



BSI Standards Publication

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

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Part 1: Instruments

## National foreword

This British Standard is the UK implementation of EN ISO 18563-1:2022. It is identical to ISO 18563-1:2022. It supersedes BS EN ISO 18563-1:2015, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee WEE/46/3, Ultrasonic Testing.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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English Version

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of ultrasonic phased array equipment - Part 1: Instruments  
(ISO 18563-1:2022)

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de l'appareillage de contrôle par ultrasons en  
multiéléments - Partie 1: Appareils (ISO 18563-  
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Zerstörungsfreie Prüfung - Charakterisierung und  
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COMITÉ EUROPÉEN DE NORMALISATION  
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

## European foreword

This document (EN ISO 18563-1:2022) has been prepared by Technical Committee ISO/TC 135 "Non-destructive testing" in collaboration with Technical Committee CEN/TC 138 "Non-destructive testing" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2023, and conflicting national standards shall be withdrawn at the latest by March 2023.

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

This document supersedes EN ISO 18563-1:2015.

Any feedback and questions on this document should be directed to the users' national standards body/national committee. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

## Endorsement notice

The text of ISO 18563-1:2022 has been approved by CEN as EN ISO 18563-1:2022 without any modification.

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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](http://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](http://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 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](http://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](http://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**

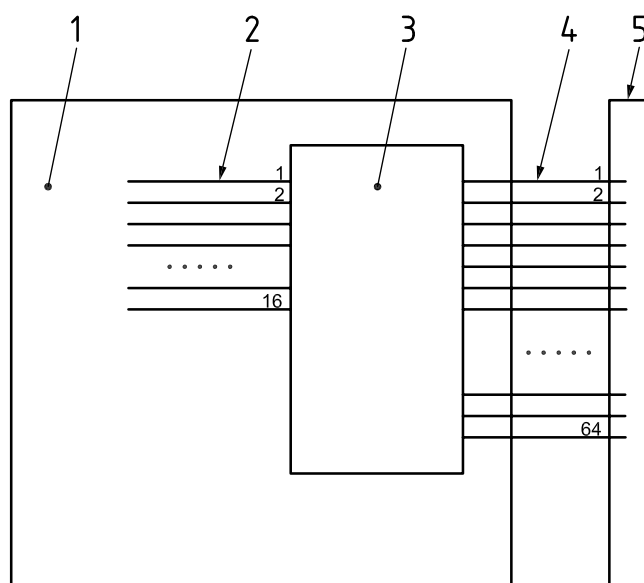
maximum number of transmitting and/or receiving channels which can be used for one shot

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                                                         |
| $\Delta f$                                                                                                    | Hz                                  | Frequency bandwidth                                                                 |
| $f_R$                                                                                                         | Hz                                  | Pulse repetition frequency (PRF)                                                    |
| FMC                                                                                                           | -                                   | Full matrix capture                                                                 |
| FSH                                                                                                           | -                                   | Full screen height                                                                  |
| $\Delta G$                                                                                                    | 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 |
| $N_{\text{in}}$                                                                                               | $\frac{\text{V}}{\sqrt{\text{Hz}}}$ | Noise per root bandwidth for receiver input                                         |
| $R_A, R_B, R_l$                                                                                               | $\Omega$                            | Termination resistors                                                               |
| $S$                                                                                                           | dB                                  | Attenuator setting                                                                  |
| $\Delta t$                                                                                                    | 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                                                                      |
| $t_{\text{final}}$                                                                                            | 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     |
| $t_{\text{RT}}$                                                                                               | s                                   | Response time                                                                       |
| $t_{\text{Target } 0}, t_{\text{Target } i}, t_{\text{PI}}, t_{\text{P } 0}, t_{\text{difi}}, t_{\text{dif}}$ | s                                   | Transmitter or receiver time delays                                                 |
| TFM                                                                                                           | -                                   | Total focusing method                                                               |
| $t_{\text{TOF}}$                                                                                              | s                                   | Time-of-flight                                                                      |
| $V_A, V_B$                                                                                                    | V                                   | Pulse voltage amplitudes                                                            |
| $V_{\text{ein}}$                                                                                              | V                                   | Equivalent input noise                                                              |
| $V_{\text{in}}$                                                                                               | 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 $\Omega$ loaded transmitter pulse                                               |
| $Z_0$                   | $\Omega$ | Output impedance of transmitter                                                                             |
| $Z_A$                   | $\Omega$ | 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                                                                                                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|-----------------------------------------------------------------------------------------------------------|
| <b>General features</b>                                                                                                                                                                 |                     |                                                                                                           |
| 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                                                                         |
| <b>Display</b>                                                                                                                                                                          |                     |                                                                                                           |
| 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                   |                                                                                                           |
| <b>Key</b>                                                                                                                                                                              |                     |                                                                                                           |
| M Measurement                                                                                                                                                                           |                     |                                                                                                           |
| OI Other information                                                                                                                                                                    |                     |                                                                                                           |

