INTERNATIONAL STANDARD

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Non-destructive testing — Ultrasonic testing — Reference blocks and test procedures for the characterization of contact probe sound beams

Essais non destructifs — Contrôles par ultrasons — Blocs de référence et modes opératoires des essais pour la caractérisation des faisceaux des traducteurs utilisés dans les contrôles par contact

Reference number
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Foreword

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*.

This second edition cancels and replaces the first edition (ISO 12715:1999), which has been technically revised.

Introduction

In ultrasonic non-destructive testing, pulse-echo contact tests with a straight-beam probe (also known as a normal-beam probe), an angle-beam probe (also known as an angle probe), or a dual-element probe (also known as a twin-crystal probe) are often used. To reliably detect and characterize a reflector inside a material, knowledge of the sound beam (or the beam profile) generated by the probe in contact with the test object is needed. This International Standard establishes two metal reference blocks to be adopted for various metals such as forged or rolled steel, aluminium, and titanium alloy products. The frequency range of the probes used in this International Standard range from 1 MHz to 15 MHz. Depending on the structure of the materials under evaluation, in general, 1 MHz to 5 MHz is most suitable for steel products and 5 MHz to 15 MHz is most suitable for aluminium and titanium alloys.

The two reference blocks introduced are the hemicylindrical-stepped (HS) and the side-drilled-hole (SDH) types, by which the beam profiles generated by straight-beam, focused beam, angle-beam, and dual-element probes can be measured. This International Standard establishes the techniques and procedures to be used for the characterization of probe beam profiles in metals.

In pulse-echo ultrasonic tests, the reflected pulse (echo) is used for the detection of discontinuities existing in a material. The discontinuities (such as porosity, voids, or cracks in different sizes and shapes) can be located close to the surface or deep inside, or close together and oriented at different angles. An ultrasonic pulse incident on such discontinuities can reflect or refract into longitudinal (also known as compressional) or transverse (also known as shear) waves, or both, possibly with multiple reflections and refractions. In order to accurately characterize the location, size, and shape of a discontinuity inside a material, it is necessary to know the sound beam transmitted and received by the probe and the instrument.

The sound beam inside a solid produced by a probe in contact testing depends on the type, size, and frequency bandwidth of the probe as well as other parameters such as focusing, beam angle of refraction in the test object, material properties, and characteristics of the ultrasonic instrument.

ISO 2400 establishes a steel reference block, known as calibration block No. 1. For straight-beam tests, this block is used, for example, for checking or establishing the near-field resolution, far-field resolution, and time base (or horizontal) linearity of the test equipment. For angle-beam tests, the block is used to determine the probe index point (probe index) and the angle of refraction (beam angle). This block also provides a means for determining the longitudinal (compressional) wave and transverse (shear) wave velocities of the material under test.

ISO 7963 establishes a small steel block, known as the calibration block No. 2, which is quite suitable for field use. ISO 7963 provides guidelines for material selection, preparation, and mechanical tolerances of the reference block. It also provides procedures for testing the angle of refraction and sensitivity settings of the signals.

The sound beam of a straight-beam probe (normal-beam probe) can be calculated or measured in immersion testing with the procedures given in ISO 10375.

In addition to ISO 2400 and ISO 7963, this International Standard introduces two ultrasonic reference blocks and provides a general methodology of using these blocks in order to establish the sound beams or beam profiles in contact tests.

The objectives of this International Standard are to

— determine probe axes so that consistent tests can be performed,

— establish a complete sound beam profile inside metals for probes of both types, straight-beam and angle-beam, including focused beam and dual-element probes,

— provide a method for calculating the correct angle of refraction when an angle-beam probe designed for use in steel is to be used in materials other than steel,

- provide a beam profile measurement capability for future applications, such as an electromagnetic acoustical transducer (EMAT),
- provide a capability for lateral angle-beam profile measurements,
- provide means for time base calibration with angle-beam probes to be used with ultrasonic imaging systems (see Annex A),
- provide means for time-of-flight (TOF) beam profile measurements for probes to be used with ultrasonic imaging systems (see Annex B),
- provide a technique by hand-held method and by using a mechanical scanner and UT imaging system to obtain both the amplitude and TOF beam profiles (see Figure B.1), and
- provide means for the determination of the skew (or squint) angle, far-field and near-field resolution of angle-beam probes (see Annex C).

Non-destructive testing — Ultrasonic testing — Reference blocks and test procedures for the characterization of contact probe sound beams

1 Scope

This International Standard introduces two metal reference blocks, the hemicylindrical-stepped (HS) block and the side-drilled-hole (SDH) block. This International Standard establishes procedures for measuring the sound beam profiles generated by probes in contact with the test object. The probes include straight-beam, angle-beam (refracted compressional and refracted shear wave), focused beam, and dual-element probes. The side dimension of the probe has to be no greater than 25 mm.

The methodology of this International Standard provides guidelines for probes to be used for different metals including forged or rolled steel, aluminium, or titanium alloy products. The frequency range of the probes used in this International Standard extends from 1 MHz to 15 MHz, where 1 MHz to 5 MHz is best suited for steels and 5 MHz to 15 MHz is best for fine grain structured alloys such as aluminium products.

If this International Standard is to be used for materials other than steels, users should be aware of the fact that the wave velocities in these materials can be different from that of steels and the angle-beam probes are normally designed based on the steel applications. Snell's law of refraction is described in this International Standard so that correct angles of refraction in other homogeneous and fine-grained materials can be calculated. This International Standard applies to angle-beam probes of all practical angles (0° to 70°) and to focused and dual-element probes. This International Standard does not address the use of surface (Rayleigh) wave probes.

This International Standard does not address the estimation of equivalent defect sizes which requires reference blocks with flat-bottomed holes. This International Standard establishes no acceptance criteria, but does establish the technical basis for criteria that can be defined by users.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

3 Terms and definitions

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

4 Symbols and abbreviated terms

4.1 Symbols

For the purposes of this document, the following symbols apply.

Symbol	Designation	Unit
A	peak echo amplitude	dB
F_w	beam width at focal distance	mm
F_D	focal distance	mm
F_L	focal length	mm
H_i	distance along the test surface from the probe index point to the *i*th hole[a]	mm
L_x, L_y, L_z	axes of probe	—
R	radius of the eight side-drilled holes[b]	mm
t_1	time from hemi-step surface 1	s
t_2	time from hemi-step surface 2	s
t_d	time delay	s
v_l	longitudinal (compressional) wave velocity in the test object	mm/s
v_s	transverse (shear) wave velocity in the test object	mm/s
v_w	longitudinal (compressional) wave velocity in the wedge material	mm/s
x, y, z	axes of the reference block (plane of *x*-*y*, surface; *z*, perpendicular to and below the surface)	mm
y_i	distance along *y*-axis from the *i*th hole to the probe location of the peak echo amplitude[c]	mm
y_{i1}, y_{i2}	locations along *y*-axis of the two 6 dB drop points	—
z_i	depth of the *i*th hole centre to one of the side surfaces[d] of the SDH block[c]	mm
z_β	longitudinal beam axis of the angle-beam probe	—
$z_{\beta i}$	distance along the beam axis from the probe index point to the *i*th hole centre[c]	mm
$z_{\beta L}$	lateral beam axis of the angle-beam probe	—
α_w	incident angle (wedge angle)	°
β	angle of refraction (beam angle)	°
β_l	refracted longitudinal (compressional) wave angle in the test object	°
β_s	refracted transverse (shear) wave angle in the test object	°
γ	skew (or squint) angle[e]	°

[a] i = 1, 2, 3...

[b] Diameter is 1,5 mm.

[c] i = 2, 3...

[d] T-, B-, R-, and L-, surfaces.

[e] See ISO 10375:1997, Figure 4.

