INTERNATIONAL STANDARD

ISO 16826

First edition
2012-04-01

Non-destructive testing — Ultrasonic testing — Examination for discontinuities perpendicular to the surface

Essais non destructifs — Contrôle par ultrasons — Contrôle des discontinuités perpendiculaires à la surface

Reference number
ISO 16826:2012(E)

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Foreword

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ISO 16826 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*.

Introduction

This International Standard is based on EN 583-4:2002+A1:2003, *Non-destructive testing — Ultrasonic examination — Part 4: Examination for discontinuities perpendicular to the surface*.

The following International Standards 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 — Transmission technique*

ISO 16826, *Non-destructive testing — Ultrasonic testing — Examination 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 — Examination for discontinuities perpendicular to the surface

1 Scope

This International Standard defines the principles for tandem- and longitudinal-longitudinal-transverse (LLT) wave examination for the detection of discontinuities perpendicular to the surface.

The general principles required for the ultrasonic examination of industrial products are described in ISO 16810. A list of symbols and equations is given in ISO 16811.

The tandem- or LLT-examination should be used for the detection of planar discontinuities with distance to the surface greater than 15 mm. This International Standard has been prepared for the examination of metallic materials with a thickness between 40 mm and 500 mm with parallel or concentric surfaces. It can, however, be used for other materials and smaller thickness provided special measures are taken.

2 Normative references

The following referenced documents are indispensable for the application 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 5577, *Non-destructive testing — Ultrasonic inspection — Vocabulary*

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

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

EN 1330-4, *Non-destructive testing — Terminology — Terms used in ultrasonic testing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577 and EN 1330-4 apply.

4 Tandem examination

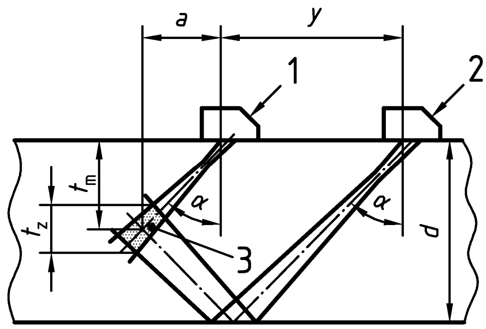
4.1 General

The examination is normally carried out using two similar 45° angle probes, one probe operating as the transmitter and the other probe as receiver. For wall thicknesses greater than approximately 160 mm, probes with different transducer sizes are preferred in order to ensure approximately the same beam diameters in the examination zone.

The use of probe angles other than 45° may be necessary to comply with particular geometrical conditions. Probe angles that give rise to mode conversions shall be avoided.

The probes are located in a line with their acoustic axis in the same direction. In this way the sound beam from the rear probe will, after reflection from the opposite surface, intersect the sound beam from the front probe at the centre of the examination zone.

Figure 1 shows the relationship between the spacing of the probes (y) and the examination depth of the crosspoint (t_m) and the height of the examination zone (t_z).



Key

1 Probe 1
2 Probe 2
3 Examination zone
a Projection distance
d Material thickness
t_m Examination depth
y Probe distance
t_z Height of examination zone

Figure 1 — Basic principle of tandem technique

When examining objects with plane parallel surfaces the distance between the probes can be defined using the following equation:

$$y = 2\tan\alpha(d - t_m) \quad (1)$$

for 45°

$$y = 2(d - t_m) \quad (2)$$

Scanning shall be performed in either of the following ways:

— both probes are moved along the surfaces with a fixed distance (y).

  In this way only one examination zone is examined at a time, and the scanning shall be repeated with different probe distance until the complete examination volume has been examined;

— both probes are moved simultaneously, such that the sum of their distances from the required plane of intersection, e.g. the vertical weld axis, remains constant, thereby scanning the full object thickness in one continuous movement.

4.2 Time base adjustment

Basically all relevant echoes will appear at the same sound path distance, which corresponds to the V-path. Therefore, the adjustment of the time base is not important. It is, however, recommended that the echo from the V-path is located at a fixed position e.g. eight scale divisions.

4.3 Setting of sensitivity

The setting of sensitivity can be performed using the following reflectors:

— opposite surface, where the V-path echo is used as backwall echo;

