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Non-destructive testing — Characterization and verification of ultrasonic phased array equipment —

Part 3: Combined systems

Essais non destructifs — Caractérisation et vérification de l'appareillage ultrasonore multi-éléments — Partie 3: Système complet

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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Foreword

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

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

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

ISO 18563 consists of the following parts, under the general title *Non-destructive testing — Characterization and verification of ultrasonic phased array systems*:

— *Part 1: Instruments*

— *Part 3: Combined systems*

Non-destructive testing — Characterization and verification of ultrasonic phased array equipment —

Part 3: Combined systems

1 Scope

This part of ISO 18563 addresses ultrasonic test systems implementing linear phased array probes, in contact (with or without wedge) or in immersion, with centre frequencies in the range of 0,5 MHz–10 MHz.

It provides methods and acceptance criteria for verifying the performance of combined equipment (i.e. instrument, probe and cables connected). The methods described are suitable for users working under on-site or shop floor conditions. Its purpose is for the verification of the correct operation of the system prior to testing, and also the characterization of sound beams or verification of the absence of degradation of the system.

The methods are not intended to prove the suitability of the system for particular applications, but are intended to prove the capability of the combined equipment to generate ultrasonic beams according to the settings used.

The calibration of the system for a specific application is outside of the scope of part of ISO 18563 and it is intended that it be covered by the test procedure.

This part of ISO 18563 does not address the following:

— encircling arrays;

— series of apertures having a different number of elements;

— different settings for transmitting and receiving (e.g. active aperture, number of active elements, delays);

— techniques using post-processing of the signals of individual elements in a more complex manner than a simple delay law (e.g. full matrix capture).

2 Normative references

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

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

ISO 18563-1, *Non-destructive testing — Characterization and verification of ultrasonic phased array equipment — Part 1: Instruments*

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

EN 16018, *Non-destructive testing — Terminology — Terms used in ultrasonic testing with phased arrays*

EN 16392-2, *Non-destructive testing — Characterization and verification of ultrasonic phased array test equipment — Part 2: Probes*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, EN 1330-4, EN 16018 and the following apply.

3.1
combined equipment
connected set including the instrument, the probe and connecting cables including adapters

3.2
system
combined equipment including the settings for a given mode of operation

Note 1 to entry: Settings are specific values or ranges of values.

3.3
reference system
system including an instrument according to ISO 18563-1 and a probe according to EN 16392-2, on which all of the Group 1 tests defined in Clause 8 and all Group 2 tests defined in Clause 9 of this part of ISO 18563-3 have been performed successfully

3.4
identical system
system in which instruments, probes and connecting cables are each from the same manufacturer and of the same product name, and the mode of operation and the settings are the same

3.5
mode of operation
specification of shots and active apertures for each position of the probe as reported in Clause 6

3.6
natural refracted beam
beam in the direction of the natural refracted beam angle

3.7
system record sheet
document for reporting the test results for a system and for comparing with the values obtained from the reference system

4 Symbols

For the purposes of this document, the symbols given in Table 1 apply.

Table 1 — Symbols

Symbol	Unit	Definitions
λ	mm	Wavelength
ΔS_{el}	dB	Relative sensitivity of an element
a_i	mm	*Contact probe*: distance between the orthogonal projection of the axis of the hole and the front surface of the probe, see Figure 4 *Immersion probe*: distance between the orthogonal projection of the axis of the hole and the centre of the probe surface
A_{el}	V or %-FSH	Amplitude of one elementary signal
A_{mean}	V or %-FSH	Mean value of the amplitudes of all elementary signals
A_{ref}	V or %-FSH	Mean value of the amplitudes of all elementary signals, excluding the dead elements,

Table 1 *(continued)*

D	mm	Diagonal of the active aperture
d_i	mm	Depth of the holes
G_0	dB	Calibrated gain
G_{ref}	dB	Reference gain for the amplitude – distance measurements
N	mm	Near field length associated with the active aperture
Θ	°	Angle of refraction
p	mm	Pitch
X	mm	Distance between the probe front surface and the probe index point

5 General requirements for conformity

The tests to be performed prior to the first use of the system for a given application (mode of operation and settings) are described in Clause 8 (Group 1 tests) and in Clause 9 (Group 2 tests), except the tests described in 9.3, 9.8 and 9.9 which are already performed for Group 1.