4.2 Abbreviated terms

FSH	full screen height of display graticule
HS	hemicylindrical-stepped
IP	initial pulse
P	probes
P_i	probe position on the reference block
R	receiver connector
SDH	side-drilled hole
SDH_i	*i*th side-drilled hole
B-surface	bottom surface of the SDH block
F-surface	front surface of the SDH block
L-surface	left surface of the SDH block
R-surface	right surface of the SDH block
T-surface	top surface of the SDH block
T	transmitter connector

5 Descriptions of the reference blocks

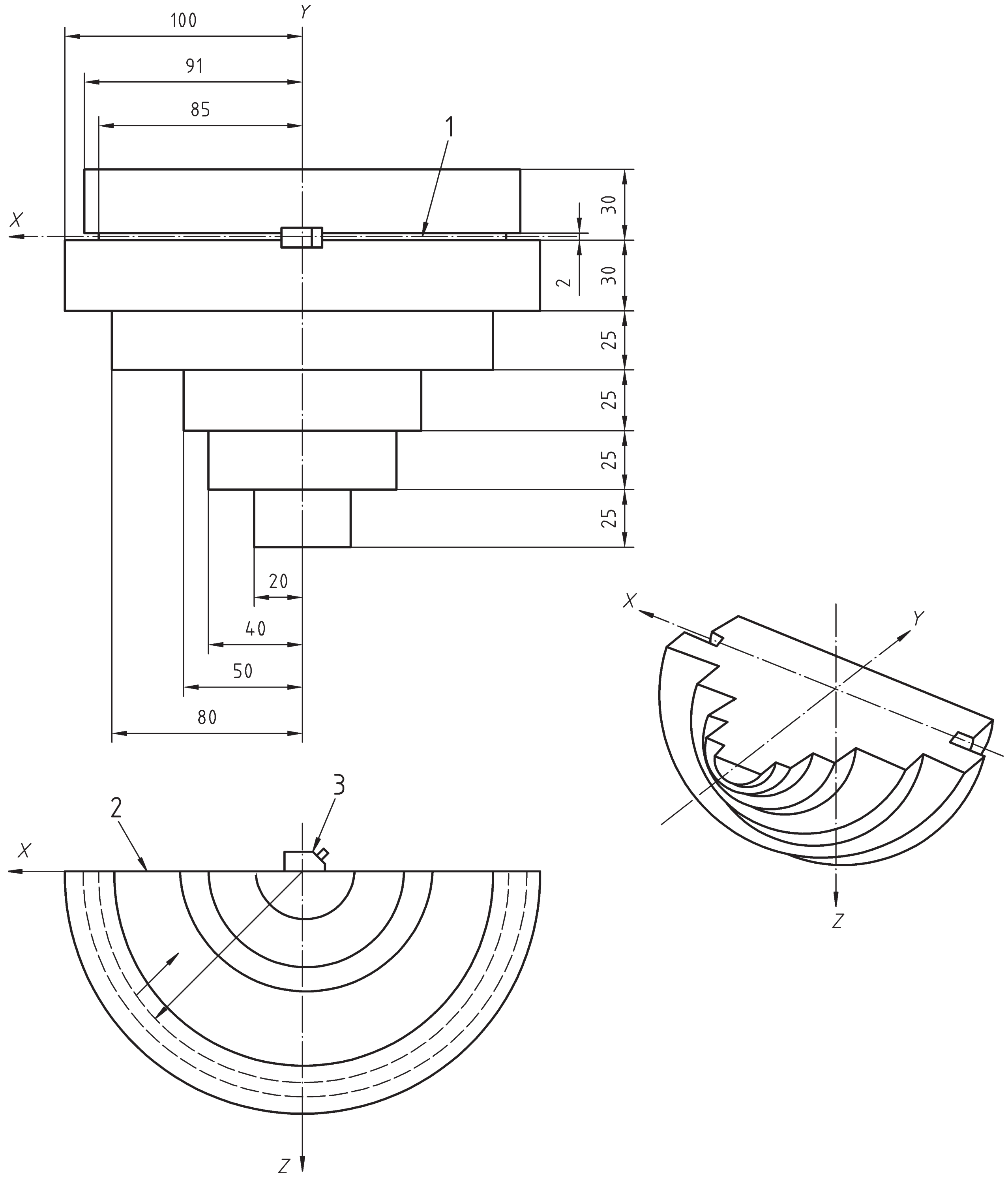
5.1 General

The two reference blocks in this International Standard are made of metal. The reference blocks shall be fabricated using a material with acoustical properties similar or equivalent to that of the test object. The general requirements for the mechanical tolerances of the blocks, surface roughness, and engraved scale should be the same as stated in ISO 7963. The geometry and dimensions of the two blocks are specified in 5.2 and 5.3.

5.2 Hemicylindrical-stepped block

Figure 1 shows the dimensions of the HS block. It shall be machined from a solid cylinder. After it is machined into cylindrical step shape, it is cut along the longitudinal axis and machined to the required surface finish. The radii of the hemicylindrical steps are 20 mm, 40 mm, 50 mm, 80 mm, 100 mm, and a slot of 85 mm and 91 mm. The width of the 20 mm to 80 mm radial steps is 25 mm; the width of the 100 mm step is 30 mm; the width of the 85 mm slot is 2 mm and the width of the 91 mm radius step is 28 mm. A line along the centre section of the slot (the *x*-axis), a centre line dividing the HS block in symmetry (the *y*-axis), and boundary lines between adjacent steps, on the flat surface, shall be engraved. When in use, the block should rest on an appropriate support. The support frame shall cause neither mechanical damage to the block nor any acoustical damping effect due to the support.

Dimensions in millimetres



Key

1 centre line of slot

2 front surface

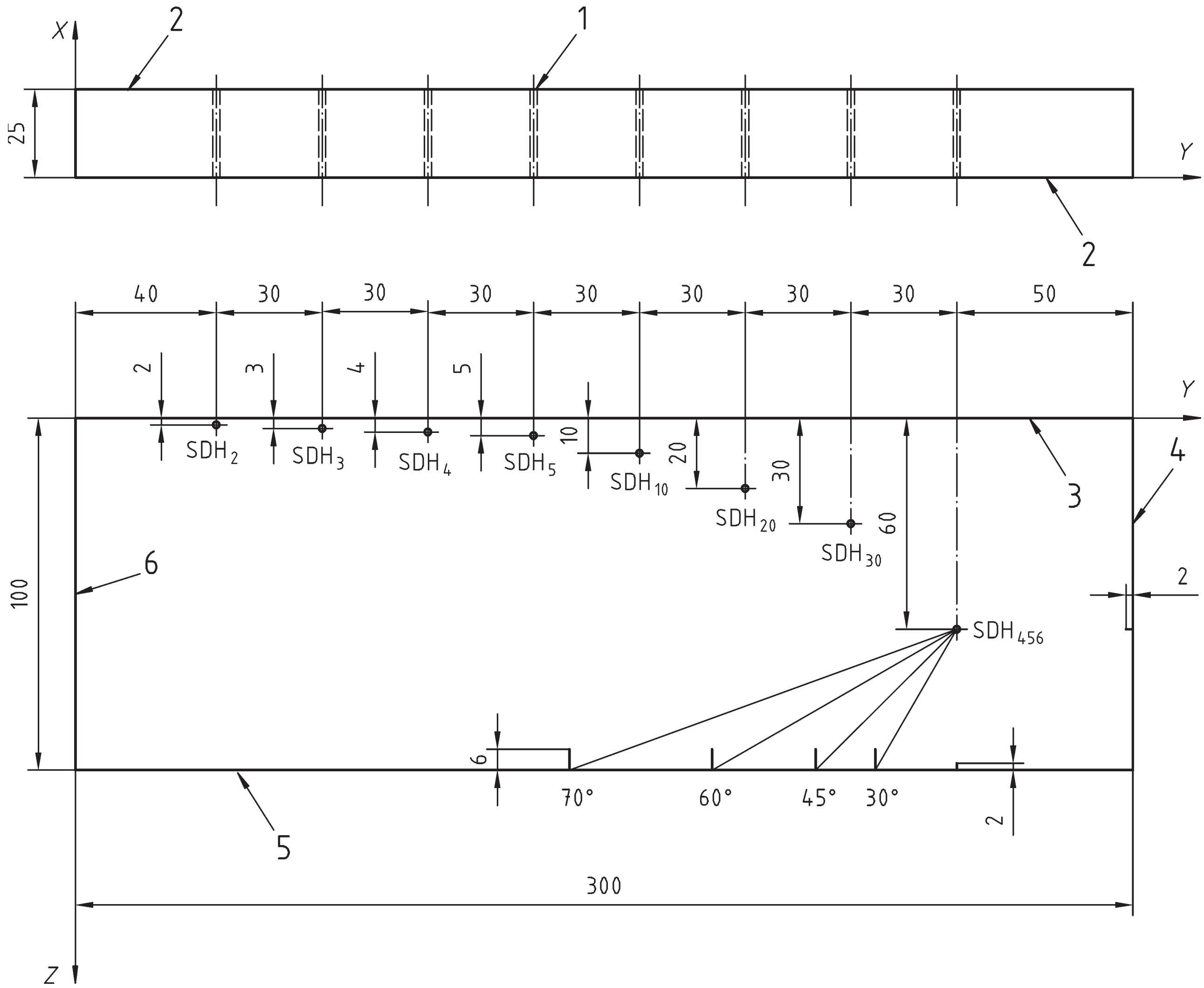
3 angle-beam probe

Figure 1 — Hemicylindrical-stepped (HS) block

5.3 Side-drilled-hole block

Figure 2 shows the dimensions of the SDH block. It is 300 mm long by 25 mm wide by 100 mm high with eight identical side-drilled holes 1,5 mm in diameter. They are identified as SDH_2, SDH_3, SDH_4, SDH_5, SDH_{10}, SDH_{20}, SDH_{30}, and SDH_{456}. The longitudinal axis of the holes shall be parallel to the top and bottom surfaces of the block. The surfaces of the block are identified as the T- (top), B- (bottom), R- (right) and L- (left), and F- (front) surface, which refers to either side of the large surfaces. The location of the hole is measured from the centre of the hole to the top, bottom, or end surface of the block. Short lines on the edge of the F- and T-surfaces are engraved indicating the locations of the SDH centre lines. The location of the SDH_{456} is engraved on all the T-, B-, R-, and F-surfaces. Except for the SDH_{456} hole, the number affixed to the SDH indicates the distance of the hole centre to the T-surface. For example, the distance from the SDH_2 hole centre to the T-surface is 2 mm. The distances from the SDH_{456} centre to the B-, R-, and T-surfaces are 40 mm, 50 mm, and 60 mm, respectively. The first hole, the SDH_2, is 40 mm from the L-surface, and the distance between the adjacent holes is 30 mm. Angles of refraction (0° to 70°) are indicated by short lines engraved on the F-surfaces at the edge between the F- and the B-surfaces. The nominal longitudinal and transverse wave velocities of the material, determined empirically after the block has been machined, can be engraved on one of the F-surfaces of the SDH block.

