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

Part 1: Instruments

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

Partie 1: Appareils

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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).

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For an explanation of 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 www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 18563-1:2015), which has been technically revised.

The main changes are as follows:

— test methods introduced in ISO 22232-1 have been incorporated;

— the layout has been rearranged to follow the layout of ISO 22232-1;

— the sequence of tests has been modified to follow the sequence of tests in ISO 22232-1.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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

Part 1: Instruments

1 Scope

This document specifies the functional characteristics of multi-channel ultrasonic phased array instruments used for array probes and provides methods for their measurement and verification.

This document is also applicable to ultrasonic phased array instruments in automated systems; but other tests can be needed to ensure satisfactory performance. When the phased array instrument is a part of an automated system, the acceptance criteria can be modified by agreement between the parties involved.

This document also can partly be applicable to FMC instruments and TFM instruments.

This document gives the extent of the verification and defines acceptance criteria within a frequency range of 0,5 MHz to 10 MHz.

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

ISO 22232-1, *Non-destructive testing — Characterization and verification of ultrasonic test equipment — Part 1: Instruments*

ISO 23243, *Non-destructive testing — Ultrasonic testing with arrays — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, ISO 22232-1, ISO 23243 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

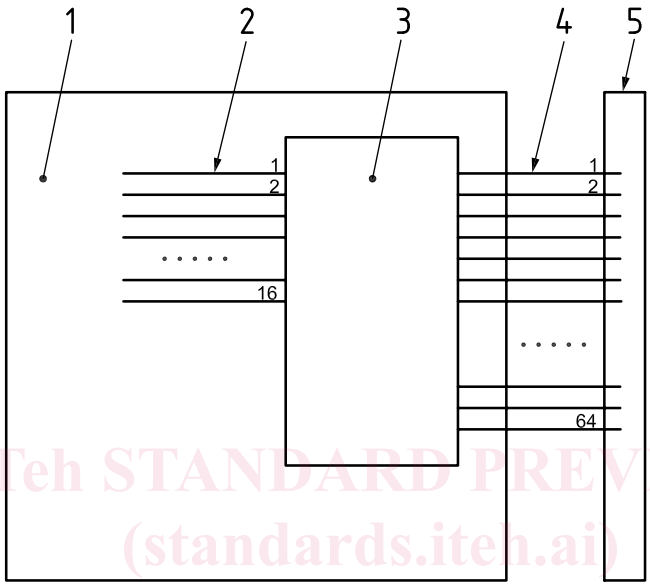
— IEC Electropedia: available at https://www.electropedia.org/

3.1
maximum number of channels that can be simultaneously activated
maximum number of transmitting and/or receiving channels which can be used for one shot

Note 1 to entry: An ultrasonic phased array instrument featuring a *maximum number of channels that can be simultaneously activated* (3.1) equal to the number of channels in the phased array instrument is indicated as parallel ultrasonic phased array instrument.

3.2
multiplexed ultrasonic phased array instrument
ultrasonic phased array instrument featuring a *maximum number of channels that can be simultaneously activated* (3.1) smaller than the number of channels in the ultrasonic phased array instrument and which are controlled by an internal multiplexing device

EXAMPLE In a type 16/64 multiplexed ultrasonic phased array instrument, the maximum number of channels that can be simultaneously activated is 16 and the total number of channels available is 64. See Figure 1.



Key
1 ultrasonic phased array instrument
2 multiplexer input channels (1 to 16)
3 multiplexer
4 multiplexer output channels (1 to 64)
5 array probe

NOTE 16 is the maximum number of channels that can be activated simultaneously.
64 is the number of channels in the ultrasonic phased array instrument.

