INTERNATIONAL STANDARD

ISO 20601

First edition
2018-12

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

Reference number
ISO 20601:2018(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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.

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).

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.

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.

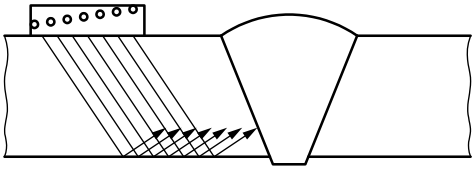
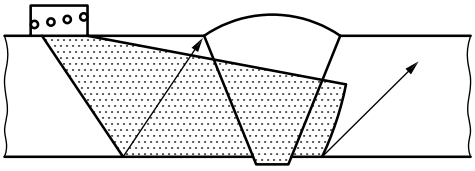
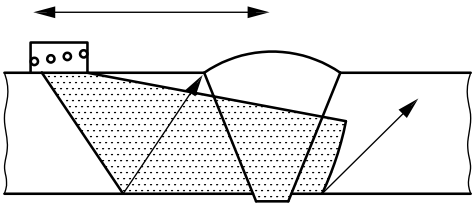
Table 1 — Recommended testing levels

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.

Adaptation of probes to curved scanning surfaces shall comply with ISO 17640. Probes shall have shoes sufficiently adapted to the surface curvature, so that the probe shoe to surface distance does not exceed 0,5 mm.

Formula (1) gives the relation between the maximal distance between the flat probe shoe and the component surface, g_{flat}, the probe shoe size in the direction of curvature, a, and the object diameter, D:

$$g_{flat} = \frac{a^2}{4D} \tag{1}$$

For a given test object of diameter D, the maximum acceptable dimension, a_{max}, in the direction of the curvature of the flat probe shoe that shall be used (provided that $g_{flat} \leq 0{,}5$ mm) is given in Table 3 for some values of D.

Table 3 — Examples of maximum size, a_{max}, of a flat probe shoe for a test object of diameter, D

D mm	a_{max} mm
50	10
200	20
450	30
800	40
1 250	50

Because the curvature of the test object has influence on the sound beam, the beam width along the weld shall be suitable (using geometrical or electronical beam focusing, for example) for the determination of the discontinuity length specified in the acceptance criteria.

6.2.4 Scanning mechanisms

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

The distance between the probe and the weld centre line shall be constant with a maximum allowable variation of ±1 mm. Otherwise, the suitability shall be proven on a reference block.

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 parent material for at least 1,25 t (thickness) on each side of the weld (1 t for laser welds and for electron beam welds), or the proven width of the heat-affected zone (based on the manufacturer's information). It needs to be proven that the sound beam(s) cover(s) the volume to be tested. A scan plan shall be provided to document this.

7.2 Verification of test set-up

The capability of the test set-up shall be verified by the use of reference blocks and test blocks, where applicable.

7.3 Scan increment setting

The scan increment along the weld shall be no more than 0,5 mm, unless testing level D is specified. In this case, the value of the scan increment shall be justified.

The scan increment setting perpendicular to the weld, when applicable, shall be chosen in order to ensure the coverage of the examination testing volume.

7.4 Geometry considerations

Care should be taken when testing welds of complex geometry, e.g. weld joining materials of unequal thicknesses, materials that are joined at an angle or nozzles. These tests should be planned carefully and require in-depth knowledge of sound propagation and shall always be carried out under testing level D.

7.5 Preparation of scanning surfaces

Scanning surfaces shall be clean in an area wide enough to permit the testing volume to be fully covered.

Scanning surfaces shall be even and free from foreign matter likely to interfere with probe coupling (e.g. rust, loose scale, weld spatter, notches, grooves). The condition of the test surface shall result in a gap not exceeding 0,5 mm between the probe and the surface. These requirements shall be ensured by dressing the scanning surface, if necessary.

Scanning surfaces may be assumed to be satisfactory if the surface roughness, *Ra*, is not greater than 6,3 µm for machined surfaces, or not greater than 12,5 µm for shotblasted surfaces.

When coating, e.g. paint, is present and is not to be removed, test blocks with corresponding coating, are required. In addition, the required corrective actions shall be specified and applied.

7.6 Temperature

When not using special high-temperature phased array probes and couplants, the surface temperature of the test object under testing shall be between 0 °C and 50 °C.

For temperatures outside this range, the suitability of the equipment shall be verified.

7.7 Couplant

In order to generate proper phased array images, a couplant shall be used which provides a constant transmission of ultrasound between the probes and the test object.