Dimensions in millimetres



Key

1 side-drilled hole of diameter 1,5 mm
2 F-surface
3 T-surface
4 R-surface
5 B-surface
6 L-surface

Figure 2 — Side-drilled-hole (SDH) block

6 Techniques and procedures

6.1 Straight-beam probes (normal-beam probes)

6.1.1 Amplitude beam profile of straight-beam probe

Place the probe on the T-surface, on top of the first SDH as shown in Figure 3. If the echo signal on the screen of the instrument is within the dead zone of the probe, ignore this hole and proceed testing with the next hole until the echo signal is able to be resolved. Move the probe such that the signal reflected from the hole is at its maximum. Adjust the gain such that the signal amplitude is about 80 % of full screen height (FSH) of the instrument display graticule. The signal shall be at least 20 dB greater than the background noise level. Move the probe along the y-axis to and from the peak amplitude position such that the signal amplitude drops 6 dB from the peak amplitude. Record the gain for the peak echo amplitude (A), the probe location (y_i) of the peak amplitude, the two 6 dB drop (−6 dB) points (y_{i1}, y_{i2}), and the depth (z_i) of the hole in the test.

Repeat the above tests for all of the holes of interest on the SDH block. The depth (z_i) of the SDH$_i$ is measured from the centre of the hole and the wave is reflected from the top surface of the hole. For engineering accuracy, no radius corrections are needed, since the error caused by this difference is relatively small compared to other uncertainties in ultrasonic tests. Figure 4 shows the beam profile in the test object produced by a straight-beam probe.

It should be noted that the amplitude varies in the near field due to diffraction from the transducer edges. Beyond the near field is the far field where the amplitude decreases with increasing distance. The calculation of the near-field length is given in ISO 10375.

6.1.2 Amplitude beam profile of focused straight-beam probe

Repeat the procedures specified in 6.1.1. The result is plotted in Figure 5.

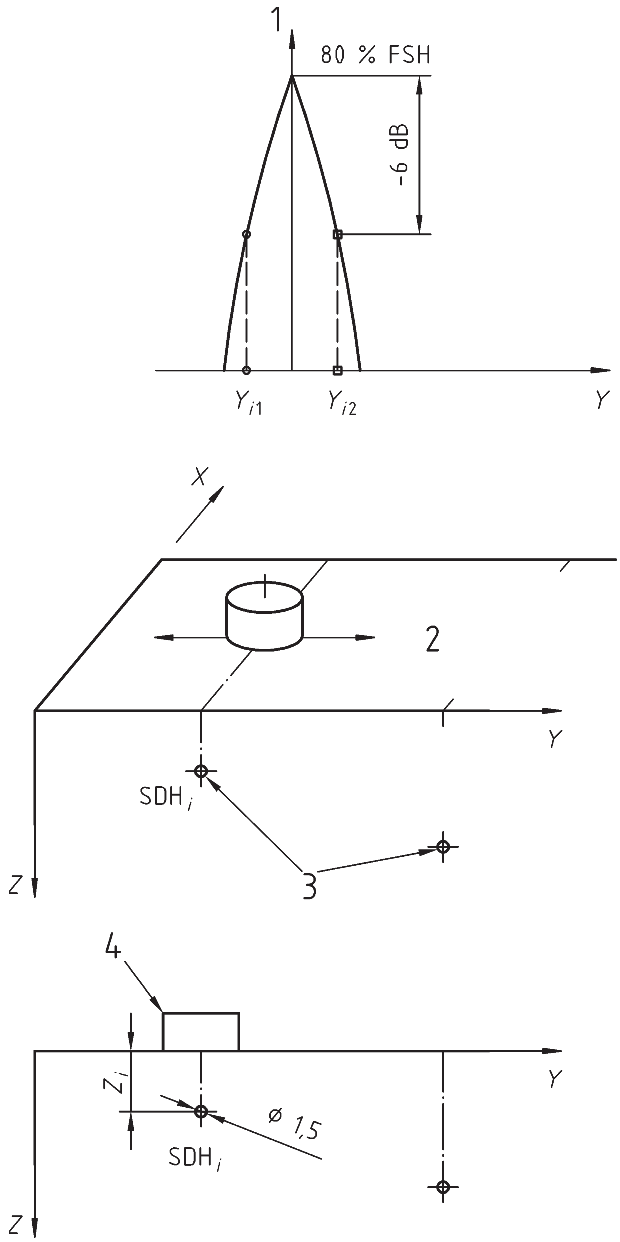
a) The line joining the peak amplitude at each depth is the sound beam axis.

b) The location of the signal at maximum amplitude is the focal point.

c) The distance from the test surface to the focal point is the focal distance(F_D).

d) The distance between the two 6 dB drop points along the beam axis is the focal length (F_L).

e) At the focal point, the distance between the two 6 dB drop points in a plane perpendicular to the beam axis is the focal beam width (F_w).



Key

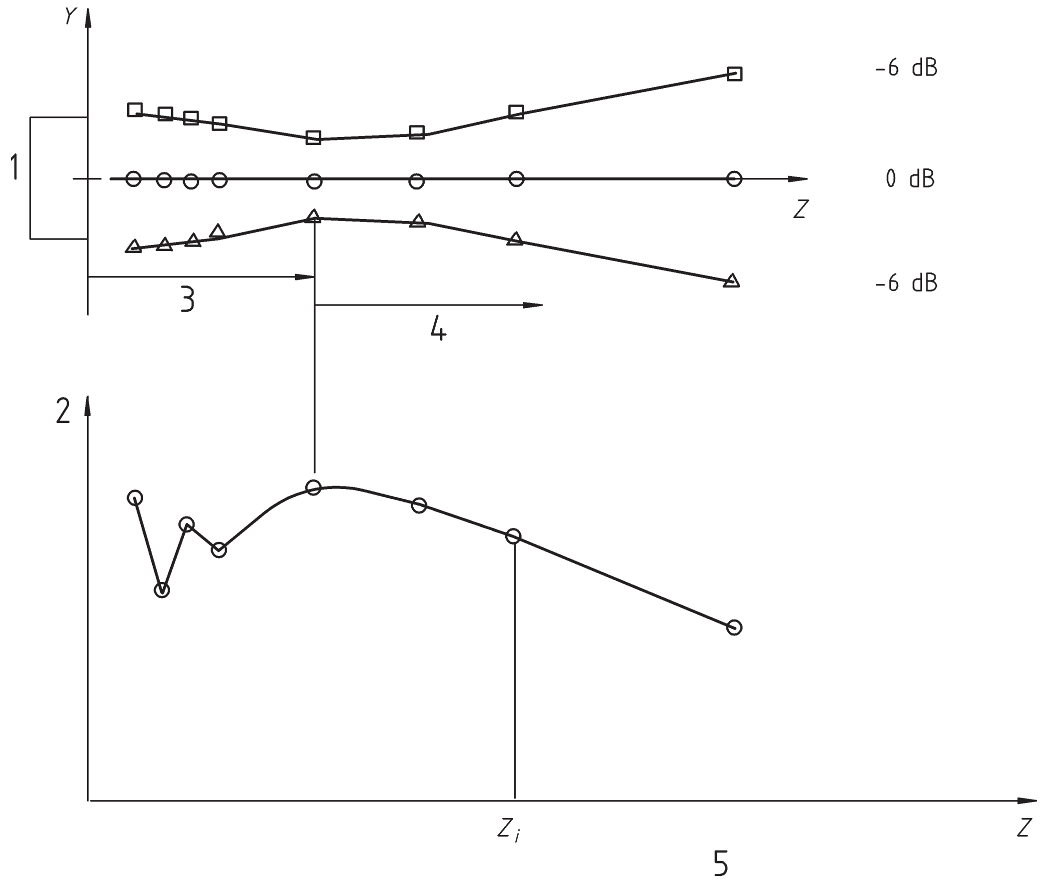
1 peak amplitude (dB)

