INTERNATIONAL STANDARD

ISO 16831

First edition
2012-04-01

Non-destructive testing — Ultrasonic testing — Characterization and verification of ultrasonic thickness measuring equipment

Essais non destructifs — Contrôle par ultrasons — Caractérisation et vérification des appareils de mesure de l'épaisseur par ultrasons

Reference number
ISO 16831:2012(E)

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Published in Switzerland

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 16831 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*.

Introduction

This International Standard is based on EN 15317:2007, *Non-destructive testing — Ultrasonic testing — Characterization and verification of ultrasonic thickness measuring equipment.*

The following International Standards are linked.

ISO 16810, *Non-destructive testing — Ultrasonic testing — General principles*

ISO 16811, *Non-destructive testing — Ultrasonic testing — Sensitivity and range setting*

ISO 16823, *Non-destructive testing — Ultrasonic testing — Transmission technique*

ISO 16826, *Non-destructive testing — Ultrasonic testing — Examination for discontinuities perpendicular to the surface*

ISO 16827, *Non-destructive testing — Ultrasonic testing — Characterization and sizing of discontinuities*

ISO 16828, *Non-destructive testing — Ultrasonic testing — Time-of-flight diffraction technique as a method for detection and sizing of discontinuities*

Non-destructive testing — Ultrasonic testing — Characterization and verification of ultrasonic thickness measuring equipment

1 Scope

This International Standard specifies methods and acceptance criteria for assessing the performance of instruments for measuring thickness using pulse-echo ultrasound.

This International Standard covers both direct (digital) reading and waveform display types using single or dual element probes.

This International Standard can be used for verifying equipment covered by EN 12668 when used for thickness measurement.

2 Normative references

The following referenced documents are indispensable for the application 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 inspection — Vocabulary*

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

EN 10025-2, *Hot rolled products of structural steels — Part 2 : Technical delivery conditions for non-alloy structural steels*

EN 12668-2, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 2: Probes*

3 Terms and definitions

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

4 General requirements for compliance

Ultrasonic thickness measuring equipment complies with this standard if it satisfies all the following conditions:

a) ultrasonic instrument and probe comply with the technical requirements of this standard;

b) either a declaration of conformity, issued by an organization certified in accordance with ISO 9001; or a certificate issued by an organization accredited according to ISO/IEC 17050-1 and ISO/IEC 17050-2, or a test report issued by an organization performing in-house calibration;

c) ultrasonic instrument and probe are clearly marked to identify the manufacturer, type and series, and carry a unique serial number;

d) user instruction manual for the particular type and series of the ultrasonic equipment is available;

e) manufacturer's technical specification for the appropriate type and series of ultrasonic equipment which defines the performance criteria in accordance with this standard is available.

NOTE The manufacturer's technical specification does not in itself constitute the certificate of measured values required in b).

5 Manufacturer's technical specification for ultrasonic thickness measuring equipment

5.1 General

The manufacturer's technical specification for a particular model of ultrasonic thickness measuring equipment shall contain, as a minimum, the information listed in 5.2 to 5.5. Values obtained from the tests described in Clause 7 shall be quoted as nominal values with tolerances given as indicated.

5.2 General attributes

The following shall be detailed:

a) size;

b) mass (at an operational stage);

c) type(s) of power supply;

d) type(s) of probe sockets;

e) battery operational time (as new, at maximum power consumption with a specified duty cycle);

f) temperature and voltage (mains and/or battery) ranges, in which operation complies with the technical specification – if a warm-up period is necessary, the duration of this shall be stated;

g) form of indication given when a low battery voltage takes the ultrasonic instrument performance outside of specification;

h) pulse repetition frequencies (PRFs) (switched positions and/or variable ranges);

i) if available, monitor outputs to indicate when the measurement values fall outside a set tolerance;

j) if equipment can measure through coatings;

k) minimum measurable and maximum measurable thicknesses on a defined material;

NOTE A minimum measurable thickness of zero cannot be verified and therefore not specified.

l) accuracy and resolution shall be stated in mm for steel (longitudinal waves).

5.3 Display

The following shall be detailed:

a) type of display (alphanumeric or graphical and also whether LED, LCD or CRT);

b) dimension of alphanumeric display;

c) dimension of graphical display.

5.4 Transmitter

The following shall be detailed:

a) shape of transmitter pulse;

b) at each pulse energy setting with the output connected to a suitable specified probe or a defined artificial load:

   1) transmitter pulse voltage (peak-to-peak);

   2) pulse rise time;

   3) pulse duration (for square wave, the range over which the pulse duration can be set).