When all tests are successful, the system is considered to conform to this part of ISO 18563 and becomes a reference system. If no component and/or setting of the system is modified or replaced, it remains a reference system. Using the system with other settings does not void the reference system, if the original settings can be restored. The results of the tests shall be reported on the system record sheet.

On a system identical to a reference system, only the Group 2 tests have to be performed. When all tests are successful, the system is considered to conform to this part of ISO 18563. During the first performance of the tests, the system record sheet is initialized with the values obtained on the reference system and is completed with the values obtained after the tests.

The Group 2 tests have then to be performed periodically, on any system, on workshop or on site. After each performance of the Group 2 tests, the system record sheet shall be updated.

Table 2 presents the different tests to be performed on a system, featuring an immersion or contact probe.

A summary of all tests to be carried out, including their acceptance criteria, is given in Table A.1.

Table 2 — Tests to be performed

	Contact probe	Immersion probe
Group 1 tests		
Elements and channels		
Channel assignment	8.2.2	8.2.2
Relative sensitivity of elements	8.2.3	8.2.3
Beam characterization		
Absence of saturation	8.3.2	8.3.2
Angle of refraction — Probe index point	8.3.3.2	
Angle of refraction — Point of incidence on the test object		8.3.4.2
Sensitivity along the beam axis	8.3.3.3	8.3.4.3
Beam dimensions	8.3.3.4	8.3.4.4
Squint angle	8.3.3.5	
Grating lobes (recommended)	8.3.3.6	

[a] For the reference system, the test need not to be repeated because it was performed in Group 1.

Table 2 *(continued)*

	Contact probe	Immersion probe
Imaging check		
Reflector positioning	8.4.2	8.4.2
−6 dB spot size	8.4.3	8.4.3
Amplitude comparison	8.4.4	8.4.4
Group 2 tests		
Visual inspection of the equipment	9.2	9.2
Relative sensitivity of elements[a]	9.3	9.3
Linearity of the amplification system	9.4	9.4
Absolute sensitivity of virtual probes	9.5	9.5
Relative sensitivity of virtual probes	9.6	9.6
Probe index points[a]	9.7	
Angle(s) of refraction[a]	9.8	9.8
Squint angle[a]	9.9	

[a] For the reference system, the test need not to be repeated because it was performed in Group 1.

6 Modes of operation

During ultrasonic testing with phased arrays, a set of beams is generally produced from each position of the probe.

Each beam corresponds to one shot, each being defined by the active aperture and by the delay laws applied. The modes of operation are characterized by the number of apertures (one or multiple) and the number of shots per aperture (one or multiple).

The tests described only address applications in which the transmitting elements are also receiving.

In the scope of this standard, only one received signal is considered for each shot.

Depending on the application the following variants of phased array technique (modes of operation) can be used/combined:

— number of active apertures (one or multiple);

— number of shots or delay laws (one or multiple) per active aperture;

— type of delay law (beam steering, beam focusing or combined).

If multiple active apertures are used, then the same set of delay laws may be used for all active apertures, or a different set of delay laws may be used for each active apertures. The latter may be required to compensate for the orientation of the array relative to the object surface (wedge angle for contact technique, array tilt for immersion technique).

The verification tests for the different modes shall be performed as follows:

Mode 1

— Only one beam is created.

— Tests are performed with this beam.

Mode 2

— Multiple beams are created with the same active aperture.

— Tests are performed with a minimum of three beams corresponding to the extremes and median delay laws.

Mode 3

— Only applicable for an array parallel to the test surface.

— Multiple active apertures are used, all using the same delay law.

— Tests are performed with a minimum of one aperture.

Mode 4:

— Multiple active apertures are used, all using the same set of delay laws.

— Tests are performed with a minimum of one aperture and with a minimum of three beams corresponding to the extremes and median delay laws.

Mode 5

— Multiple active apertures are used, all using a single delay law but different for each active aperture.

— Alternatively, multiple active apertures are used, all using the same delay law, if the array is not parallel to the test surface.

— Tests are performed with a minimum of three apertures corresponding to the extreme and median positions.

