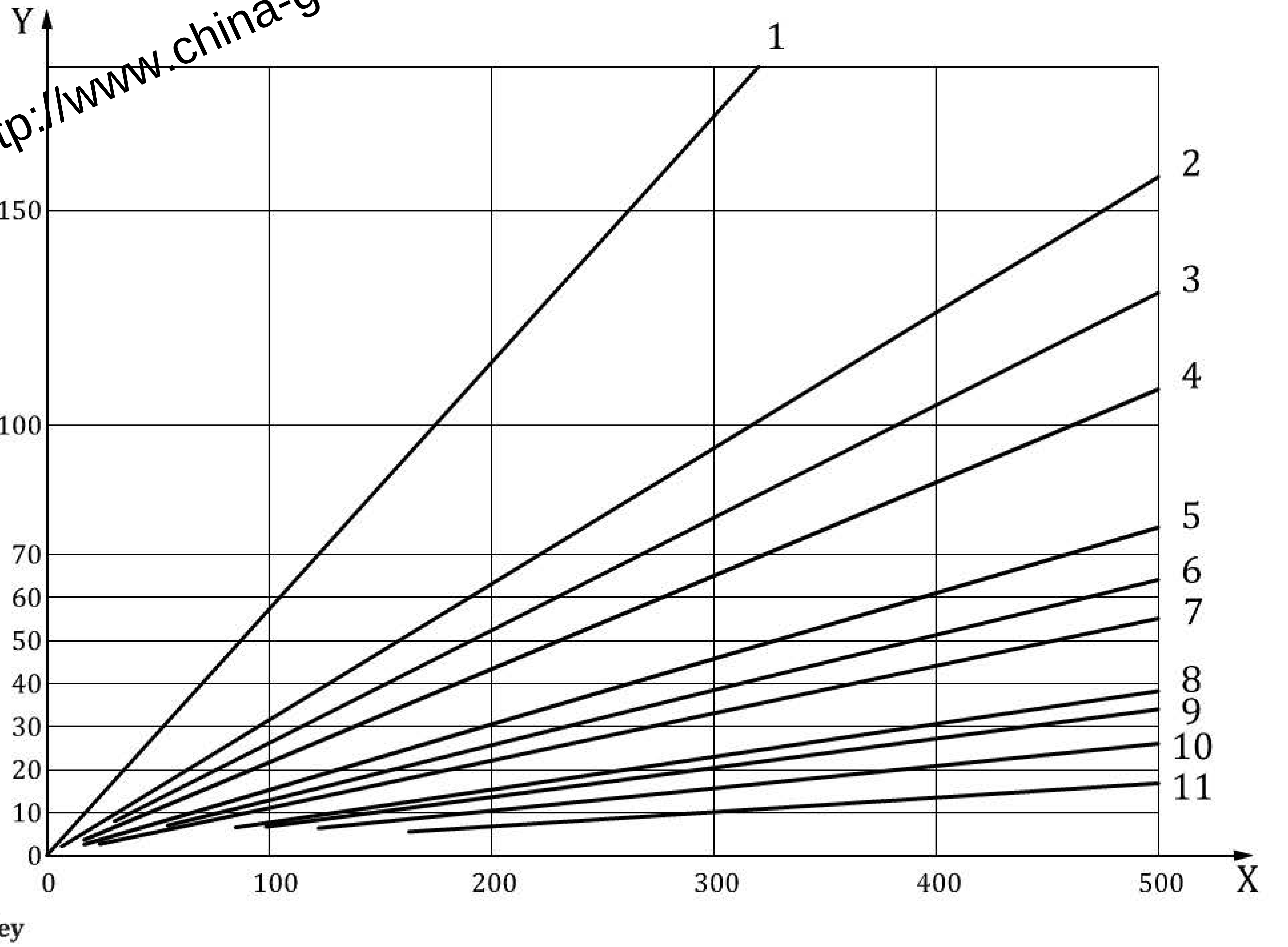
s_1, s_2 length of the sound path

Figure 4 — Measurement of the dimension of discontinuities in the through-wall direction with normal-beam probes

Annex A
(informative)

Sound-beam diameters

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



Key

1 1 MHz, L, Ø 10
2 2 MHz, L, Ø 10
3 1 MHz, L, Ø 24
4 2 MHz, T, 8 × 9
5 4 MHz, L, Ø 10
6 2 MHz, L, Ø 24
7 4 MHz, T, 8 × 9
8 2 MHz, T, 20 × 22
9 4 MHz, L, Ø 24
10 5 MHz, L, Ø 24
11 4 MHz, T, 20 × 22
X sound path, in millimetres
Y sound-beam diameter (−6 dB), in millimetres

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

Table A.1 — Near-field lengths of various probes

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

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

$$N = \frac{D_c^2}{4\lambda} \tag{A.1}$$

$$D_F = \frac{\lambda s}{D_c} \tag{A.2}$$

where

N is the near-field length, in millimetres;

D_c is the transducer diameter, in millimetres;

λ is the wavelength, in millimetres;

s is the sound path in millimetres;

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

Annex B
(informative)

Types of indications generated by typical discontinuities

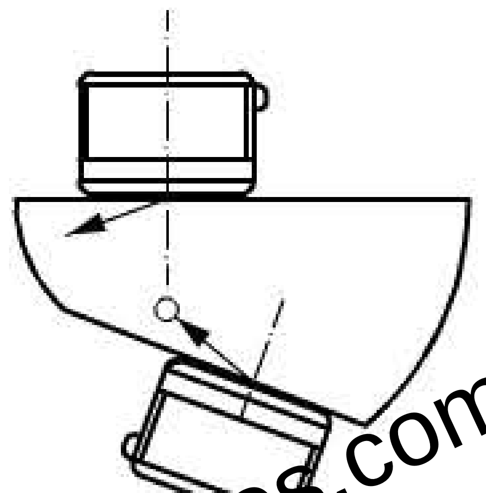
Figures B.1 to B.11 show how typical types of indications and their echo dynamics are linked to typical types of discontinuities.

For the identification of the discontinuity type, the test sensitivities may be changed according to:

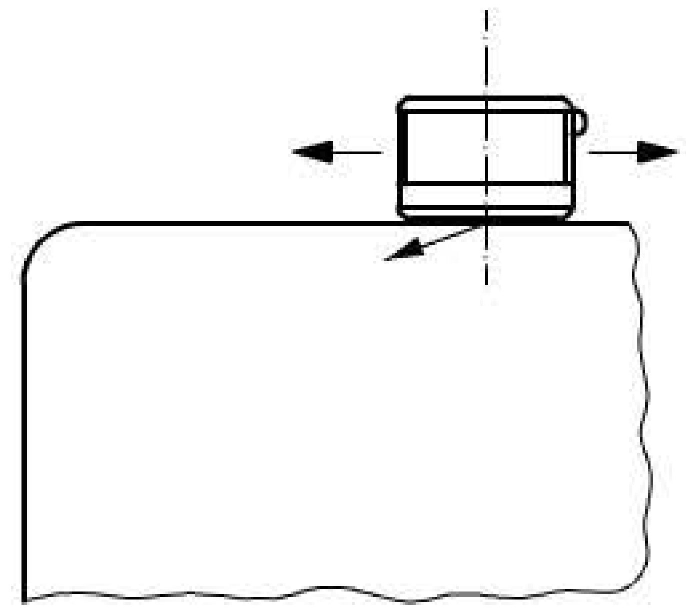
a) the distance between the test surface and the discontinuity;

b) the geometrical shape of the discontinuity;

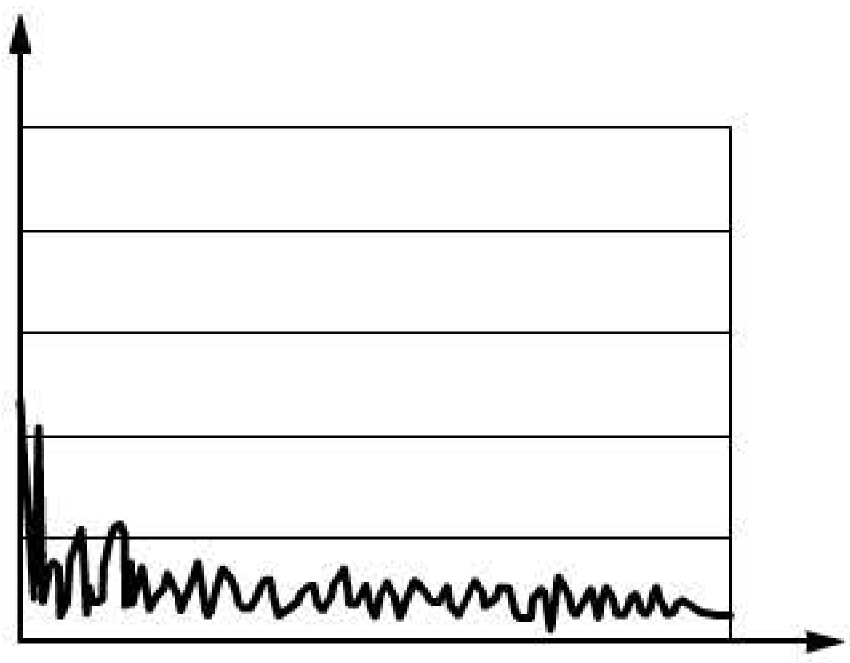
c) the test surface finish.



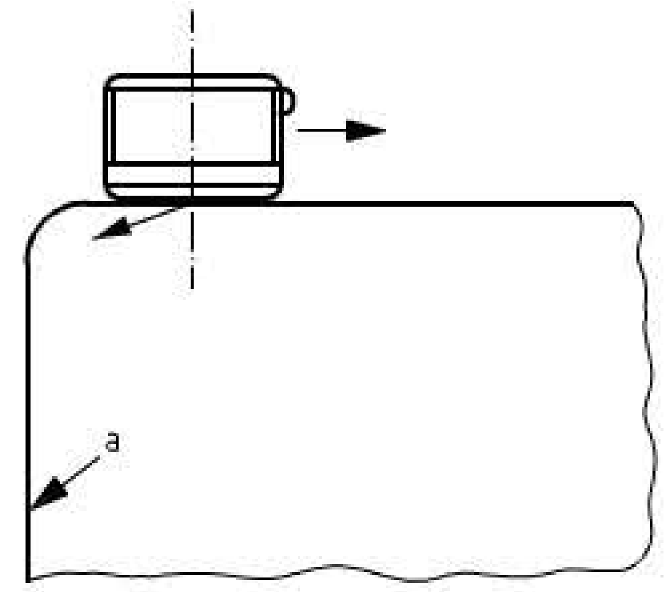
a) Probe positions on calibration block no. 2