Figure 1 — Diagram of a 16/64 multiplexed ultrasonic phased array instrument

3.3
time resolution of the ultrasonic phased array instrument
inverse of the maximum digitization frequency without processing

4 Symbols and abbreviated terms

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

Table 1 — Symbols and abbreviated terms and their units and meanings

Symbol/Abbreviated term	Unit	Meaning
A_{min}	%	Minimum amplitudes measured on a screen
A_{max}	%	Maximum amplitudes measured on a screen
A_0, A_n	dB	Attenuator settings used during tests
CT	dB	Cross-talk attenuation
f_0	Hz	Centre frequency
f_u	Hz	Upper frequency limit at −3 dB
f_l	Hz	Lower frequency limit at −3 dB
f_{max}	Hz	Frequency with the maximum amplitude in the frequency spectrum
f_h	Hz	Highest digitized frequency
Δf	Hz	Frequency bandwidth
f_R	Hz	Pulse repetition frequency (PRF)
FMC	-	Full matrix capture
FSH	-	Full screen height
ΔG	dB	Channel gain variation
G_D	dB	Input signal dynamic range
G_i	dB	Instrument gain on channel *i*
H_R	%	Reference screen height
I_{max}	A	Amplitude of the maximum current that can be driven by the proportional gate output
N_{in}	$\frac{V}{\sqrt{Hz}}$	Noise per root bandwidth for receiver input
R_A, R_B, R_l	Ω	Termination resistors
S	dB	Attenuator setting
Δt	s	Time increment
t	s	Time delay
t_0	s	Time to the start of distance-amplitude curve
t_1	s	Dead time
t_d	s	Pulse duration
t_{final}	s	Time to the end of distance-amplitude curve
t_r	s	Transmitter pulse rise time from an amplitude of 10 % to 90 % of peak amplitude
t_{RT}	s	Response time
$t_{Target\ 0}$, $t_{Target\ i}$, t_{Pi}, $t_{P\ 0}$, t_{difi}, t_{dif}	s	Transmitter or receiver time delays
TFM	-	Total focusing method
t_{TOF}	s	Time-of-flight
V_A, V_B	V	Pulse voltage amplitudes
V_{ein}	V	Equivalent input noise
V_{in}	V	Input voltage when measuring the equivalent input noise
V_l	V	Output voltage modified when measuring the output impedance of the analogue gate
V_{min}	V	Minimum input voltage of the receiver
V_{max}	V	Maximum input voltage of the receiver

Table 1 *(continued)*

Symbol/Abbreviated term	Unit	Meaning
V_0	V	Output voltage to get an indication at 80 % of FSH when measuring the output impedance of the analogue gate
V_{50}	V	Voltage amplitude of the 50 Ω loaded transmitter pulse
Z_0	Ω	Output impedance of transmitter
Z_A	Ω	Output impedance of proportional output

5 General requirements of conformity

An ultrasonic phased array instrument conforms with this document if it fulfils all of the following requirements:

a) the ultrasonic phased array instrument shall conform with Clause 7;

b) a declaration of conformity shall be available, issued by either the manufacturer operating a quality management system (e.g. in accordance with ISO 9001) or by an organization operating a laboratory (e.g. in accordance with ISO/IEC 17025);

c) the ultrasonic phased array instrument shall carry a unique serial number;

d) a manufacturer's technical specification corresponding to the phased array instrument, which defines the performance criteria in accordance with Clause 6, shall be available.

6 Manufacturer’s technical specification for ultrasonic phased array instruments

The manufacturer’s technical specification relative to a specific model of an ultrasonic phased array instrument shall contain, as a minimum, the information listed in Table 2. Table 2 specifies the information which shall be supplied by the manufacturer in the ultrasonic phased array instrument’s technical specification.

The values obtained from the tests described in Clause 7 shall be established as nominal values, with tolerances given as indicated.