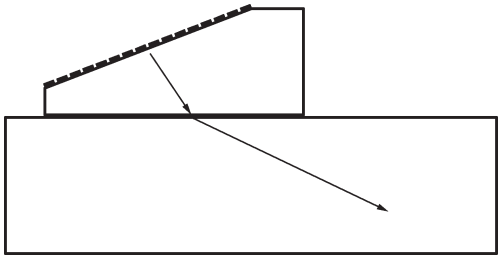
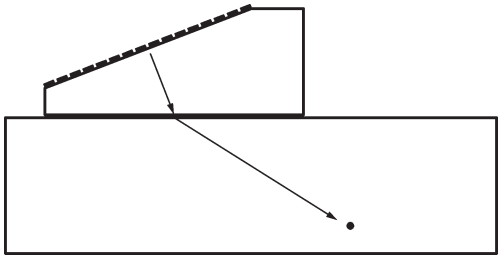
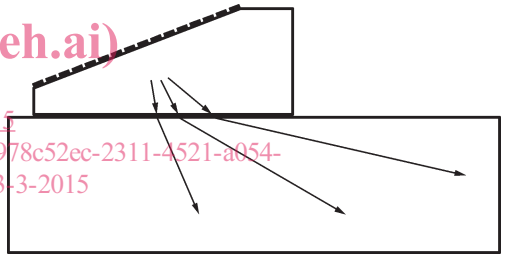
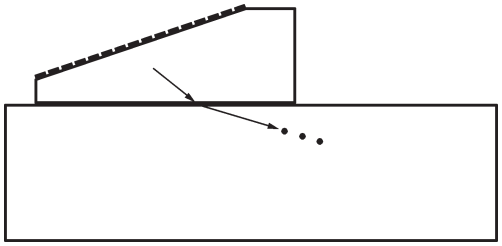
Mode 6

— Multiple active apertures are used, each using a different set of delay laws.

— Tests are performed with a minimum of three apertures corresponding to the median and extreme positions and, for each of these apertures, on three beams corresponding to the extremes and median delay laws.

The modes are described and illustrated in Table 3.

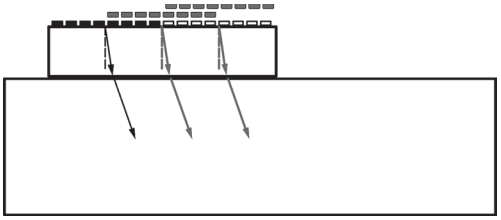
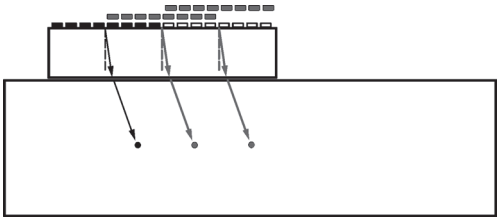
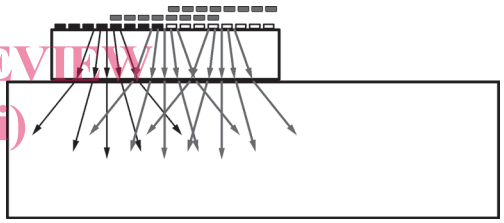
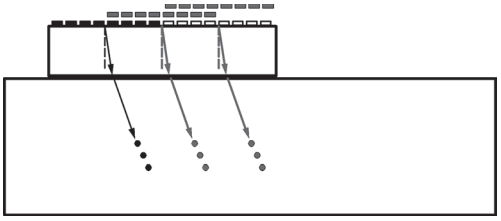
Table 3 — Modes of operation

Modes	Number of active apertures	Number of delay laws per active aperture	Identical or different delay laws for each aperture	Examples
Mode 1	One	One	Not applicable	 Beam steering
			Not applicable	 Focusing on one point
Mode 2	One	Multiple	Not applicable	 Sectorial electronic scanning
			Not applicable	 Focusing on several points

NOTE 1 For simplicity only the beam centre lines are indicated. An arrow indicates the beam direction, dots indicate focal points.

NOTE 2 The medium between array and test object can be a fluid (immersion) or a solid (e.g. wedge).

Table 3 *(continued)*

Modes	Number of active apertures	Number of delay laws per active aperture	Identical or different delay laws for each aperture	Examples
Mode 3	Multiple	One	Identical beams for each aperture	 Beam steering
			Identical beams for each aperture	 Focusing on one depth
Mode 4	Multiple	Multiple	Set of beams identical for each aperture	 Sectorial electronic scanning
			Set of beams identical for each aperture	 Focusing on several points

NOTE 1 For simplicity only the beam centre lines are indicated. An arrow indicates the beam direction, dots indicate focal points.

NOTE 2 The medium between array and test object can be a fluid (immersion) or a solid (e.g. wedge).