2 T-surface

3 side-drilled holes

4 straight-beam probe

Figure 3 — Measurement of the beam profile of a straight-beam probe



Key

1 probe

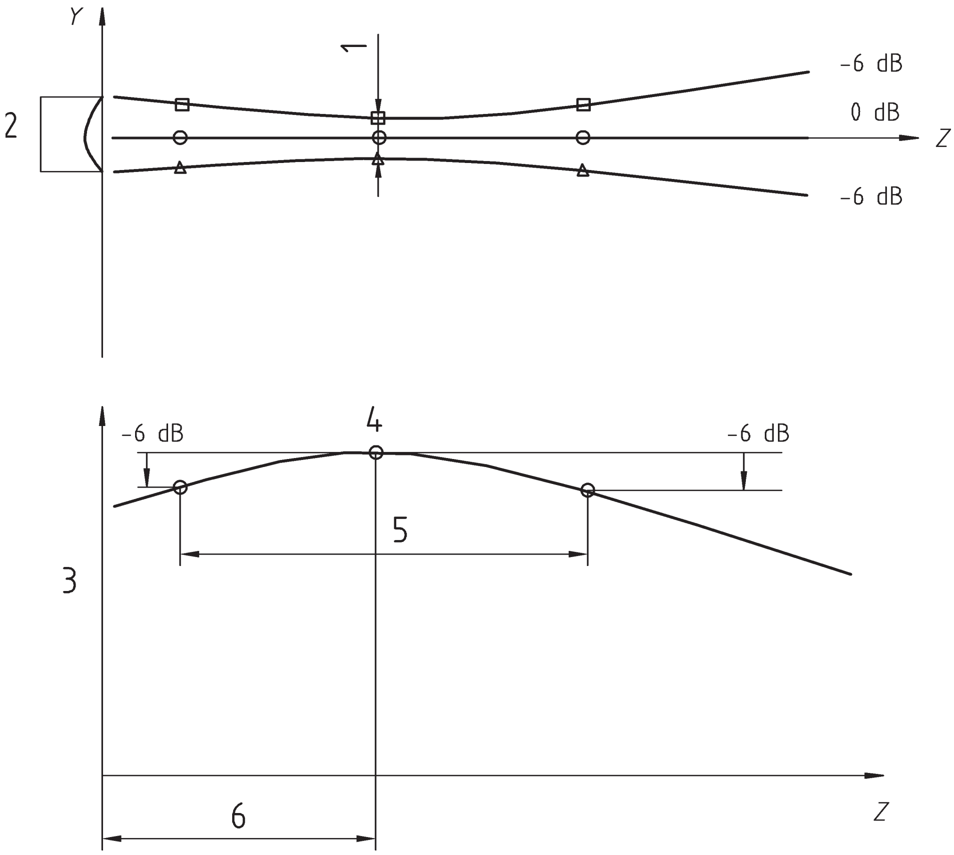
2 peak amplitude (dB)

3 near field

4 far field

5 distance (mm)

Figure 4 — Beam profile of a straight-beam probe



Key

1 beam width (F_W) at focal point
2 focusing probe
3 echo amplitude (dB)
4 peak amplitude (dB)
5 focal length (F_L)
6 focal distance (F_D)

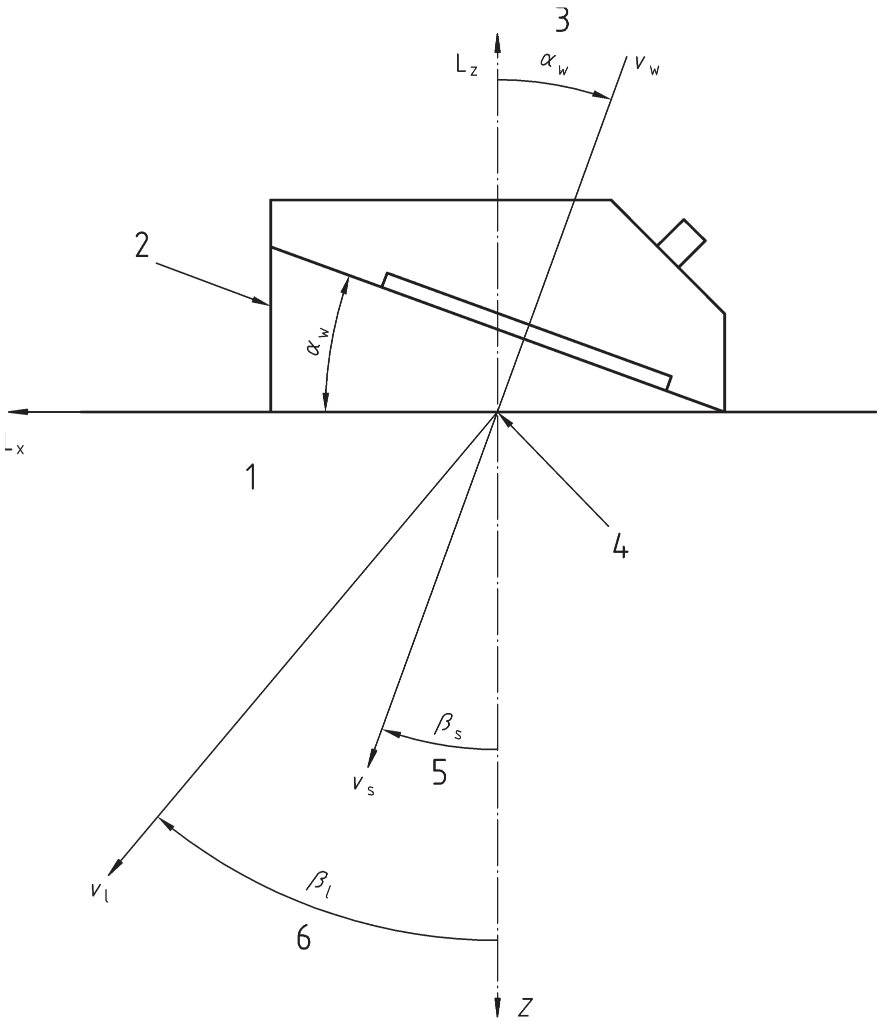
Figure 5 — Beam profile of a focusing straight-beam probe

6.2 Angle-beam probe

6.2.1 General

Most angle-beam probes are identified by their nominal size, nominal frequency, nominal beam angle, and the velocity of propagation of transverse (shear) waves in steel. Angle-beam probes used in different materials which have different sound velocities yield different angles of refraction. An angle-beam probe can generate a refracted longitudinal (compressional) wave, a refracted transverse (shear) wave, or both inside a test object.

The relationship between the angle of incidence (wedge) and the refracted angle in terms of the wave velocities in the wedge and in the test object is shown in Figure 6.



Key

1	test object	4	probe index point (I)
2	wedge	5	refracted longitudinal wave angle
3	angle of incidence	6	refracted transverse wave angle

Figure 6 — Snell's law of refraction

Snell's law of refraction is given as follows.

Refracted longitudinal (compressional) wave:

$$\frac{v_w}{v_l} = \frac{\sin\alpha_w}{\sin\beta_l} \qquad (1)$$

Refracted transverse (shear) wave:

$$\frac{v_w}{v_s} = \frac{\sin\alpha_w}{\sin\beta_s} \qquad (2)$$

Formulae (1) and (2) provide a means for the calculation of correct angle of refraction when the angle-beam probe designed for use in steel is to be used in materials other than steel.

6.2.2 Longitudinal amplitude beam profile of an angle-beam probe

Place the probe on the T-surface, on top of the first hole of the SDH block, with the longitudinal axis (L_x) of the probe perpendicular to the longitudinal axis (x) of the hole as shown in Figure 7. Aim the angle beam toward the hole and obtain the peak signal. Adjust the gain such that the peak signal amplitude is about 80 % FSH of the instrument. Move the probe along the y-axis on the block to and from the peak amplitude point such that the signal amplitude drops 6 dB from the peak amplitude. Record the peak echo amplitude (A), the probe location (y_i) of the peak amplitude, the two 6 dB drop points (y_{i1}, y_{i2}), and the depth (z_i) of the hole in the test. The distance along the beam axis from the probe index point to the ith hole centre is $z_{\beta i}$. It can be obtained using Formula (3).

$$z_{\beta i} = \left[(z_i)^2 + (y_i)^2 \right]^{\frac{1}{2}} \tag{3}$$

Repeat the preceding tests for all of the holes of interest. The axial beam profile in the test block, produced by an angle-beam probe, is shown in Figure 8. In addition, the peak amplitudes vs depth (z) below the test surface are plotted for practical applications and the peak amplitudes along the beam axis (z_β) are plotted for theoretical analyses.