Table 2 — Technical characteristics to be shown in the ultrasonic phased array instrument's technical specification

Information	Type of information	Remarks
General features		
Size	OI	Width (mm) × Height (mm) × Depth (mm)
Weight	OI	At an operational stage including all batteries
Type(s) of power supply	OI	
Type(s) of instrument sockets	OI	Including the wiring diagram
Battery operational time	M	At fully charged new batteries
Number and type of batteries	OI	
Stability against temperature	M	
Stability after warm-up time	M	
Stability against voltage variations	M	
Temperature and voltage (mains and/or batteries) ranges in which the ultrasonic phased array instrument operates in accordance with the technical specification (operation and storage)	OI	When a warm-up time is necessary, its duration shall be stated
Form of indication given when a low battery voltage takes the performance of the ultrasonic phased array instrument outside of specification	OI	
Pulse repetition frequencies	M	Minimum and maximum values
Maximum power consumption	OI	V·A (volt-amperes)
Protection grade	OI	
Environment	OI	For example: restriction of hazardous substances (RoHS), explosive atmosphere (ATEX), vibration, humidity
Multi-channel configuration	OI	Number of channels controlled simultaneously and number of available channels
Extension of the number of channels by interconnection of the ultrasonic phased array instruments	OI	
Available measurement units	OI	For example: mm, inches, %, dB, V
Display		
Screen size and resolution	OI	
Range of sound velocities	OI	
Time base range	OI	
Time base delay range	OI	
List of available views	OI	
Response time for A-scan presentations	M	
Maximum digitization frequency without processing	OI	
Digitization frequency with processing	OI	For example: interpolation
Vertical resolution of digitizer	OI	In bits
Highest digitized frequency	M	

Key

M Measurement

OI Other information

Table 2 *(continued)*

Information	Type of information	Remarks
Deviation of time base	M	
Inputs/outputs		
Signal unrectified output (i.e. radio frequency, RF) and/or rectified available on the output socket	OI	
Number and characteristics of logic and analogue control outputs	OI	Including the wiring diagram
Number and characteristics of encoder inputs	OI	Including the wiring diagram
Power input	OI	AC, DC, voltage range, power (W)
Available power supply for external devices	OI	Voltage, power
Synchronization input/output	OI	
Beam forming		
Maximum number of channels active simultaneously	OI	
Maximum number of delay laws	OI	
Maximum number of groups of shots	OI	
Summation	M	
Transmitter		
Number of transmitters available simultaneously	OI	
Shape of transmitter pulse and where applicable, polarity	OI	I.e. rectangular, unipolar, bipolar, arbitrary pulse
Transmitter voltage rise time	M	
Transmitter voltage fall time	M	
Transmitter voltage duration	M	
Output impedance	M	
Maximum time delay	OI	
Resolution of time delay	M	
Linearity of time delays	M	
Possibility to apply different voltages on each channel	OI	
Maximum power available per transmitter	OI	
Receiver		
Number of receivers available simultaneously	OI	
Characteristics of the gain control, i.e. range in decibels, value of increments	OI	
Characteristics of the logarithmic amplifier	OI	
Input voltage at FSH	OI	
Maximum input voltage	M	
Linearity of vertical display	M	
Key M Measurement OI Other information		

Table 2 *(continued)*

Information	Type of information	Remarks
Linearity of the vertical display over the frequency ranges of the ultrasonic phased array instrument	M	
Frequency response	M	
Dead time after transmitter pulse	M	
Equivalent input noise	M	
Dynamic range	M	
Input impedance	M	
Maximum time delay	OI	
Resolution of time delay	M	
Time-corrected gain (TCG)	M	
Possibility to apply different gain values on each channel	OI	
Cross-talk attenuation between receivers	M	
Linearity of time delays	M	
Linearity of gain	M	
Variation of channel gain	M	
Data acquisition		
Transfer rate and type of connection between the external storage unit and the ultrasonic phased array instrument	OI	Interface type; Megabytes/s
Maximum number of A-scans stored per second	OI	A-scan characteristics shall be stated
Maximum number of C-scans stored per second	OI	C-scan characteristics shall be stated
Maximum number of samples per A-scan	OI	
Storage capacity	OI	Mbytes
Gates		
Number of gates	OI	
Threshold operation	OI	For example: coincidence or anticoincidence
Measurement mode	OI	For example: threshold, max, zero crossing
Synchronisation of gates	OI	For example: transmission pulse, first echo
Characteristics of gates	OI	Threshold, position, duration
Resolution of measurements	OI	
Trigger of alarms	OI	For example: number of sequences before an alarm is triggered
Linearity of monitor gate amplitude	M	
Linearity of time-of-flight in the gate	M	
Impedance of analogue output	M	
Linearity of analogue output	M	
Influence of the measurement signal position in the gate on the analogue gate output	M	