5.5 Receiver

The following shall be detailed:

a) characteristics of gain control if user selected;

b) frequency range of operation.

5.6 Other information

In addition to the information given in 5.2 to 5.5, details should be supplied on the principles of:

a) data output and storage facilities (memory capacity);

b) calibration setting storage;

c) calibration mechanisms;

d) display and recall facilities;

e) display response time;

f) number of pixels to display the waveform;

g) printer output.

Where applicable, these details should also include sampling rates used, effect of pulse repetition frequency or display range on the sampling rate and response time.

In addition, the principles of any algorithm used to process data for display should be described.

6 Calibration blocks

6.1 General

In order to verify the ultrasonic thickness measuring equipment, it is necessary to take measurements on defined calibration blocks. These blocks are specified in 6.2 and 6.3.

6.2 Material

Blocks shall be manufactured from steel grade S355J0 specified in EN 10025-2.

Blocks shall be rough-machined before heat treatment which shall consist of:

— austenitizing at 920 °C for 30 min;

— rapid cooling (quenching) in water;

— tempering by heating to 650 °C for 3 h; and then

— cooling in air.

The velocity for longitudinal waves in the calibration block material shall be (5 920 ± 30) ms^{-1}.

The surfaces used for measurement shall be machined to an Ra value not greater than 0,8 µm.

Prior to final machining, the block shall be proved free from internal discontinuities.

It is permissible to chromium plate or electroless nickel plate the surfaces of the block to a maximum of 0,5 % of the block thickness.

NOTE If chromium plating is used, care should be taken to use a thickness of plating that will avoid separation.

6.3 Shape and size

6.3.1 Accuracy blocks

These calibration blocks shall be cylinders with diameter, D, and length, L, and as shown in Table 1.

Table 1 – Size of calibration blocks

Block	Diameter D	Length L
A	≥0,5L	Minimum specified thickness
B	≥0,5L	L_A+ 0,25 (L_E – L_A)
C	≥0,5L	L_A + 0,50 (L_E – L_A)
D	≥0,5L	L_A + 0,75 (L_E – L_A)
E	≥0,5L	Maximum specified thickness

where

L_A is the height of block A; and

L_E is the height of block E.

NOTE If L_A < 0,1 L_E the subtraction of L_A may be omitted.

D shall not be <3 times the probe face diagonal dimension.

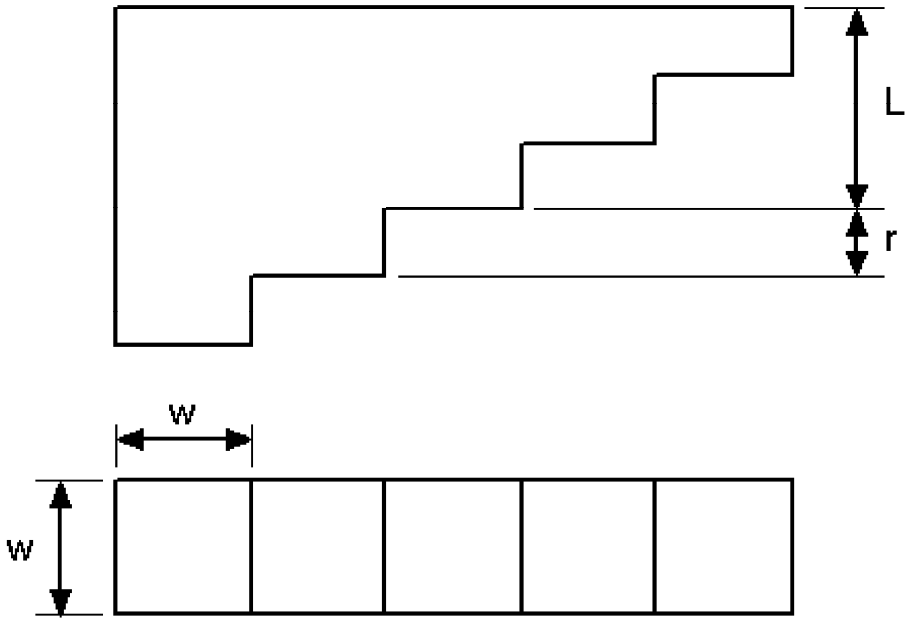
The values 0,25, 0,5 and 0,75 may be varied by up to 10 % of the value in question.