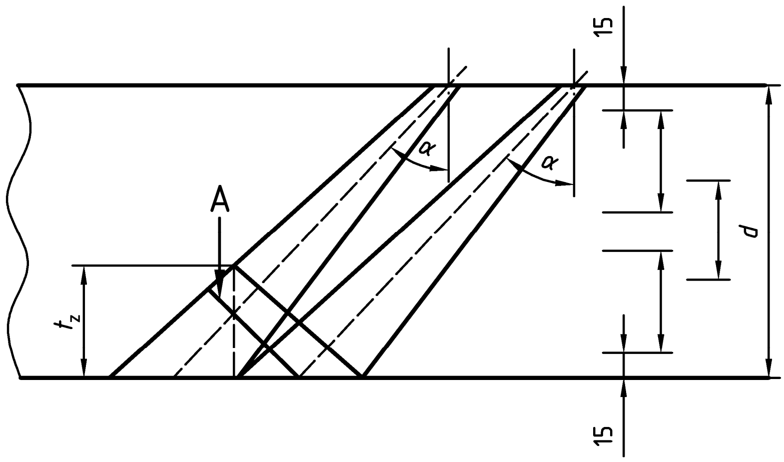
— disk-shaped reflectors perpendicular to the scanning surface (flat-bottomed holes). The reflectors shall be located at the intersection of the beam axes;

— side drilled holes located at the intersection of the beams and at the borders of the examination zones.

4.4 Determination of examination zones

The division into equally sized examination zones ensures that the sensitivity throughout the thickness does not fall below a certain level. The height of the examination zones is calculated so that the sensitivity at the edges of the examination zones is not more than 6 dB below the sensitivity in the intersection point of the beam axes, see Figure 2.

All dimensions in millimetres



Key

A Sound beam diameter
d Material thickness
t_z Height of examination zone

Figure 2 — Examination zones

The height of the examination zone (t_z) can be determined by using a reference block with reflectors in differentiated depths or calculated as follows based on the diameter of the direct beam and the largest sound path in the examination zone closest to the opposite surface (all dimensions in millimetres):

$$t_z \approx \frac{\lambda(d - 15\,\text{mm})}{\sin\alpha \cdot \cos\alpha \cdot D_{\text{eff}}} \tag{2}$$

for 45°

$$t_z \approx \frac{2 \cdot \lambda \cdot (d - 15\,\text{mm})}{D_{\text{eff}}}$$

where

D_{eff} effective transducer diameter.

The number of examination zones is calculated as follows:

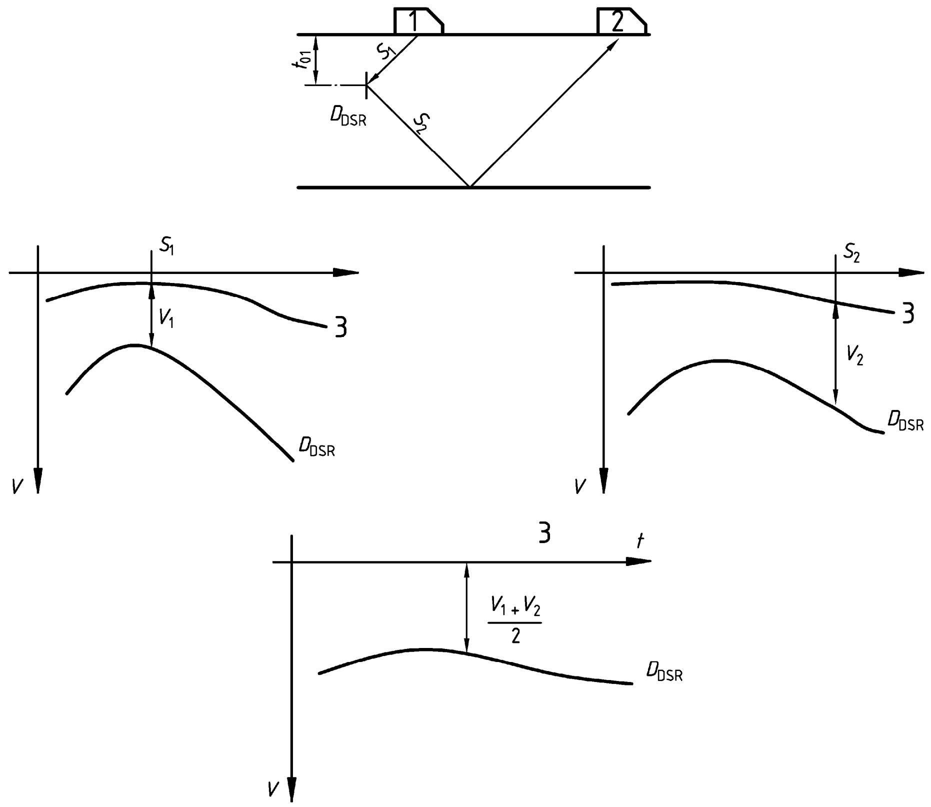
$$n_{tz} = \left| \frac{d - 30\,\text{mm}}{t_z} + 1 \right|, \quad n_{tz} = 1, 2, 3 \tag{3}$$

The probe distance, y, see Figure 1, is adjusted for each examination zone with the intersection of the beam axes in the centre of the zone. Alternatively, the width and number of the examination zones can be determined graphically using scale drawings of the calculated or measured 6 dB beam profiles.

