International Standard

ISO 16811

Second edition
2025-03

Non-destructive testing — Ultrasonic testing — Sensitivity and range setting

Essais non destructifs — Contrôle par ultrasons — Réglage de la sensibilité et de la base de temps

Reference number
ISO 16811:2025(en)

Contents

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 document 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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This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 138 *Non-destructive testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 16811:2012), which has been technically revised.

The main changes are as follows:

— normative references have been updated;

— Annex A and Annex B from the prior edition have been moved to the main text;

— document has been editorially revised.

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.

Introduction

The following standards on ultrasonic testing are linked:

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

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

— ISO 16823, Non-destructive testing — Ultrasonic testing — Through transmission technique;

— ISO 16826, Non-destructive testing — Ultrasonic testing — Testing for discontinuities perpendicular to the surface;

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

— ISO 16828, Non-destructive testing — Ultrasonic testing — Time-of-flight diffraction technique as a method for detection and sizing of discontinuities.

Non-destructive testing — Ultrasonic testing — Sensitivity and range setting

1 Scope

This document specifies the general rules for setting the time-base range and sensitivity (i.e. gain adjustment) of a manually operated ultrasonic instrument with A-scan display in order that reproducible determinations can be made of the location and echo height of a reflector.

This document is applicable to contact techniques employing a single probe with either a single transducer or dual transducers. This document does not apply to the immersion technique and techniques employing more than one probe.

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*[1)]

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

ISO 7963, *Non-destructive testing — Ultrasonic testing — Specification for calibration block No. 2*[1)]

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

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

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

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

3 Terms and definitions

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

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

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

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

4 Quantities and symbols

A full list of the quantities and symbols used throughout this document is given in Table 1.

1) In the next revision of the standard, the term "calibration block" is intended to be replaced by the term "standard block".

Table 1 — Quantities and symbols

Symbol	Quantity	Unit
A	Normalized distance in DGS diagram	
A'	Probe coordinate	mm
a	Projected sound path length	mm
a'	Reduced projected sound path length	mm
α	Beam angle in steel	°
α_r	Beam angle in a non-alloy steel reference block	°
α_d	Incident angle (beam angle in delay block or wedge)	°
α_t	Beam angle in test object	°
β	Angle of incidence	°
c_r	Sound velocity in reference block	m/s
c_t	Velocity of transverse waves in test object	m/s
c_d	Velocity of longitudinal waves in delay block or wedge	m/s
D_{obj}	Outer diameter of test object or curvature of scanning surface	mm
d	Wall thickness	mm
D_{eff}	Effective transducer size	mm
D_f	Equivalent reflector diameter	mm
D_{SSH}	Diameter of spherical-shaped reflector	mm
D_{DSR}	Diameter of disc-shaped reflector	mm
D_{ps}	Diameter of probe shoe	mm
D_{SDH}	Diameter of side-drilled hole	mm
e_1 to e_7	Reference block dimensions	mm
g	Depth of contour on probe contact surface	mm
G	Normalized diameter of disc-shaped reflector in DGS-Diagram	
λ	Wavelength	mm
ΔH_u	Difference between the echo height from a reference reflector and the echo height from a discontinuity	dB
l_{ps}	Length of probe shoe	mm
l_d	Length of delay path	mm
Δl_{ps}	Length of contoured probe face	mm
N_{eff}	Effective near field length	mm
P_r	Reference point at s_{max}	
P_j	Reference point at s_j	
q	Coordinate of reflector	mm
s	Sound path length (single trip)	mm
s_d	Equivalent sound path distance in the delay block	
s_j	Sound path length of reference reflector	mm
s_{max}	Maximum sound path length	mm
s_u	Sound path length associated with evaluated signal	mm
s_v	Acoustic equivalent to delay path in test object	mm
t	Depth coordinate of reflector	mm
V	Gain in DGS diagram	dB
V_j	Basic gain	dB
V_r	Recording gain	dB
V_t	Gain for determining ΔV_t	dB

Table 1 *(continued)*

Symbol	Quantity	Unit
V_u	Indication gain	dB
ΔV	Gain difference	dB
$\Delta V_\sim$	Correction for ΔV_t	dB
ΔV_k	Gain correction for cylindrical reflector surface	dB
ΔV_s	Gain difference associated with sound path length	dB
ΔV_t	Transfer correction (average)	dB
$V_{t,r}$	Gain for back wall echo on reference block	dB
$V_{t,t}$	Gain for back wall echo on test object	dB
ΔV_u	Difference between indication gain and recording gain	dB
w_{ps}	Width of probe shoe	mm
Δw_{ps}	Width of contouring of the probe face	mm
x	Distance between probe index point and front edge of probe, for an uncontoured probe	mm
Δx	Probe index shift	mm

5 Qualification of personnel

a) The testing shall be performed by personnel qualified in accordance with ISO 9712.

b) The requirements for qualification of test personnel shall be specified in the product standards and/or other applicable documents.

6 Test equipment

6.1 Instrument

The ultrasonic instrument shall fulfil the requirements of ISO 22232-1.

6.2 Probes

6.2.1 General

The probe(s) shall initially fulfil the requirements of ISO 22232-2.

6.2.2 Probe selection

The choice of the probe depends on the purpose of the testing and the requirements of the referencing standard or specification. It depends on:

— the material thickness, shape and surface condition of the test object;

— the type and metallurgical condition of the material to be tested;

— the type, position and orientation of discontinuities to be detected and assessed.

The probe parameters listed in 6.2.3, 6.2.4 and 6.2.5 shall be considered in relation to the characteristics of the test object stated above.

6.2.3 Frequency and dimensions of transducer

The frequency and dimensions of a transducer determine the shape of the sound beam (near field and beam divergence).

a) The selection shall assure that the characteristics of the beam are the optimum for the testing by a compromise between the following:

   1) the near-field length which shall remain, whenever possible, smaller than the thickness of the test object.

      NOTE It is possible to detect discontinuities in the near field, but their characterization is less accurate and less reproducible than in the far field.

   2) the beam width, which shall be sufficiently small within the test volume furthest from the probe to maintain an adequate detection level;

   3) the beam divergence, which shall be sufficiently large to detect planar discontinuities that are unfavourably orientated.

b) Apart from the above considerations, the selection of frequency shall take into account the influence of the sound attenuation in the material and the reflectivity of discontinuities.

The higher the frequency, the greater the test resolution, but the sound waves are more attenuated (or the spurious signals due to the structure are greater) than with lower frequencies.

The choice of frequency thus represents a compromise between these two factors.

Most ultrasonic tests are performed at frequencies between 1 MHz and 10 MHz.

6.2.4 Dead zone

The choice of the probe shall take into account the influence of the dead zone in relation to the test volume.

6.2.5 Damping

The probe selection shall also include consideration of the damping which influences the axial resolution as well as the frequency spectrum.

6.2.6 Focusing probes

Focusing probes are mainly used for the detection of small discontinuities and for sizing reflectors.

Their advantages in relation to non-focused single-transducer probes are an increased lateral resolution and a higher signal-to-noise ratio than with non-focussing probes.

a) Their sound beams shall be described by the focal distance, the focal zone and the width of the focal zone.

b) The sensitivity setting shall be carried out by using reference reflectors.

6.3 Coupling media

a) Different coupling media can be used, but their type shall be compatible with the materials to be tested. Examples are:

   — water, possibly containing an agent, e.g. wetting, anti-freeze, corrosion inhibitor;

   — contact paste;

   — oil;

   — grease;

— cellulosic paste containing water

b) The characteristics of the coupling medium shall remain constant throughout the verification, the setting operations and the testing.

c) If the constancy of the characteristics cannot be guaranteed between setting and testing, a transfer correction may be applied.

One method for determining the necessary correction is described in 12.5.

d) The coupling medium shall be suitable for the temperature range in which it will be used.

e) After testing is completed, the coupling medium shall be removed if its presence will adversely affect subsequent operations or use of the test object.

6.4 Standard blocks

The blocks used for setting up the ultrasonic test equipment shall be in accordance with those specified in ISO 2400 and ISO 7963.

The stability of test equipment and setting can be verified by using the blocks given in ISO 2400 and ISO 7963.

6.5 Reference blocks

a) When amplitudes of echoes from the test object are compared with echoes from a reference block, certain requirements relating to the material, surface condition, geometry and temperature of the block shall be observed.

b) Where possible, the reference blocks shall be made from a material with acoustic properties which are within a specified range with respect to the material to be tested and shall have a surface condition comparable to that of the test object.

c) If these characteristics are not the same, a transfer correction shall be applied.

A method for determining the necessary correction is described in 12.5.

d) The geometrical conditions of the reference blocks and the test object shall be considered.

For further details, see Clause 8.

e) The geometry of the reference blocks, its dimensions, and the position of any reflectors, shall be indicated on a case by case basis in the specific standards and specifications.

f) The position and number of reflectors shall relate to the scanning of the entire test volume.

g) The most commonly used reflectors are:

   1) large planar reflectors, compared to the beam width, perpendicular to the beam axis (e.g. back wall);

   2) flat-bottomed holes;

   3) side-drilled holes;

   4) grooves or notches of various cross-sections

h) When reference blocks are submerged, e.g. for immersion testing, the influence of water in the holes shall be considered or the ends of the holes shall be plugged.

i) The consequences of temperature differences between test object, probes, and reference blocks shall be considered and compared to the requirements for the accuracy of the test.

j) If necessary, the reference blocks shall be maintained within the specified temperature range during the testing.