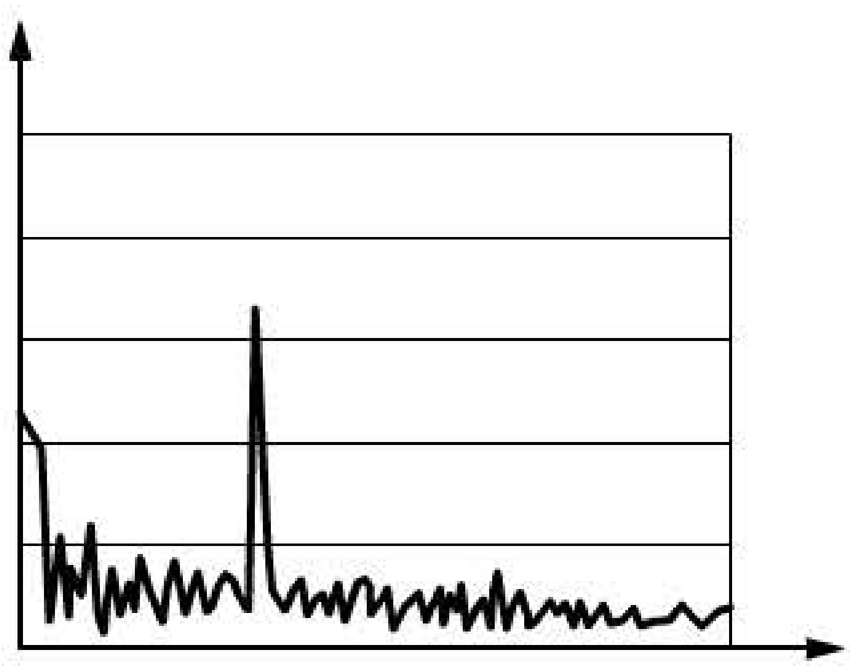
b) Probe on test object without discontinuities



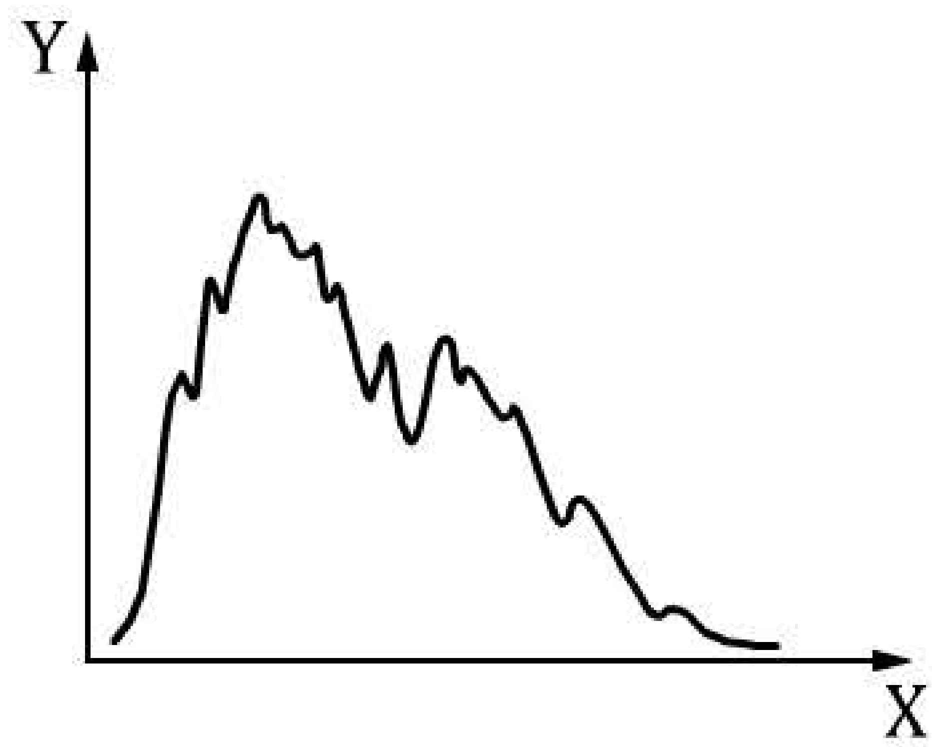
c) Display for Figure B.1 b) showing the average noise level



d) Probe on test object with discontinuity



e) Display for Figure B.1 d) showing the echo of the discontinuity



f) Typical echo dynamic pattern

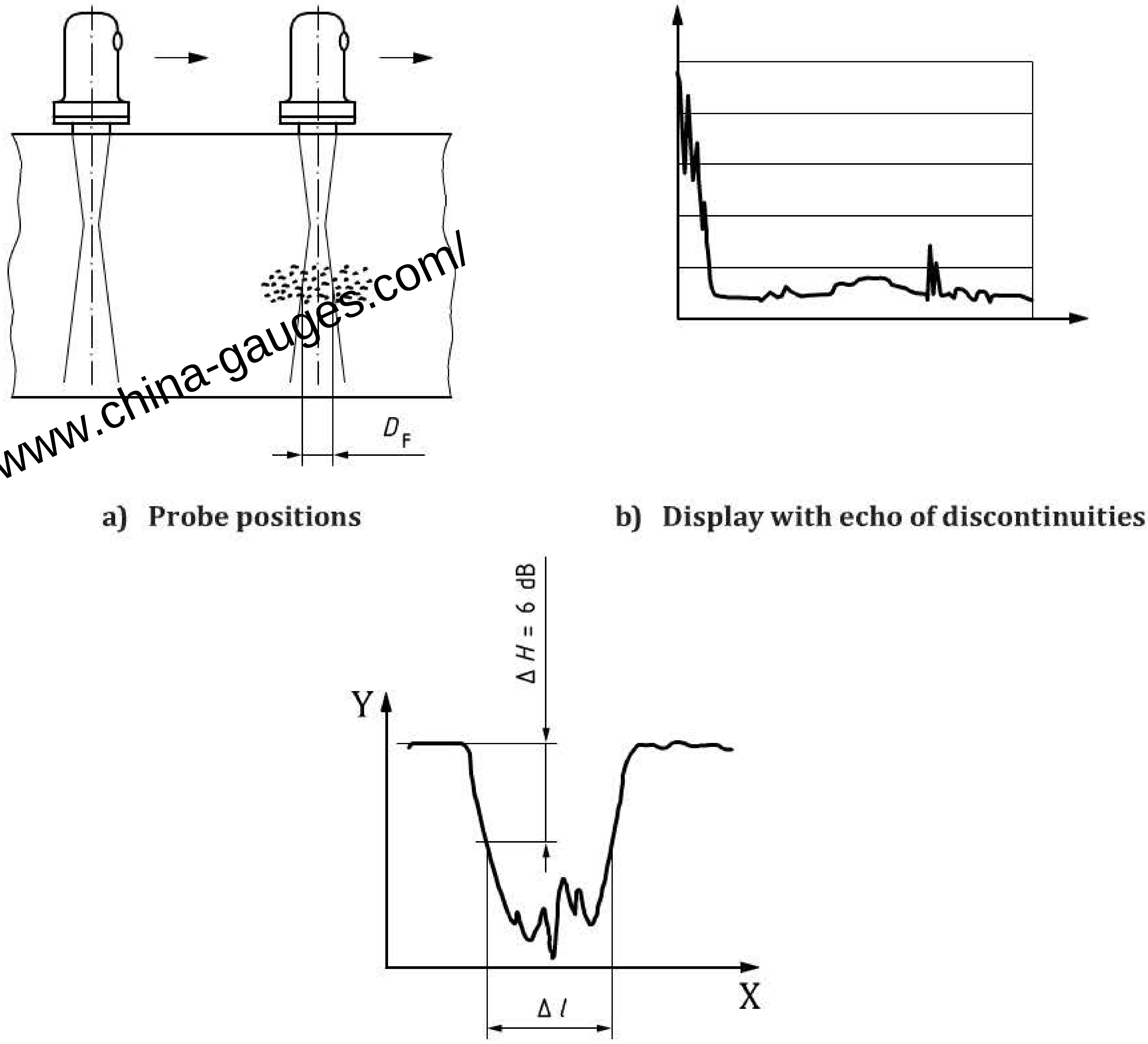
Key

X probe movement

Y echo height

[a] As-cast surface.

Figure B.1 — Range setting and sensitivity setting of the ultrasonic instrument when scanning with a dual-element angle-beam probe (4 MHz, 60° angle) to detect discontinuities with a measurable dimension mainly orientated in the through-wall direction in the rim zone



a) **Probe positions**

b) **Display with echo of discontinuities**

c) **Back-wall echo drop**

Key

ΔH reduction of back-wall echo

X probe movement

Y echo height

Typical indication:

Reduction of back-wall echo by more than 12 dB. Indications from discontinuities that are frequently invisible.

Origin: Spongy shrinkage, gas holes, inclusions or large inclined discontinuity.

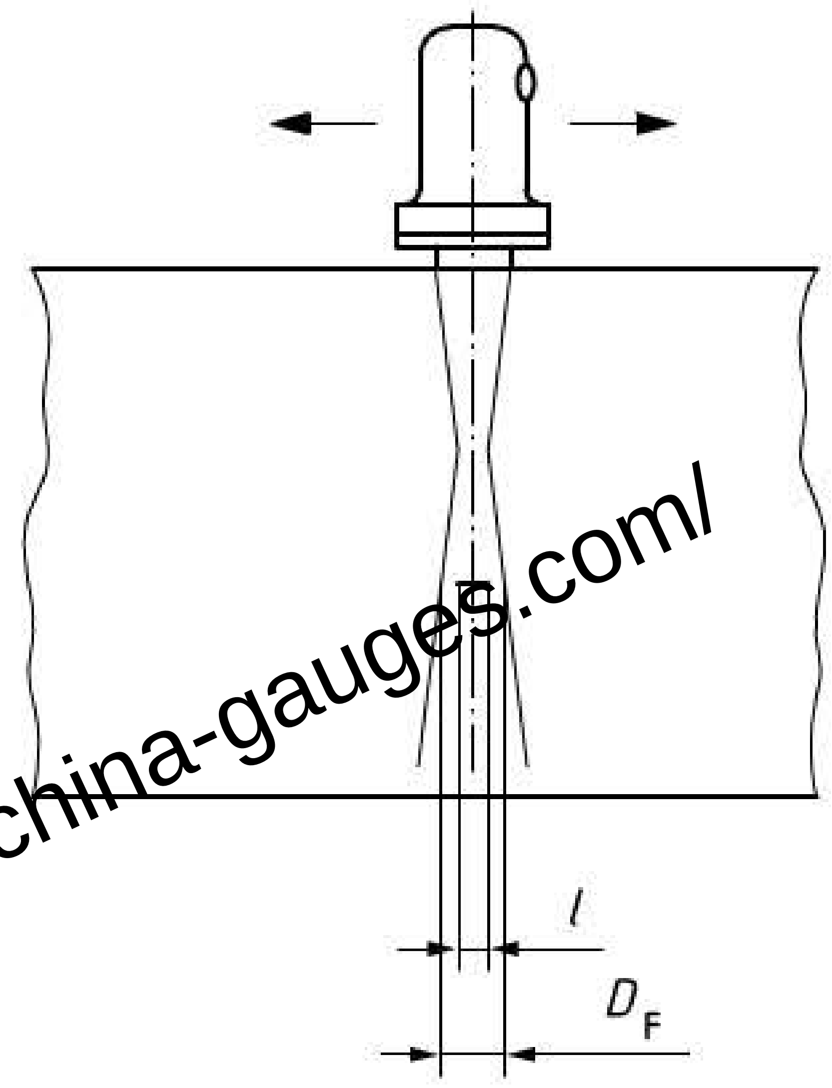
$\Delta l > D_F$

where

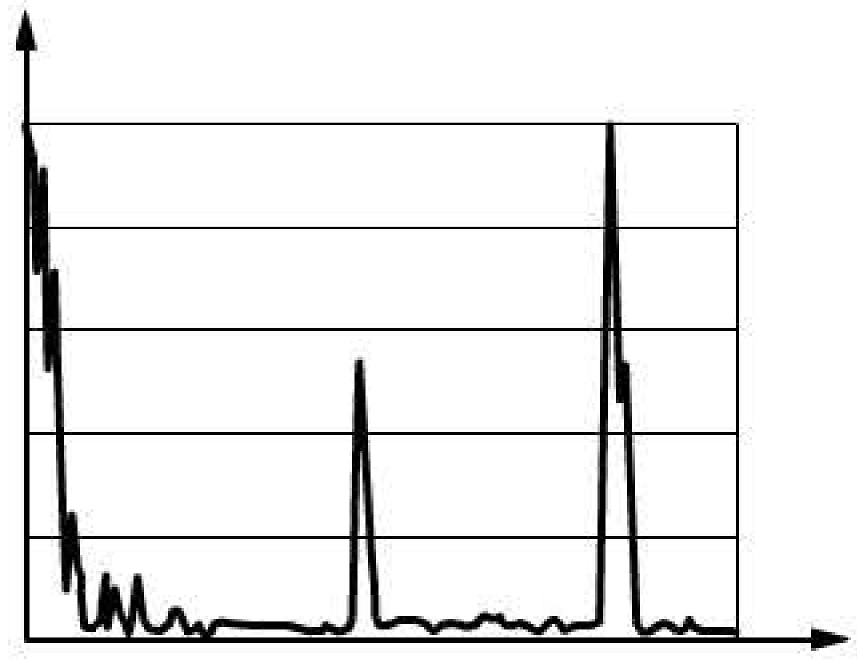
D_F is the sound-beam diameter;

Δl is the dimension of the discontinuity.