4.5 DGS-diagram for tandem examination

DGS-diagrams for tandem examination may be derived from the general DGS-diagram or based on probe specific diagrams.

The diagrams are prepared as shown in Figure 3. The mean value of the gain differences V_1 and V_2 are derived from the specific diagrams for the probes or from the general DGS diagram. These are used to establish a distance amplitude curve (DAC) for specific tandem examinations, based on this disk-shaped reflector (DSR).



Key

D_{DSR} Disk-shaped reflector
S Sound path distance
t Depth
V Gain
1, 2 Probe 1, probe 2
3 Backwall

Figure 3 — Preparation of tandem DGS-diagram

4.6 Corrections of sensitivity

Depending on the method used for sensitivity setting, corrections for transfer and attenuation losses may be applicable.

In addition to this, compensation shall be made for the reduction of sensitivity that will occur at the edges of the examination zone. Either 6 dB or the value measured on disk-shaped reflectors (flat-bottomed holes) at the border of the examination zones should be used.

4.7 Object with concentric surfaces

The use of 45° angle probes is limited to $d/D \leq 0{,}04$ for convex scanning surfaces and $d/D \leq 0{,}05$ for concave scanning surfaces. Where applicable, the angles of incidence shall be changed to prevent mode conversions that can result in reduced sensitivity.

The probe spacing (y) for the examination of such surfaces may be calculated using the equations in 4.7.1 or 4.7.2.

Alternatively, the probe spacing can be determined graphically using scale drawings of the calculated or measured 6 dB beam profiles.

NOTE In Annex A, nomograms are given for the determination of the distances for concave and convex scanning surfaces without calculation.

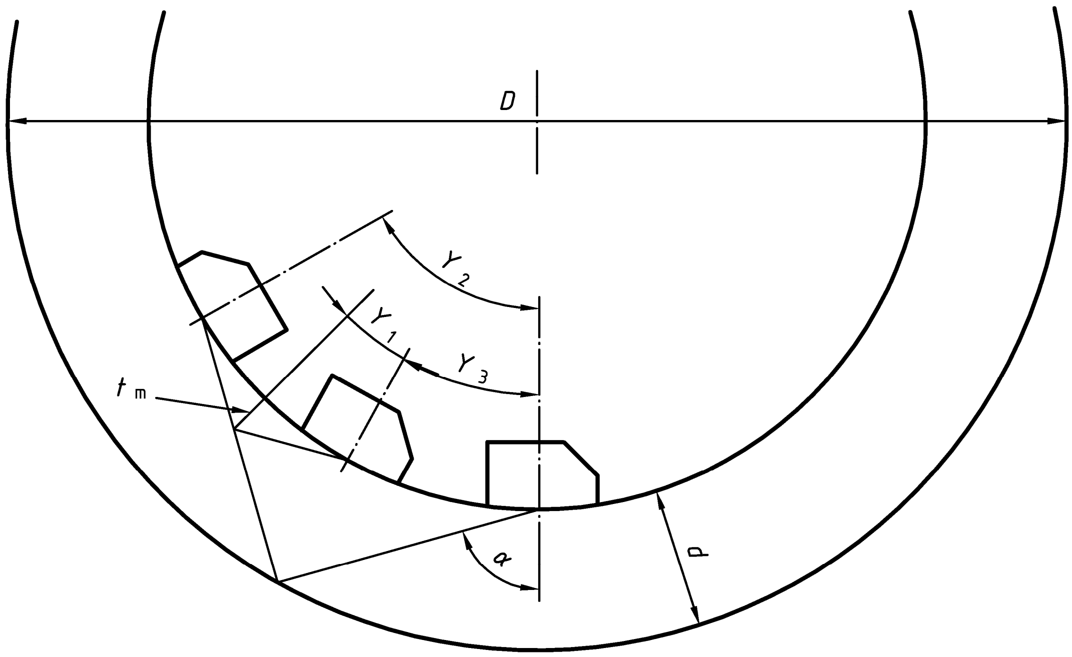
4.7.1 Concave scanning surface

$$y_1 = \frac{\pi(D-2d)}{360°}\left\{\alpha - \arcsin\left[\left(\frac{1}{1+\frac{2t_\mathrm{m}}{(D-2d)}}\right)\sin\alpha\right]\right\} \tag{4}$$

Tandem zone:

$$y_2 = \frac{\pi(D-2d)}{180°}\left\{\alpha - \arcsin\left[\left(1-\frac{2d}{D}\right)\sin\alpha\right]\right\} \tag{5}$$

$$y_3 = \frac{\pi(D-2d)}{180°}\left\{\arcsin\left[\left(\frac{1}{1+\frac{2t_\mathrm{m}}{(D-2d)}}\right)\sin\alpha\right] - \arcsin\left[\left(1-\frac{2d}{D}\right)\sin\alpha\right]\right\} \tag{6}$$