6.6 Specific test blocks

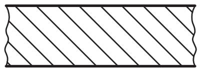
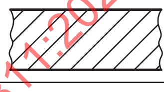
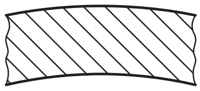
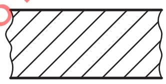
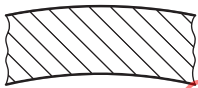
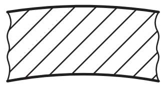
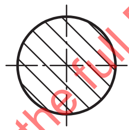
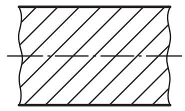
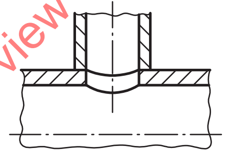
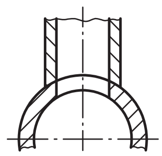
In certain cases, specific blocks, e.g. with identified natural discontinuities, can be used to optimise the test technique and to check the stability of the test sensitivity.

7 Categories of test objects

The requirements for range and sensitivity setting will depend on the geometrical form of the test object.

Five categories of test objects are specified in Table 2.

Table 2 — Categories of test objects

Category	Feature	Section in *x*-direction	Section in *y*-direction
1	Plane parallel surfaces (e.g. plate/sheet)		
2	Parallel, uniaxially curved surfaces (e.g. tubes)		
3	Parallel surfaces curved in more than one direction (e.g. dished ends)		
4	Solid material of circular cross section (e.g. rods and bars)		
5	Complex shapes (e.g. nozzles, sockets)		

8 Test objects, reference blocks and reference reflectors

Requirements for geometrical features of test objects, reference blocks and reference reflectors in general are contained in Table 3 and Table 4.

Table 3 — Reference blocks — Requirements for scanning surface, wall thickness and reflectors

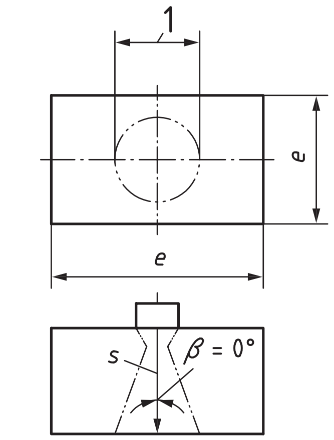
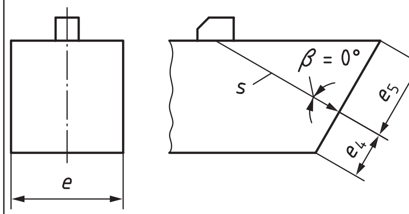
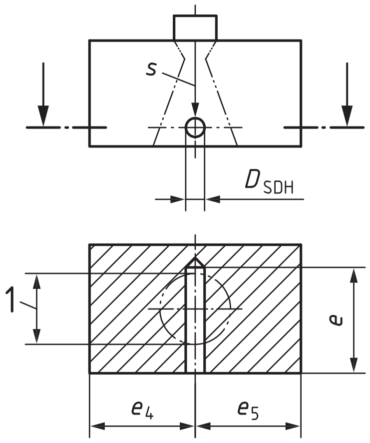
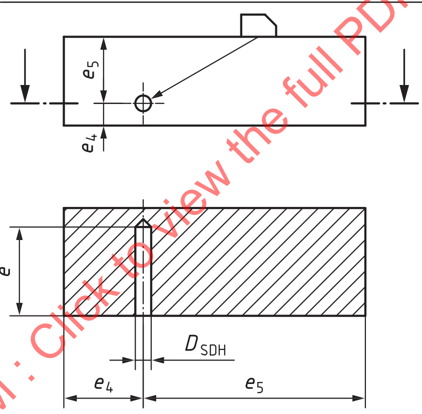
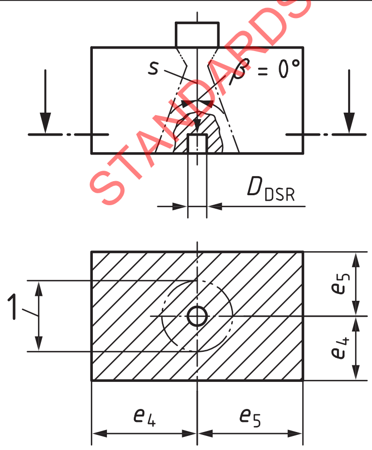
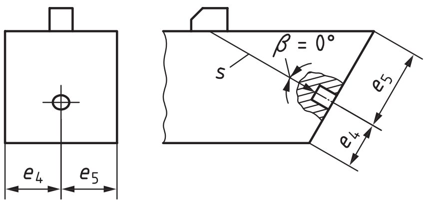
Requirements when using back-wall echoes		
Straight-beam probe	Angle-beam probe	Condition
 **Key** 1 sound beam diameter		$e > \frac{2\lambda s}{D_{\text{eff}}}$ $e_4, e_5 > \frac{\lambda s}{D_{\text{eff}}}$
Requirements when using side-drilled holes		
Straight-beam probe	Angle-beam probe	Condition
		$D_{\text{SDH}} \geq 1{,}5\lambda$ $e > \frac{2\lambda s}{D_{\text{eff}}}$ $e_4, e_5 > \frac{\lambda s}{D_{\text{eff}}}$ $s > 1{,}5 N_{\text{eff}}$
Requirements when using disc-shaped reflectors		
Straight-beam probe	Angle-beam probe	Condition
 **Key** 1 sound beam diameter		$D_{\text{DSR}} < \frac{\lambda s}{D_{\text{eff}}}$ $e_4, e_5 > \frac{\lambda s}{D_{\text{eff}}}$ $s > 0{,}7 N_{\text{eff}}$

Table 3 *(continued)*

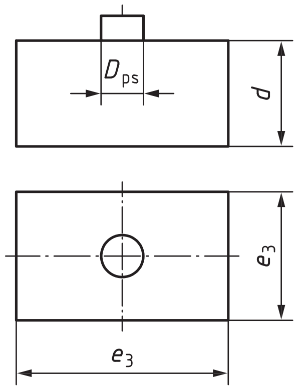
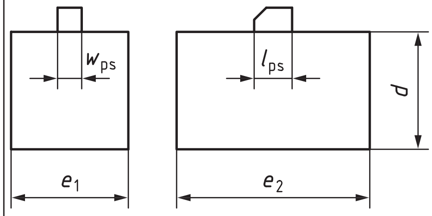
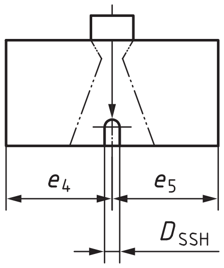
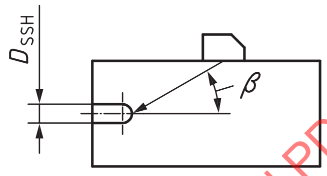
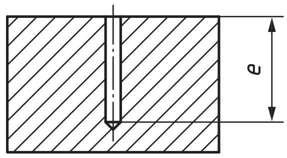
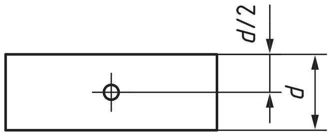
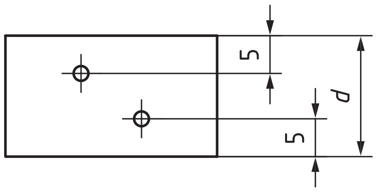
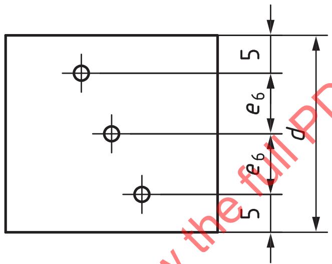
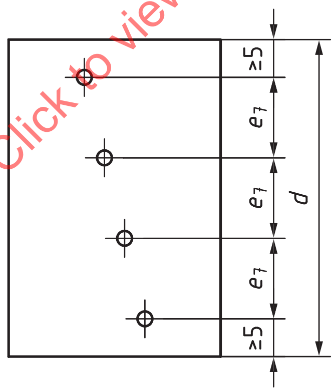
Requirements for test surface and wall thickness		
Straight-beam probe	Angle-beam probe	Condition
		d larger than the length of the dead zone for α equal to 0°. $d > 5\ \lambda$ for $\alpha > 0°$ $e_1 > 1{,}5\ w_{ps}$ $e_2 > 1{,}5\ l_{ps}$ $e_3 > 1{,}5\ D_{ps}$
Requirements when using spherical-shaped reflectors		
Straight-beam probe	Angle-beam probe	Condition
		$s > 1{,}5\ N_{eff}$ with $D_{SSH} < \frac{\pi \lambda s^2}{D_{eff}^2}$ $\beta \leq 60°$ $e_4, e_5 > \frac{\lambda s}{D_{eff}}$

Table 4 — Reference blocks and reference reflectors for category 1 objects

Wall thickness, *d*, in mm	Reference blocks and reference reflectors	Conditions
		$e > \dfrac{2\lambda s}{D_{\text{eff}}}$
$10 \leq d \leq 15$		
$15 \leq d \leq 20$		
$20 \leq d \leq 40$		$D_{\text{SDH}} \geq 1{,}5\lambda$ $e_6 = \dfrac{d-10}{2}$
$d > 40$		$e_7 \leq \dfrac{d-10}{3}$

9 Probes

9.1 General

Contouring of the probe shoe, for categories 2 to 5 of Table 2, may be necessary to avoid probe rocking, i.e. to ensure good, uniform, acoustic contact and a constant beam angle in the test object.

Contouring is only possible with probes having a hard-plastic delay block (normally dual-transducer straight-beam probes or angle-beam probes with wedges).

The following conditions for the different categories exist (see Table 2 and Figure 1):

— Category 1: No probe contouring necessary in either *x*- or *y*-direction;

— Categories 2 and 4: Contouring in *x*-direction for all probes (angle-beam probe orientation in *x*-direction shall be longitudinally curved; angle-beam probe orientation in *y*-direction shall be transversely curved);

— Categories 3 and 5: Contouring in both x- or y-directions: Probe face longitudinally and transversely curved.