The overall height of the block shall be ≤3 ($10^{-4}L$) across the measurement faces.

The fixed dimension for L shall be measured at the centre of the block to an accuracy of 10^{-4} L.

The blocks shall be permanently, circumferentially marked with the actual length L, e.g. L = 50,333 mm, and a unique identity (serial number).

6.3.2 Resolution block (see Figure 1)



Key

w step width
r step height
L length of block C (see Table 1)

Figure 1 – Resolution block

Where w shall be ≥3 times the diagonal dimension of the probe face and r shall be less than or equal to the specified resolution.

The block shall provide a minimum of five steps.

7 Performance requirements for ultrasonic thickness measuring equipment

To comply with this standard, ultrasonic thickness measuring equipment shall be verified using the tests described below and shown in Table 2.

Group 1: Tests to be performed by the manufacturer (or the manufacturer's agent) on a representative sample of the ultrasonic thickness measuring equipment produced. These tests allow the manufacturer to verify and support the technical specification for the equipment.

Group 2: Tests to be performed on all ultrasonic thickness measuring equipment:

1) by the manufacturer, or the manufacturer's agent prior to the supply of the equipment (pre-commissioning test);

2) by the manufacturer, the owner, or a laboratory at annual intervals to verify the performance of the equipment during its lifetime;

3) following any equipment repairs.

Group 3: Tests to be completed by the operator on site prior to and at the completion of any series of measurements.

Table 2 – List of tests for ultrasonic thickness measuring equipment

Title of test	Group 1	Group 2	Group 3
Physical			
General mechanical state and external aspects		See 10.4	See 10.4 and 11.2
General characteristics			
Stability against temperature	See 9.3		
Low battery warning	See 9.4	See 9.4	
Battery operational time	See 9.5		
Operational voltage range	See 9.6	See 9.6	
Operational current range	See 9.7	See 9.7	
Operational temperature range	See 9.8		
Transmitter			
For each pulse width and energy setting…			
PRF	See 9.9	See 9.9	
Transmitter pulse shape, rise-time and peak voltage	See 9.10	See 9.10	
Receiver			
Frequency range of operation	See 9.11		
Performance			
Minimum and maximum measurable thicknesses	See 9.12	See 9.12	
Accuracy and resolution	See 9.13	See 9.13	
Range of velocity setting	See 9.14		
Calibration mechanisms	See 9.15		See 11.3
Calibration setting storage	See 9.16	See 9.16	See 11.4
Display/Data			
Data storage	See 9.17		See 11.5
Printing	See 9.18		
Display and recall	See 9.19	See 9.19	
Display response time	See 9.20		
Probe	See 8		

8 Probes

Use EN 12668-2 to verify that the centre frequency of all probes specified by the manufacturer for use with the measuring equipment is in agreement with the indicated frequency.

9 Group 1 tests

9.1 General

These tests shall be performed by the manufacturer (or manufacturer's agent) on a representative sample of the ultrasonic thickness measuring equipment produced.

9.2 Equipment required for Group 1 tests

Items essential to perform Group 1 tests on ultrasonic thickness measuring equipment are as follows:

a) digital or analogue oscilloscope with a minimum bandwidth of 100 MHz with attenuating or high voltage probes;

b) 1×50 Ohm $\pm$ 1 % or 1×75 Ohm $\pm$ 1 % non-reactive resistor depending on the oscilloscope used;

c) variable d.c. power supply;

d) digital or analogue voltmeter;

e) digital or analogue ammeter;

f) elapsed time recorder or stop clock;

g) environmental test chamber.

All the equipment used to measure or generate test signals shall be suitably calibrated and capable of measuring with accuracy.

9.3 Stability against temperature

9.3.1 Procedure

The measuring equipment (instrument and probe) shall be calibrated on a specified test block which is approximately half the specified range at 20 °C and then in an environmental test chamber, the equipment and the test block shall be exposed to the minimum specified temperature, mid range of the specified range and the maximum specified temperature.

At the specified temperatures thickness readings have to be taken and recorded.

This test shall be repeated for each probe type and at each operational range at which the equipment will typically operate.

9.3.2 Acceptance criterion

The deviation between the recorded and calibrated readings shall be within the manufacturer's specified accuracy.

9.4 Low battery warning

9.4.1 Procedure

Remove the equipment batteries. Set equipment into a measuring condition powered from the d.c. power supply with the output voltage set to mid-range of that which is specified.

Observe the readings while adjusting the power supply output down to the minimum power supply output specified for the low battery warning voltage.