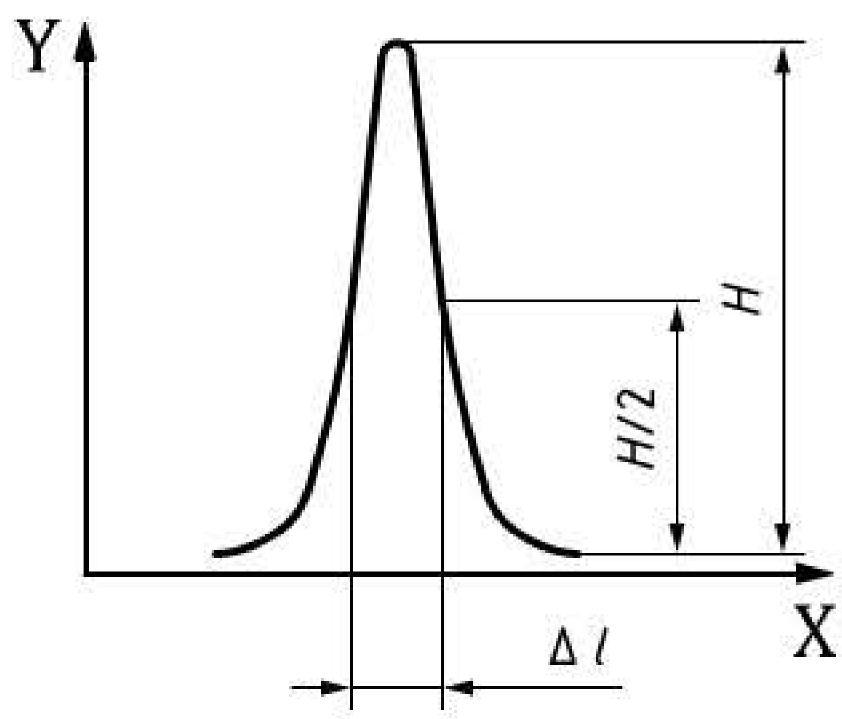
Figure B.2 — Reduction of back-wall echo by more than 12 dB, measurable dimension of a discontinuity



a) Probe movement



b) Display of echoes



c) Determination of half-value dimension

Key

l lateral dimension of discontinuity

Δ*l* half-value dimension of indication

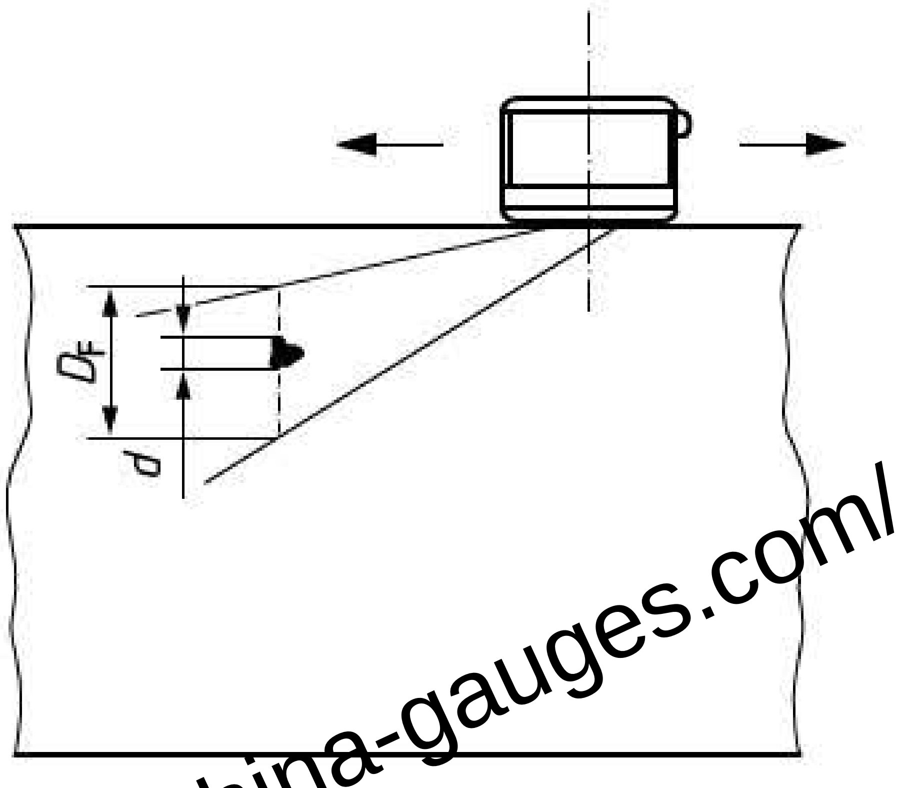
H maximum echo height of individual indication

X probe movement

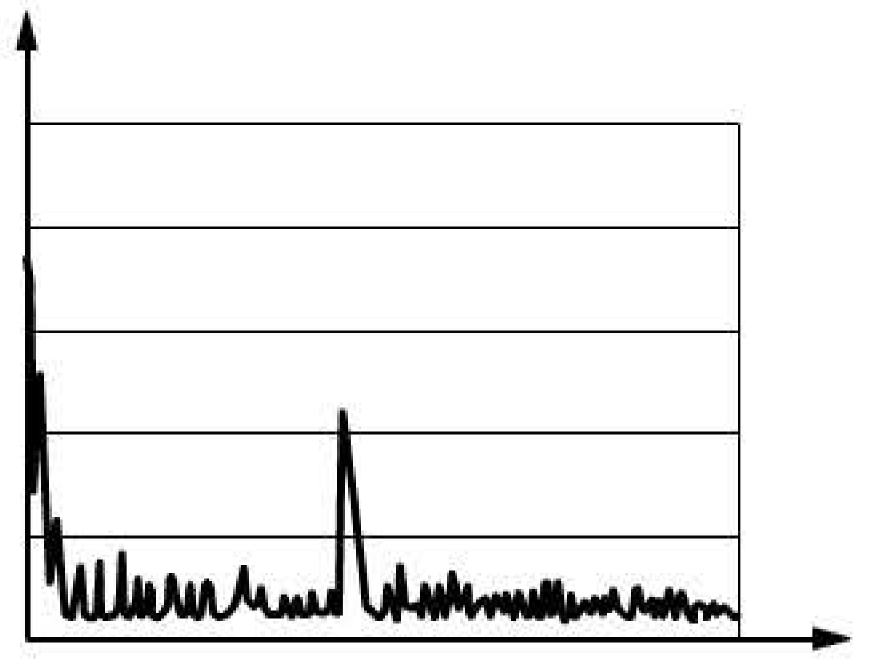
Y echo height

Typical indication:
Individual indication, half-value dimension Δ*l* smaller than or equal to the sound-beam diameter D_F at reflection point.

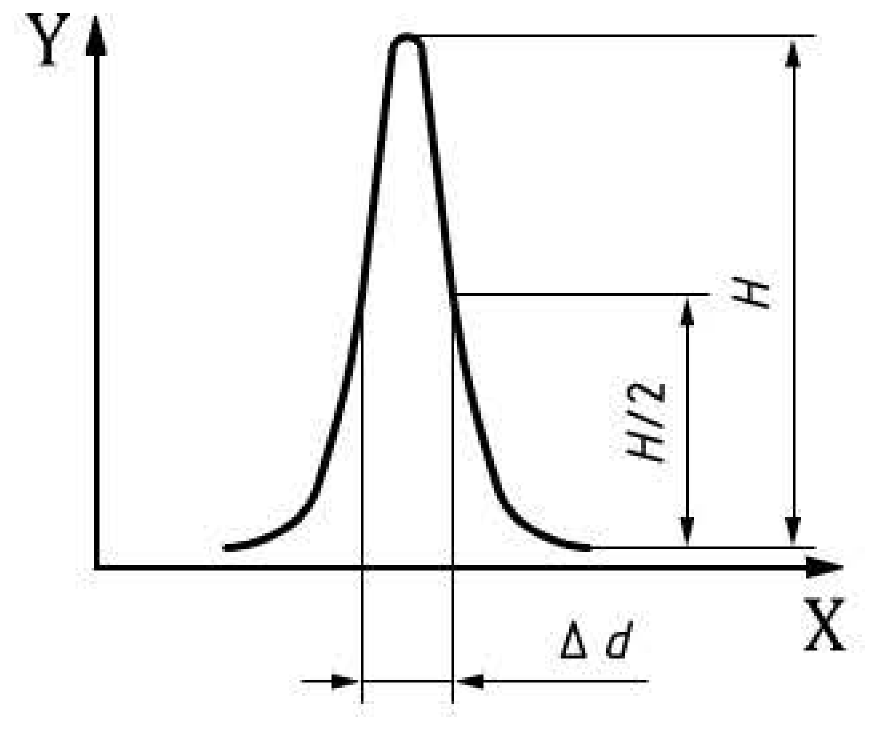
Figure B.3 — Individual discontinuity without measurable dimensions