The use of contoured probes necessitates setting the range and sensitivity on reference blocks contoured similar to the test object, or the application of mathematical correction factors.

When using Formula (1) or Formula (2), problems due to low energy transmission or beam misalignment are avoided.

9.2 Longitudinally curved probes

9.2.1 Convex scanning surface

For scanning on convex surfaces, the probe face shall be contoured when the diameter of the test object, D_{obj}, is below ten times the length of the probe shoe, l_{ps}, (see Figure 1):

$$D_{obj} < 10 l_{ps} \tag{1}$$

9.2.2 Concave scanning surface

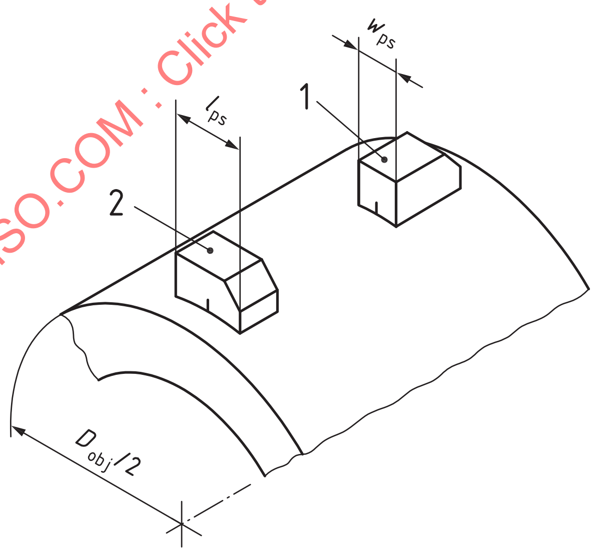
On a concave scanning surface, the probe face shall always be contoured, unless adequate coupling can be achieved due to very large radii of curvature.

9.3 Transversely curved probes

9.3.1 Convex scanning surface

For scanning on convex surfaces, the probe face shall be contoured when the diameter of the test object, D_{obj}, is below ten times the width of the probe shoe, w_{ps}, (see Figure 1):

$$D_{obj} < 10 w_{ps} \tag{2}$$



Key

1 transversely curved

2 longitudinally curved

Figure 1 — Length, l_{ps}, and width, w_{ps}, of probe shoe in direction of curvature of the test object

9.3.2 Concave scanning surface

On a concave scanning surface, the probe face shall always be contoured, unless adequate coupling can be achieved due to very large radii of curvature.

10 Determination of probe index point and beam angle

10.1 General

a) For straight-beam probes there is no requirement to determine probe index point and beam angle as it is assumed that the probe index point is in the centre of the probe face and the angle of refraction is zero degrees.

b) When using angle-beam probes, these parameters shall be determined in order that the position of a reflector in the test object can be determined in relation to the probe position.

The techniques and reference blocks employed depend on the contouring of the probe face.

c) Measured beam angles depend on the sound velocity of the reference block used.

If the block is not made of non-alloy steel, its velocity shall be determined and recorded.

10.2 Flat angle-beam probes

10.2.1 Calibration block technique

Probe index point and beam angle shall be determined using calibration block No. 1 or calibration block No. 2 according to the specifications given in ISO 2400 or ISO 7963 respectively, depending on the size of the probe.

10.2.2 Reference block technique

An alternative technique using a reference block containing at least 3 side-drilled holes may be used. In this case, a block as given in ISO 22232-3 shall be used.

10.3 Angle-beam probes curved longitudinally

10.3.1 Mechanical determination

a) Before contouring the probe face, the probe index point and beam angle shall be measured as described in 10.2.1.

b) The incident angle at the probe face (α_d) shall be calculated from the determined beam angle (α) and a line, originating from the probe index point and parallel to the incident beam, shall be marked on the side of the probe, as shown in Figure 2.

c) The incident angle is given by Formula (3):

$$\alpha_d = \arcsin\left(\frac{c_d}{c_t}\sin\alpha\right) \tag{3}$$

where

c_d is the longitudinal wave velocity in the probe wedge (normally 2 730 m/s for acrylic glass);

c_t is the transverse wave velocity in the test object (3 255 m/s ± 15 m/s for non-alloy steel).

d) After contouring, the probe index point will have moved along the marked line, and its new position can be measured by mechanical means directly on the probe housing, as shown in Figure 2.

e) The beam angle shall be determined by maximizing the echo from a side-drilled hole satisfying the conditions given in Table 3.

f) The beam angle may then be determined directly on the test object, on the reference block, or on a scale drawing. See Figure 3.

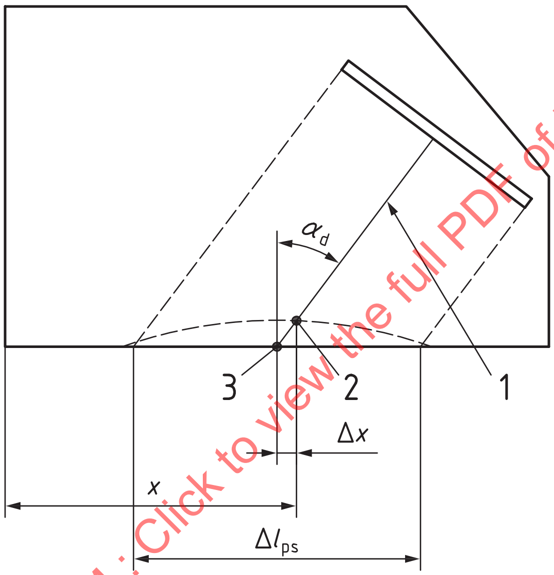
g) Alternatively, the beam angle may be determined by calculation on the basis of the sound path length measured on the reference block by mechanical means, using Formula (4).

This may be accomplished together with the range setting as described in 11.4.4:

$$\alpha = \arccos\left\{\frac{\left[(D_{\mathrm{SDH}}/2)^2 + s^2 - t^2 + sD_{\mathrm{SDH}} + tD_{\mathrm{Obj}}\right]}{D_{\mathrm{obj}}\left[s + (D_{\mathrm{SDH}}/2)\right]}\right\} \tag{4}$$

The symbols used in this equation are illustrated in Figure 3.

h) The radius of curvature of the surface used for the calibration shall be within ±10 % of that of the test object.



Key

1 marked line for index shift

2 index point after contouring

3 index point before contouring

Figure 2 — Determination of index shift for longitudinally curved probes

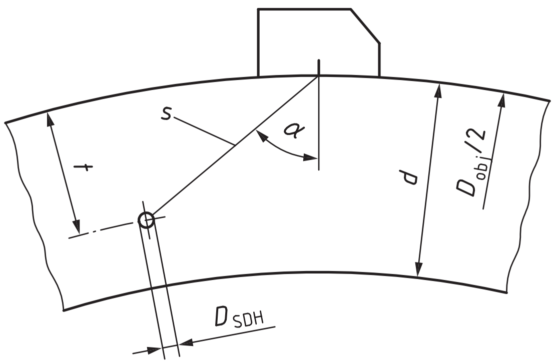


Figure 3 — Determination of beam angle *α* for a longitudinally contoured probe

10.3.2 Reference block technique

This technique is similar to that referenced in 10.2.2, except that the test block shall have a radius of curvature within ±10 % of that of the test object.

10.4 Angle-beam probes curved transversely

10.4.1 Mechanical determination

a) Before contouring the probe face the probe index point and beam angle shall be determined as described in 10.2.1.

b) After contouring, either:

1) a line representing the incident beam, originating from the probe index point, shall be marked on the side of the probe. The new position of the probe index point shall be measured on the side of the probe as shown in Figure 4;

2) the shift in probe index point position (Δx) shall be calculated using Formula (5):

$$\Delta x = g \tan(\alpha_d) \tag{5}$$

The symbols used in this equation are illustrated in Figure 4.

c) For acrylic glass wedges (c_d = 2 730 m/s) and non-alloy steel test objects (c_t = 3 255 m/s) the shift in the probe index point position (Δx), for the three most commonly used beam angles, shall be read from Figure 5 in relation to the depth of contouring (g).

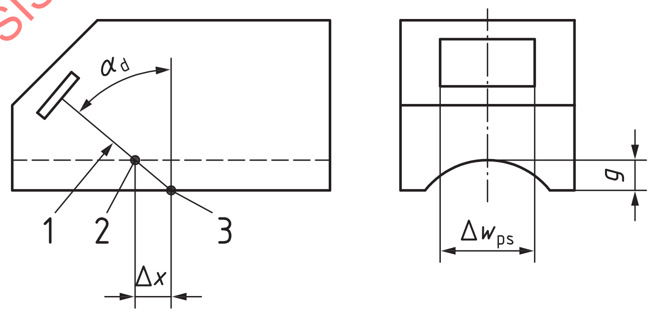
d) The beam angle shall not change during contouring.

e) However, if it is not known, or if there is any variation in the depth of contouring along the length of the probe, it shall be determined on a suitably contoured reference block using a side drilled hole satisfying the conditions given in Table 3. The beam angle shall be determined:

— by drawing a straight line between the hole and the probe index point on a scale drawing; or

— by calculation using Formula (6) for the setup illustrated in Figure 6:

$$\alpha = \arctan\left[\frac{A' + x - q}{t}\right] \tag{6}$$



Key

1 marked line for index shift

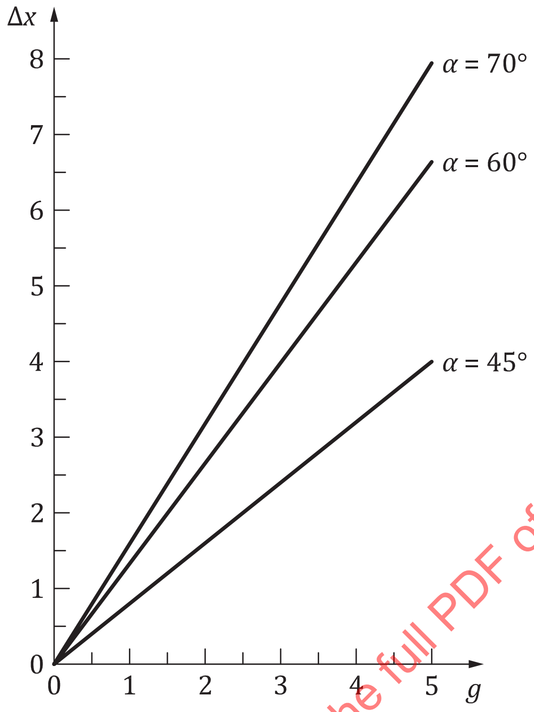
2 index point after contouring

3 index point before contouring

Figure 4 — Determination of index shift for transversely curved probes

10.4.2 Reference block technique

This technique is similar to that referenced in 10.2.2 except that the test block shall be curved transversely in relation to the probe, and shall have a radius of curvature not exceeding 10 % greater, or 30 % lower, than that of the test object.

