INTERNATIONAL STANDARD

ISO 18563-2

First edition
2017-07

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

Part 2: Probes

Essais non destructifs — Caractérisation et vérification de l'appareillage de contrôle par ultrasons en multiéléments —

Partie 2: Traducteurs

Reference number
ISO 18563-2:2017(E)

COPYRIGHT PROTECTED DOCUMENT

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

Contents

Page

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 voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html

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 TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 18563 series can be found on the ISO website.

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

Part 2: Probes

1 Scope

This document specifies the characterization tests performed at the end of the fabrication of a phased array probe. It defines both methodology and acceptance criteria.

This document is applicable to the following phased array probes used for ultrasonic non-destructive testing in contact technique (with or without a wedge) or in immersion technique, with centre frequencies in the range 0,5 MHz to 10 MHz:

a) non-matrix array probes:

- linear;
- encircling;
- partial annular sectorial (type "daisy");

b) 2D-matrix array probes.

This document does not give methods and acceptance criteria to characterize the performance of an ultrasonic phased array instrument or the performance of a combined system. These are given in ISO 18563–1 and in ISO 18563–3.

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*

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

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

3 Terms and definitions

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

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

- ISO Online browsing platform: available at http://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

3.1
probe data sheet
document giving technical specifications of the same type of phased array probes

3.2
probe test report
document showing compliance with ISO 18563-2 giving the measured values of the required parameters of one specific phased array probe, including test equipment and conditions

3.3
element out of specification
element which does not meet the acceptance criteria of one of the tests defined in 8.3 and 8.4

4 Symbols

Symbol	Unit	Meaning
CT	dB	Inter-element cross-talk
f_0	Hz	Centre frequency
f_u	Hz	Upper frequency limit at –3 dB
f_l	Hz	Lower frequency limit at –3 dB
Δf	Hz	Frequency bandwidth
Δf_{rel}	%	Relative bandwidth
S_{el}	dB	Relative pulse-echo sensitivity variation of each element
S_{pr}	dB	Probe sensitivity
V_{av}	V	Arithmetic mean of V_{el}
V_{el}	V	Amplitude of reference echo
V_{exc}	V	Amplitude of excitation burst
V_{rec}	V	Amplitude received by an adjacent element
V_{ref}	V	Amplitude of reference exciting signal

5 General compliance

An ultrasonic phased array probe complies with this document if it fulfils all of the following requirements.

a) A probe data sheet corresponding to the probe which defines the performance criteria in accordance with Clause 6 shall be available.

b) The ultrasonic phased array probe shall comply with Clause 8.

c) The probe shall be clearly marked to identify the manufacturer and carry a unique serial number or show a permanent reference number from which information can be traced to the probe data sheet.

d) A declaration of conformity shall be available, issued by either the manufacturer, by the purchaser or by a third party that could be a test laboratory.

6 Technical information for phased array probes

Technical information listed in Table 1 shall be supplied with the probe (M = measurement, OI = other information). Optional technical information is listed in Table 2.

Table 1 — List of information to be given in a probe data sheet or probe test report

Information required	Information type	Comments
Trade name	OI	—
Identification	OI	Serial number, reference
Probe type	OI	—
Probe dimensions	OI	Outer dimensions
Geometry of the array	OI	Shape, orientation, arrangement, dimension, pitch, space between elements and element dimensions
Type of connector	OI	Commercial name
Wiring plan	OI	Details of connections between elements and connector
Cable	OI	Cable length, outer diameter and outer material
Dimensions, geometry and material of integrated wedge	OI	Only valid for contact probes with integrated wedge
Physical aspects	OI	e.g. housing material and shape of the contact face; see 8.2
Nominal frequency, nominal relative bandwidth, nominal pulse duration	OI	—
Centre frequency, relative bandwidth and pulse duration	M	Measured for each element; see 8.4
Average centre frequency, average bandwidth and average pulse duration	M	Calculated for probe; see 8.4
Relative pulse-echo sensitivity	M	See 8.3
Nominal probe sensitivity	OI	—
Probe sensitivity	M	See 8.5
Nominal inter-element cross-talk	OI	Minimum value of the inter-element cross-talk
Maximum allowable squint angle (for contact probes only)	OI	Maximum value of the squint angle with indication of the plane of reference
Echo from the transducer backing	OI	Maximum amplitude of the backing echo compared to a reference echo (dB difference)
Environmental conditions	OI	For example, temperature range, humidity, sealing, pressure
Equipment and procedure reference used for characterization tests	OI	—
Special conditions	OI	For example, for storage, for protection during transportation

Table 2 — Optional technical information to be given

Optional information	Information type	Comments
General drawing and tolerances	OI	—
Inter-element cross-talk	M	Measured cross-talk value corresponding to the probe; see 8.6
Squint angle (for contact probe only)	M	Measured squint angle value with indication of the plane of reference
Echo from the transducer backing	M	Amplitude of the backing echo compared to a reference echo (dB difference)

7 Test equipment

7.1 Electronic equipment

The measurement equipment used for the tests specified in Clause 8 shall be stated in the probe test report. Conformity of this equipment shall be checked periodically.