a) **Probe position**



b) **Display of echo**



c) **Determination of half-value dimension**

Key

d dimension of discontinuity in the through-wall direction

Δ*d* half-value dimension of indication

H maximum echo height of individual indication

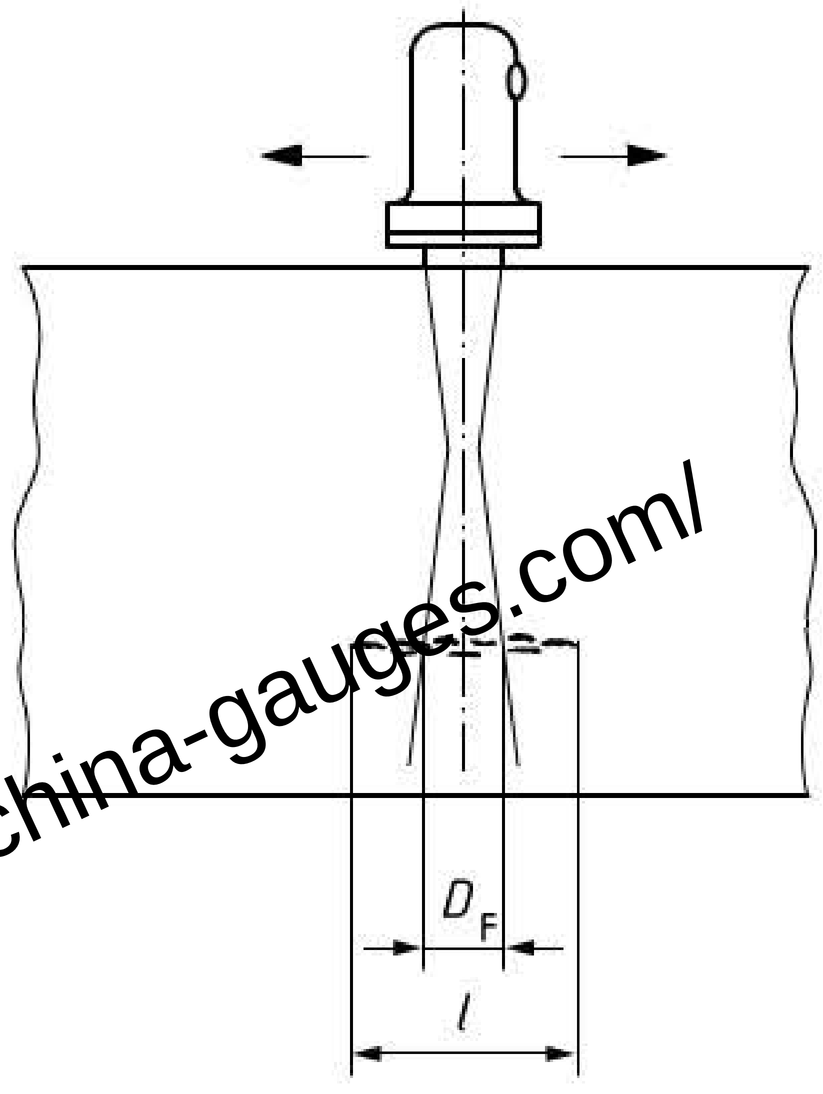
X probe movement

Y echo height

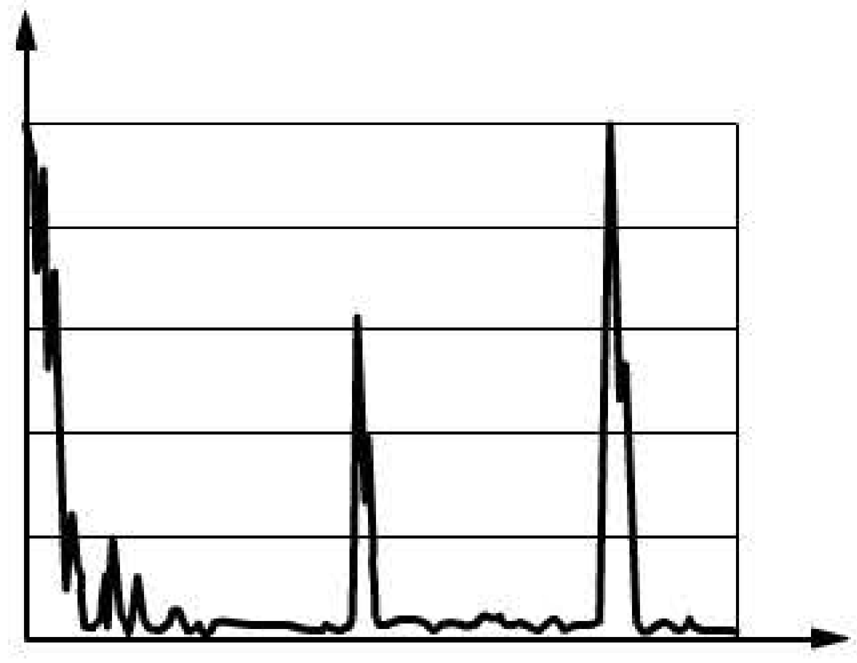
Typical indication:

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

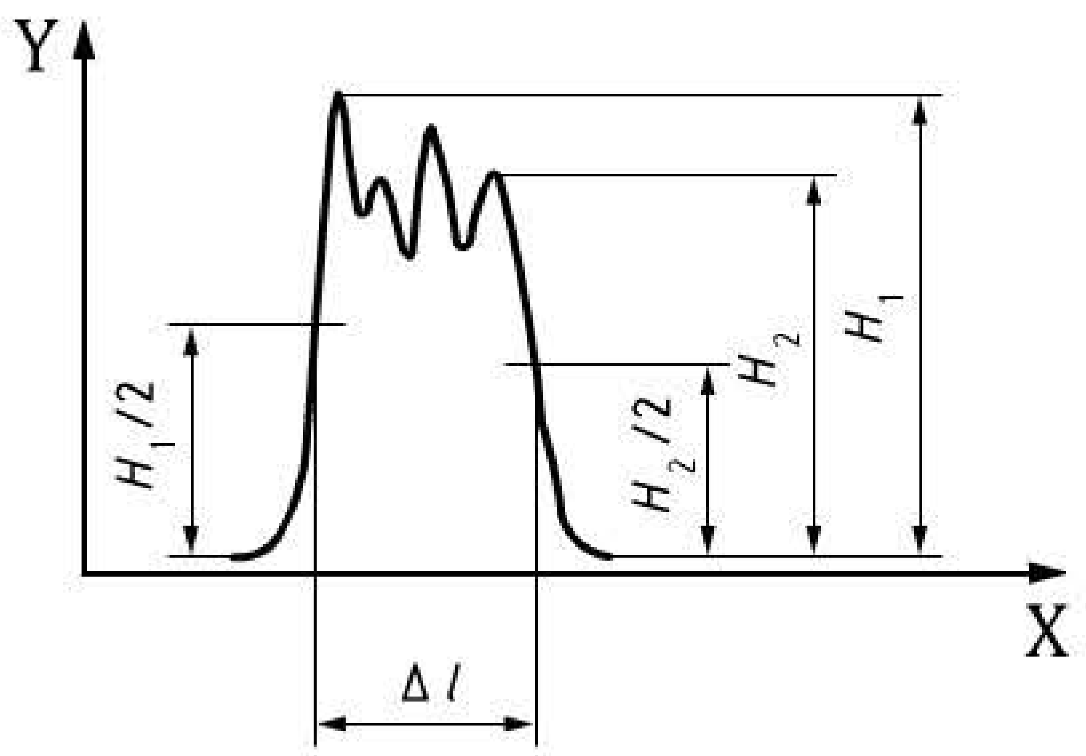
Figure B.4 — Individual discontinuity without measurable dimensions; individual indication with one measurable dimension parallel to the test surface and without a measurable dimension in the through-wall direction



a) Probe movement



b) Related display (A-scan)



c) Determination of half-value dimension

Key

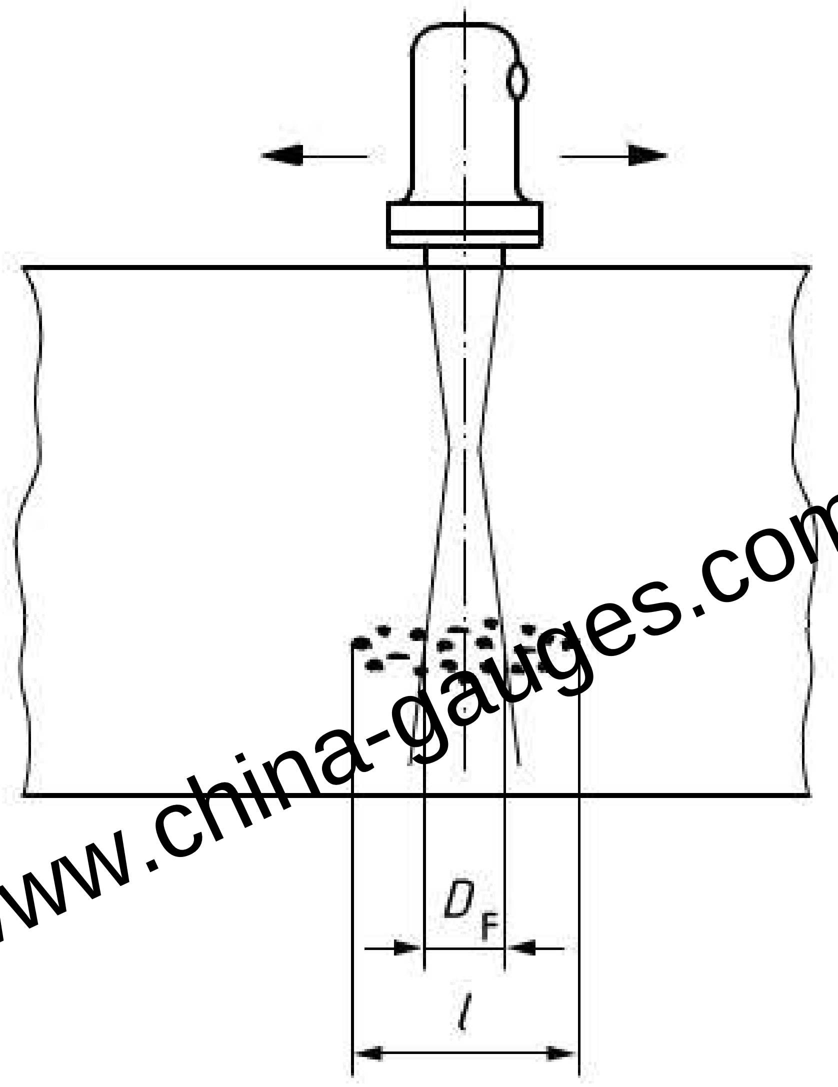
l	lateral dimension of discontinuity
Δ*l*	half-value dimension of indication
H_1, H_2	last maximum echo heights on opposite sides of indication
X	probe movement
Y	echo height

Typical indication:

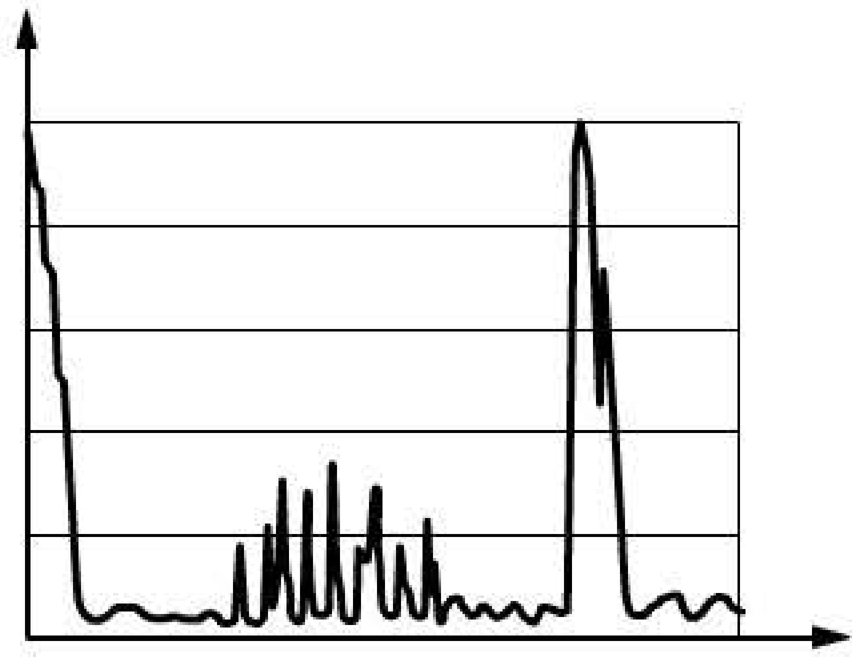
Individual discontinuities, mainly from the same position in the through-wall direction.

