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Non-destructive testing of welds — Ultrasonic testing — Use of automated phased array technology for thin-walled steel components

Essais non destructifs des assemblages soudés — Contrôle par ultrasons — Utilisation de la technique multi-éléments automatisés pour les composants en acier à paroi mince

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Contents

Page

Foreword

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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).

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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.

Non-destructive testing of welds — Ultrasonic testing — Use of automated phased array technology for thin-walled steel components

1 Scope

This document specifies the application of phased array technology for the semi- or fully automated ultrasonic testing of fusion-welded joints in steel parts with thickness values between 3,2 mm and 8,0 mm. This meets the typical range of tube wall thickness values in boilers, which is an important application of this testing technology. The minimum and maximum value of the wall thickness range can be exceeded, when testing level "D" of this document is applied. This document applies to full penetration welded joints of simple geometry in plates, tubes, pipes, and vessels, where both the weld and parent material are low-alloy and/or fine grained steel.

NOTE "Semi-automated testing" encompasses a controlled movement of one or more probes on the surface of a component along a fixture (guidance strip, ruler, etc.), whereby the probe position is unambiguously measured with a position sensor. The probe is moved manually. "Fully automated testing" includes mechanized propulsion in addition.

Where material-dependent ultrasonic parameters are specified in this document, they are based on steels having a sound velocity of (5 920 ± 50) m/s for longitudinal waves, and (3 255 ± 30) m/s for transverse waves. It is necessary to take this fact into account when testing materials with a different velocity.

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

This document specifies two testing levels:

— level "C" for standard situations;

— level "D" for different situations/special applications.

This document describes assessment of discontinuities for acceptance purposes based on:

— height and length;

— amplitude (equivalent reflector size) and length;

— go/no-go decision.

This document does not include acceptance levels for discontinuities.

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 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 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*

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

3 Terms and definitions

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

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

— ISO Online browsing platform: available at 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 may need further evaluation

3.3
phased array set-up
probe arrangement defined by probe characteristics (e.g. frequency, probe element size, beam angle, wave mode), probe position, and the number of probes, adaptation to the curvature of the test object

3.4
scan increment
distance between successive data collection points in the direction of scanning (mechanically or electronically)

3.5
skewed scan
scan performed with a skewed beam angle

Note 1 to entry: The skewed beam angle can be achieved electronically or by changing the probe orientation.

4 Testing levels

Quality requirements for welded joints are mainly associated with the material, welding process and service conditions. To accommodate all of these requirements, this document specifies two testing levels “C” and “D”. A written procedure is mandatory for both testing levels C and D.

Testing level C applies to the standardized approach for thin-walled components (see Tables 1 and 2), e.g. testing from two sides or testing from one side of the weld with the cap removed.

Testing level D shall be agreed upon for special applications, e.g. tests on wall thickness below 3,2 mm, varying thicknesses (counter bore) and tests at object temperatures outside the range specified in 7.6. For testing level D, verification on test blocks is mandatory.

In general, the testing levels are related to quality levels (given in ISO 5817, for example). The appropriate testing level can be specified by standards for weld testing (e.g. ISO 17635), product standards or other specifications. When ISO 17635 is specified, the recommended testing levels are as given in Table 1.

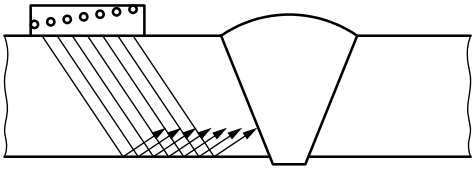
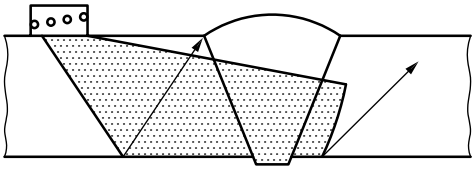
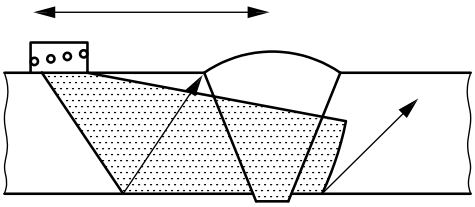
Table 1 — Recommended testing levels

Testing level	Quality level in ISO 5817
C	B, C, D
D	Special applications

Table 2 shows the minimum requirements for the individual test modes for testing levels C and D. The set-up shall be verified with reference and/or test blocks; as described in 7.2. In cases where scanning is performed from one scanning surface (e.g. the outer surface of a vessel), at least half and full skip shall be used. If scanning is performed from both scanning surfaces (e.g. top and bottom surfaces), testing at half skip could be sufficient, depending on weld and probe dimensions.

If the evaluation of the indications is based on amplitude only, the deviation of the beam axis from the normal to the weld bevel shall not exceed 6°. In case it is not possible to stay within this 6° value, 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 the areas outside the 6° requirement are covered with sufficient sensitivity.

Table 2 — Description of testing levels

Mode	Testing levels		Examples
	C test set-up	D test set-up	
E-scan at fixed probe position to weld (line scan)	Two sides	To be specified	
S-scan at fixed probe position to weld (line scan)	Two sides or two probe positions on the same side	To be specified	
S-scan raster	One side, weld cap removed	To be specified	
Skewed scan[a]	Not applicable	To be specified	

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

5 Information required before testing

5.1 Items to be specified before procedure development

Information on the following items is required:

a) purpose and extent of testing;

b) type(s) of parent material (i.e. cast, forged, rolled), grain size;

c) testing levels;

d) acceptance criteria;

e) specification of reference blocks;

f) manufacturing or operational stage at which the testing has to be carried out;

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

h) requirements for access, surface conditions and temperature;

i) personnel qualifications;

j) 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 specified in 5.1, together with the following additional information:

a) written test procedure;

b) joint preparation and dimensions;

c) relevant information on the welding process;

d) time of inspection relative to any post-weld heat treatment.

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) test equipment to be used (including frequency, sampling rate, pitch between elements, element size);

f) reference and/or test blocks;

g) calibration and example of reference scan;

h) sensitivity and range setting of test equipment;

i) available access and surface conditions;

j) testing of parent material;

k) evaluation of indications;

l) acceptance levels and/or recording levels;

m) reporting requirements;

n) environmental and safety issues;

o) scan plan showing probe placement, movement, and component coverage that provides a standardized and repeatable methodology for weld testing. The scan plan shall also include weld thickness and weld geometry, beam angles used, beam directions with respect to the weld centre line, and tested volume examined 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.

If characterization of indications is required, then a documented training on the following items is required:

— knowledge of welding process and weld shape encountered in the job;

— correctly setting up the PAUT system with a welding contour;

— use of echo static & dynamic response for characterization of defects (ISO 23279);

— correctly setting up the display settings of PAUT instruments for characterization e.g. no echo envelope;

— dealing with the requirement to hit the weld bevel perpendicular or within ±6°.

6.2 Test equipment

6.2.1 General

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

6.2.2 Instruments and display

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.

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 Probes

Probes for longitudinal, transverse and creeping waves can be used.

The probe frequency shall be at least 5 MHz and suitable for the thickness of the component.