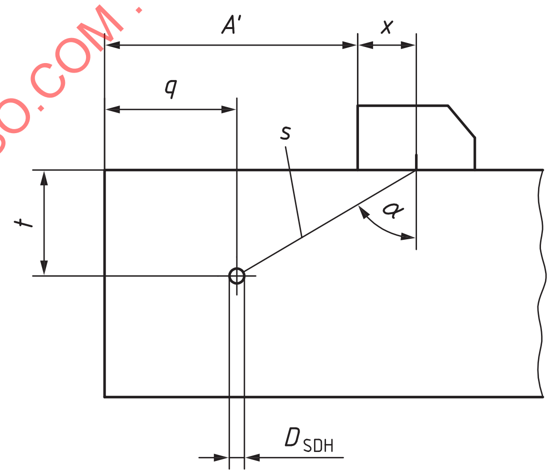


Key

g depth of contouring

Δx probe index point shift

Figure 5 — Probe index shift, Δx, for delay paths in acrylic glass



Key

A' probe coordinate

x distance of probe index point and front edge of probe

q coordinate of reflector

s sound path length

t depth coordinate of reflector
D_{SDH} diameter of side-drilled hole
α beam angle in steel

Figure 6 — Determination of beam angle using a side-drilled hole

10.5 Probes curved in two directions

Unless the need for multiaxial curving of the probe face can be avoided, e.g. by use of smaller probes, the procedures specified in 10.2, 10.3 and 10.4 shall be followed as appropriate.

10.6 Probes for use on materials other than non-alloy steel

If the sound velocity in the material under test is markedly different from that in non-alloy steel, the beam angle will be significantly changed.

The use of the radii on calibration block No. 1 or calibration block No. 2 then may lead to confusing results.

If the sound velocity is known, the beam angle can be calculated using Formula (7):

$$\alpha_t = \arcsin\left(\frac{c_t}{c_r}\sin\alpha_r\right) \tag{7}$$

where

α_r is the beam angle in a non-alloy steel reference block;

α_t is the beam angle in the test object;

c_t is the transverse wave velocity in the test object;

c_r is the transverse wave velocity in the non-alloy steel reference block (3 255 m/s ± 15 m/s).

If the sound velocity is not known, the beam angle can be determined using an echo from a side-drilled hole in a sample of the material to be tested, as illustrated in Figure 6, or as described in 10.3.1 or in 10.4.1, as appropriate.

11 Time base setting

11.1 General

a) For all tests using the pulse-echo technique, the time base of the ultrasonic instrument shall be set to indicate, on the screen, the sound propagation time, or, more usually, some parameters directly related to it.

   Such parameters may be the sound path length of a reflector, its depth below the test surface, its projected sound path length, *a*, or its reduced projected sound path length, *a*′, see Figure 7.

   Unless otherwise noted, the procedures described below refer to setting the time base in terms of the sound path length as single trip (an echo travels this path twice).

b) Time base setting shall be carried out with two reference echoes having a known time or distance interval between them.

c) Depending on the intended setting, the respective sound paths, depths, projected sound path lengths, or reduced projected sound path lengths shall be known.

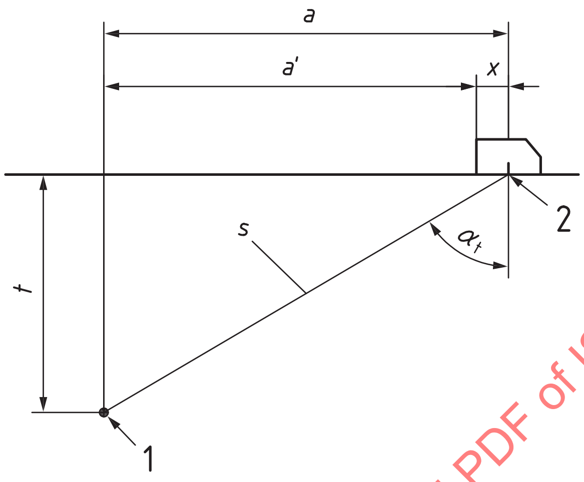
   This technique ensures that correction is automatically made for the sound propagation time through the delay block (e.g. probe wedge).

Only in the case of equipment employing an electronically calibrated time base is one echo sufficient, provided the sound velocity of the reference block is known.

d) The distance between the reference echoes shall be as large as practicable within the time base range.

e) The rising edge of each echo shall be set, using the time base shift and expansion controls, to correspond to a predetermined position along the horizontal screen graticule.

f) Where appropriate, the setting shall comprise a check signal, which shall not coincide with either one of the setting signals, but shall appear at the calculated screen position.



Key

1 reflector

2 index point

Figure 7 — Definitions for setting of the time base in terms of e.g. reduced projected sound path length

11.2 Reference blocks and reference reflectors

a) For the testing of ferritic steel, the use of a block as specified in ISO 2400 and ISO 7963 is recommended.

b) If a reference block or the test object itself is used for the setting of the instrument, faces opposite to the test surface or appropriate reflectors at different known sound path lengths may be used as applicable.

c) Reference blocks shall either have a sound velocity within ±5 % of that of the test object, or correction for the velocity difference shall be made.

11.3 Straight-beam probes

11.3.1 Single-reflector technique

a) This requires a reference block having a thickness not greater than the time base range to be set.

Suitable back wall echoes may be obtained from the 25 mm or 100 mm thickness of the block specified in ISO 2400, or the 12,5 mm thickness of the block specified in ISO 7963.

b) Alternative reference blocks, having parallel or concentric surfaces, known thickness, and the same sound velocity as the test object, may also be used.

11.3.2 Multiple-reflector technique

a) This requires a reference block (or separate blocks) having two reflectors (e.g. side-drilled holes) at different known sound path lengths.

b) The probe shall be repeatedly repositioned to maximize the echo from each reflector.

c) The position of the echo of the nearest reflector shall be adjusted using the shift (or zero) control and that of the echo of the other reflector using the expansion (or distance) control until an accurate time base setting is achieved.

11.4 Angle-beam probes

11.4.1 Radius technique

Range setting can be performed using the radii reflectors of a block as described in ISO 2400 or ISO 7963 respectively.

11.4.2 Straight-beam probe technique

For transverse wave probes, the range setting can be carried out using a longitudinal straight-beam probe on the 91 mm thickness of the block specified in ISO 2400, corresponding to a sound path length of 50 mm for transverse waves in steel.

To complete the range setting it is necessary to obtain an echo, with the angle-beam probe to be used for testing, from a suitable reflector at a known sound path distance, and using the zero-shift control only, to position this echo at the correct location along the time base.

11.4.3 Reference block technique

This is similar in principle to that described in 11.3.2 for straight-beam probes.

a) However, to achieve adequate accuracy it is necessary to mark the probe index points on the surface of the block at which each echo is first maximized, and then mechanically measure the distance between each mark and the corresponding reflector.

b) For all subsequent time base adjustments, the probe shall be repositioned on these marks.

11.4.4 Contoured probes

a) Range setting shall first be performed using a probe with a flat face, as described in 11.4.1 to 11.4.3.

b) The contoured probe shall then be positioned on a suitable contoured reference block having at least one reflector at a known sound path length.

c) The position of the echo from this reflector shall be adjusted to the correct position along the time base using only the shift control.