Key

D External diameter of concentric surface
d Material thickness
t_m Examination depth of the crosspoint

Figure 4 — Concave scanning surface

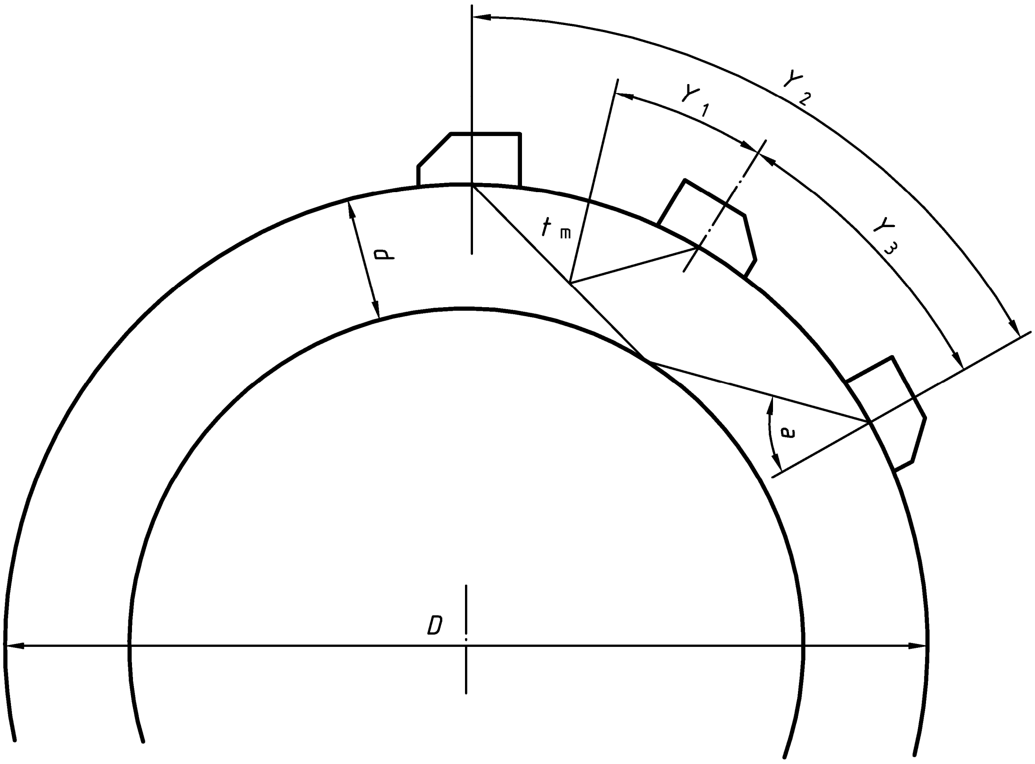
4.7.2 Convex scanning surface

$$y_1 = \frac{\pi D}{360°}\left\{\arcsin\left[\left(\frac{1}{1-\frac{2t_m}{D}}\right)\sin\alpha\right]-\alpha\right\} \tag{7}$$

Tandem zone:

$$y_2 = \frac{\pi D}{180°}\left\{\arcsin\left[\left(\frac{1}{1-\frac{2d}{D}}\right)\sin\alpha\right]-\alpha\right\} \tag{8}$$

$$y_3 = \frac{\pi D}{180°}\left\{\arcsin\left[\left(\frac{1}{1-\frac{2d}{D}}\right)\sin\alpha\right]-\arcsin\left[\left(\frac{1}{1-\frac{2t_m}{D}}\right)\sin\alpha\right]\right\} \tag{9}$$



Key

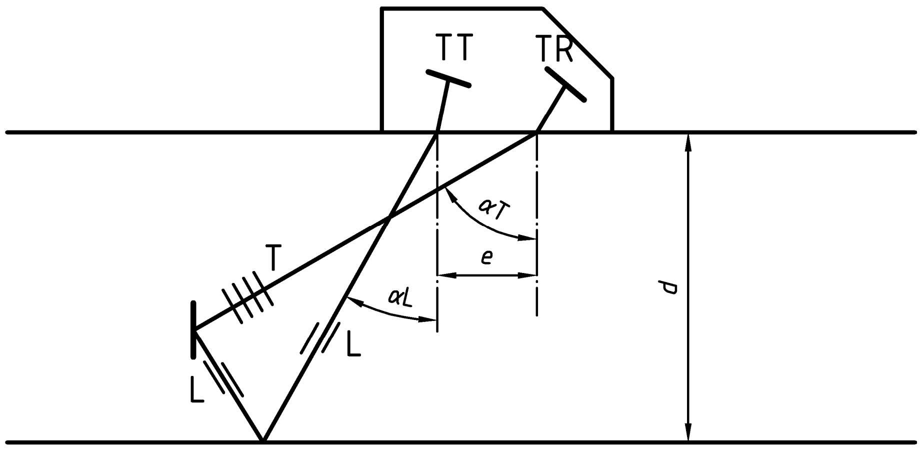
D External diameter of concentric surface
d Material thickness
t_m Examination depth of the crosspoint