Testing shall be carried out with the probe cables and matching devices specified on the probe data sheet.

In addition to the ultrasonic phased array instrumentation or laboratory pulser-receiver, the following equipment or its equivalent is essential to test phased array probes in accordance with this document:

a) an oscilloscope with a minimum bandwidth of 100 MHz;

b) a frequency spectrum analyser with a minimum bandwidth of 100 MHz or an oscilloscope performing Fast Fourier Transform (FFT).

7.2 Test blocks and other equipment

7.2.1 General

Phased array probes can be used in contact technique (with or without a wedge) or in immersion technique. Depending on this, the performance tests shall be carried out under corresponding conditions.

Details of the test block (geometry, material, reflector type, shape and position, sound speed) shall be stated in the probe test report.

For partial annular sectorial array probe (type “daisy”), the measurement shall be performed directly on a flat reflector.

7.2.2 Contact technique

If the wedge can be removed, the tests shall preferably be performed without the wedge.

a) With wedge (integrated or not integrated): A block of the same material as the wedge and proper dimensions shall be used so that the total ultrasonic path is the same for each element.

b) Without wedge: A block of the material to be tested shall be used so that the total ultrasonic path is the same for each element. If no material is specified, a block of steel grade according to ISO 2400 shall be used.

7.2.3 Immersion technique

Performance tests shall be carried out in immersion fluid using a defined reflector. If no fluid is specified, water shall be used.

8 Performance tests for phased array probes

8.1 General

Measurements shall be performed at the probe connector once the probe is completely assembled.

It should be noted that acceptance criteria are only valid under the test conditions defined for the considered probe.

For 2D-matrix array probes, a number of elements which do not fulfil the criteria are accepted. The criteria are defined in 8.7.

8.2 Physical aspects

8.2.1 Method

Visually inspect the outside of the probe for correct identification and assembly.

Verify that the physical geometry of the probe agrees with the intended design.

8.2.2 Acceptance criterion

The probe physical geometry falls within the prescribed tolerances in the probe data sheet.

8.3 Relative pulse-echo sensitivity variation

8.3.1 General

Measurements shall be done on all elements of the same shape and size.

8.3.2 Method

Measurements are performed in transmit–receive mode according to 7.2.

The transmitter pulse shall be either a negative square pulse with duration equal to half the period corresponding to the nominal probe frequency or a negative spike pulse.

The echo of the reflector shall be placed in a time window, the duration of which is at least twice the echo pulse duration measured at –20 dB of the signal amplitude.

The amplitude in volts, V_{el}, of the reflector echo of each element shall be measured and recorded. The arithmetic mean value, V_{av}, of the V_{el} amplitudes shall be calculated and recorded.

Relative pulse-echo sensitivity variation, S_{el}, of each element shall be calculated using Formula (1):

$$S_{el} = 20 \lg \frac{V_{el}}{V_{av}} \tag{1}$$

8.3.3 Acceptance criteria

8.3.3.1 Non-matrix array probes

The relative pulse-echo sensitivity variation, S_{el}, over all the elements shall be within ±3 dB for all elements having the same size and shape. For “daisy” and encircling probes, the variation for all the elements shall be within ±4 dB.

8.3.3.2 2D-matrix array probes

The acceptable relative pulse-echo sensitivity variation, S_{el}, over all the elements is given in Table 3.

Table 3 — Acceptable relative sensitivity variation for 2D-matrix array probes

Frequency (MHz)	Element area ≥ 1 mm²		
	$n \leqq 64$	$64 < n \leqq 128$	$128 < n \leqq 512$
$0{,}5 \leqq f \leqq 1$	±5 dB	±5 dB	±5 dB
$1 < f \leqq 1{,}5$	±4 dB	±4 dB	±5 dB
$1{,}5 < f \leqq 5$	±3 dB	±4 dB	±5 dB
$5 < f \leqq 10$	±4 dB	±5 dB	±5 dB
	Element area < 1 mm²		
$0{,}5 \leqq f \leqq 10$	±5 dB	±5 dB	±5 dB
NOTE n: total number of elements.			

8.4 Frequency, bandwidth and pulse duration

8.4.1 General

Measurements shall be done on each element of the probe, excluding elements that have been defined as "out of specification" in 8.3.3.