11.5 Alternative range settings for angle-beam probes

11.5.1 Flat surfaces

Instead of setting in terms of sound path length, the time base may be set to indicate directly the depth of a reflector below the test surface, or its distance in front of the probe, see Figure 7.

a) Therefore, having selected the time base in terms of depth or projected sound path length, the echoes from the reference block, at known sound path lengths, shall be set along the time base at the positions corresponding to the equivalent depths, or projected sound path length, which may be determined as follows:

b) For a flat plate they may be determined for a given beam angle, either from a scale drawing, or from Formulas (8), (9) or (10):

— depth (t):

$$t = s \cos \alpha_t \quad (8)$$

— projected sound path length (a):

$$a = s \sin \alpha_t \quad (9)$$

— reduced projected sound path length (a'):

$$a' = (s \sin \alpha_t) - x \quad (10)$$

11.5.2 Curved surfaces

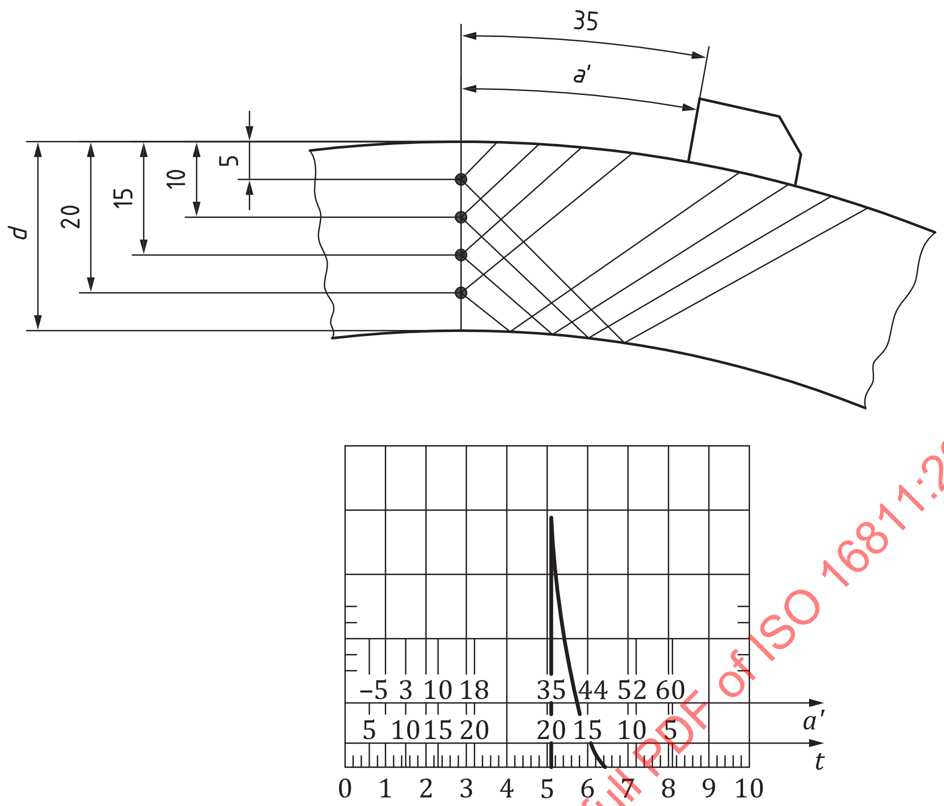
Whilst the same principles of range setting described in 11.5.1 still apply, the time base is not linear with respect to depth or projected sound path length.

a) A non-linear graticule scale may be constructed by taking measurements at a number of positions on a scale drawing of the sound path, or by calculation using suitable equations.

b) The sound path distance to the opposite surface of a concentrically curved object may be determined using the equations given in Annex A.

c) Alternatively, the graticule intervals may be determined on the basis of the maximized echoes from a series of reflectors in a curved reference block, the intermediate values being obtained by interpolation. See Figure 8.

Dimensions in millimetres



Key

a' reduced projected sound path length

d wall thickness

t depth coordinate of reflector

Figure 8 — Example of screen graticule for location of reflectors with a time base set in terms of reduced projected sound path length and depth (α_t = 51°, s_{max} = 100 mm)

12 Sensitivity setting and echo height evaluation

12.1 General

a) After the time base has been set, the sensitivity (or gain adjustment) of the ultrasonic instrument shall be set using one of the following techniques:

1) Single-reflector technique

A single reference reflector, e.g. a back wall, or a notch, may be used when evaluating echoes occurring within the same range of sound path distance.

2) Distance-Amplitude Curve (DAC)-technique

This technique uses the echo heights from a series of identical reflectors (e.g. side-drilled holes or flat-bottomed holes) at different sound path lengths in suitable reference blocks (see 12.3).

3) Distance-gain-size (DGS) technique

This technique uses a series of theoretically derived curves relating the sound path length, the instrument gain, and the size of a disc-shaped reflector perpendicular to the beam axis (see 12.4).

b) Techniques 2 and 3 attempt to compensate for the change in the echo height from a reflector with increasing sound path distance.

   However, for all three techniques, a transfer correction shall be applied, where necessary, to compensate for any coupling losses and differences in material attenuation (see 12.5).

Using ideal reflectors of simple shape, e.g. side-drilled holes or flat-bottomed holes, for sizing of natural discontinuities will not give the true size but only an equivalent value.

The true size of the real discontinuity may be much larger than this equivalent value.

12.2 Angle of incidence

a) When using angle-beam probes on curved test objects in conjunction with indirect scanning (i.e. after the half skip position), the angle of incidence at the back wall, i.e. the angle of impingement, shall be considered.

   For cylindrical components scanned from the outer surface, the angle of incidence at the inner surface may be much larger than the beam angle.

   Conversely, when scanning from the inner surface the incident angle at the outer surface may be much smaller than the beam angle (see Annex A).

b) For transverse wave probes, the beam angle shall be chosen to avoid angles of incidence outside the range 35° to 70°, because in that case severe loss in sound energy will occur due to mode conversion.

   Moreover, additional echoes from other wave modes may disturb the echo evaluation.

   A technique for determining the angle of incidence at the inner and outer surfaces of a cylinder is described in Annex A together with methods of calculating the sound path distance to the opposite surface.

12.3 Distance-amplitude curve (DAC) technique

12.3.1 Reference blocks

a) A DAC reference block is required having a series of equal-sized reflectors at different sound path distances over the time base range to be used for the test.

   Details of the spacing and minimum size of block and reflectors are given in Table 3.

b) The specifications given in Table 3 apply for category 1 test objects, and, where appropriate, for category 2 to category 5 test objects.

   It should be noted that there are minimum sound path lengths below which signals cannot be satisfactorily evaluated due to e.g. dead zone effects or near field interference.

c) The DAC reference block shall be either:

   1) a general-purpose block of uniform low attenuation and specified surface finish, and having a thickness within ±10 % of the test object; or

   2) a block of the same acoustic properties, surface finish, shape and curvature as the test object.

   In the case of block type 1), correction for any differences in attenuation, curvature and coupling losses may be necessary before the distance-amplitude curve can be directly applied.

12.3.2 Preparation of a distance-amplitude curve

12.3.2.1 General

The distance-amplitude curve shall be either shown directly on the screen of the instrument, or plotted on a separate graph, as described in 12.3.2.2 and 12.3.2.3.

This may be supported by electronic means. When using equipment with time-controlled gain, TCG, gain will be controlled such that the DAC will become a straight horizontal line.

12.3.2.2 Plotting on screen

a) The time base shall be first set to accommodate the maximum sound path length to be used, and the gain shall be adjusted so that the echoes from the series of reflectors fall within 20 % and 80 % of full screen height (FSH).

b) For angle-beam probes, the reflectors may be used in either the 0 to half skip, or in half to one skip positions.

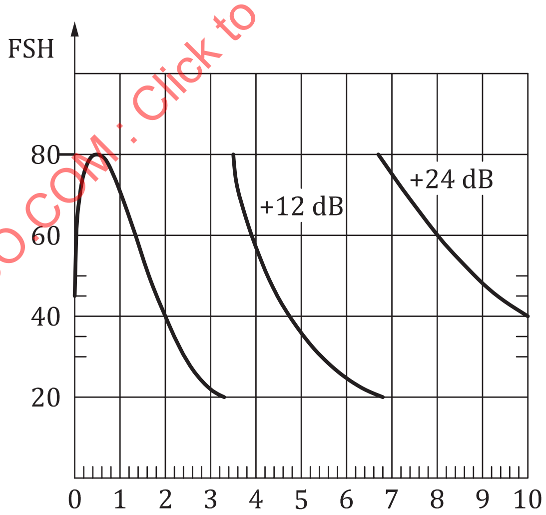
c) The position of the tip of each maximized echo, at a constant gain setting, shall be then marked on the screen, and the distance-amplitude curve shall be drawn through the points.

d) If the difference in height between the largest and smallest echoes exceeds the range 20 % to 80 % of FSH, the line shall be split, and separate curves plotted at different gain settings (see Figure 9).

e) The difference in gain between the two curves shall be recorded on the screen.

f) The gain setting used for plotting the DAC may be referenced to the echo from some other reflector, e.g. in the case of flat probes to either the 100 mm radius quadrant, or the 3 mm diameter hole of the block specified in ISO 2400.

   This will enable the gain to be reset, in future, without the use of the reference block.



Key

FSH full screen height

Figure 9 — Display of ultrasonic instrument showing a split distance-amplitude curve (DAC)

12.3.2.3 Plotting on a separate graph

The general procedure is similar to technique 12.3.2.2 except that the maximized echo from each reflector is adjusted to the same height (generally 80 % of FSH) and the gain setting noted and plotted against the sound path length on a separate graph or stored in the instrument as time-corrected gain (TCG).

12.3.2.4 Transfer correction

After determining transfer differences using the data obtained under 12.5, the distance-amplitude curve, as produced to 12.3.2.2 and 12.3.2.3, shall be corrected accordingly.

This may be achieved by either:

a) correcting the DAC during its preparation;

b) drawing a second, corrected DAC;

c) applying appropriate correction values in the evaluation process.

While techniques a) and b) can be preferable if a sound path dependent attenuation correction is needed, technique c) may be more suitable in cases where allowance is required only for a constant transfer correction.

12.3.3 Evaluation of signals using a distance-amplitude curve

12.3.3.1 Setting the test sensitivity

a) The test sensitivity shall be set by maximizing the echo from one of the reference reflectors in the DAC reference block and adjusting the gain to bring the peak of the echo up to the DAC.

b) The gain shall then be increased by the transfer correction at the appropriate sound path length, if it has not been incorporated in the DAC itself (techniques a) and b) in 12.3.2.4).

c) Alternatively, if the gain setting for the distance-amplitude curve has been referenced to another reflector, this may be used instead, using the appropriate gain correction.

d) The gain shall then be increased (or decreased) prior to scanning by the value specified in the relevant standard or procedure.