6.2.3 Lateral amplitude beam profile of an angle-beam probe

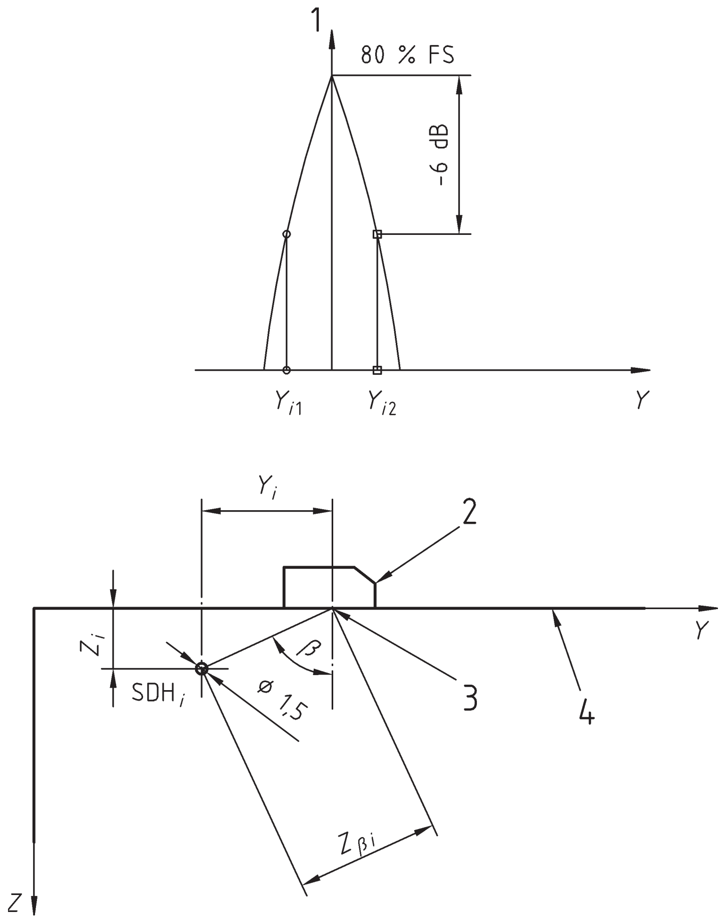
The lateral amplitude beam profile of an angle-beam probe can best be measured with the HS block as shown in Figure 9.

Place the angle-beam probe on the HS block with its beam toward the 100 mm radius surface, identified temporarily as the step 2 surface. With the aid of a straight edge, slide the angle-beam probe along the y-direction. Record the position $y = 0$, where the signal amplitude (A) is maximum at 80 % FSH of the instrument. For position $y < 0$, the amplitude from the step 2 surface starts to fall; for position $y > 0$, the amplitude remains at about the same level of 80 % FSH.

Record the position y_{i1}, where the amplitude (A) from step 2 surface (100 mm) is 40 % FSH. The half lateral beam width, at z_β = Step 1, is y_{i1}.

Repeat the measurements for all adjacent steps, i.e. 80 mm to 50 mm, 50 mm to 40 mm, and 40 mm to 20 mm, on both sides (sides 1 and 2) of the HS block, without changing the receiver gain. Figure 10 is the lateral amplitude beam profile in the test object produced by an angle-beam probe.

It should be noted that, depending on the probe characteristics, the amplitude on each hemi-step can vary due to differing interference. The signal amplitude, consisting of a main signal level, can contain several distinctive high amplitude peaks. In such cases, the distinctive high amplitude peaks are ignored and the main signal levels from each step surface are used for the amplitude beam profile measurements. The time-of-flight (TOF) beam profiles should also be measured to supplement the amplitude beam profiles (see Annex B).



Key

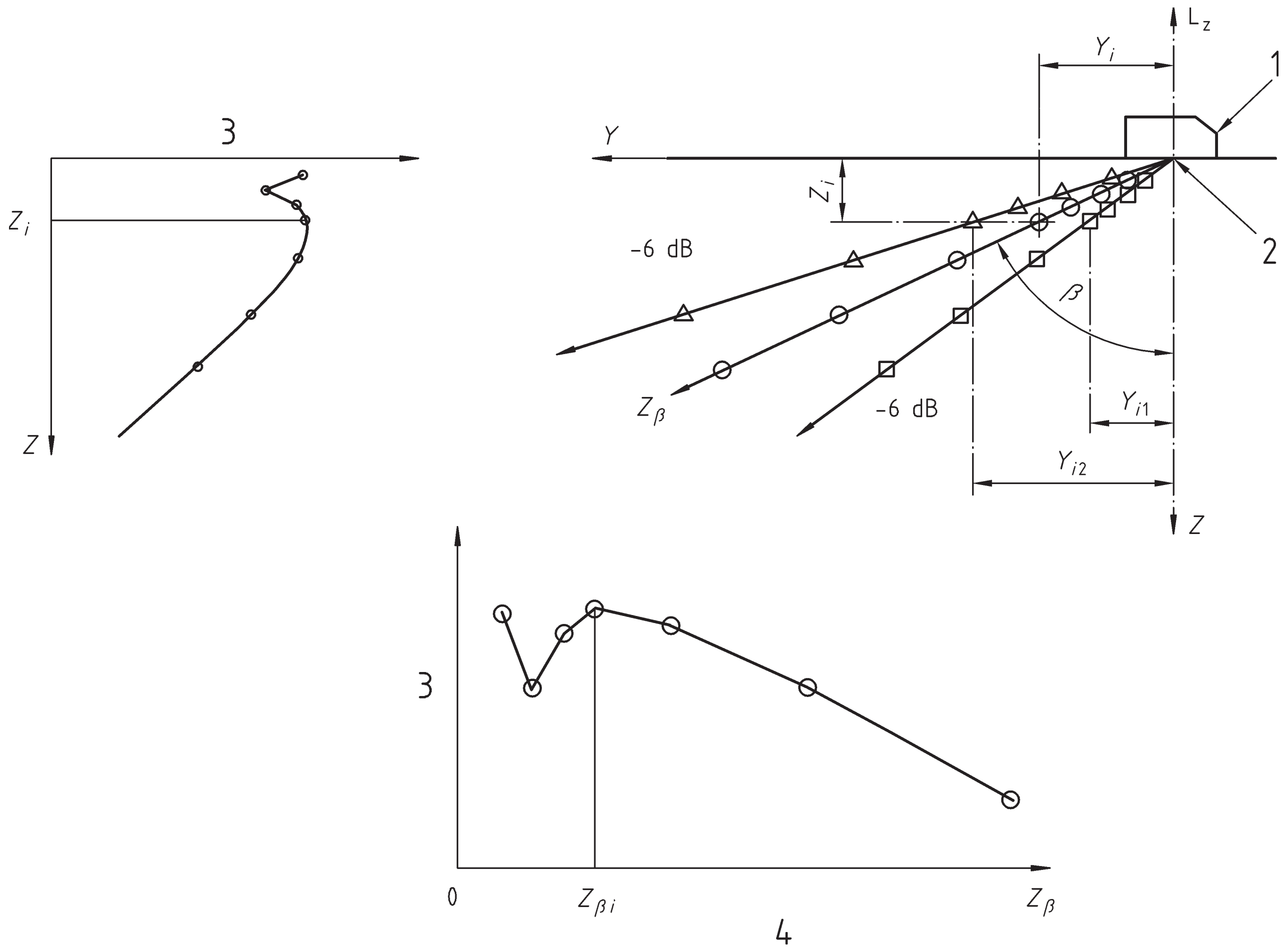
1 echo amplitude (dB)

2 angle-beam probe

3 probe index point (I)

