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Non-destructive testing of welds — Ultrasonic testing — Use of automated phased array technology

Essais non destructifs des assemblages soudés — Contrôle par ultrasons — Utilisation de la technique multi-éléments automatisés

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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 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*.

Any feedback, question or request for official interpretation related to any aspect of this document should be directed to the Secretariat of ISO/TC 44/SC 5 via your national standards body. A complete listing of these bodies can be found at www.iso.org/members.html. Official interpretations, where they exist, are available from this page: https://committee.iso.org/sites/tc44/home/interpretation.html.

This second edition cancels and replaces the first edition (ISO 13588:2012), which has been technically revised. The main changes compared to the previous edition are as follows:

— Clauses 2 and 3 have been updated;

— a method of length and height measurement has been added;

— new Annex B has been added;

— the document has been editorially updated.

Non-destructive testing of welds — Ultrasonic testing — Use of automated phased array technology

1 Scope

This document specifies the application of the phased array technology for the semi- or fully automated ultrasonic testing of fusion-welded joints in metallic materials of minimum thickness 6 mm. It applies to full penetration welded joints of simple geometry in plates, pipes, and vessels, where both the weld and the parent material are low-alloy and/or fine grained steel. For the testing of welds in other steel materials this document gives guidance. For coarse-grained or austenitic steels, ISO 22825 applies in addition to this document.

This document provides guidance on the specific capabilities and limitations of the phased array technology for the detection, location, sizing and characterization of discontinuities in fusion-welded joints. Phased array technology can be used as a stand-alone technology or in combination with other non-destructive testing (NDT) methods or techniques, for manufacturing inspection, pre-service and for in-service inspection.

This document specifies four testing levels, each corresponding to a different probability of detection of imperfections.

This document permits assessment of discontinuities for acceptance purposes based either on amplitude (equivalent reflector size) and length, or on height and length.

This document does not include acceptance levels for discontinuities.

This document is not applicable for automated testing of welds during the production of steel products covered by ISO 10893-8, ISO 10893-11 and ISO 3183.

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 5817, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 17640, *Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment*

ISO 10863, *Non-destructive testing of welds — Ultrasonic testing — Use of time-of-flight diffraction technique (TOFD)*

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

ISO 18563-2, *Non-destructive testing — Characterization and verification of ultrasonic phased array equipment — Part 2: Probes*

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

ISO 19285, *Non-destructive testing of welds — Phased array ultrasonic testing (PAUT) — Acceptance levels*

ISO 22825, *Non-destructive testing of welds — Ultrasonic testing — Testing of welds in austenitic steels and nickel-based alloys*

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

3 Terms and definitions

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

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

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

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

3.1
phased array image
one- or two-dimensional display, constructed from the collected information of phased array operation

3.2
indication
phased array indication
pattern or disturbance in the *phased array image* (3.1) which can need further evaluation

3.3
phased array setup
probe arrangement defined by probe characteristics (e.g. frequency, probe element size, beam angle, wave mode), *probe position* (3.4), and the number of probes

3.4
probe position
PP
distance between the front of the wedge and the weld centre line

3.5
scan increment
distance between successive data collection points in the direction of scanning (mechanically or electronically)

3.6
skewed scan
scan performed with a skewed angle

Note 1 to entry: The skewed angle can be achieved electronically or by means of probe orientation.

3.7
mode
phased array mode
combination of ultrasonic beams created by phased array technology, e.g. fixed angle, E-scan, S-scan

4 Testing levels

Quality requirements for welded joints are mainly associated with the material, welding process and service conditions. To comply with all of these requirements, this document specifies four testing levels (A, B, C and D).

From testing level A to testing level C, an increasing probability of detection is achieved by an increasing testing coverage, e.g. number of incidences, combining techniques.

Testing level D may be agreed for special applications using a written procedure which shall take into account the general requirements of this document. This includes tests of metals other than ferritic steel, tests on partial penetration welds, tests with automated equipment and tests at object temperatures outside the range. For coarse-grained or austenitic steels, ISO 22825 shall also be used.

In general, the testing levels are related to quality levels (e.g. according to ISO 5817). The appropriate testing level can be specified by standards for the testing of welds (e.g. ISO 17635), by product standards or by other documents. When ISO 17635 is specified, the testing levels in relation to ISO 5817 as given in Table 1 shall be used.

Table 1 — Quality levels of ISO 5817 and corresponding testing levels

Testing level	Quality level in ISO 5817
A	C, D
B	B
C	by agreement
D	special application

Table 2 shows the minimum requirements and in all cases, as described in 7.2, the setup shall be verified with a reference block. In cases where scanning is performed from one face (excluding TOFD), half and full skip shall be used and stored; if scanning is performed from both faces, half skip is sufficient.

If diffraction signals are detected they may be used for sizing.

If the evaluation of the discontinuities is based on amplitude only, the deviation of the beam direction from the normal to the weld bevel shall not exceed 6°. If this is not possible because of the geometry of the test object (e.g. weld cap, narrow gap weld), the scan plan shall describe the corrective measures and explain how these areas to be tested shall be covered with enough sensitivity