Figure 5 — Convex scanning surface

5 LLT-examination

5.1 General

The principle of the LLT-examination is shown in Figure 6. The transmitting transducer TT generates a longitudinal wave at an angle α_L which will be between 7° and 45°. This wave is reflected at the back wall of the specimen and impinges on the discontinuity assumed to be oriented perpendicularly. Here, most of the energy is mode converted to a transverse wave, which travels back to the probe at an angle α_T and is detected by the receiver TR. The relation between angles α_L and α_T is given by the equation [10] where c_T and c_L are the transverse and longitudinal wave velocities, respectively.



Key

TT Transducer transmitter
TR Transducer receiver
e Distance between index points of the transducers
d Material thickness
L Sound path of longitudinal wave
T Sound path of transverse wave

Figure 6 — Basic principle of LLT-examination

$$\alpha_{\mathrm{T}} = \arccos\left(\frac{c_{\mathrm{T}}}{c_{\mathrm{L}}}\cos\alpha_{\mathrm{L}}\right) \tag{10}$$

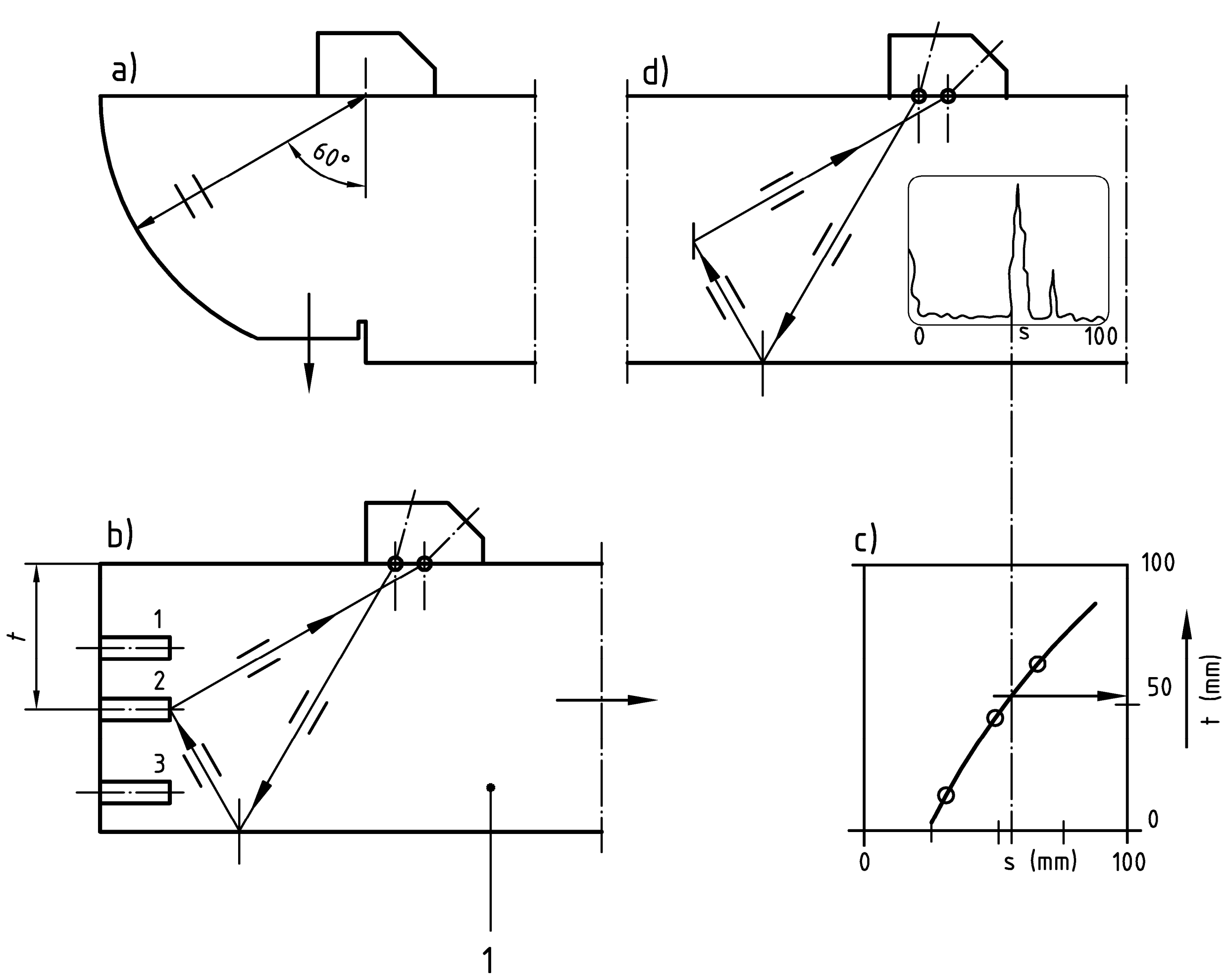
For full through wall examination several probes will normally have to be used; each covering a specific examination zone.