The couplant used for calibration shall be the same as that used in subsequent testing and post-calibrations.

8 Testing of parent material

The parent material, in the scanning zone area shall be tested, to demonstrate that the angle-beam testing of the weld is not influenced by the presence of imperfections.

Where imperfections are found, their influence on the proposed angle-beam testing shall be assessed and, if necessary, the techniques adjusted correspondingly. When satisfactory coverage by ultrasonic testing is seriously affected, other test techniques (e.g. radiography) shall be considered.

9 Range and sensitivity settings

9.1 Settings

9.1.1 General

Setting of range and sensitivity shall be carried out before each test in accordance with this document. Any change of the phased array set-up, e.g. probe position and steering parameters, requires a new setting.

Signal-to-noise ratio should be optimized with a minimum of 12 dB for the reference signals, when using A-scans, or with a minimum of 6 dB when using phased array images.

9.1.2 Pulse-echo time window

If applicable, the time window used for pulse-echo signals shall include the volume of interest and be specified in the written test procedure.

Ensure that the combination of beams covers the area of interest.

9.1.3 Pulse-echo sensitivity settings

9.1.3.1 General

After selection of the mode (E-scan, S-scan), the following shall be carried out:

a) the sensitivity shall be set for each beam generated (beam angle, focal point etc.) by the phased array probe;

b) when a probe with wedge is used, the sensitivity shall be set with the wedge in place.

9.1.3.2 Focusing

Different modes of focusing can be applied with phased array probes, e.g. static and dynamic depth focusing (DDF).

When focusing is used, the sensitivity shall be set for each focused beam.

9.1.3.3 Gain corrections

The use of angle-corrected gain (ACG) and time-corrected gain (TCG) enables the display of signals for all beam angles and all distances with the same amplitude. At least two points/distances shall be used for the ACG or TCG.

9.1.3.4 Sensitivity settings for different modes of phased array testing

For weld testing, different modes can be applied, e.g. E-scans, S-scans. After the previous steps, the reference sensitivity for each generated beam is a distance-amplitude curve (DAC) or time-corrected gain (TCG) for side-drilled holes with diameter according to 9.3.4., including transfer correction, according to ISO 17640, if applicable.

9.2 Checking of the settings

The settings shall be checked at least every 4 h and after completion of the testing. If the single test takes more than 4 h, the settings shall be checked after completion of the test.

If a reference block was used for initial setting, the same reference block shall be used for checking. Alternatively, a smaller block with known transfer properties may be used.

If deviations from the initial settings, in accordance with 9.1, are found during these checks the corrections given in Table 4 shall be carried out.

Table 4 — Sensitivity and range corrections

Sensitivity	
Deviations ≤4 dB	No action required; data may be corrected by software
Deviations >4 dB	The complete chain of measurement shall be checked. If no defective components are identified, settings shall be corrected and all tests carried out since the last valid check shall be repeated
The required signal-to-noise ratio shall be achieved.	
Range	
Deviations ≤0,5 mm or 2 % of depth range, whichever is greater	No action required
Deviations >0,5 mm or 2 % of depth range, whichever is greater	Settings shall be corrected and all tests carried out since the last valid check shall be repeated

9.3 Reference blocks

9.3.1 General

Reference blocks shall be used for testing level C and D to set the test sensitivity and determine the adequacy of testing. (e.g. coverage). Recommendations for reference blocks are shown in Annex A. The block in Figure A.1 is preferred for settings/correction of time delays and TCG.

9.3.2 Material

Reference blocks as shown in Figure A.1 shall be made from the same material group (according to ISO/TR 15608) to the test object (e.g. with regard to sound velocity, grain structure, and surface condition). For testing on group 2 material the reference blocks can be made from group 1 material or from group 2 material.

Reference blocks as shown in Figure A.2 shall be made from the same material group (according to ISO/TR 15608) to the test object (e.g. with regard to sound velocity, grain structure, and surface condition).

9.3.3 Dimensions and shape

The thickness of at least one of the reference blocks shall be the same as the test object and in accordance with the specified material tolerances.

The curvature of the reference block shall be similar to the components curvature to be tested within a range. For testing of longitudinal welds in cylindrical test objects, curved reference blocks shall be used, having diameters from 0,8 to 1,2 times the test object diameter. For test objects having a diameter greater than or equal to 300 mm, a flat reference block may be used.

In all cases, with regard to the diameter or curvature, the requirements mentioned in 6.2.3 shall apply. The maximum allowed gap between probe shoe and reference block is 0,5 mm.