Table 2 — Description of testing levels

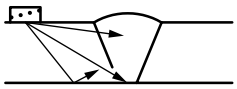
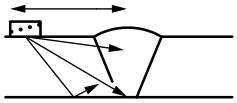
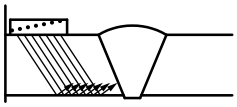
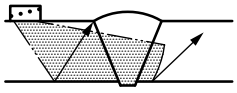
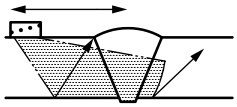
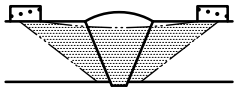
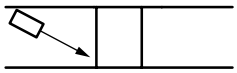
Mode	Testing levels			Example of sketches
	A	B	C	
	Reference blocks (see Annex A)			
	Block A	Block B	Block C	
Test set-up				
Fixed angles at fixed probe position to weld (line scans)[a]	Two sides	Not suitable as single technique	Two sides	
Fixed angles with raster scanning[a]	One side	One side	One side	
E-scan at fixed probe position (line scan)[a]	One side	Two sides with two angles [c]	Two sides	
S-scan at fixed probe position to weld (line scan)[a]	One side	Two sides or two probe positions	Two sides or two probe positions	

Table 2 *(continued)*

Mode	Testing levels			Example of sketches
	A	B	C	
	Reference blocks (see Annex A)			
	Block A	Block B	Block C	
S-scan raster	Not recommended		One side	
TOFD generated with phased array[a]	Not recommended, TOFD testing in accordance with ISO 10863		One setup	
Skewed scan[b]	If required by specification			

[a] For testing level C, at least two different test setups from this table shall be combined; at least one of them shall be S-scan or TOFD.

[b] If detection of transverse discontinuities is required by specification, a suitable additional test setup shall be applied. Skewed probe or electronically skewed beam can be used.

[c] At least 10° difference between angles.

5 Information required prior to testing

5.1 Items to be defined prior to procedure development

Information on the following items is required:

a) purpose and extent of testing;

b) testing levels;

c) acceptance criteria;

d) specification of reference blocks;

e) manufacturing or operation stage at which the testing is to be carried out;

f) weld details and information on the size of the heat-affected zone;

g) requirements for access and surface conditions and temperature;

h) personnel qualifications;

i) reporting requirements.

5.2 Specific information required by the operator before testing

Before any testing of a welded joint can begin, the operator shall have access to all the information as specified in 5.1 together with the following additional information:

a) written test procedure;

b) type(s) of parent material and product form (i.e. cast, forged, rolled);

c) joint preparation and dimensions;

d) welding instruction or relevant information on the welding process;

e) time of testing relative to any post-weld heat treatment;

f) result of any parent metal testing carried out prior to and/or after welding.

5.3 Written test procedure

For all testing levels, a written test procedure is required.

The procedure shall include the following information as a minimum:

a) purpose and extent of testing;

b) testing techniques;

c) testing levels;

d) personnel qualification/training requirements;

e) equipment requirements (including but not limited to frequency, sampling rate, pitch between elements, element size);

f) reference and/or test blocks;

g) setting of equipment;

h) available access and surface conditions;

i) testing of parent material;

j) evaluation of indications;

k) acceptance levels and/or recording levels;

l) reporting requirements;

m) environmental and safety issues.

The procedure shall include a documented testing strategy or scan plan showing probe position, probe movement, and component coverage that provides a standardized and repeatable methodology for weld testing. The scan plan shall also include ultrasonic beam angles used, beam directions with respect to the weld centre line, and the volume to be tested for each weld.

6 Requirements for personnel and test equipment

6.1 Personnel qualifications

Personnel performing testing in accordance with this document shall be qualified to an appropriate level in accordance with ISO 9712 or equivalent in the relevant industrial sector.

In addition to general knowledge of ultrasonic weld testing, the operators shall be familiar with, and have practical experience in, the use of ultrasonic phased arrays. Specific training and examination of personnel should be performed on representative pieces. These training and examination results should be documented. If this is not the case, specific training and examination should be performed with the finalized ultrasonic testing procedures and selected ultrasonic test equipment on representative samples containing natural or artificial reflectors similar to those expected. These training and examination results should be documented.

6.2 Test equipment

6.2.1 General

In selecting the system components (hardware and software), ISO/TS 16829 gives useful information.

Ultrasonic equipment used for phased array testing shall be in accordance with the requirements of ISO 18563-1, ISO 18563-2, and ISO 18563-3 when applicable.

6.2.2 Ultrasonic instrument

The instrument shall be able to select an appropriate portion of the time base within which A-scans are digitized.

It is recommended that a sampling rate of the A-scan be used of at least six times the nominal probe frequency.

6.2.3 Ultrasonic probes

Both longitudinal and shear waves may be used.

Adaptation of probes to curved scanning surfaces shall comply with ISO 17640. When adapted probes are used, the influence on the sound beam shall be taken into account.

The number of dead elements on each active aperture shall be a maximum of 1 out of 16 and dead elements are not allowed to be adjacent. For active apertures using less than 16 elements, no dead element is allowed, unless adequate performance is demonstrated.

6.2.4 Scanning mechanisms

To achieve consistency of the images (collected data), guiding mechanisms and scan encoder(s) shall be used.

7 Preparation for testing

7.1 Volume to be tested

The purpose of the testing shall be defined by specification. Based on this, the volume to be tested shall be determined.

For tests at the manufacturing stage, the testing volume shall include the weld and the parent material for at least 10 mm on each side of the weld (5 mm for laser welds and for electron beam welds), or the width of the heat-affected zone (based on the manufacturer's information), whichever is greater.

A scan plan should be provided. The scan plan should show the beam coverage, the weld thickness and the weld geometry.

It shall be ensured that the sound beam(s) cover(s) the volume to be tested.

7.2 Verification of the test setup

The capability of the test setup shall be verified by the use of reference blocks (see 9.3).

7.3 Scan increment setting

The scan increment setting along the weld is dependent upon the wall thickness to be tested. For thicknesses up to 10 mm, the scan increment shall be no more than 1 mm. For thicknesses between