9.4.2 Acceptance criterion

The indicated reading shall remain within the specified accuracy and resolution at that range and the low battery warning shall be displayed within ±5 % of the specified voltage.

If the equipment is designed to power-down or sound an alarm at this point, then the function shall happen subtly yet noticeably.

9.5 Battery operational time

9.5.1 Procedure

Switch the equipment on, set into a normal measuring condition continually measuring on a given calibration block. Time the elapsed measuring period until “Low Battery Warning” is achieved.

This test shall be repeated for all the recommended battery types.

9.5.2 Acceptance criterion

Measured period of time shall be within ±5 % of the time specified.

If the specified time is related to a duty cycle, the measured time shall be modified to reflect that.

9.6 Operational voltage range

9.6.1 Procedure

Connect the voltmeter to measure the output from the d.c. power supply. The measuring equipment (instrument and probe) shall measure on a specified test block powered from the d.c. power supply with the output voltage set to be mid-range of that which is specified.

Observe the readings while adjusting the power supply output between the minimum power supply output specified to the maximum power supply output specified voltage.

This test shall be repeated with all the typically recommended probe types.

9.6.2 Acceptance criterion

The indicated reading shall remain within the specified accuracy and resolution at that range.

9.7 Operational current range

9.7.1 Procedure

Connect the equipment as described in 9.5.1. Set the ammeter to measure the current from the d.c. power supply. While conducting the operational voltage range tests as in 9.6.1, observe the current at the minimum operational voltage and maximum operational voltage.

This test shall be repeated with all the recommended probe types.

9.7.2 Acceptance criterion

The indicated current shall be within ±10 % of that specified at the minimum and maximum specified voltage.

9.8 Operational temperature range

9.8.1 General

This test is required for equipment and couplant, which is specified to measure at temperatures above and below those specified in 5.2 f).

9.8.2 Procedure

The test block shall be brought to the specified temperature. The measuring equipment shall be prepared to work with the specified probe and the recommended couplant. Measurements shall be taken at regular intervals as specified by the manufacturer, over a period of time considered to be operationally practical.

The readings obtained shall be recorded.

9.8.3 Acceptance criterion

To comply with this standard, the readings shall satisfy the manufacturer's specified accuracy.

At the conclusion of the test period the specified probe shall be free from any damage.

9.9 Pulse repetition frequency, PRF

9.9.1 Procedure

If applicable, switch the ultrasonic instrument to double probe working (separate transmitter and receiver) and connect an oscilloscope to the transmitter terminal.

Check that the oscilloscope input cannot be damaged by the high transmitter voltage.

Connect the non-reactive resistor [see 9.2. b)] across the transmitter output socket. Measure the pulse repetition frequency, using the oscilloscope, at each setting which gives a different pulse repetition frequency. Where more than one combination of controls result in the same pulse repetition frequency (usually the range and pulse repetition frequency), then the pulse repetition frequency only needs to be measured with one of the combinations. For ultrasonic instruments with a continuously adjustable pulse repetition frequency control, a setting shall be chosen as given in the manufacturer's technical specification.

9.9.2 Acceptance criterion

At each setting the measured value of the pulse repetition frequency shall be within ±20 % of that given in the manufacturer’s technical specification.

9.10 Transmitter pulse shape, rise-time and peak voltage

9.10.1 Procedure

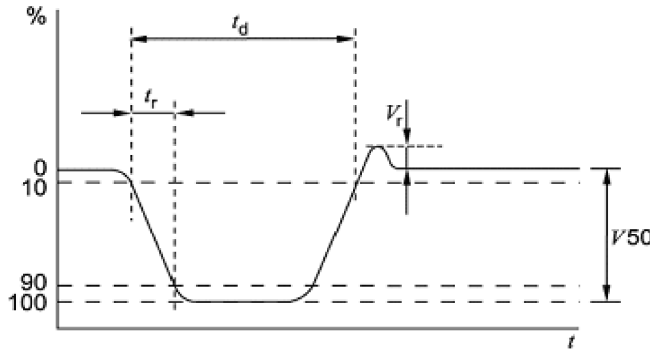
If applicable, switch the ultrasonic instrument to double probe working (separate transmitter and receiver) and connect an oscilloscope to the transmitter terminal.

Connect the non-reactive resistor [see 9.2 b)] across the transmitter output socket (as specified by the manufacturer).