8.4.2 Method

Measurements are performed in transmit–receive mode according to 7.2.

The measurement is performed under the same conditions as those for 8.3.

The frequency spectrum shall be determined on the signal in the used time window.

The frequencies intersecting the spectrum at –6 dB of the maximum amplitude of the spectrum shall be determined.

From the upper and lower frequencies, f_u and f_l, thus obtained, the centre frequency, f_0, is calculated using Formula (2):

$$f_0 = \frac{f_u + f_l}{2} \tag{2}$$

The bandwidth is calculated using Formula (3):

$$\Delta f = f_u - f_l \tag{3}$$

And the relative bandwidth is calculated in % using Formula (4):

$$\Delta f_{rel} = \left(\frac{\Delta f}{f_0} \right) \times 100 \tag{4}$$

The average centre frequency is the average of the calculated f_0 values. The average relative bandwidth is the average of the calculated Δf_{rel} values.

8.4.3 Acceptance criteria

The average centre frequency shall be within ±10 % of the nominal frequency stated in the probe data sheet.

The centre frequency of each element shall be within ±10 % of the average centre frequency.

The –6 dB average relative bandwidth shall be equal to or larger than the relative bandwidth stated in the probe data sheet.

The average pulse duration shall be smaller than or equal to the pulse duration stated in the probe data sheet.

8.5 Probe sensitivity

8.5.1 General

Measurements shall be done to compare probes of the same design.

8.5.2 Method

The measurement is performed under conditions as those for 8.3.

The reference excitation signal amplitude, V_{ref}, shall be measured with one channel of the instrument considering one element connected.

The signal is considered as the reference excitation signal used for all elements.

The average element sensitivity (arithmetic mean), V_{av}, over all elements is calculated (see 8.3.2).

The probe sensitivity, S_{pr}, shall be calculated using Formula (5):

$$S_{pr} = 20 \lg \frac{V_{av}}{V_{ref}} \tag{5}$$

8.5.3 Acceptance criteria

8.5.3.1 General

The acceptance criteria are valid only for probes based on the same design manufactured in quantities ≥ 10.

For probes manufactured in smaller quantities (<10), no acceptance criteria are specified.

8.5.3.2 Non-matrix array probes

The probe sensitivity, S_{pr}, shall be within ±3 dB of the value stated in the probe data sheet.

8.5.3.3 2D-matrix array probes

The probe sensitivity, S_{pr}, shall be within ±5 dB of the value stated in the probe data sheet.

8.6 Inter-element cross-talk (optional)

8.6.1 General

The inter-element cross-talk shall be determined on two locations for an array with up to 64 elements and on four locations for an array with more than 64 elements.

8.6.2 Method

The inter-element cross-talk shall be measured by exciting one element selected randomly and measuring the signals received on the adjacent elements. A network analyser can be used for a direct measurement.

When the measurements are performed using an oscilloscope, the excitation signal should be a sine burst of the nominal frequency with a duration of at least six periods.

The cross-talk shall be measured by connecting an oscilloscope or network analyser to an adjacent element. In case of a contact probe, the probe's matching face shall be in contact with a test block. In case of an immersion probe, the probe shall be immersed. The setup shall be chosen in a way that the measurement is not influenced by reflections from the test block or from the immersion tank.

Inter-element cross-talk, CT, is calculated as follows:

$$\mathrm{CT} = 20 \lg \frac{V_{\mathrm{exc}}}{V_{\mathrm{rec}}} \tag{6}$$

where

V_{rec} is the voltage received by an adjacent element;

V_{exc} is the voltage of the excitation burst.

8.6.3 Acceptance criterion

The inter-element cross-talk according to Formula (6) shall be at least 25 dB.

8.7 Number of elements "out of specification"

8.7.1 General

This subclause defines the maximum allowable number of elements "out of specification".

8.7.2 Method

Count the elements that are "out of specification" in 8.3 or 8.4.

8.7.3 Acceptance criteria

8.7.3.1 Non-matrix array probes

No elements "out of specification" are accepted.

8.7.3.2 2D-Matrix array probes

The maximum number of elements "out of specification" shall not be more than the values given in Table 4.

Table 4 — Maximum number of elements "out of specification"

	0,5 < f ≦ 5 MHz	**5 < f ≦ 10 MHz**
Total number of elements >64	2 %	3 %
Total number of elements ≤64	0	0

Each element "out of specification" shall have only one adjacent element "out of specification".

Bibliography

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

[2] ISO 18563–3, *Non-destructive testing — Characterization and verification of ultrasonic phased array equipment — Part 3: Combined systems*

ICS 19.100

Price based on 9 pages