Table 2 (continued)

| Information                                                                                          | Type of information | Remarks                                              |
|------------------------------------------------------------------------------------------------------|---------------------|------------------------------------------------------|
| Deviation of time base                                                                               | M                   |                                                      |
| <b>Inputs/outputs</b>                                                                                |                     |                                                      |
| 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                  |                                                      |
| <b>Beam forming</b>                                                                                  |                     |                                                      |
| Maximum number of channels active simultaneously                                                     | OI                  |                                                      |
| Maximum number of delay laws                                                                         | OI                  |                                                      |
| Maximum number of groups of shots                                                                    | OI                  |                                                      |
| Summation                                                                                            | M                   |                                                      |
| <b>Transmitter</b>                                                                                   |                     |                                                      |
| 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                  |                                                      |
| <b>Receiver</b>                                                                                      |                     |                                                      |
| 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                   |                                                      |
| <b>Key</b>                                                                                           |                     |                                                      |
| 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                   |                                                               |
| <b>Data acquisition</b>                                                                                           |                     |                                                               |
| 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                                                        |
| <b>Gates</b>                                                                                                      |                     |                                                               |
| 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                   |                                                               |
| <b>Key</b>                                                                                                        |                     |                                                               |
| 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                   |                                                                                                                      |
| <b>Signal processing</b>          |                     |                                                                                                                      |
| Processing features               | OI                  | For example: averaging, fast Fourier transform (FFT), rectification, envelope, compression, dimensional measurements |
| <b>Key</b>                        |                     |                                                                                                                      |
| 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<br>Manufacturing test | Group 2<br>Periodic and repair test |
|-------------------------------------------------------------------------|-------------------------------|-------------------------------------|
|                                                                         | Subclause                     | Subclause                           |
| Physical state and external aspects                                     | <a href="#">9.2</a>           | <a href="#">9.2</a>                 |
| <b>Portable or battery operated ultrasonic phased array instruments</b> |                               |                                     |
| Battery operational time                                                | <a href="#">8.2</a>           |                                     |
| <b>Stability</b>                                                        |                               |                                     |
| Stability after warm-up time                                            | <a href="#">8.3</a>           |                                     |
| Stability against temperature                                           | <a href="#">8.4</a>           |                                     |
| Stability against voltage variations                                    | <a href="#">8.5</a>           |                                     |
| <b>Display</b>                                                          |                               |                                     |
| Deviation of time base                                                  | <a href="#">8.6</a>           |                                     |
| Highest digitized frequency                                             | <a href="#">8.10</a>          |                                     |
| Response time of ultrasonic phased array instrument                     | <a href="#">8.11</a>          |                                     |
| <b>Beam forming</b>                                                     |                               |                                     |
| Summation                                                               | <a href="#">8.8.9</a>         |                                     |
| <b>Transmitter</b>                                                      |                               |                                     |
| Pulse repetition frequency                                              | <a href="#">8.7.2</a>         |                                     |
| Effective output impedance                                              | <a href="#">8.7.3</a>         |                                     |
| Resolution of time delay                                                | <a href="#">8.7.4</a>         |                                     |
| Transmitter pulse voltage, rise time and duration                       | <a href="#">9.3.2</a>         | <a href="#">9.3.2</a>               |
| Linearity of time delays                                                | <a href="#">9.3.3</a>         | <a href="#">9.3.3</a>               |
| <b>Receiver</b>                                                         |                               |                                     |
| Resolution of time delay                                                | <a href="#">8.7.4</a>         |                                     |
| Cross-talk attenuation between receivers                                | <a href="#">8.8.2</a>         |                                     |
| Dead time after the transmitter pulse                                   | <a href="#">8.8.3</a>         |                                     |
| Dynamic range and maximum input voltage                                 | <a href="#">8.8.4</a>         |                                     |
| Receiver input impedance                                                | <a href="#">8.8.5</a>         |                                     |
| Time-corrected gain (TCG)                                               | <a href="#">8.8.6</a>         |                                     |
| Linearity of vertical display against frequency                         | <a href="#">8.8.8</a>         |                                     |
| Frequency response                                                      | <a href="#">9.4.2</a>         | <a href="#">9.4.2</a>               |
| Linearity of gain                                                       | <a href="#">9.4.4</a>         | <a href="#">9.4.4</a>               |
| Equivalent input noise                                                  | <a href="#">9.4.3</a>         | <a href="#">9.4.3</a>               |
| Variation of channel gain                                               | <a href="#">9.4.5</a>         | <a href="#">9.4.5</a>               |
| Linearity of vertical display                                           | <a href="#">9.4.6</a>         | <a href="#">9.4.6</a>               |
| Linearity of time delays                                                | <a href="#">9.4.7</a>         | <a href="#">9.4.7</a>               |
| <b>Monitor gate</b>                                                     |                               |                                     |
| Linearity of gate amplitude                                             | <a href="#">8.9.2</a>         |                                     |
| Linearity of time-of-flight in the gate                                 | <a href="#">8.9.3</a>         |                                     |
| Impedance of analogue output                                            | <a href="#">8.9.4.1</a>       |                                     |
| Linearity of the analogue output                                        | <a href="#">8.9.4.2</a>       |                                     |
| Influence of signal position within gate                                | <a href="#">8.9.4.3</a>       |                                     |