4 T-surface

Figure 7 — Measurement of the longitudinal beam profile of an angle-beam probe



Key

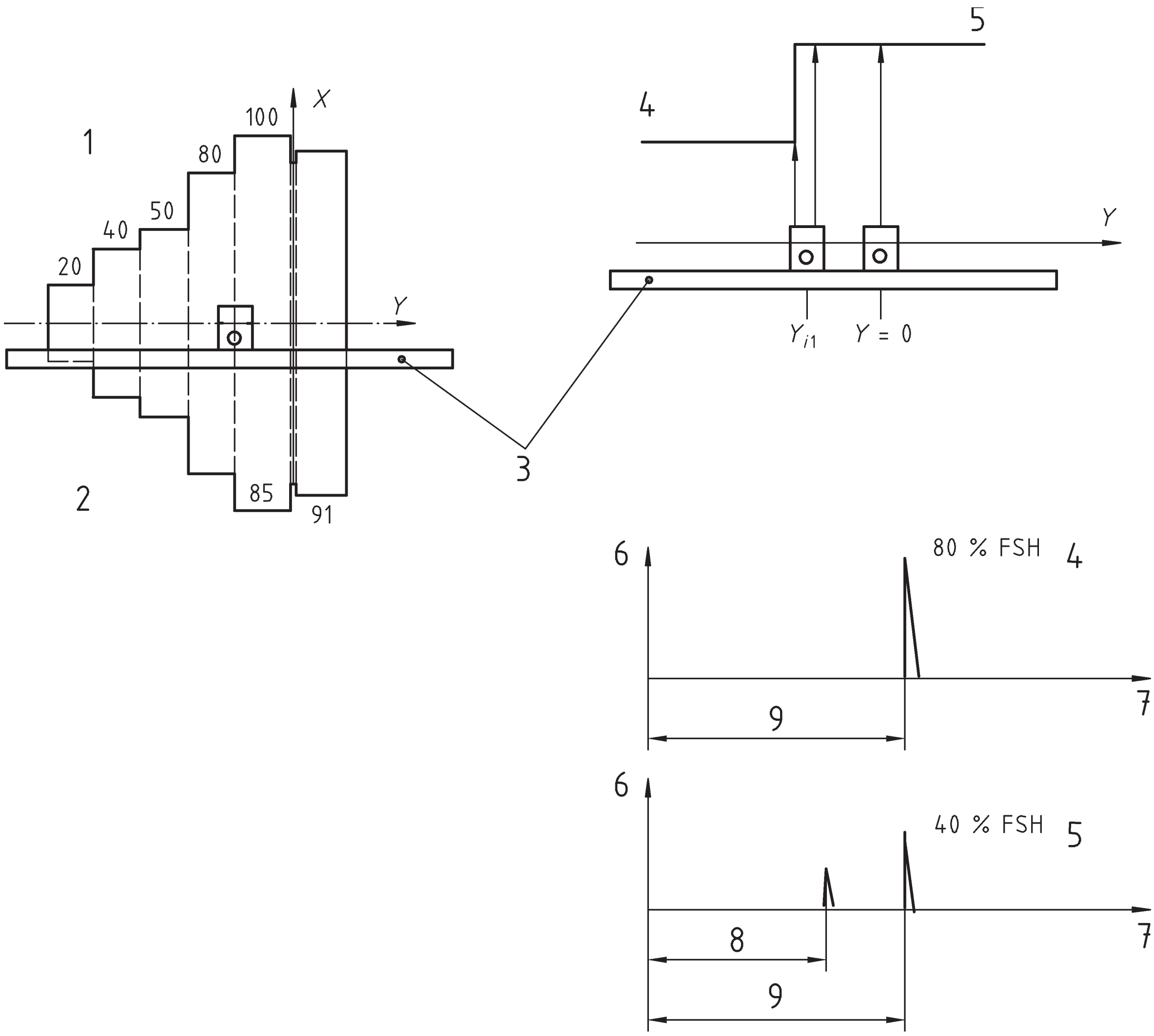
1 angle-beam probe

2 probe index point (I)

3 echo amplitude (dB)

4 distance in mm

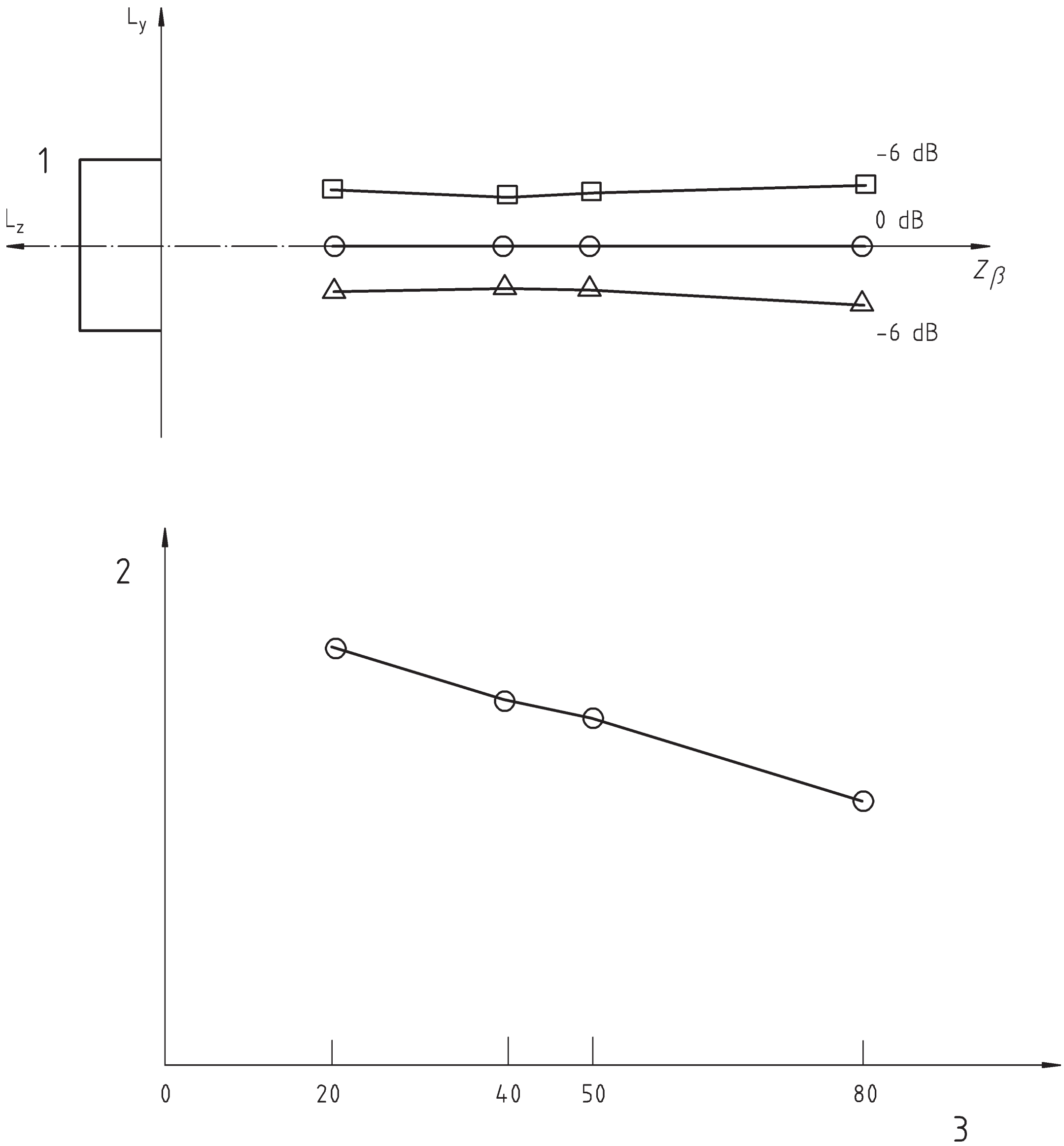
Figure 8 — Longitudinal sound beam profile of an angle-beam probe



Key

1 side 1
2 side 2
3 straight edge
4 step 1
5 step 2
6 echo amplitude (%)
7 time or distance
8 distance of signal from step 1 (4)
9 distance of signal from step 2 (5)

Figure 9 — Lateral half beam width of an angle-beam probe at step 1



Key

1 angle-beam probe

2 echo amplitude (dB)

3 distance along axis z_{β} (mm)

Figure 10 — Lateral beam profile of an angle-beam probe

6.2.4 Longitudinal amplitude beam profile of a focusing angle-beam probe

Repeat the same procedures as specified in 6.2.2. The beam profile of a focusing angle-beam probe is shown in Figure 11. The amplitudes vs depth (z) and vs the beam axis (z_{β}) are also plotted in Figure 11.

a) The line linking the peak amplitudes at each depth is the longitudinal amplitude curve (distance amplitude curve).

b) The position of the signal at maximum amplitude is the focal point.

c) The distance from the probe index point to the focal point along the longitudinal beam axis is the focal distance (F_D).

d) The distance between the two 6 dB drop points along the longitudinal beam axis is the focal length (F_L).

e) At the focal point, the distance between the two 6 dB drop points on a plane perpendicular to the longitudinal beam axis is the focal width (F_W).

6.2.5 Lateral amplitude beam profile of a focusing angle-beam probe

Repeat the same procedure as specified in 6.2.3. The result of the lateral beam profile of a focusing angle-beam probe is shown in Figure 12.

a) The line linking the peak amplitudes at each depth is the lateral beam axis, $z_{\beta L}$.

b) The position of the signal at maximum amplitude is the focal point.

c) The distance from the probe index point to the focal point along the lateral beam axis is the focal distance (F_D).

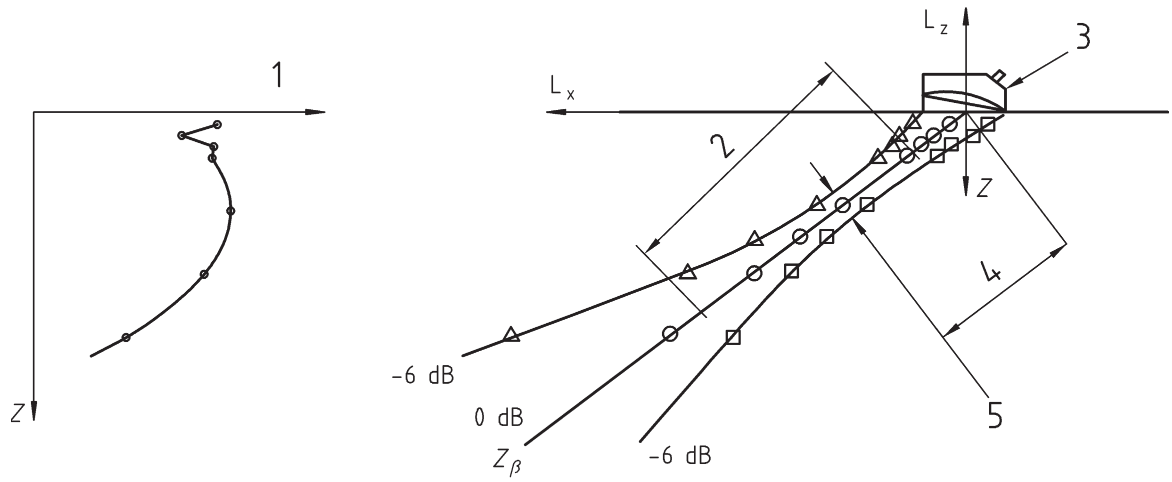
d) The distance between the two 6 dB drop points along the lateral beam axis is the focal length (F_L).