12.3.3.2 Measurement of echo height

a) The height of any echo which requires to be evaluated shall be adjusted using the calibrated gain control, to bring it to the DAC, and recorded in terms of the increase or decrease in gain setting compared to the original value at which the DAC was plotted.

b) If not already incorporated in the DAC, appropriate values for transfer correction shall be added if necessary.

c) The resulting echo height difference shall be evaluated as follows:

   1) Where the gain setting had to be increased from the original value by x dB, the echo height is assigned a value (reference level $-x$) dB.

   2) Where the gain setting had to be decreased from the original value by y dB, the echo height is assigned a value (reference level $+y$) dB.

12.3.4 Evaluation of signals using a reference height

This method compares the discontinuity echo with the echo from a reference reflector having the same or larger sound path length.

a) The two signals shall be set to equal screen height (i.e. the reference height), using gain settings for indication gain V_u and recording gain V_r, respectively.

b) The reference height shall be within 40 % and 90 % of FSH.

c) The echo height difference, ΔH_u, shall then be calculated using Formula (11):

$$\Delta H_u = V_r - V_u \quad (11)$$

12.4 Distance-gain-size (DGS) technique

12.4.1 General

The DGS technique uses the theoretically derived distance-amplitude curves of disc-shaped reflectors to evaluate the echo height of unknown reflectors.

In the general DGS diagram, distance and reflector size are normalized. Therefore, it is independent of transducer (element) size and frequency.

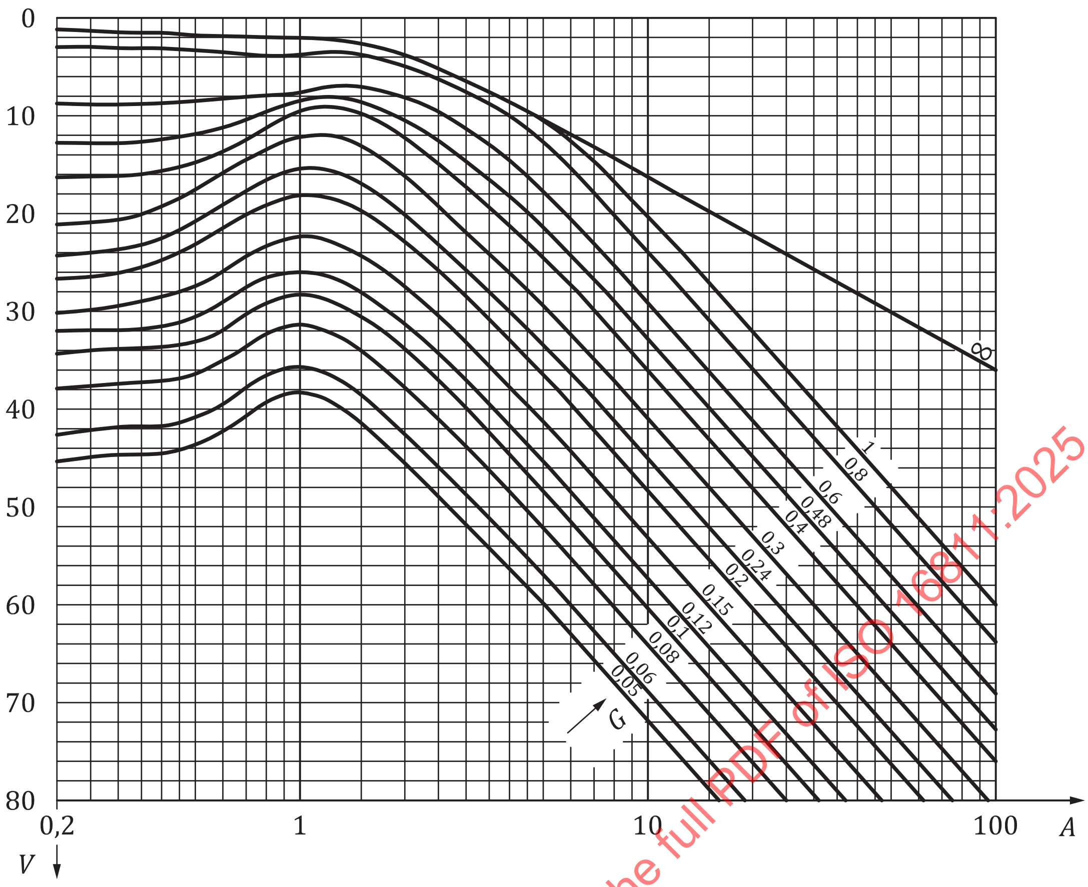
It shows distance as multiples of the effective near field length N_{eff} of the probe, and reflector sizes as multiples of the effective transducer size D_{eff} (see Figure 10 and Annex B).

From this general DGS diagram, special DGS diagrams, for common types of probes, are derived for steel which allow the direct reading of equivalent reflector size without calculation (see Figure 11).

The echo height from a reflector shall be recorded in terms of either:

a) the number of dB above or below the DGS curve for a specified reflector diameter;

b) the diameter of a disc-shaped reflector that would give the same echo height under ideal conditions and at the same sound path distance (equivalent disc).



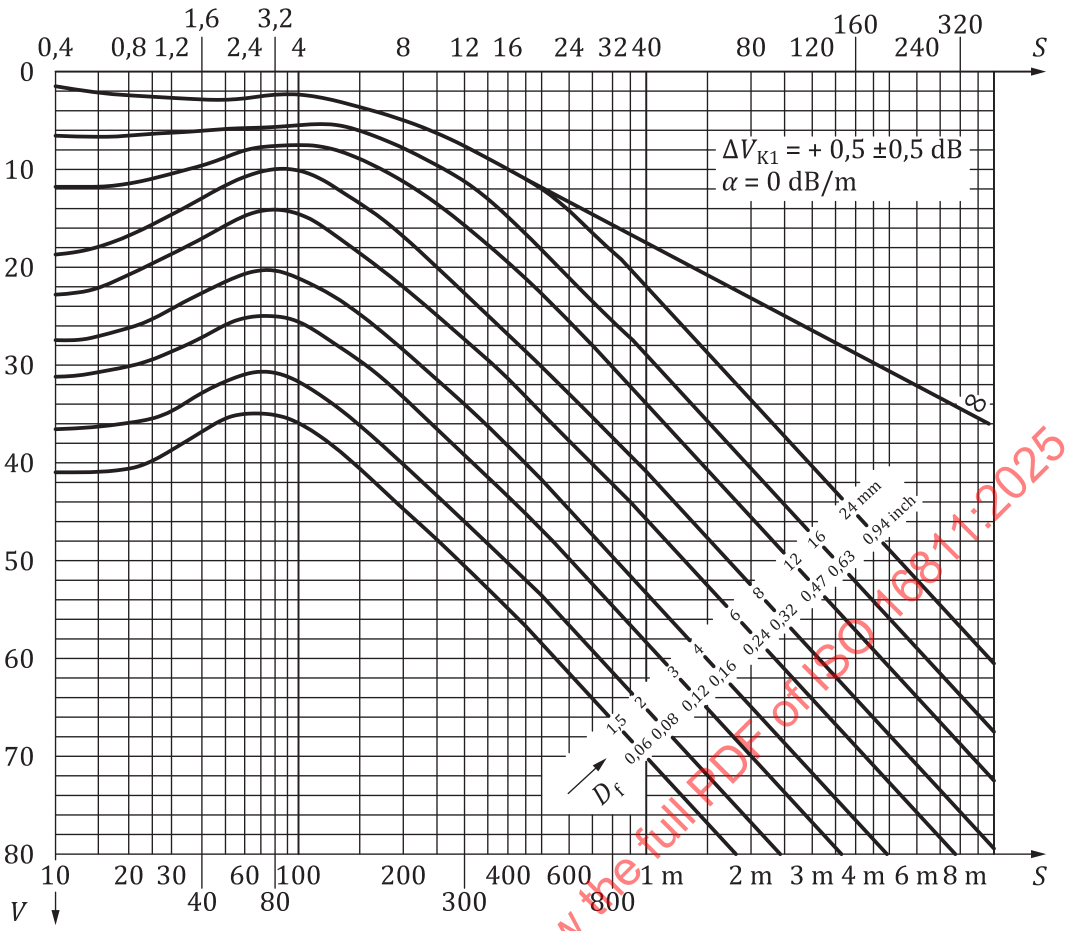
Key

A normalized distance

V gain in dB

G normalized reflector size

Figure 10 — General DGS diagram



Key

S	reflector distance
V	gain in dB
D_f	equivalent reflector diameter

Figure 11 — Example of a specific DGS diagram for a specific angle-beam probe on steel

12.4.2 Reference blocks

When using the DGS technique for setting the test sensitivity, or recording echo height, an applicable reference block, as specified in Table 3, shall be employed. This is in order to relate the gain values shown in the DGS diagram to the echo height from a suitable reference reflector.

The test object may be used as the reference block.

a) Reference blocks for angle-beam probes shall be large enough to permit the through-transmission tests to be made necessary for determining transfer loss.

b) All test surfaces of the reference blocks shall have the same finish.

c) Concave cylindrical reflecting surfaces (e.g. the quadrants of calibration block No. 1 and calibration block No. 2 as specified in ISO 2400 or in ISO 7963) shall only be employed for the setting of sensitivity by the DGS technique, if the probe specific correction factor, ΔV_k, for these blocks is known.

   This is in order that compensation can be made for the difference in reflection of the quadrant compared to that of a plane back wall.

   If the sign of ΔV_k is positive it means that the gain for the test has to be increased by that value and vice versa.

d) To prevent total reflection of the sound beam at the surface of a curved reference block, or test object, the diameter of curvature, D_{obj}, shall fulfil Formula (12):

$$D_{obj} > D_{eff}\left(\frac{c_t}{c_d} \times \frac{1}{1-\sin\alpha_t}\right) \quad (12)$$

where

D_{eff} is the effective diameter of the transducer;

c_t is the sound velocity of transverse wave in the test object;

c_d is the longitudinal wave velocity in the delay block;

α_t is the beam angle.