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

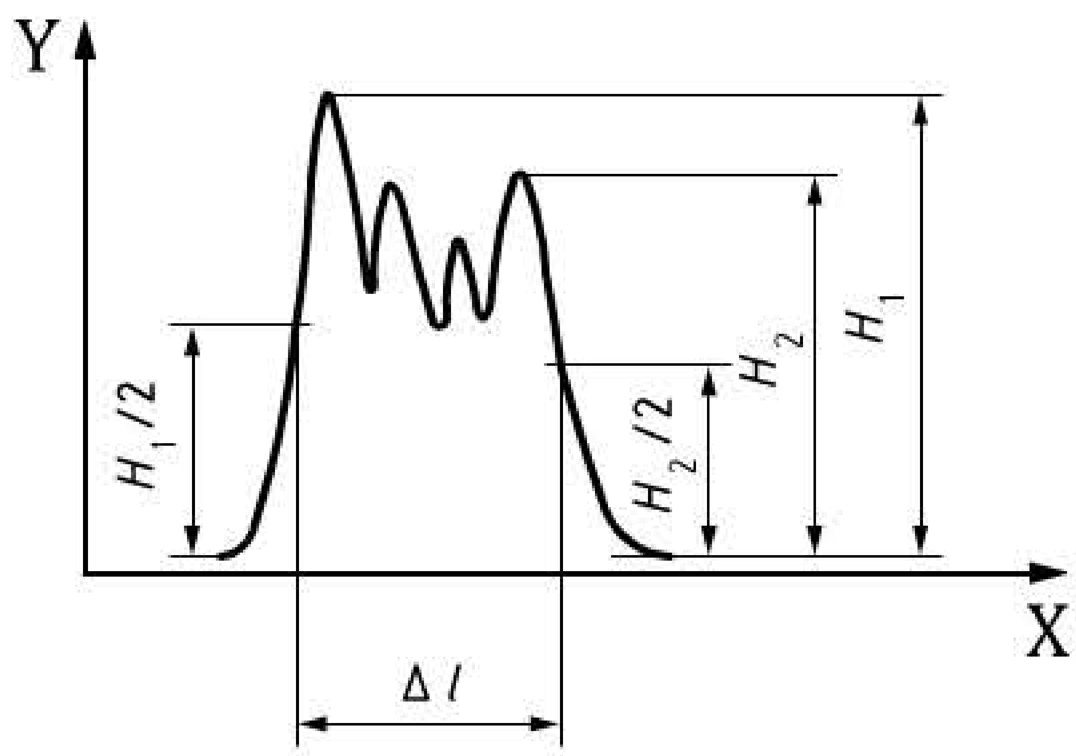
Figure B.5 — Individual discontinuity with measurable dimensions: measurable length, non-measurable width; measurable length, measurable width



a) Probe movement



b) Related display



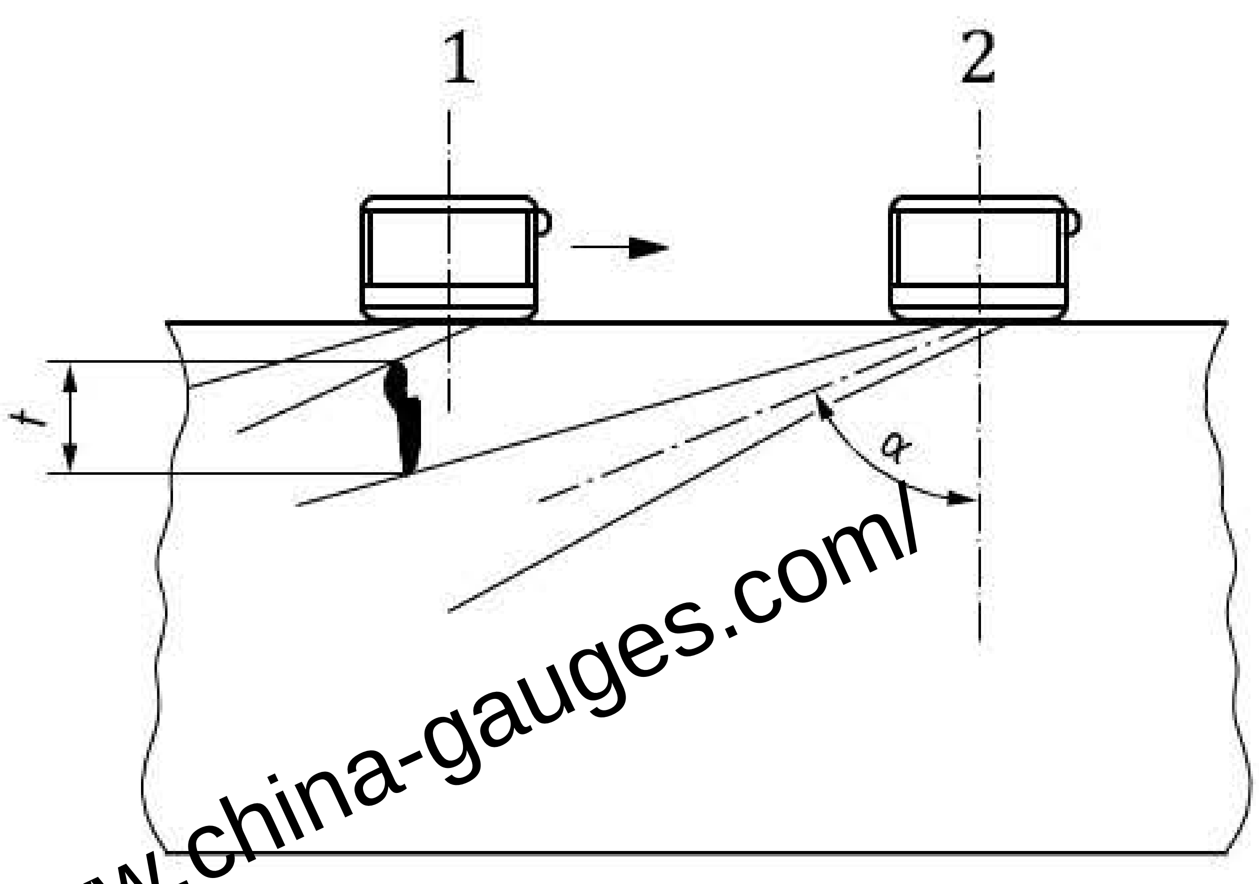
c) Determination of half-value dimension

Key

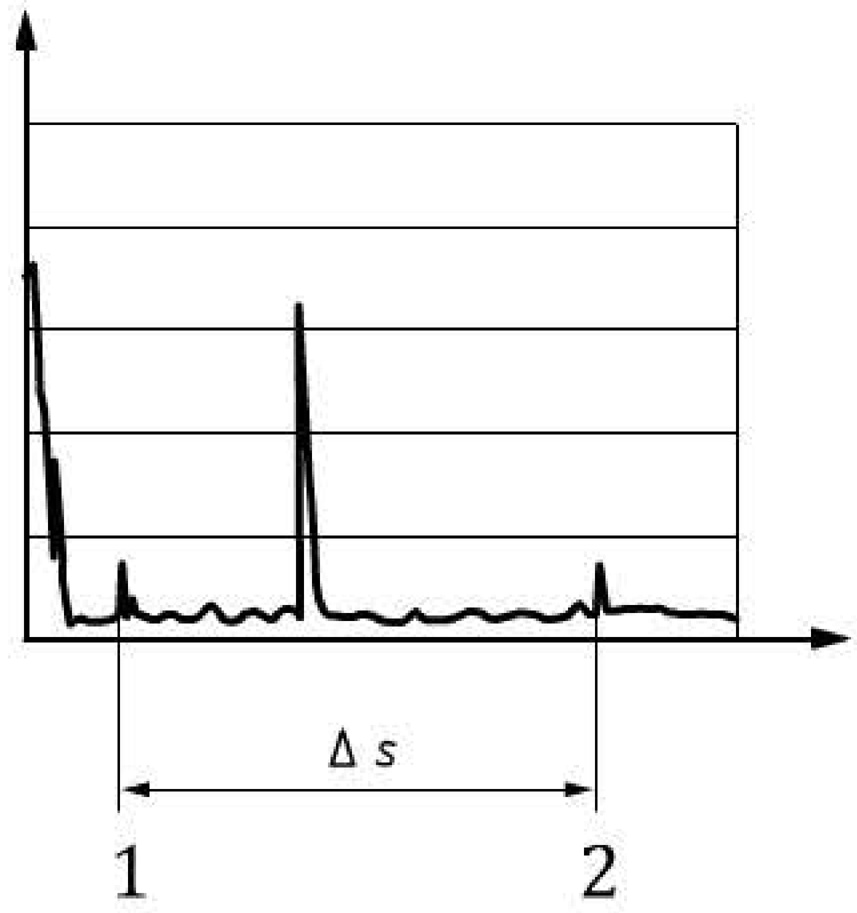
l	lateral dimension of discontinuity
Δl	half-value dimension of indication
H_1, H_2	last maximum echo heights on opposite sides of indication
X	probe movement
Y	echo height

Typical indication:
Clustering of indications, mainly resolvable with non-measurable dimensions.
Dimension of discontinuity range equal to or larger than the sound-beam diameter D_F.