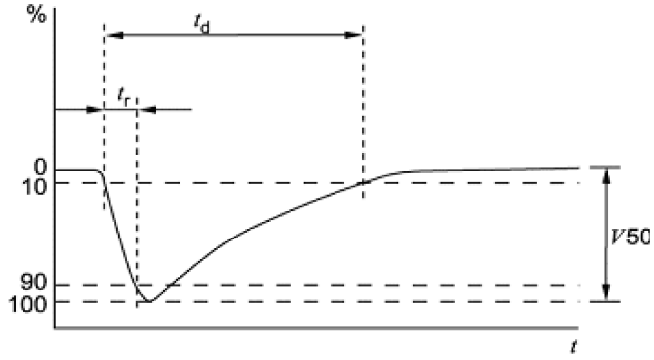
Set the pulse repetition frequency to maximum. Using the oscilloscope, measure the transmitter pulse voltage, V_{50}. Measure the pulse rise time, duration and amplitude of any reverberation as shown in Figure 2.

Repeat the measurements at each pulse energy setting and/or transmitter pulse frequency setting and with maximum and minimum damping.

Repeat the tests with the minimum pulse repetition frequency that gives a clearly defined trace on the oscilloscope screen.



a) Square



b) Spike

Key

t_d pulse duration
t_r pulse rise time
V_r pulse reverberation
V_{50} transmitter pulse voltage, loaded

Figure 2 – Transmitter pulse parameters to be measured

9.10.2 Acceptance criterion

At maximum and minimum pulse repetition frequency and on each pulse energy and/or transmitter pulse frequency band:

a) transmitter pulse voltage (loaded, i.e. V_{50}) shall be within ±10 % of the manufacturer's specification;

b) pulse rise time t_r, shall be less than the maximum value quoted in the manufacturer's technical specification;

c) pulse duration t_d, shall be within ±10 % of the value quoted in the manufacturer's technical specification;

d) any pulse reverberation V_r shall be less than 4 % of the peak to peak transmitter pulse voltage.

9.11 Receiver frequency range of operation

9.11.1 Procedure

Calibrate the instrument with all the recommended probes on a calibration block approximately mid-range of the manufacturer's recommended range for the probe selected.

9.11.2 Acceptance criterion

The readings obtained shall meet the manufacturer's specified accuracy and resolution.

9.12 Minimum and maximum measurable thicknesses

9.12.1 Procedure

The equipment shall be tested with all the specified probes on the range of calibration blocks in question.

9.12.2 Acceptance criterion

The readings obtained shall be within the manufacturer's specified accuracy and resolution.

9.13 Accuracy and resolution

9.13.1 Procedure

The equipment shall be tested with all the specified probes on the calibration blocks A to E of Table 1 to verify accuracy.

The equipment shall be tested with all the specified probes on the resolution test block shown in Figure 1 to verify resolution.

9.13.2 Acceptance criterion

The readings obtained shall be within the manufacturer's stated accuracy and resolution.

9.14 Range of velocity setting (calibration)

The procedures for determining the minimum and maximum measurable thicknesses with accuracy and resolutions as specified are only for steel (5 920 ms^{-1}). Performance on other materials shall be verified separately.

9.15 Calibration mechanisms

9.15.1 General

Step 1 of 9.15.2 need only be carried out when the instrument is used in a mode other than mode 3 of ISO 16809 (multiple echo).

The procedures in this clause shall be carried out using all the recommended probes for the system.

9.15.2 Procedure

Step 1: Complete the probe zeroing operation according to manufacturer's instructions.

Step 2: Adjust the system's velocity using calibration block C. Take measurements on the other calibration blocks.

9.15.3 Acceptance criterion

The readings obtained shall be within the manufacturer's stated accuracy.

9.16 Calibration setting storage

9.16.1 Procedure

Calibrate the instrument with the recommended probe on calibration block C. Take a set of readings on calibration blocks A to E. Repeat this for the following 3 tests:

— shut-down the instrument deliberately;

— allow the equipment to turn off automatically (if applicable);

— disconnect the battery (if applicable).

Leave the equipment off for at least 3 min. Turn on the equipment, repeat the measurements on calibration blocks A to E.

9.16.2 Acceptance criterion

The readings obtained shall be within the manufacturer's stated accuracy and resolution.

9.17 Data storage

9.17.1 Procedure

With the equipment in a typical operational mode, readings shall be taken and stored according to the product's specification. The readings taken shall be stored by the system and separately using other techniques. The total number of readings taken shall be the maximum number that can be stored plus 1.