EXAMPLE For a 45° angle-beam probe with an effective transducer diameter of 20 mm the value of D_{obj} (steel) shall be greater than 82 mm.

12.4.3 Use of DGS diagrams

12.4.3.1 Reference height technique

a) The recording gain V_r, at which scanning shall be carried out, shall be calculated from Formula (13):

$$V_r = V_j + \Delta V + \Delta V_k + \Delta V_t \quad (13)$$

where

V_j is the gain setting required to set the echo from a reference reflector, meeting the requirements of Table 3, to a given reference height on the screen (not less than 20 % of FSH);

ΔV is the gain difference between the DGS curve corresponding to the minimum equivalent disc-shaped reflector (i.e. the recording level), measured at the maximum sound path length s_{max}, and the reference reflector, measured at its sound path length s_j;

ΔV_k is a correction factor when using a concave reflecting surface as reference reflector, (see 12.4.2);

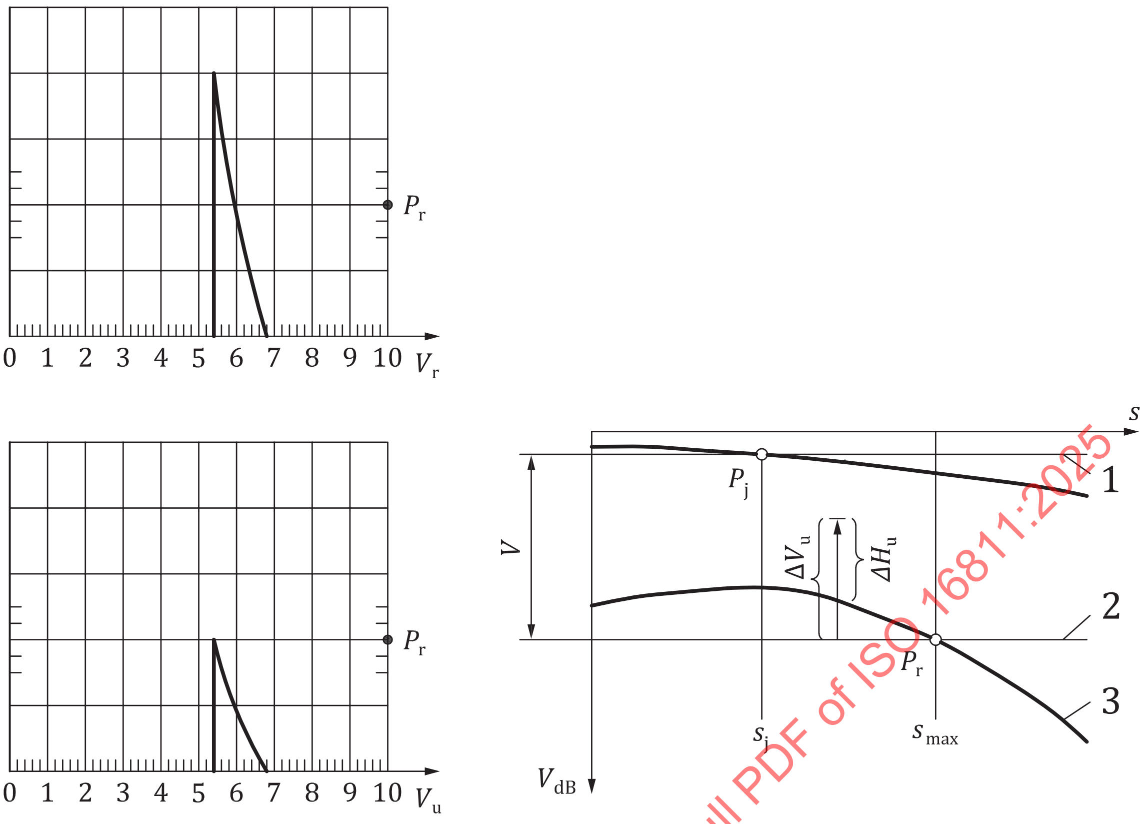
ΔV_t is the transfer correction (see 12.5).

b) The height of any echo observed during scanning which meets or exceeds the reference height on the screen, shall be assessed as follows.

1) The gain V_u necessary to bring the echo to the reference height shall be noted.

2) A line representing the reference height shall then be drawn on the DGS diagram, and the gain difference $\Delta V_u = V_u - V_r$ marked off from the reference height at the corresponding sound path distance, s_u (see Figure 12).

3) If the marked point is above the DGS curve associated with the recording level, the echo height ΔH_u shall be recorded in terms of the number of dB by which it exceeds the DGS curve at the same sound path distance.



Key

1 adjustment height

2 reference height

3 reference line

s sound path of the reflector

Figure 12 — Example of echo height evaluation using the reference height technique

12.4.3.2 Reference line technique

a) The curve on the DGS diagram, associated with the recording limit, shall be transferred as a reference line from the DGS diagram to the screen.

Note that the relationship between the difference in gain of the DGS diagram (ΔV) at different sound paths is a logarithmic one, whereas the corresponding scaling on the screen is linear, see Formula (14):

$$\Delta V = -20\log_{10}\left(\frac{h_1}{h_2}\right) \qquad (14)$$

where

h_1 and h_2 are the actual physical screen heights, e.g. expressed as a percentage of full screen height (FSH);

ΔV is the difference in gain, given in dB.

b) The difference in gain (ΔV) between the echo from the reference reflector and the DGS curve corresponding to the recording limit, at the same sound path distance, shall be determined on the DGS diagram.

c) The echo from the reference reflector shall then be maximized, and the gain adjusted to set the tip of the echo to a convenient height on the screen.

d) This position shall be marked, and the transferred DGS curve shall be drawn through it.

e) The reference line shall be between 20 % and 80 % of full screen height. To achieve this, the reference line and recording gain may be raised or lowered within a particular section, as shown in Figure 9.

f) The gain for scanning shall then be changed by ΔV and by the possible corrections as given in 12.4.3.1.

g) The height of any echo observed during scanning, equal to or exceeding the corrected DGS curve, shall be recorded in terms of either:

   1) the number of dBs that it exceeds the corrected DGS curve at the same sound path distance;

   2) the equivalent disc-shaped reflector diameter, shown on the DGS diagram, that corresponds to the difference in echo height measured in g) 1).

12.4.4 Restrictions on use of the DGS technique due to geometry

Echo height evaluation using the DGS method is only applicable if contouring of the probe shoe is not required, see Clause 8.

a) The conditions given in Table 2 for reference blocks, shall also apply to the relevant surfaces of the test object.

b) For echo height evaluation, the normalized distance A shall satisfy Formula (15) (see Annex B for the calculation of A):

$$A \geq 0{,}7 \quad (15)$$

c) With regard to the wall thickness d, conditions (16) and (17) shall also be satisfied for straight-beam scanning without delay path, and for angle-beam scanning, respectively:

$$d > 0{,}7\, N_{\text{eff}} \quad (16)$$

where N_{eff} is the effective near field length;

$$d > 5\lambda \quad (17)$$

where λ is the wavelength in the test object.

12.5 Transfer correction

12.5.1 General

Unless the test sensitivity is set on a test block which is acoustically representative of the test object, a transfer correction shall be determined, and applied if necessary, when setting the test sensitivity or determining the echo height of any discontinuity.

The transfer correction ΔV_t is made up of two parameters:

— one due to coupling losses at the contact surface and independent of sound path length;

— one due to material attenuation and dependent on sound path length.

Two techniques are described, namely:

— a simple fixed path length technique where compensation is made for coupling loss, and for attenuation at the maximum sound path length only, see 12.5.2;

— a comparative technique where full compensation is made for both parameters, see 12.5.3.

12.5.2 Fixed path length technique

This technique is only applicable where either the loss in acoustic energy due to attenuation is small compared to the coupling loss, or the reflector, whose echo height is to be measured, lies close to the back wall of the test object.

a) When using a straight-beam probe, the gain values required to bring the first back wall echoes from the reference block and the test object, to the same height on the screen shall be measured in dB ($V_{t,t}$ and $V_{t,r}$ respectively).

b) When using an angle-beam probe, two identical probes shall be employed as separate transmitter and receiver in V-formation to produce the corresponding echoes.

c) The theoretical difference in gain between the two echoes (ΔV_s), due to their different sound path lengths, shall be determined on the DGS curve for an infinite reflector, and the transfer correction (ΔV_t) calculated using Formula (18):

$$\Delta V_t = V_{t,t} - V_{t,r} - \Delta V_s \qquad (18)$$

12.5.3 Comparative technique

12.5.3.1 Straight-beam probe

a) Place the probe on the reference block and determine the gain settings required to bring the first and second back wall echo up to the same height on the screen.

b) Record these values as V_{A1} and V_{A2}, see Figure 13.

c) Plot these values against the sound path length and draw a line 2 through them.

d) Reposition the probe on the test object and repeat the above procedure (values V_{B1} and V_{B2} and line 1 in Figure 13).

e) Then the transfer correction (ΔV_t) at the appropriate sound path length (s_u) is given by the difference in gain between the two lines, see Figure 13.

Note that the slope of the line plotted through V_{B1} and V_{B2} does not give the true attenuation in the test object, since no account is taken of the losses caused by beam divergence and the energy transmitted into the probe at each multiple reflection at the test surface. Annex C gives a method to experimentally determine those contact transfer losses at each multiple reflection.

12.5.3.2 Angle-beam probe

The technique is similar in principle to that for straight-beam probes, except that two identical angle-beam probes, operating as separate transmitter and receiver, are used.