Key

M Measurement

OI Other information

Table 2 *(continued)*

Information	Type of information	Remarks
Rise time of analogue gate output	M	
Fall time of analogue gate output	M	
Hold time of analogue gate output	M	
Signal processing		
Processing features	OI	For example: averaging, fast Fourier transform (FFT), rectification, envelope, compression, dimensional measurements
Key M Measurement OI Other information		

7 Performance requirements for ultrasonic phased array instruments

In order to fulfil the requirements of this document, ultrasonic phased array instruments shall be verified with the following tests depending on the situation.

— Group 1 tests: to be performed by the manufacturer (or his or her agent) on a representative sample of the ultrasonic phased array instruments.

High-level measuring instruments are required for these tests.

— Group 2 tests: to be performed on every ultrasonic phased array instrument:

a) by the manufacturer (or his or her agent) prior to the supply of the ultrasonic phased array instrument (zero point tests);

b) by the manufacturer, the owner, or a laboratory, at 12-month intervals, to verify the performance of the ultrasonic phased array instrument during its lifetime;

c) following the repair of the ultrasonic phased array instrument.

Only basic electronic measuring instruments are needed for group 2 tests.

By agreement between the parties involved, these tests may be supplemented with additional tests from group 1.

A third group of tests for the combined system (ultrasonic phased array instrument and connected probes) is given in ISO 18563-3, these tests shall be performed at regular intervals on site.

For ultrasonic phased array instruments marketed before the introduction of this document, continuing fitness for purpose shall be demonstrated by performing the periodic group 2 tests every 12 months.

Following the repair, all parameters which can have been influenced by the repair shall be checked using the appropriate group 1 or group 2 tests.

Table 3 contains all tests to be performed on ultrasonic phased array instruments.

Table 3 — List of tests for ultrasonic phased array instruments

Title of the test	Group 1 Manufacturing test	Group 2 Periodic and repair test
	Subclause	Subclause
Physical state and external aspects	9.2	9.2
Portable or battery operated ultrasonic phased array instruments		
Battery operational time	8.2	
Stability		
Stability after warm-up time	8.3	
Stability against temperature	8.4	
Stability against voltage variations	8.5	
Display		
Deviation of time base	8.6	
Highest digitized frequency	8.10	
Response time of ultrasonic phased array instrument	8.11	
Beam forming		
Summation	8.8.9	
Transmitter		
Pulse repetition frequency	8.7.2	
Effective output impedance	8.7.3	
Resolution of time delay	8.7.4	
Transmitter pulse voltage, rise time and duration	9.3.2	9.3.2
Linearity of time delays	9.3.3	9.3.3
Receiver		
Resolution of time delay	8.7.4	
Cross-talk attenuation between receivers	8.8.2	
Dead time after the transmitter pulse	8.8.3	
Dynamic range and maximum input voltage	8.8.4	
Receiver input impedance	8.8.5	
Time-corrected gain (TCG)	8.8.6	
Linearity of vertical display against frequency	8.8.8	
Frequency response	9.4.2	9.4.2
Linearity of gain	9.4.4	9.4.4
Equivalent input noise	9.4.3	9.4.3
Variation of channel gain	9.4.5	9.4.5
Linearity of vertical display	9.4.6	9.4.6
Linearity of time delays	9.4.7	9.4.7
Monitor gate		
Linearity of gate amplitude	8.9.2	
Linearity of time-of-flight in the gate	8.9.3	
Impedance of analogue output	8.9.4.1	
Linearity of the analogue output	8.9.4.2	
Influence of signal position within gate	8.9.4.3	