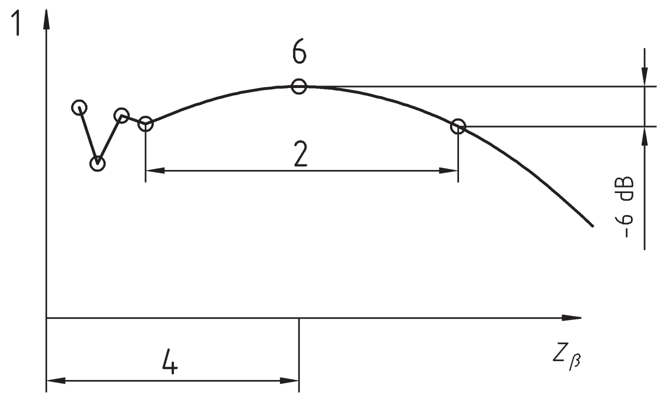
e) At the focal point, the distance between the two 6 dB drop points on a plane perpendicular to the lateral beam axis is the focal width (F_W).

6.3 Dual-element probe

The straight-beam dual-element probe is often used for testing thin materials or detecting imperfections (discontinuities) immediately beneath the surface of the test object or testing of coarse-grained materials. It is constructed with two transducers mounted on a delay material inside one housing, one acting as transmitter, one as receiver only. Some dual-element probes can have a slight angle, known as the roof angle. For correct use, a dual-element probe should be marked with the longitudinal L_x-axis and the lateral L_y-axis as well as the transmitting (T) and receiving (R) connectors.

The procedures for determining the beam profiles for a straight-beam dual-element probe and an angle-beam dual-element probe are the same as given in 6.1 and 6.2, respectively. The orientation of the dual-element probe relative to the axis of the SDH as well as the ultrasonic instrument used for the checks shall be recorded.

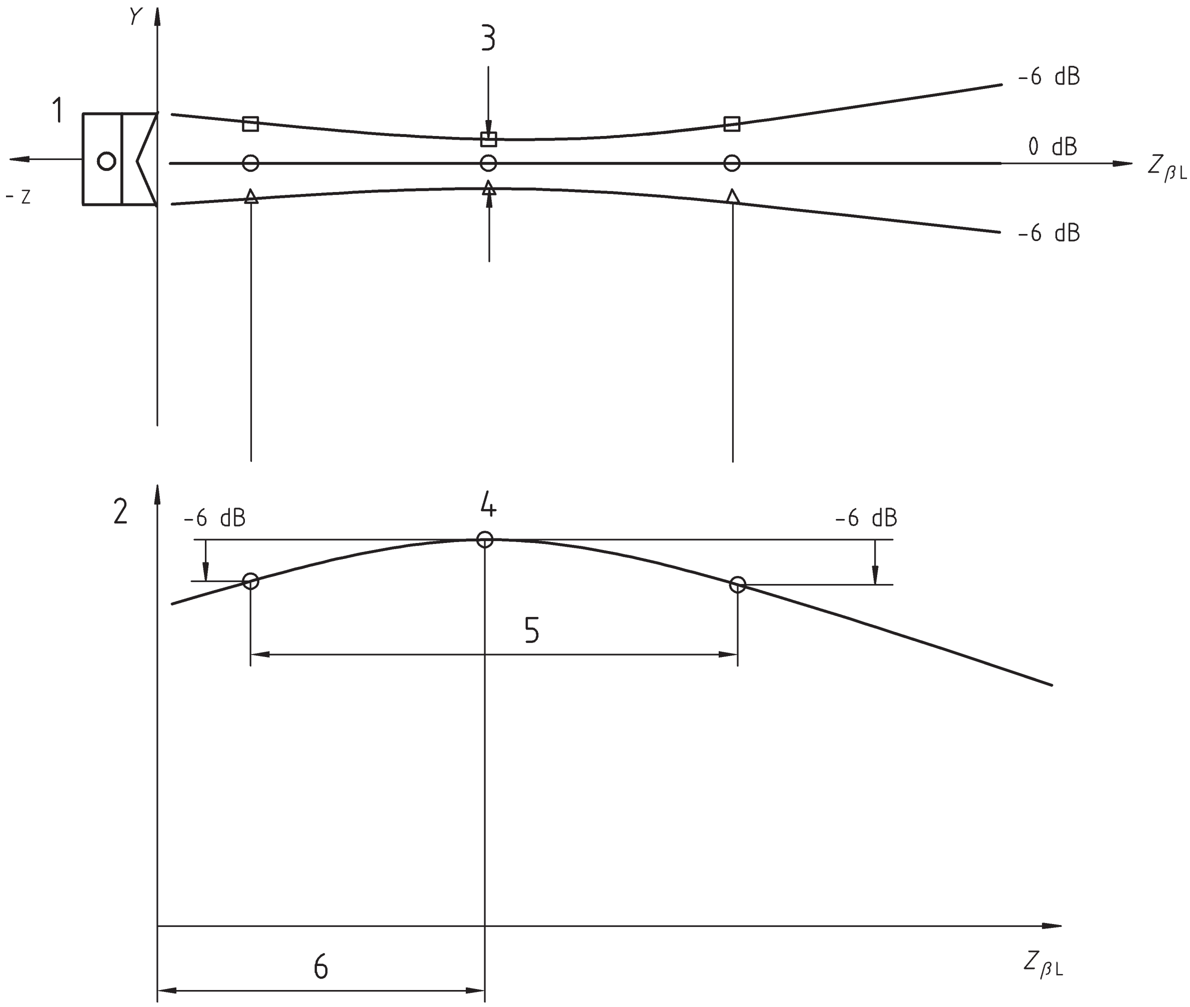




Key

1	echo amplitude *A* (dB)	3	focusing angle-beam probe	5	focal beam width
2	longitudinal focal length	4	longitudinal focal distance	6	focal point peak echo amplitude

Figure 11 — Longitudinal beam profile of a focusing (point-focusing) angle-beam probe



Key

1	probe	3	beam width at focal point	5	lateral focal length
2	echo amplitude (dB)	4	lateral focal point peak echo amplitude	6	lateral focal distance

Figure 12 — Lateral sound beam profile of focusing angle-beam (point-focusing) probe

Annex A
(normative)

Time base setting (range setting)

The double distance features of the HS block shall provide a capability for the time base setting for angle-beam probes. The procedure is as follows.

— Select the maximum thickness range of interest, and test on two surfaces with double distance feature, for example 20 mm and 40 mm, 40 mm and 80 mm, or 50 mm and 100 mm.

— Place the angle-beam probe on the HS block, with the probe index aligned with the centre line of the HS block, with its beam direction toward the stepped surface.

— Set the sensitivity level such that the signals are between 80 % and 100 % FSH.

— The signal reflected from the smaller step surface (hemi-surface 1) of a step pair shall be noted as t_1 and the signal reflected from the larger step (hemi-surface 2) of that pair shall be noted as t_2.

