
**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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Contents

Page

Foreword	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Symbols	2
5 General requirements for conformity	3
6 Modes of operation	4
7 Equipment required for tests	8
8 Group 1 tests	9
8.1 General	9
8.2 Elements and channels	9
8.2.1 General	9
8.2.2 Channel assignment	9
8.2.3 Relative sensitivity of elements	10
8.3 Beam characterization	12
8.3.1 General	12
8.3.2 Absence of saturation	13
8.3.3 Beam characterization for contact probes	14
8.3.4 Beam characterization for immersion probes	21
8.4 Imaging check	24
8.4.1 General	24
8.4.2 Reflector positioning	25
8.4.3 -6 dB spot size	25
8.4.4 Amplitude comparison	25
9 Group 2 tests	25
9.1 General	25
9.2 Visual inspection of equipment	26
9.2.1 Operating procedure	26
9.2.2 Acceptance criteria	26
9.3 Relative sensitivity of elements	26
9.3.1 General	26
9.3.2 Operating procedure	26
9.3.3 Identification of dead elements	27
9.3.4 Compensation of sensitivity variation	27
9.3.5 Acceptance criteria	27
9.4 Linearity of amplification system	27
9.4.1 Operating procedure	27
9.4.2 Acceptance criteria	27
9.5 Absolute sensitivity of virtual probes	28
9.5.1 General	28
9.5.2 Operating procedure	28
9.5.3 Acceptance criterion	28
9.6 Relative sensitivity of virtual probes	28
9.6.1 General	28
9.6.2 Operating procedure	28
9.6.3 Acceptance criterion	29
9.7 Probe index points	29
9.7.1 General	29
9.7.2 Operating procedure	29
9.7.3 Acceptance criteria	29
9.8 Angle(s) of refraction	29

9.8.1	General.....	29
9.8.2	Operating procedure.....	30
9.8.3	Acceptance criterion.....	30
9.9	Squint angle for contact probes.....	30
9.9.1	General.....	30
9.9.2	Operating procedure.....	30
9.9.3	Reporting.....	30
10	System record sheet.....	30
Annex A (informative) Tests to be performed and their acceptance criteria.....		32
Bibliography.....		34

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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	<i>Contact probe</i> : distance between the orthogonal projection of the axis of the hole and the front surface of the probe, see Figure 4 <i>Immersion probe</i> : 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

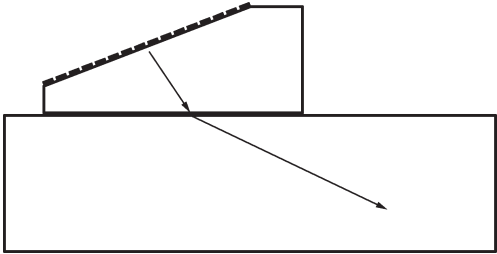
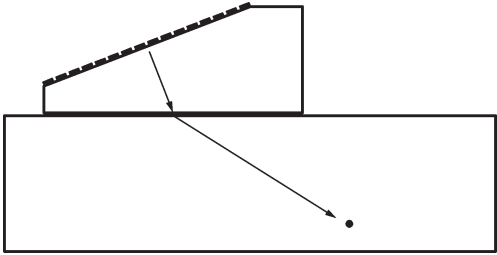
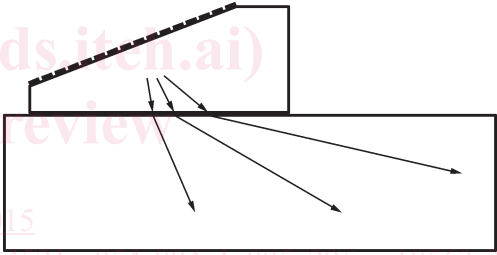
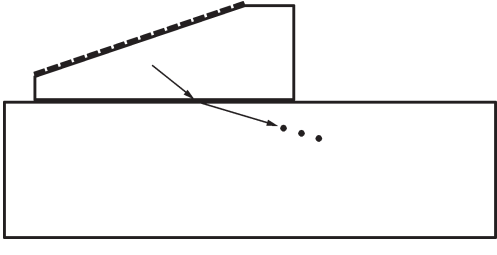
- Multiple active apertures are used, all using a single delay law but different for each active aperture.
- Alternatively, multiple active apertures are used, all using the same delay law, if the array is not parallel to the test surface.
- Tests are performed with a minimum of three apertures corresponding 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	 <p>Beam steering</p>
			Not applicable	 <p>Focusing on one point</p>
Mode 2	One	Multiple	Not applicable	 <p>Sectorial electronic scanning</p>
			Not applicable	 <p>Focusing on several points</p>

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).