5.2 Time base adjustment and determination of discontinuity depth

The time base of the instrument is calibrated for transverse waves using transducer, TR, of the LLT probe as a transceiver, see Figure 7a).

The probe is then used in the LLT mode (with transducer, TT, operating as transmitter, and transducer, TR, as receiver) on a reference block having the same thickness as the object to be examined and containing a number of vertical disk-shaped reflectors at different depths, see Figure 7b). The observed sound path distance along the time base for each of these reflectors should be noted in a table or a diagram against their depth from the scanning surface, see Figure 7c).

This table or diagram is then used to determine the depth, t, of a discontinuity from a measurement of its observed sound path distance, see Figure 7c) and 7d).



Key

1 Reference block
t Depth from the scanning surface
s Sound path distance

Figure 7 — Determination of discontinuity depth

5.3 Setting of sensitivity

The setting of sensitivity can be performed using the following reflectors:

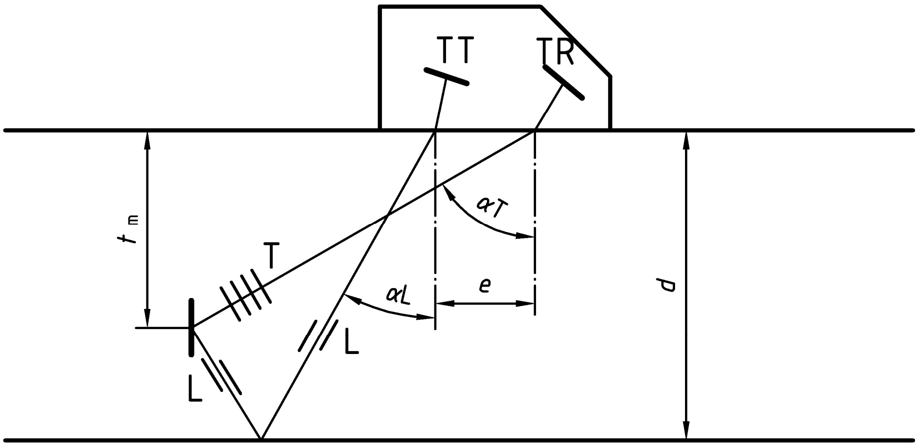
— endface perpendicular to the scanning surface;

— disk-shaped reflector perpendicular to the scanning surface (flat-bottomed holes).

5.4 Determination of examination depth

As with the tandem technique the LLT-technique has the highest sensitivity at the intersection point of the acoustic axes of the transmitter and the receiver. The depth position t_m of this intersection point, see Figure 8, depends on the choice of the pair of angles α_L, α_T, on the thickness, d, of the specimen and on the distance, e, between the beam index (TT) and the beam index (TR). If the beam index (TT) of the transmitter is situated in the front of the beam index (TR), this depth position is given by:

$$t_m = \frac{2\,d \tan \alpha_L + e}{\tan \alpha_L + \tan \alpha_T} \quad (11)$$



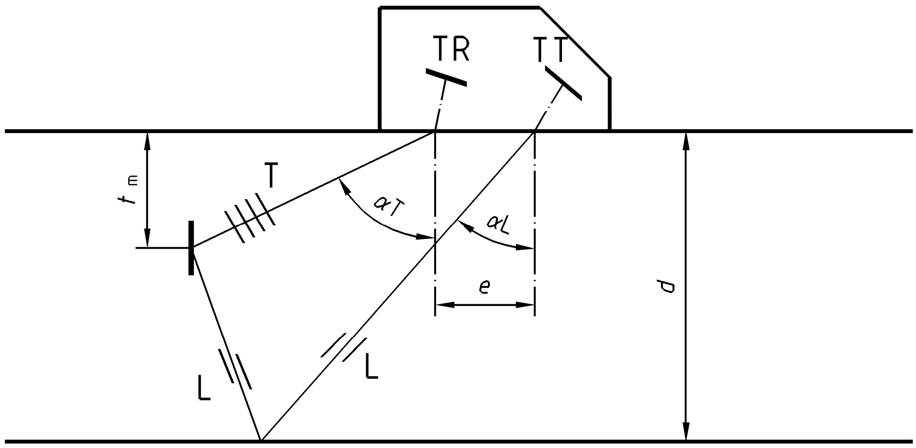
Key

TT transducer transmitter
TR transducer receiver
e distance between index points of the transducers
d material thickness
t_m examination depth of the crosspoint
L sound path of longitudinal wave
T sound path of transverse wave

Figure 8 — Determination of examination depth, TR mode

In the case where the beam index (TT) is behind the beam index (TR), see Figure 9, t_m is given by:

$$t_m = \frac{2\,d \tan \alpha_L - e}{\tan \alpha_L + \tan \alpha_T} \quad (12)$$



Key

TT transducer transmitter
TR transducer receiver
e distance between index points of the transducers
d material thickness
t_m examination depth of the crosspoint
L sound path of longitudinal wave
T sound path of transverse wave

Figure 9 — Determination of examination depth, RT mode

The equations (11) and (12) are valid even if the transmitter and receiver are contained in separate housings.