The length and width of the reference block should be chosen such that all the artificial reflectors can be properly scanned.

9.3.4 Reference reflectors

The reference block as shown in Figure A.1 shall at least contain two side-drilled holes (SDH).

The reference block shall at least contain one side-drilled hole (SDH) and two notches (Figure A.2) or alternatively two flat-bottomed holes (FBH) or two round-bottomed holes (RBH). The length of the side-

drilled holes and notches shall be equal or larger than the beam width. Recommended hole diameters are specified in Annex A (see Table A.1).

If notches are used for sensitivity setting then beam angles with possible mode conversion shall be avoided because the signal amplitudes of different beam angles are strongly affected.

Notches can also be used to show coverage of the volume to be tested.

NOTE For shear waves in steel, mode conversion occurs at an incident angle of less than about 33°. For a corner reflection, e.g. at a notch, this means that a beam angle of higher than about 57° is also affected.

9.4 Test blocks testing level D

9.4.1 General

With testing level D, test blocks shall be used in addition to the use of a reference block as described in 9.3, to determine the adequacy of the testing (e.g. coverage, sensitivity setting).

The test block may replace the reference block if the test block has also all specified reference reflectors required per 9.3.4.

9.4.2 Material

Test blocks shall be made from the same material group (according to ISO/TR 15608) as the test object (e.g. with regard to sound velocity, grain structure, and surface condition).

A test block shall contain a weld according to the same welding procedure, made from the same material and having a similar (weld) geometry as the test object.

9.4.3 Dimensions and shape

The thickness of the test block shall be the same as that of the test object. The curvature of the test block shall be equal to the curvature of the test object.

The length and width of the reference block should be chosen such that all the required reflectors can be properly scanned.

9.4.4 Reflectors in test blocks

The test block shall contain reflectors in or at real welds (ID, OD and embedded), representing possible production defects. Two types of reflectors can be used:

a) real discontinuities (deliberately applied welding defects);

b) artificial discontinuities (machined reflectors, i.e. notches, side-drilled holes and flat-bottomed holes).

Real discontinuities are usually preferred. Alternatively, artificial discontinuities may be applied. The type and required number of discontinuities used shall be agreed between the contracting parties.

The discontinuities shall be tested, for example, by X-ray and assessed (ISO 17636-1 class B, ISO 5817 level 1), with additional technology (RT tomography) or macroscopic sectioning of twin samples.

10 Equipment checks

Verify that all relevant channels, probes, and cables of the ultrasonic phased array system are functional. These checks shall be performed daily before and after testing. If any item of the system fails, corrective action shall be taken and the system shall be retested.

11 Verification of the test procedure

For testing level D, verification of the procedure is required. The test procedure shall have been demonstrated to perform acceptably on test blocks as described in 9.4.

A satisfactory procedure verification shall take place before the first testing of the test objects.

A satisfactory procedure verification includes:

a) detection of all required reflectors in accordance with the requirements of 9.1.1;

b) amplitude differentiation as specified;

c) proof of coverage in depth and width.

12 Weld testing

Before initial testing, the coverage shall be verified with the scan plan and demonstrated on a suitable reference block.

Acceptable deviations of probe position relative to the weld centre line shall be specified in the test procedure, and shall be covered in the scan plan and shown on a reference block.

Some discontinuities detected during the initial scanning can require additional evaluation, offset-scans, scans perpendicular to the discontinuity, complementary phased array set-ups.

Scanning speed shall be chosen such that satisfactory phased array images are generated (see 14.1). The scanning speed shall be selected depending on factors such as number of delay laws, scan resolution, signal averaging, pulse repetition frequency, data acquisition frequency, and volume to be tested. Missing scan lines indicate that too high a scanning speed has been used. A maximum of 5 % of the total number of lines collected in one single scan may be missed, but no adjacent lines shall be missed.

If the length of a weld is scanned in more than one section, an overlap of at least 20 mm between the adjacent scans is required. When scanning circumferential welds, the same overlap is required for the end of the last scan with the start of the first scan.

If applicable, a control function for the coupling efficiency is recommended.

13 Data storage

Ultrasonic testing shall be performed using a device employing automatic computer-based data acquisition. All A-scan data covering the test area shall be stored and all data sets with set-up parameters shall be included in the data record.

All data shall be stored for a period as specified.

