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

Contrôles 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

[Revision of first edition (ISO 12715:1999)]

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12715 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*.

This second edition cancels and replaces the first edition of ISO 12715, of 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, a 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 blocks) and the side-drilled-hole blocks (SDH blocks), 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, may be located close to the surface or deep inside, or close together and oriented at different angles. An ultrasonic pulse incident on such discontinuities may 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, the sound beam transmitted and received by the probe and the instrument must be known.

The sound beam inside a solid produced by a probe in contact testing depends on the type, size, and frequency bandwidth of the probe and other parameters such as focusing, beam refraction angle 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 e.g. 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 refraction angle 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 the International Standards mentioned above, the present 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 the following:

— To determine probe axes so that consistent tests can be performed;

— To 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;

- To provide a method for calculating the correct refraction angle when an angle-beam probe designed for use in steel is to be used in materials other than steel;
- To provide a beam profile measurement capability for future applications, such as an Electromagnetic Acoustical Transducer (EMAT);
- To provide a capability for lateral angle-beam profile measurements;
- To provide means for time base calibration with angle-beam probes to be used with ultrasonic imaging systems (see annex A);
- To provide means for time-of-flight (TOF) beam profile measurements for probes to be used with ultrasonic imaging systems (see annex B);
- To 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);
- To provide means for the determination of the skew (or squint) angle, far field and near field resolutions of angle-beam probe (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 diameter or the side dimension of the probe shall 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 probe 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 material other than steels, users should be aware of the fact that the wave velocities in these materials may 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 refraction angles in other homogene 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 will require reference blocks with flat-bottomed holes. This International Standard establishes no acceptance criteria; but does establish the technical basis for criteria that may be defined by users.

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

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

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

ISO 10375:1997, *Non-destructive testing — Ultrasonic inspection — Characterization of search unit and sound field*

3 Terms and definitions

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

4 Symbols and abbreviations

4.1 Symbols

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 beam index to the *i*th hole[a]	mm
L_x, L_y, L_z	Axes of probe	–
P_i	Probe position on the reference block[a]	–
R	Radius of the eight side-drilled holes[b]	mm
SDH_i	*i*th side drilled hole	–
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	mms^{-1}
v_s	Transverse (shear) wave velocity in the test object	mms^{-1}
v_w	Longitudinal (compressional) wave velocity in the wedge material	mms^{-1}
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	–
$Z_{\beta \cdot i}$	Distance along the beam axis from the beam index to the *i*th hole centre[c]	mm
$Z_{\beta \cdot L}$	Lateral beam axis of the angle-beam probe	–
α_w	Incident angle (wedge angle)	°
β	refraction angle (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 = 1,5 mm.

c i = 2, 3.....

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

e See ISO 10375:1997, Figure 4.

4.2 Abbreviations

FSH	Full screen height of display graticule
HS	Hemicylindrical-step
IP	Initial pulse
P	Probes
R_v	Receiver connector
SDH	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_r	Transmitter connector
X, Y, Z	Axes of the reference block (plane of X-Y, surface; Z, perpendicular to and below the surface)

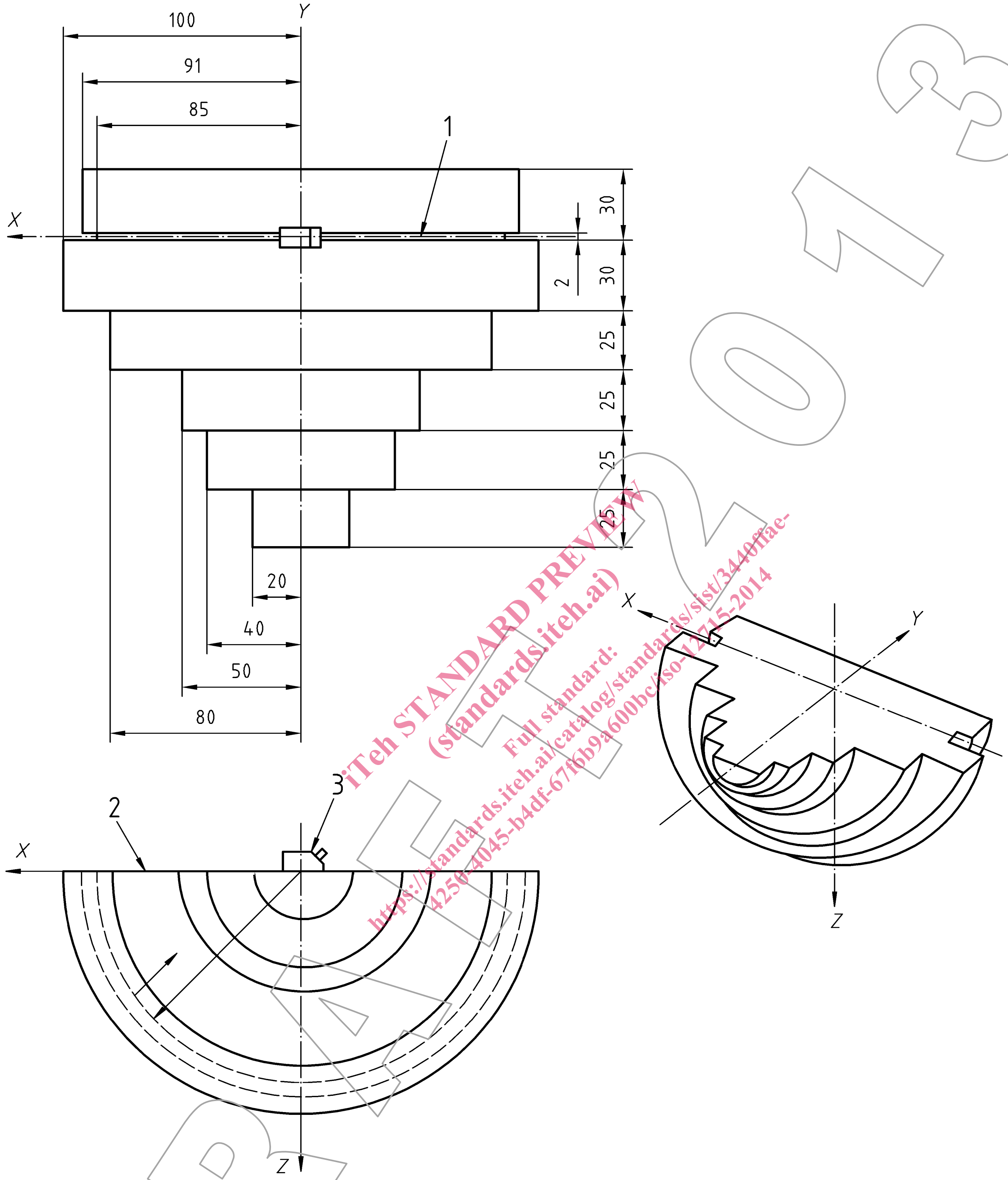
5 Descriptions of the reference blocks

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 described in 5.2 and 5.3.

5.2 Hemicylindrical-stepped (HS) block

Figure 1 shows the dimensions of the HS block in millimetre. 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 and 100 mm, 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.



Key

1 Centre line of slot
2 Front surface
3 Angle-beam probe

Figure 1 — Hemicylindrical-stepped (HS) block