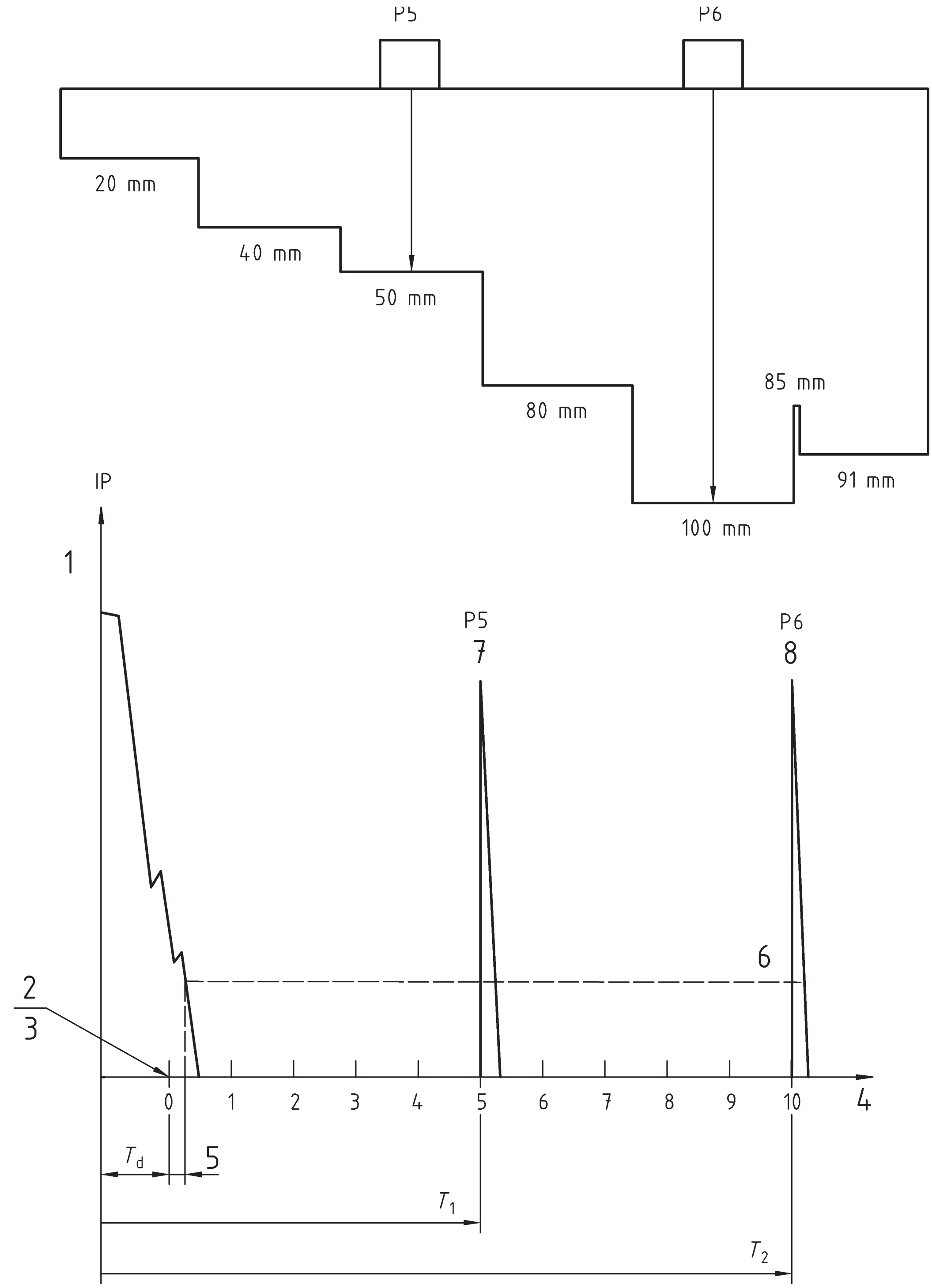
— Adjust the time scale such that t_1 and t_2 are aligned on their corresponding divisions on the screen. Each division should correspond to 10 mm in sound path. The zero location on the horizontal scale is the contact surface of the test object.

For an ultrasonic imaging system, the time delay (t_d) is calculated using Formula (A.1):

$$t_d = 2t_1 - t_2 \quad \text{(A.1)}$$

as shown in Figure A.1.

The preceding procedure is also applicable to straight-beam probes using the HS block tested along the centre line.



Key

1	peak echo amplitude	5	dead zone
2	probe index point	6	gate threshold
3	probe index point	7	first echo (hemi-step 1)
4	time or distance	8	second echo at 80 % FSH (hemi-step 2)

Figure A.1 — Time base setting

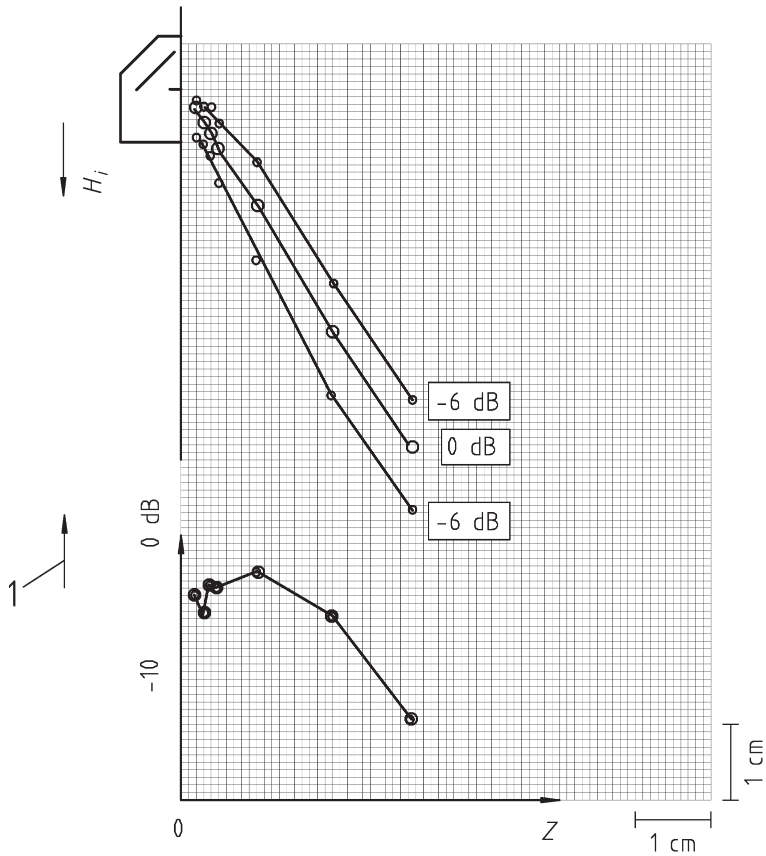
Annex B
(normative)

Time-of-flight (TOF) beam profile

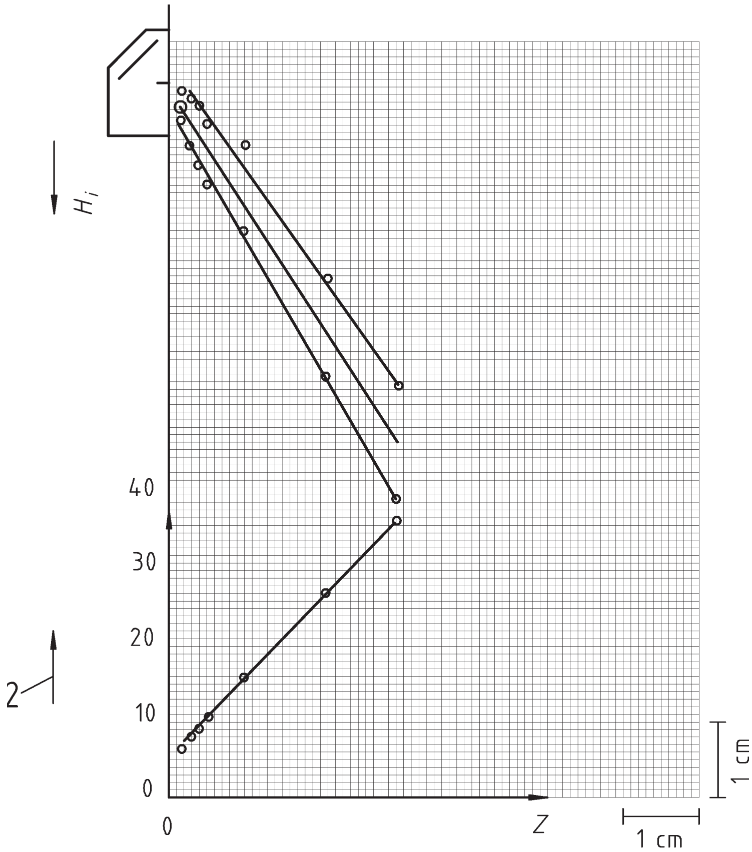
There are two principal parameters in ultrasonic tests, the amplitude and the time-of-flight (TOF) of the signal. Using the HS block and the SDH block, the TOF beam profile can be obtained in parallel to the amplitude beam profile, which is discussed in Clause 6.

To facilitate accurate beam profile tests, a mechanical scanner with an instrument that can automatically record the ultrasonic signal amplitude, TOF and probe positions, is recommended. The relevant signal information comprises the peak amplitudes (*A*), its corresponding TOF, the probe peak amplitude position, and its two 6 dB drop positions. An example of the longitudinal amplitude and TOF beam profile of an angle-beam probe is shown in Figure B.1.

Align the angle-probe index point with the centre line of the HS block and use a mechanical track to guide the probe connected to an instrument to automatically record the amplitude and TOF measurements along both the positive and negative track directions. The lateral beam profiles for each corresponding hemi-step surface are obtained by taking the differences between the measurements in the positive and negative track directions.



a) Amplitude versus depth *z*



b) Time-of-flight versus depth *z*

Key

1 peak amplitude

2 time-of-flight

NOTE Angle-beam probe, 5 MHz, 56°, element 6 mm × 6 mm; gate threshold to noise level −31 dB.

Figure B.1 — Angle-beam probe amplitude and time-of-flight beam profile

Annex C
(informative)

Skew (or squint) angle, far-field and near-field resolution

Place the angle-beam probe on the top surface of the HS block, with the probe index point on the centre line of the block and the beam direction toward the slot to obtain the maximum signal amplitude.

The skew or squint angle (γ) is the angular deviation of the measured horizontal beam direction from the longitudinal axis of the probe.

With the probe at this position on the HS block, three separate distinctive signals reflected from the 85 mm slot, 91 mm radius, and 100 mm radius surfaces indicate good far-field resolution of the probe.

With the probe on the T-surface of the SDH block, on top of the side-drilled holes, i.e. SDH_2, SDH_3, etc., the near-field resolution is determined by the capability of signal separation between the nearest side-drilled hole and the T-surface.

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