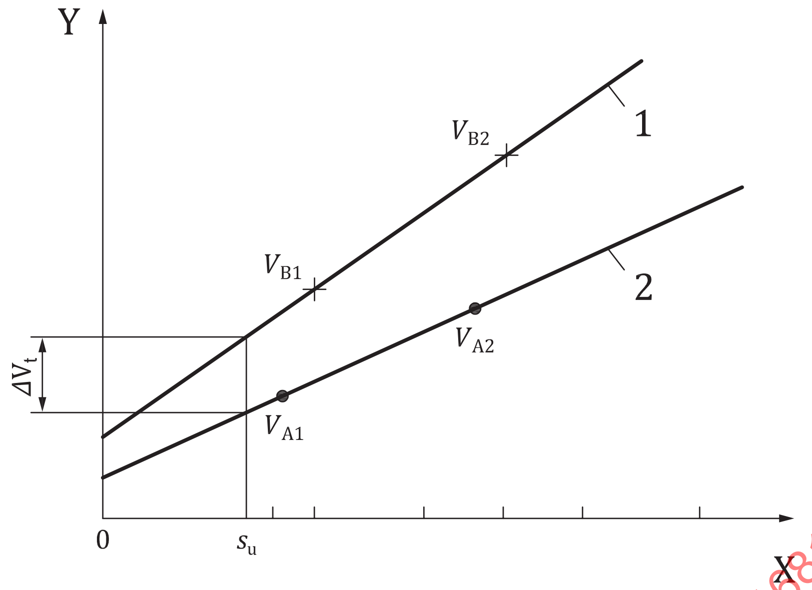
a) The frequency of these probes shall be the same as that of the probe(s) to be used for the testing of the test object.

b) The probes shall be positioned on the DAC reference block, first in V-formation, and then in W-formation, and the gain settings required to bring the echoes to the same height on the screen shall be recorded (values V_{A1} and V_{A2} respectively).

c) The probes shall then be positioned similarly on the test object, and the procedure shall be repeated (values V_{B1} and V_{B2}).

d) The recorded gain values shall be plotted against the sound path length, and lines drawn through each pair of points.

e) The transfer correction, ΔV_t, is again given by the difference in gain between the two lines at the appropriate sound path length.



Key

X sound path length
Y gain setting for 80 % of FSH
1 curve for test object
2 curve for reference block
V_{A1}, V_{A2} gain settings on the reference block
V_{B1}, V_{B2} gain settings on the test object

Figure 13 — Determination of transfer correction using the comparative method

12.5.4 Compensation for local variations in transfer correction

a) If there is reason to suspect local variations in transfer correction over the area of the test object, the transfer correction shall be determined at a number of representative positions.

b) If the variation in transfer correction between the upper and lower values does not exceed 6 dB, the value to be employed shall be the average, ΔV_t, of all the measurements made.

c) If, however, the above variation is greater than 6 dB, techniques 1) or 2) below shall be applied:

1) Increase the average transfer correction, ΔV_t, by a value equal to the average, $\Delta V_\sim$, of all the measurements above ΔV_t.

The revised transfer correction, $(\Delta V_t + \Delta V_\sim)$, shall be applied over the whole of the area to be tested.

2) Divide the area to be tested into zones, such that within each zone the variation of transfer correction does not exceed 6 dB.

A separate value of ΔV_t shall then be applied to each zone.

d) For oblique scanning, through-transmission signals shall be employed instead of back wall echoes.

Annex A
(informative)

Determination of sound path distance and angle of incidence in category 2 test objects

A.1 Angle of incidence

A nomogram for the determination of the angle of incidence is given in Figure A.1.

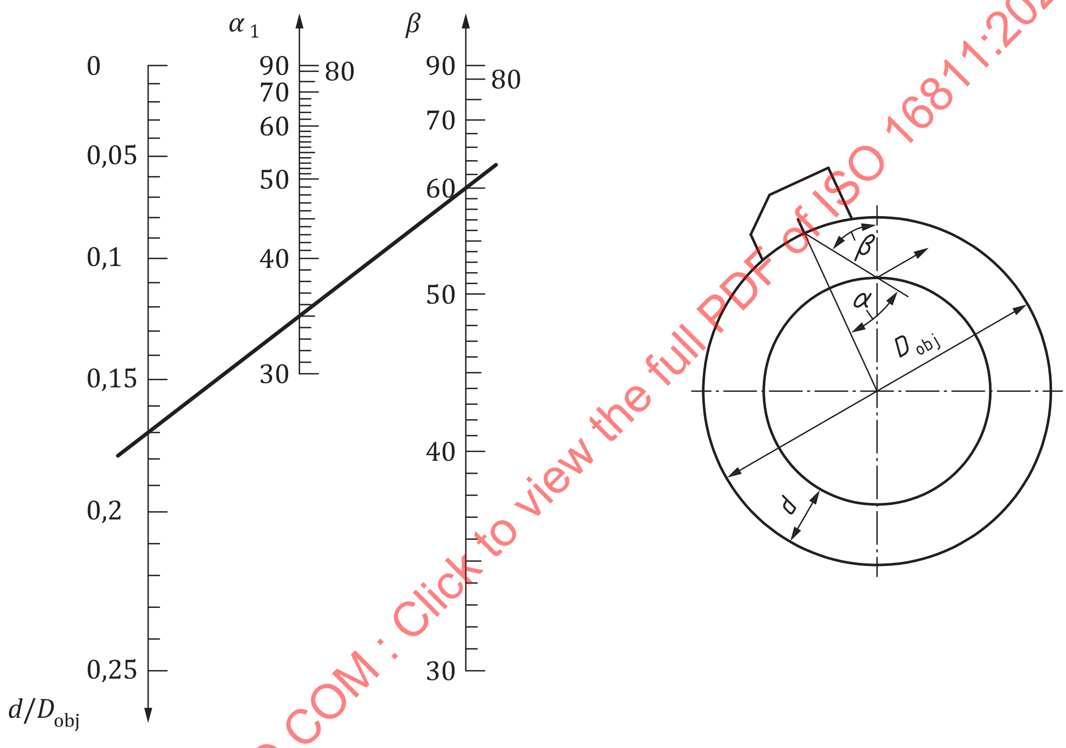


Figure A.1 — Nomogram for determination of the angle of incidence, β

A.2 Sound path when scanning from the outer (convex) surface

A.2.1 Full skip

A sketch illustrating the determination of sound path distance for scanning from the outer surface with full skip is given in Figure A.2.

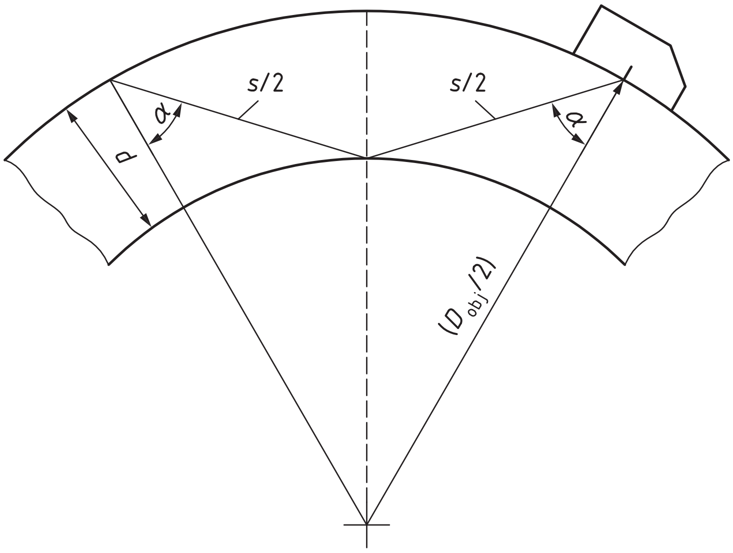


Figure A.2 — Determination of sound path distance for scanning from the outer surface with full skip

The sound path for full skip is given by Formula (A.1).

$$s = D_{obj} \cos\alpha - \sqrt{D_{obj}^2 \cos^2\alpha - 4d\left(D_{obj} - d\right)} \tag{A.1}$$

A.2.2 Between half and full skip

A sketch illustrating the determination of sound path distance for scanning from the outer surface between half and full skip is given in Figure A.3.

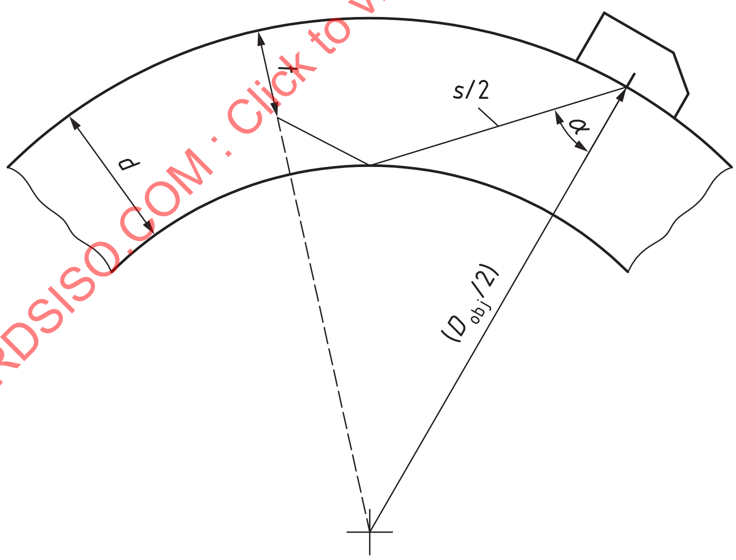


Figure A.3 — Determination of sound path distance for scanning from the outer surface between half and full skip

$$s_t = \frac{D_{obj}}{2} \cos\alpha - \sqrt{D_{obj}^2 \cos^2\alpha - 4d\left(D_{obj} - d\right)} + \frac{1}{2}\sqrt{D_{obj}^2 \cos^2\alpha - 4t\left(D_{obj} - t\right)} \tag{A.2}$$