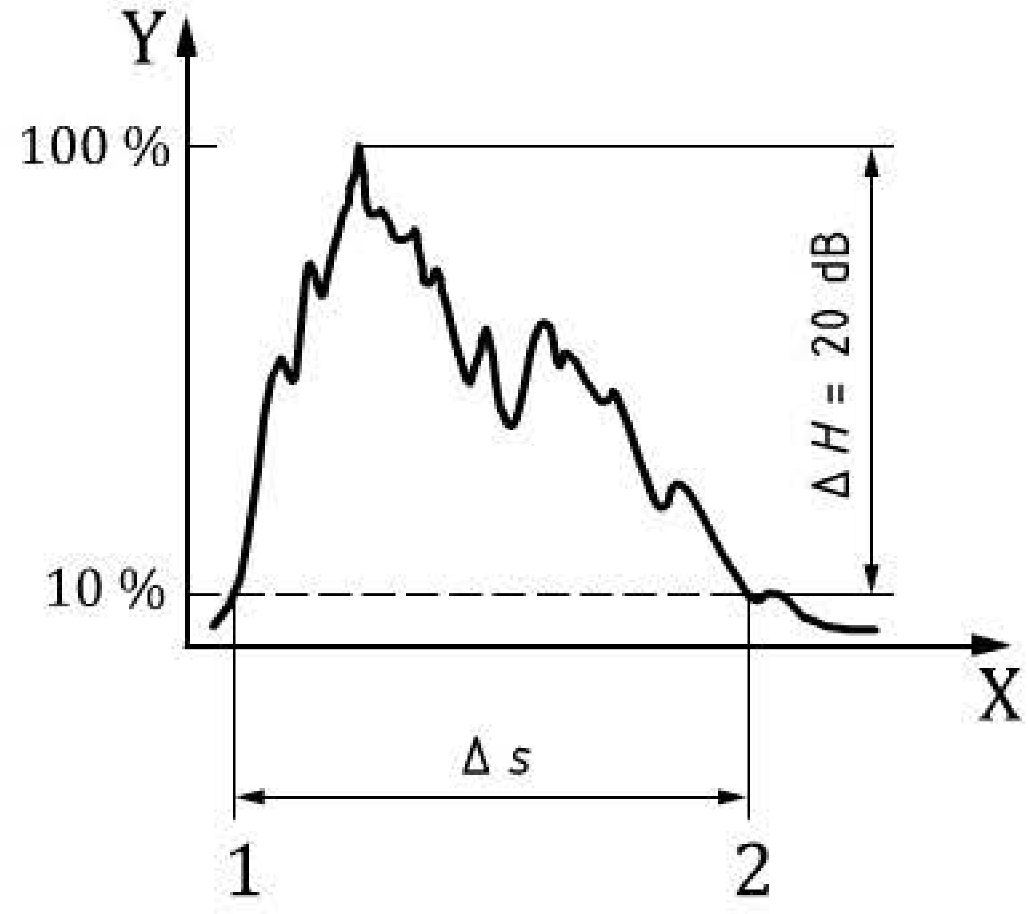
Figure B.6 — Group of resolvable discontinuities with measurable dimensions of the discontinuity range



a) Probe positions 1 and 2



b) Related display



c) Echo dynamics envelope

Key

1 probe position 1

2 probe position 2

ΔH reduction of maximum echo height of indication

X probe movement

Y echo height

Typical indication:

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

$t = \Delta s \cos \alpha$

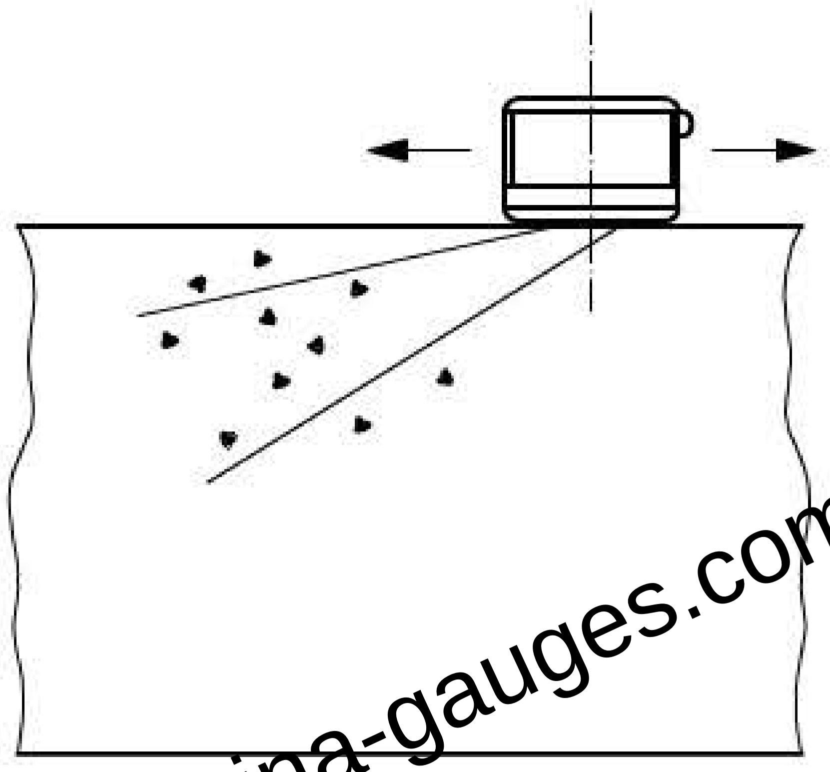
where

t is the dimension in the through-wall direction;

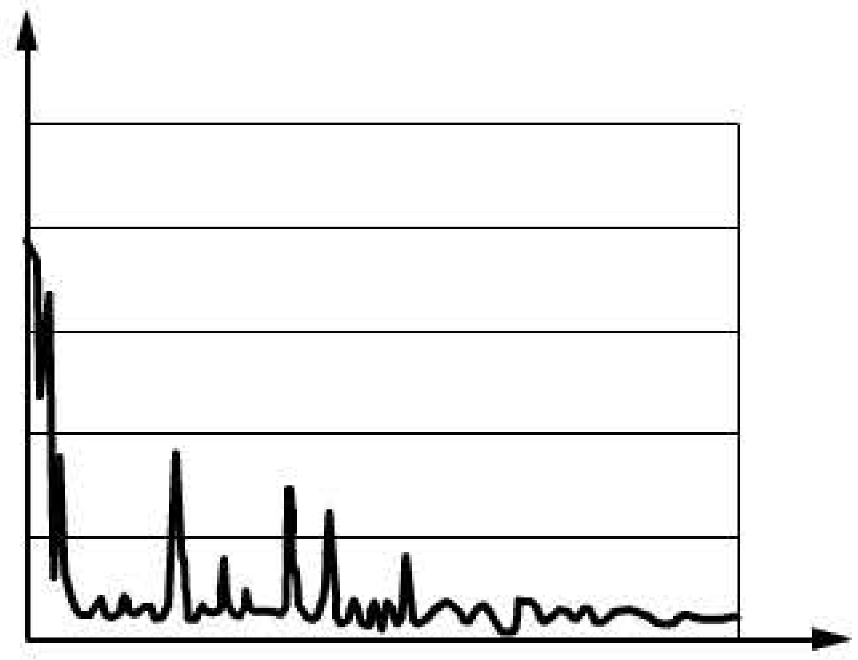
Δs is the difference of sound paths from position 2 to position 1;

α is the angle of incidence.

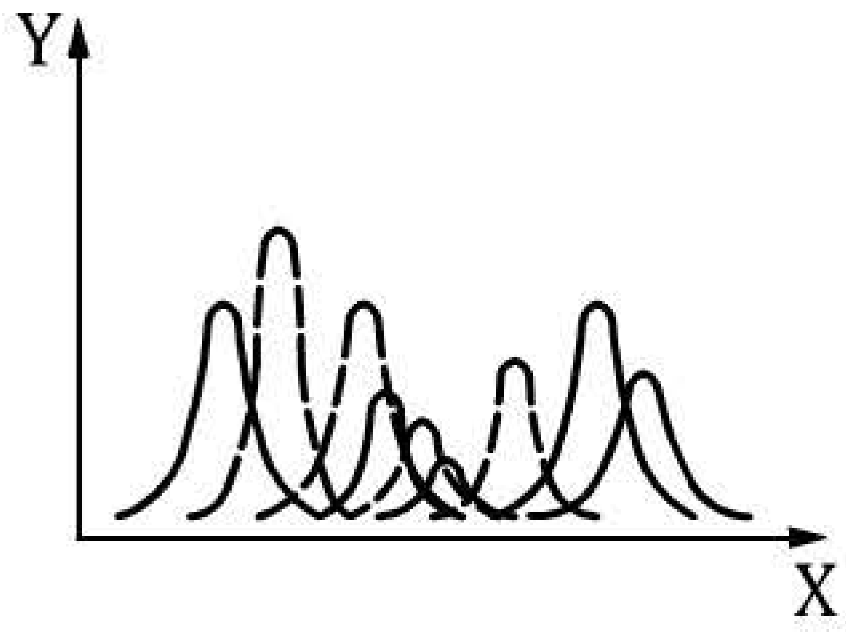
Figure B.7 — Individual discontinuity with measurable dimensions in the through-wall direction



a) Probe movement



b) Related display



c) Echo dynamics envelope

Key

X probe movement

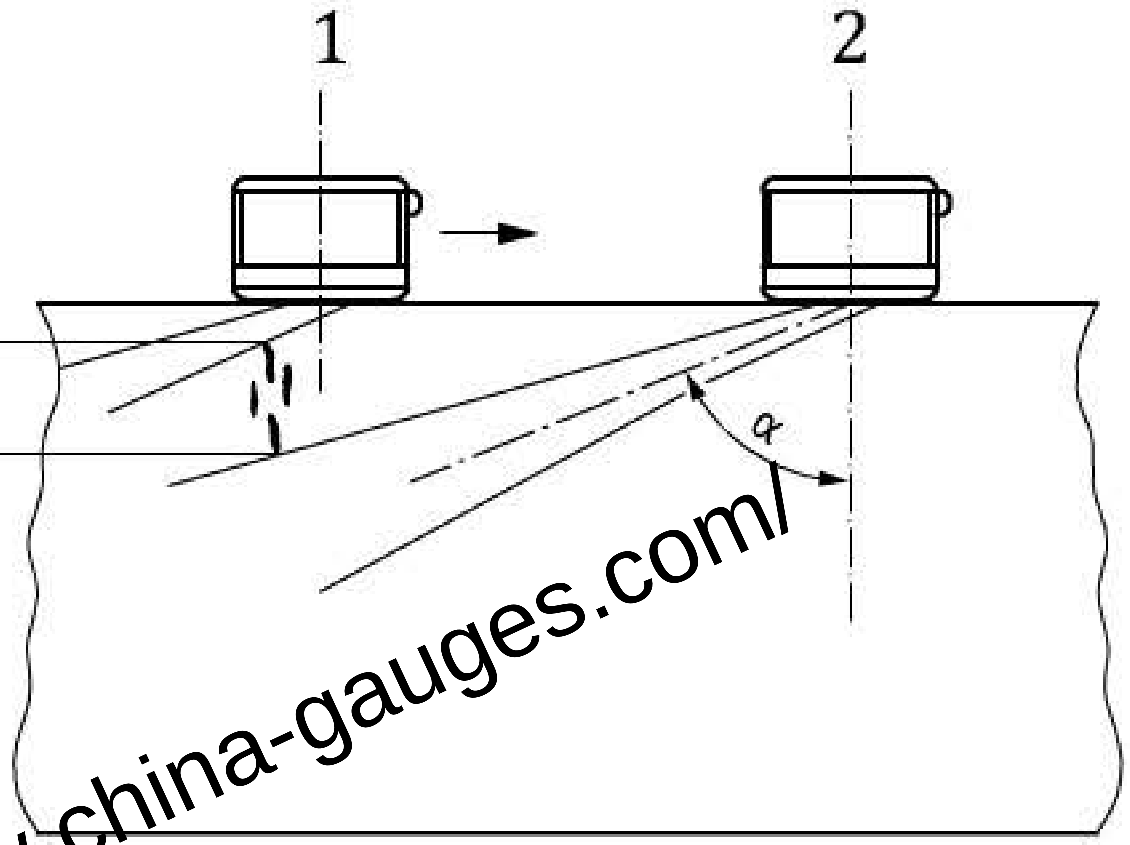
Y echo height

Typical indication:

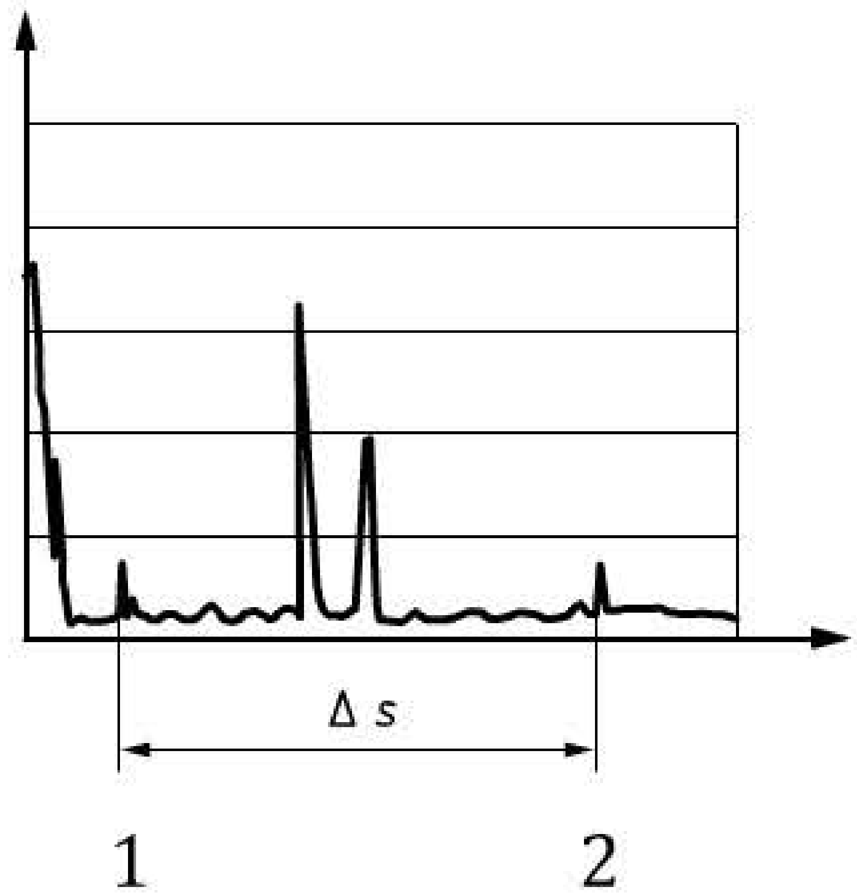
Indications from numerous individual discontinuities.

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

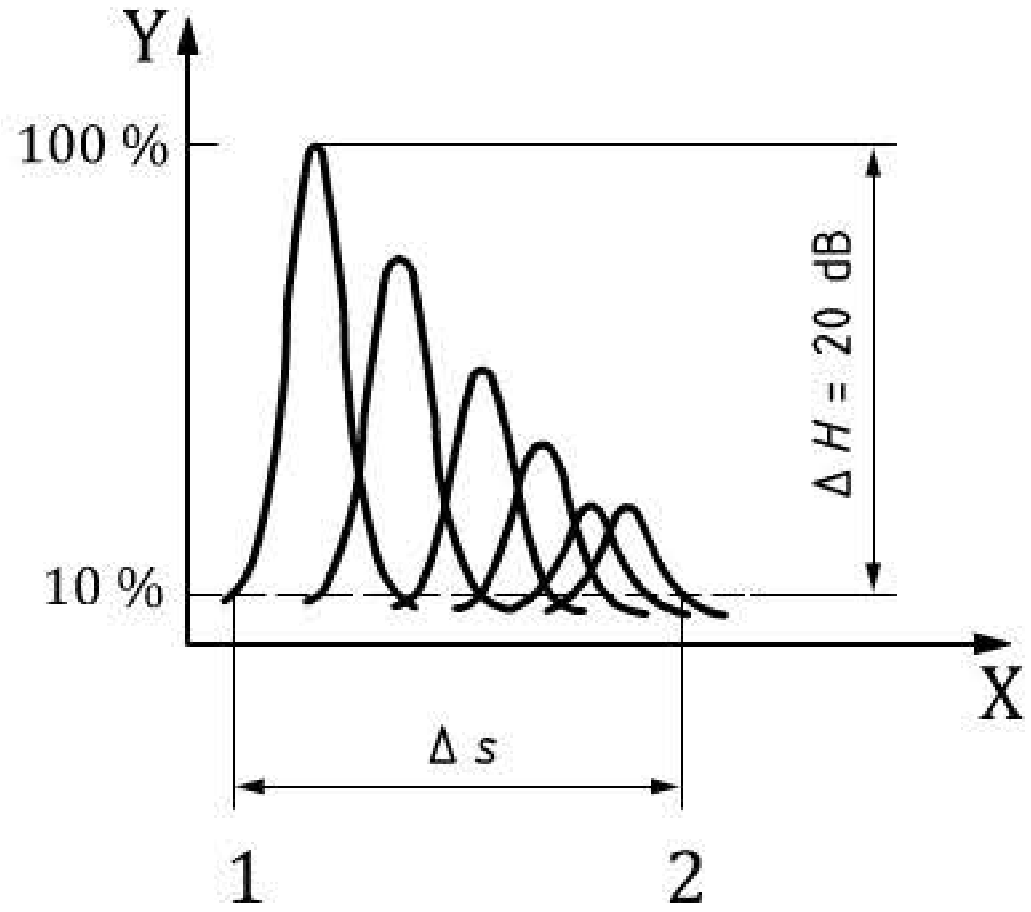
Figure B.8 — Numerous individual discontinuities without measurable dimensions but with measurable dimensions of the discontinuity range



a) Probe positions 1 and 2



b) Related display



c) Echo dynamics envelope

Key

1 probe position 1

2 probe position 2

ΔH reduction of maximum echo height of indication

X probe movement

Y echo height

Typical indication:

(Group of) Individual indications with a measurable dimension mainly in the through-wall direction:

$t = \Delta s \cos \alpha$

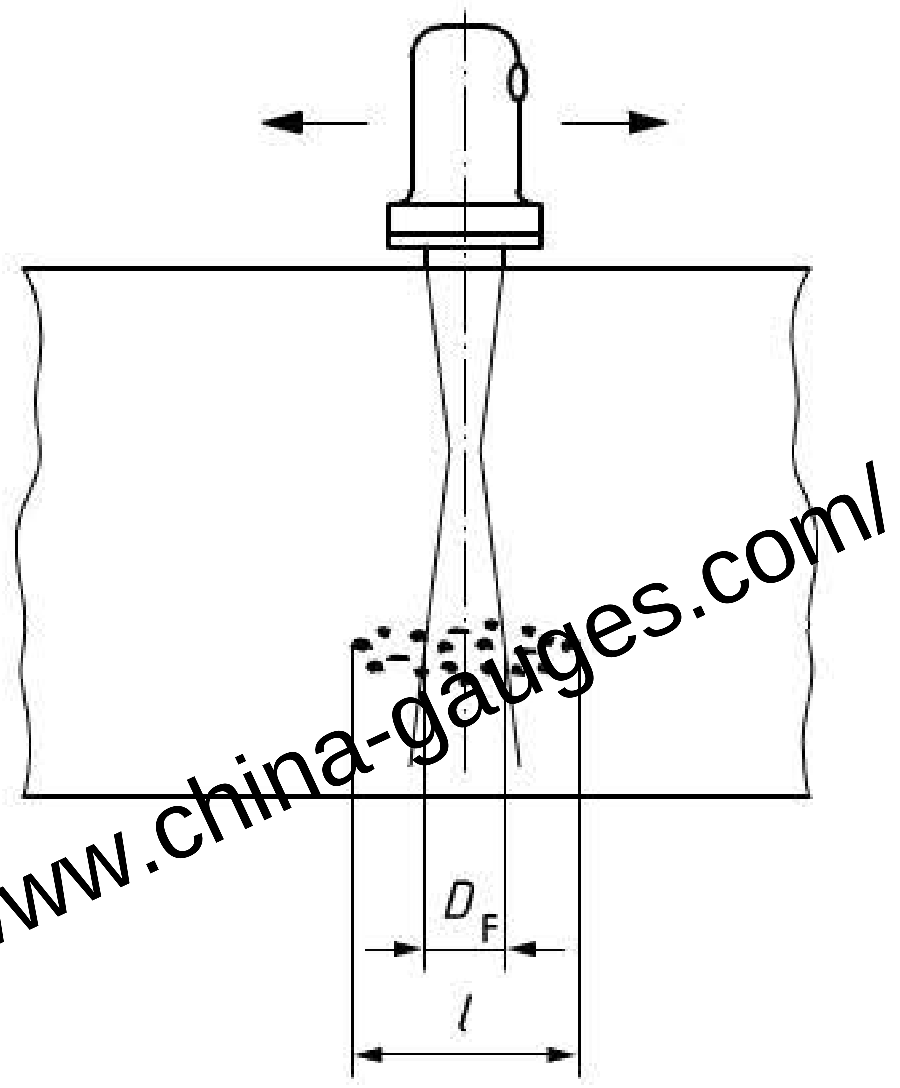
where

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

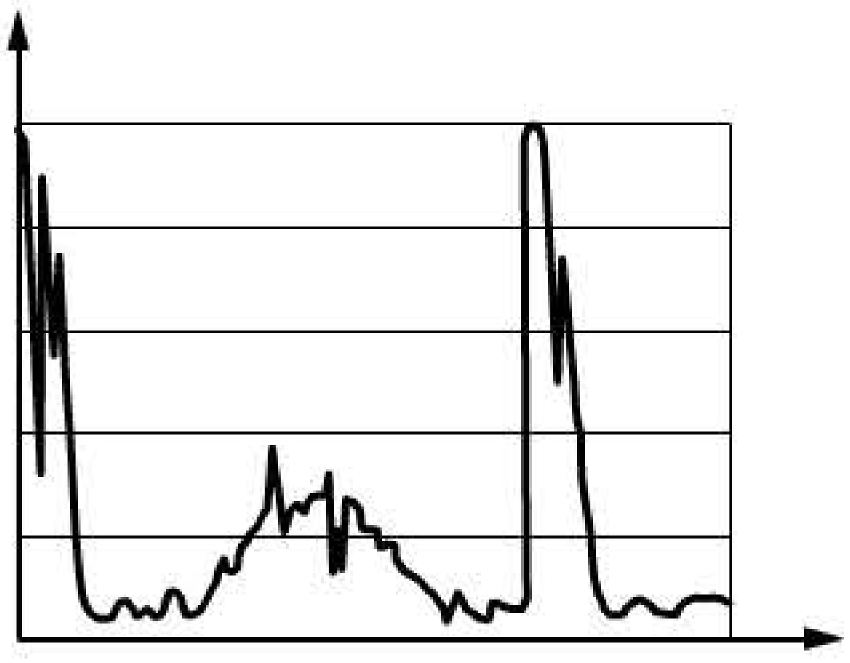
Δs is the difference of sound paths from position 2 and position 1;

a is the angle of incidence.