14 Interpretation and analysis of phased array data

14.1 General

Interpretation and analysis of phased array data are typically performed as follows:

a) assess the quality of the phased array data;

b) identify relevant indications;

c) classify relevant discontinuities as specified;

d) determine location and size of discontinuities as specified;

e) evaluate discontinuities against acceptance criteria.

14.2 Assessing the quality of the phased array data

A phased array test has to be carried out such that satisfactory phased array images are generated which can be evaluated with confidence. Satisfactory phased array images are defined by appropriate:

a) coupling;

b) range (time-base) setting;

c) sensitivity setting;

d) signal-to-noise ratio;

e) saturation indicator;

f) data acquisition.

Assessing the quality of phased array images requires skilled and experienced operators (see 6.1). The operator shall decide whether non-satisfactory phased array images require new data acquisition (re-scanning).

14.3 Identification of relevant indications

Phased array testing images: both discontinuities in the weld and geometric features of the test object.

In order to distinguish between indications and geometric features, detailed knowledge of the test object is necessary.

To decide whether an indication is relevant (caused by a discontinuity in the weld), patterns or disturbances in the phased array image shall be evaluated considering shape and signal amplitude relative to the noise level.

14.4 Classification of relevant indications

Amplitude, location and pattern of relevant indications contain information on the type of the related discontinuity.

Relevant indications shall be classified as specified.

14.5 Determination of location and length

14.5.1 Location

The location of a discontinuity parallel to the weld axis, perpendicular to the weld axis and in the through-wall direction shall be determined from the collected data.

14.5.2 Length

The length of a discontinuity is defined as the dimension along the weld. The method of determining the length shall be in accordance with the applied acceptance level.

When testing circumferential welds in small diameter pipes the length measured along the outside surface is larger than the actual length of the discontinuity, especially at lower depth (e.g. root discontinuity). This can be compensated with Formula (2):

$$l_c = l_s \times \frac{OD - 2d}{OD} \tag{2}$$

where

l_c is the corrected length;

l_s is the length measured along the surface;

OD is the outside diameter;

d is the depth of indication.

14.6 Indication assessment

14.6.1 General

This assessment can, according to specification, be based on:

— height and length;

— amplitude and length; or

— amplitude, length and characterization.

If the height of an indication can be determined directly, e.g. by using diffraction signals, this is preferred. If no diffraction signals are present or usable then the amplitude is used for evaluation.

14.6.2 Assessment based on amplitude and length

The amplitude drop can be used to determine the height and length of an indication. The maximum amplitude of the signal from each characterized indication shall be evaluated according to the specified acceptance level for that type of indication.

14.6.3 Assessment based on height and length

The height of an indication is the extent in the through-wall direction. For indications displaying varying height along their length, the height shall be determined at the scan position of maximum extent.

If a more accurate height determination is required, reconstruction algorithms may be used.

14.6.4 Characterization of discontinuities

The echo pattern, the position and orientation of the indication can be used to determine the type of the related discontinuity,

14.7 Evaluation against acceptance criteria

After classification of all relevant indications, determination of their location and length, and assessment, the indications shall be evaluated against the specified acceptance criteria.

The indications can then be categorized as “acceptable” or “not acceptable”.

15 Test report

The test report shall include at least the following information:

a) a reference to this document (i.e. ISO 20601);

b) information relating to the object under test:

   1) identification of the object under test;

   2) dimensions including wall thickness;

   3) material type and product form;

   4) geometrical configuration;

   5) location of welded joint(s) tested;

   6) reference to welding process and heat treatment;

   7) stage of manufacture;

   8) surface condition and temperature;

c) information relating to test equipment:

   1) manufacturer and type of phased array instrument including scanning mechanisms with identification numbers;

   2) manufacturer, type, frequency of phased array probes including number and size of elements, material and angle(s) of wedges with identification numbers;

   3) details of reference block(s) and/or test block(s) with identification numbers;

   4) type of couplant used;

d) information relating to test techniques:

   1) testing level and reference to a written test procedure;

   2) purpose and extent of testing;

   3) details of datum and coordinate systems;

   4) method and values used for range and sensitivity settings;

   5) details of signal processing and scan increment setting;

   6) scan plan;

   7) limitations of access and deviations from this document, if any;

e) information relating to phased array setting:

   1) increment (E-scans) or angular increment (S-scans);

   2) element pitch and gap dimensions;

   3) focus (calibration should be the same as used for scanning);

   4) virtual aperture size, i.e. number of elements and element width;

   5) element numbers used for focal laws;

   6) documentation on permitted angular range for the wedge used specified by the manufacturer;