As with the tandem technique, the height of the examination zone can be approximately determined by geometrical superposition of the transmitter and receiver beams, using the 6 dB beam edges.

5.5 DGS-diagrams for LLT-examination

The evaluation of the echo height can be performed using DGS-diagrams that are calculated, determined experimentally or supplied by the probe manufacturer.

5.6 Correction of sensitivity

Additionally to the transfer corrections (coupling and sound attenuation), a sensitivity correction factor of 6 dB has to be added to compensate for the sensitivity losses at the borders of the examination zones.

Annex A
(informative)

Nomograms for determination of tandem distances for convex (Figure A.1) and concave (Figure A.2) scanning surface

Instruction for use of the nomograms:

1) choose the examination depth;

2) draw a horizontal line to the appropriate probe angle line;

3) draw a vertical line to the dashed line;

4) draw a horizontal line to the tandem distance curves;

5) choose d/D;

6) draw a horizontal line to the appropriate probe angle curve;

7) draw a vertical line to the tandem distance curves;

8) read the tandem distance value from the crossing point of the lines 4 and 7. If the point does not fall on a curve, then interpolate the value.

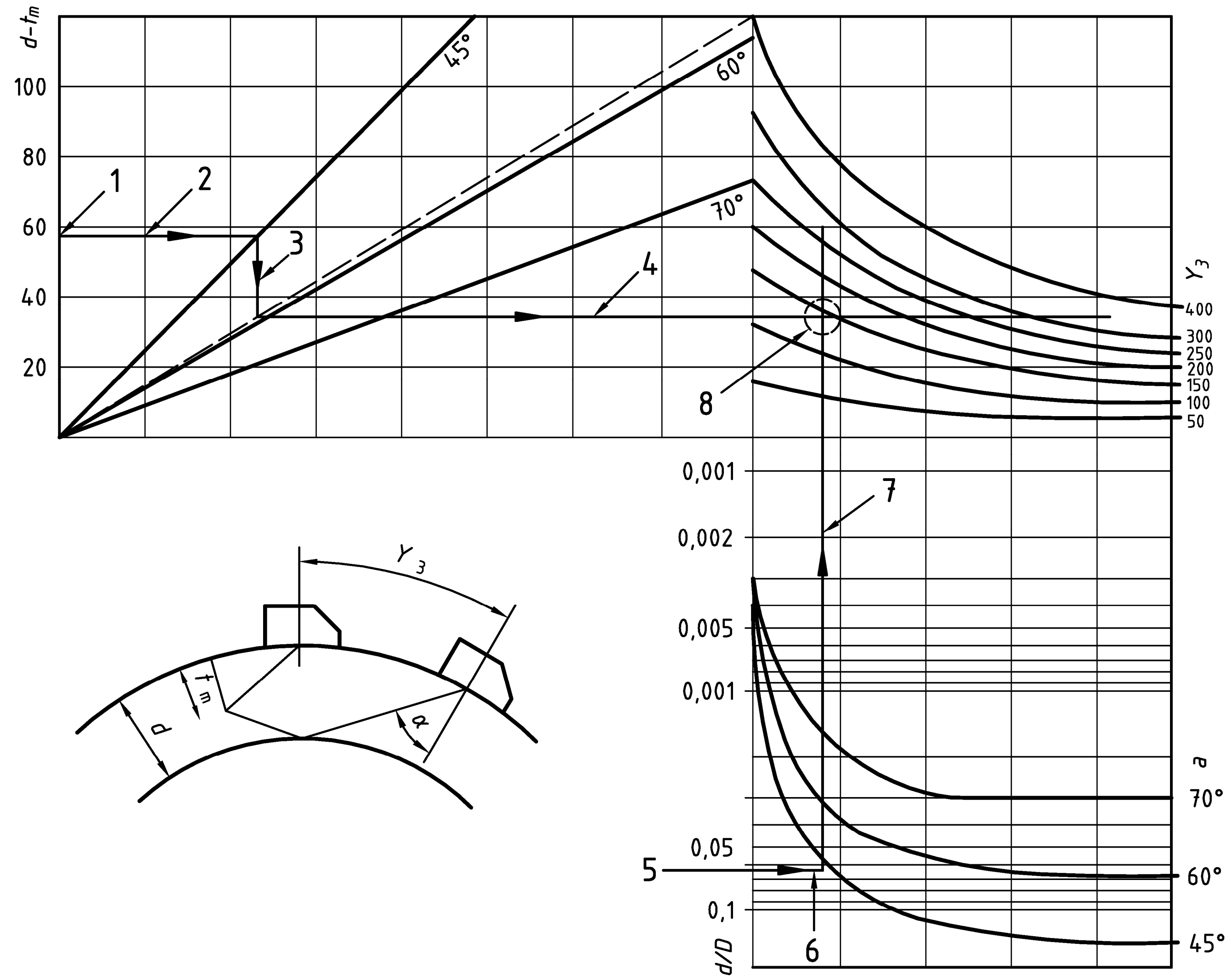


Figure A.1 — Nomogram - convex

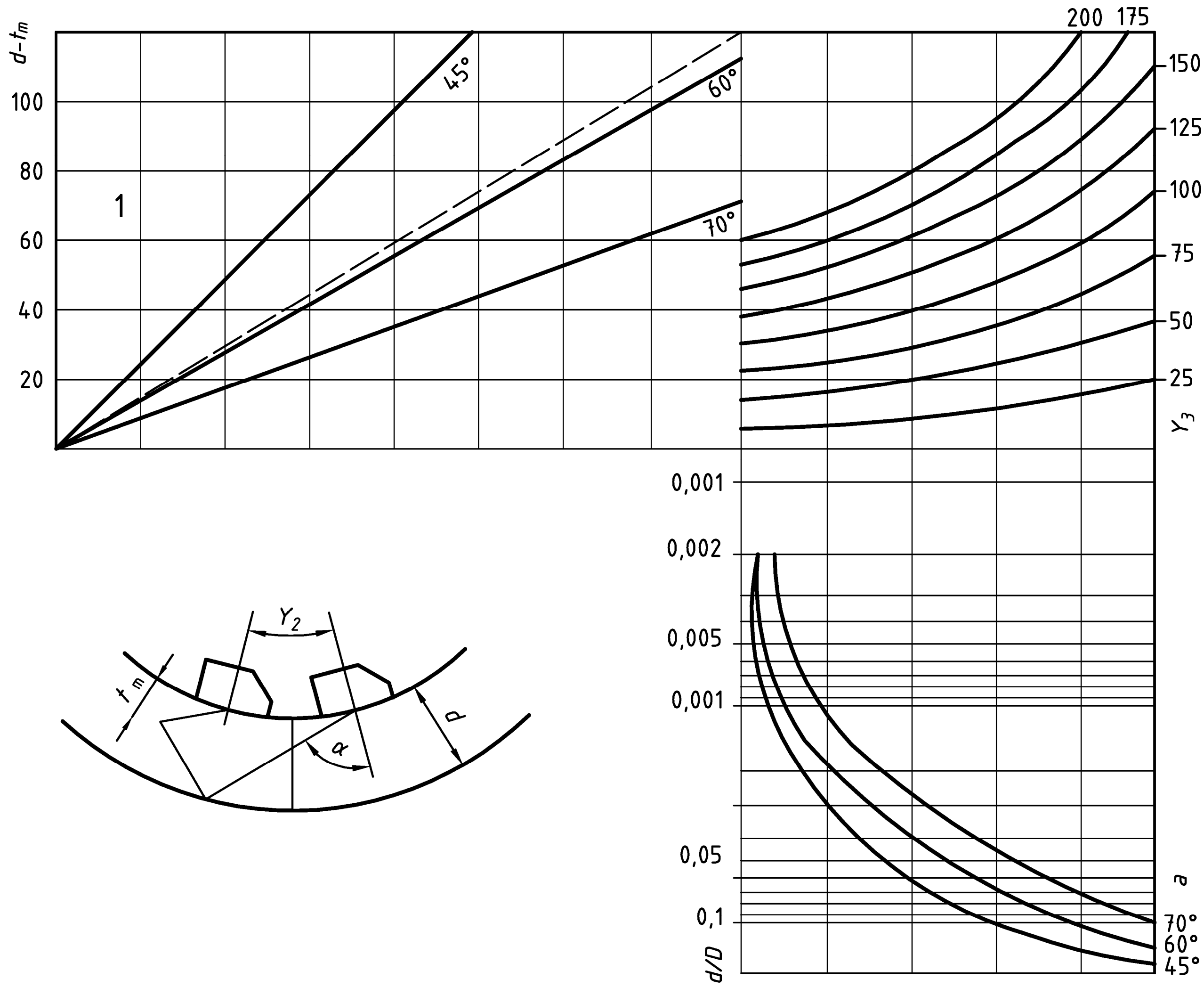


Figure A.2 — Nomogram - concave

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