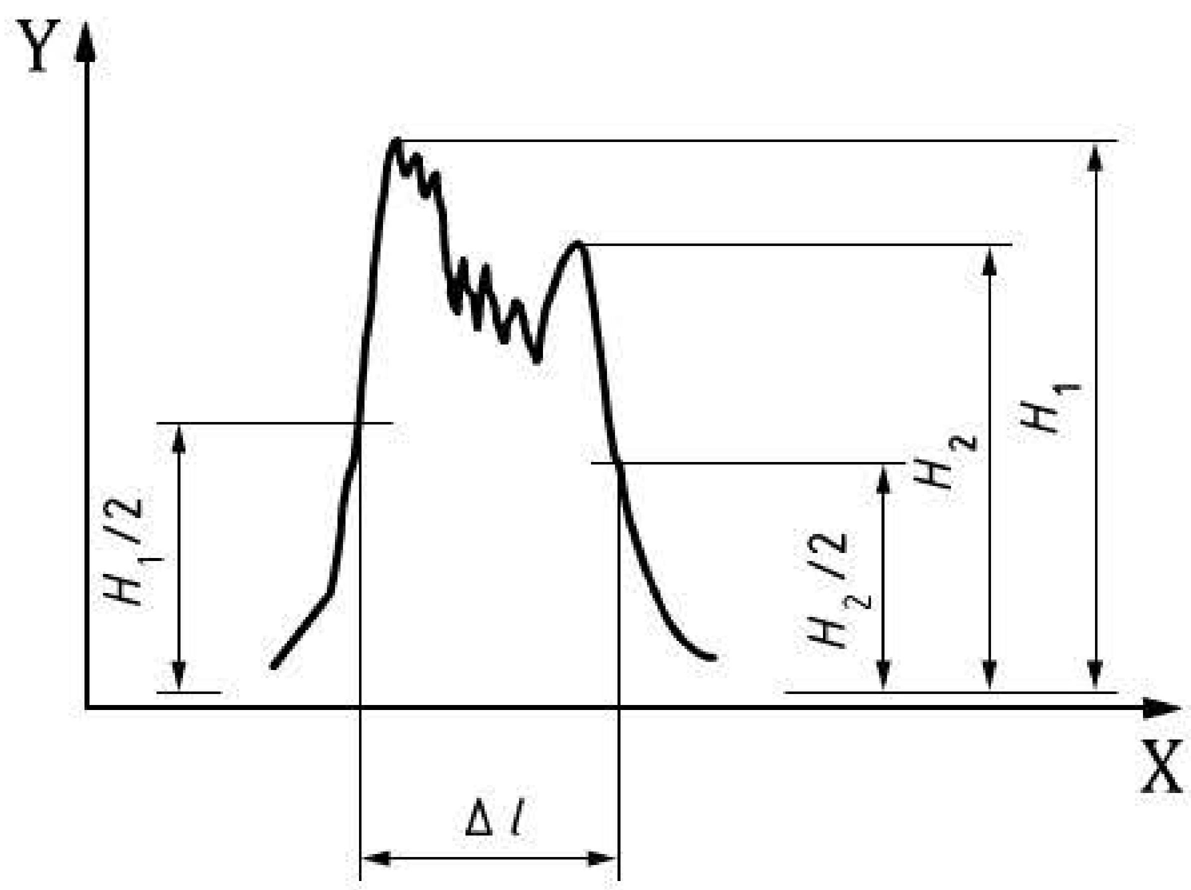
Figure B.9 — Numerous planar discontinuities with measurable dimensions in the through-wall direction



a) Probe movement



b) Related display



c) Echo dynamics envelope

Key

l	lateral extension of discontinuity
Δl	half-value dimension of indication
D_F	sound-beam diameter
H_1, H_2	last maximum echo heights on opposite sides of discontinuity
X	probe movement
Y	echo height

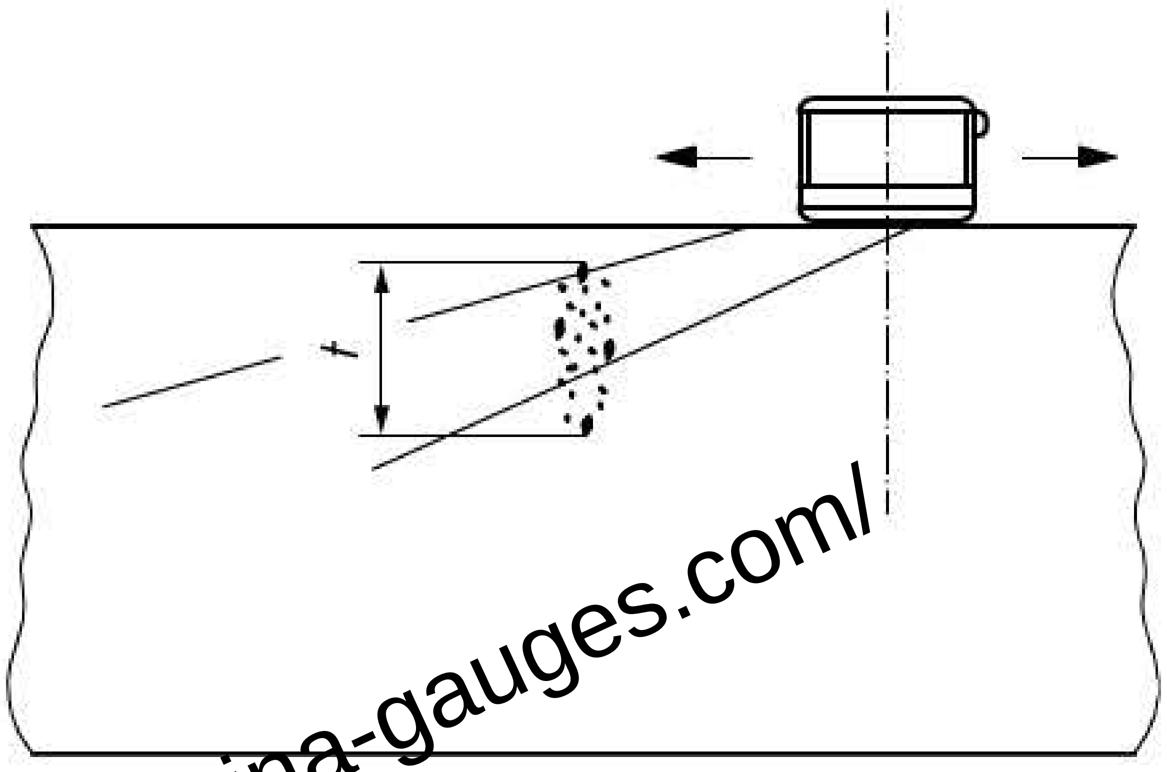
Typical indication:

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

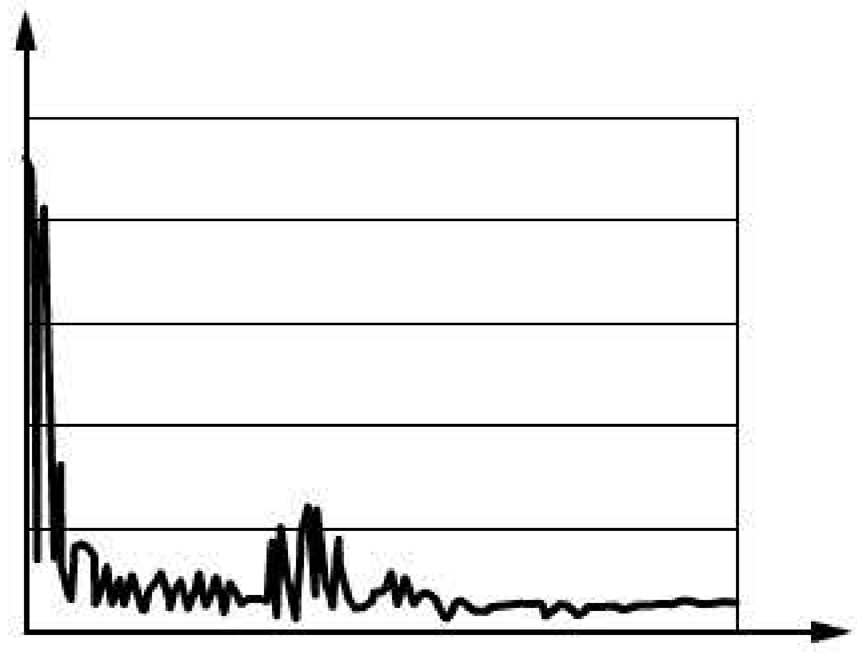
This type of indication should only be evaluated if, due to geometrical reasons, a back-wall echo cannot be obtained.

A simultaneous reduction of back-wall echo should be evaluated in accordance with Figure B.2.

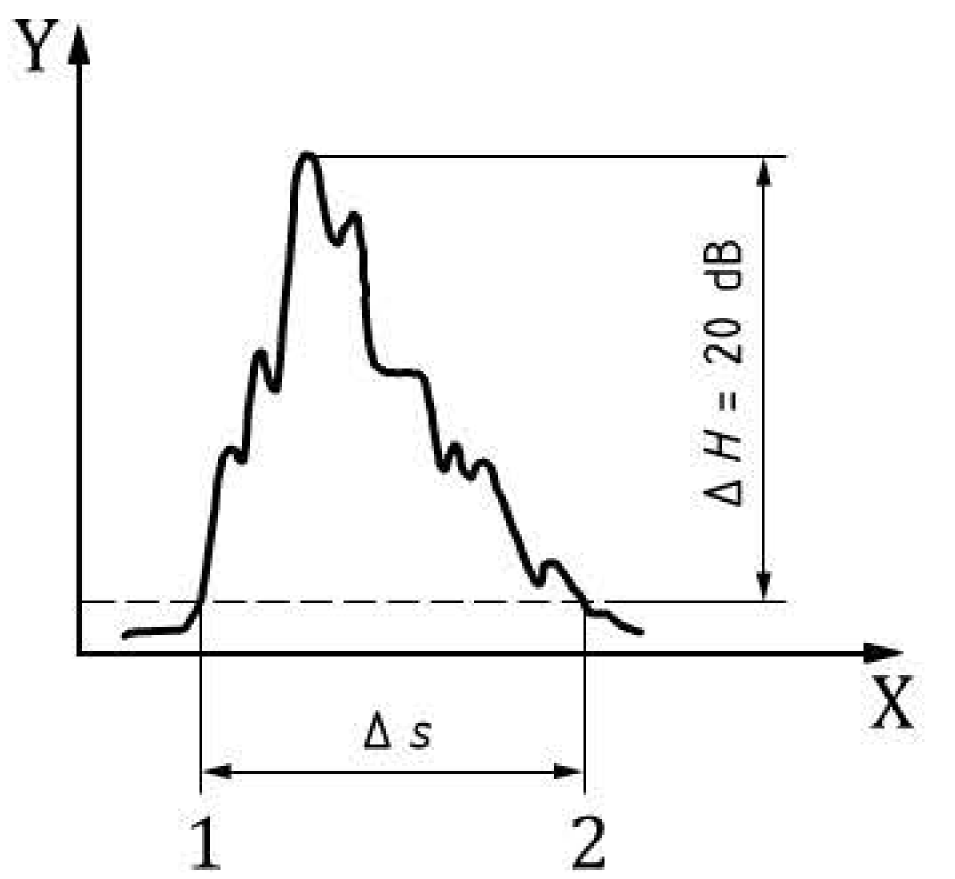
Figure B.10 — Group of non-resolvable indications with measurable dimensions of indication range (normal-beam probe)



a) Probe movement



b) Related display



c) Echo dynamics envelope

Key

1 probe position 1

2 probe position 2

ΔH reduction of maximum echo height of indication

X probe movement

Y echo height

Typical indication:

Indications from a group of mainly non-resolvable discontinuities:

$t = \Delta s \cos \alpha$

where

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

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

a is the angle of incidence.

Figure B.11 — Group of non-resolvable discontinuities with measurable dimensions of discontinuity range (angle-beam probe)

Bibliography

[1] EN 1559-2, *Founding — Technical conditions of delivery — Part 2: Additional requirements for steel castings*

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