The extra reading is to verify the system behaviour when the maximum storage is exceeded.

9.17.2 Acceptance criterion

The system, when attempting to take the extra one reading shall act in a controlled and predictable fashion such that the operator is warned when maximum storage is reached and so that pre-stored data shall not be adversely affected.

After 72 h the readings stored by the system shall be verified against those that were stored separately using whichever method the manufacturer specifies. Errors shall be flagged and investigated.

If zero errors are found the test is successful.

9.18 Printing

9.18.1 Procedure

A representative amount of stored data shall be printed in the specified fashion on all the printers specified by the manufacturer.

9.18.2 Acceptance criterion

Printed data shall conform to the manufacturer's specifications.

9.19 Display and recall

9.19.1 Procedure

A representative amount of stored data shall be viewed on the equipment display.

9.19.2 Acceptance criterion

Data shall conform to the manufacturer's specifications.

9.20 Display response time

9.20.1 Procedure

Using the resolution test block the equipment shall be used to measure across two steps by repeatedly moving the probe across any two steps. The probe shall be moved increasingly faster until the equipment fails to display the step change. The time between measurements shall be recorded.

The refresh time is determined as being half the recorded time.

The test shall be completed for each probe and range of operation specified.

9.20.2 Acceptance criterion

The readings obtained at the specified refresh/response time shall be within the manufacturer's stated accuracy and resolution.

10 Group 2 tests

10.1 General

These tests shall be performed on all ultrasonic thickness measuring equipment:

a) by the manufacturer, or the manufactuer’s agent, prior to supply of the equipment (pre-commissioning tests);

b) by the manufacturer, the owner, or a laboratory at annual intervals to verify the performance of the equipment during its lifetime;

c) following any equipment repairs.

10.2 Equipment required for Group 2 tests

Items essential to perform Group 2 tests on ultrasonic thickness measuring equipment are as follows:

a) digital or analogue oscilloscope with a minimum bandwidth of 100 MHz with attenuating or high voltage probes;

b) 1×50 Ohm $\pm$ 1 % or 1×75 Ohm $\pm$ 1 % non-reactive resistor depending on the oscilloscope to be used;

c) variable d.c. power supply;

d) digital or analogue voltmeter;

e) analogue ammeter.

10.3 General characteristics

Complete those tests in Clause 9 as specified in Table 2.

10.4 General mechanical state and external aspects

Visually inspect the outside of the ultrasonic equipment for physical damage which may influence it's current operation or future reliability.

Ensure any seals (gaskets) are in place on the equipment enclosure, sockets and probe where specified, to maintain operational integrity and prevent ingress of moisture and/or debris.

Check and ensure the probe is free from damage and/or excess wear and where appropriate the delay line (wear shoe) is fitted properly and if necessary, coupled to the probe face.

Check to ensure the integrity of all cables and connectors.

11 Group 3 tests

11.1 General

These tests shall be completed by the operator on site prior to, and at the completion of any series of measurements.

Complete those tests in Clause 9 and Clause 10 as specified in Table 2.

11.2 General mechanical state and external aspects

Ensure the manufacturer's operation manual (instruction manual) is at hand.

11.3 Calibration mechanisms

11.3.1 Procedure

Select the recommended probe for the material and range of thicknesses to be measured.

Step 1: If necessary, complete the probe zeroing operation according to the manufacturer's instructions.

Step 2: Using a calibration block made of the same material as that which is to be measured and of a thickness in the range expected to be measured, adjust the system's material velocity setting.

11.3.2 Acceptance criterion

The readings obtained shall be within the manufacturer's stated accuracy.

11.4 Calibration setting storage

11.4.1 Procedure

Calibrate the instrument with the recommended probe on the calibration block described in 11.3.1 Step 2.

Carry out the following 3 tests:

— shut-down the instrument deliberately;

— allow the equipment to turn off automatically (if applicable);

— disconnect the battery (if applicable).

Leave the equipment off for at least 3 min. Turn on the equipment and repeat the measurements on the calibration block.

11.4.2 Acceptance criterion

The readings obtained shall be within the manufacturer's stated accuracy.

11.5 Data storage

11.5.1 Procedure

With the equipment in typical operational mode, readings shall be taken and stored according to the manufacturer’s instructions.

Recall a representative amount of stored data on the equipment display.

11.5.2 Acceptance criterion

The data and it’s format shall conform to the manufacturer's specifications.

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1) To be published.

ICS 19.100

Price based on 16 pages