Technical Specification

ISO/TS 22499

Second edition
2024-02

Thermoplastic pipes for the conveyance of fluids — Inspection of polyethylene butt fusion joints using phased array ultrasonic testing

Tubes en matières thermoplastiques pour le transport des fluides — Contrôle des assemblages par soudage bout à bout en polyéthylène au moyen de la technique par ultrasons multi-éléments

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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 document 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 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 5, *General properties of pipes, fittings and valves of plastic materials and their accessories — Test methods and basic specifications*..

This second edition cancels and replaces the first edition (ISO/TS 22499:2019), which has been technically revised.

The main changes are as follows:

— clarification of the definition of "cold fusion" and "lack of fusion";

— revision of the procedure qualification.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

At the present time, laboratory experiences exist on the use of PAUT for polyethylene BF joints and/or reference blocks of wall thickness between 8 mm to 100 mm[1][2][3][4][5]. Field experience on BF joints in PE80 and PE100 materials has been reported[6].

Interlaboratory test has shown that PAUT is a viable method for enhancing the integrity assessment of butt-fusion joints[7][16].

PAUT techniques for cold fusion detection are known to be available. However further research, verification and experience are needed to transfer the technique into an ISO Standard. This document does not provide any information regarding the detection of cold fusions[16].

Thermoplastic pipes for the conveyance of fluids — Inspection of polyethylene butt fusion joints using phased array ultrasonic testing

1 Scope

This document describes the phased array ultrasonic testing (PAUT) of polyethylene butt fusion (BF) joints, including pipe-to-pipe, pipe-to-fitting and fitting-to-fitting joints, used for the conveyance of fluids. This document provides a test, whereby the presence of imperfections such as voids, inclusions, lack of fusions, misalignment and particulate contamination in the BF joints can be detected. The document is only applicable to polyethylene pipes and fittings without a barrier to ultrasonic waves.

This document also provides requirements for procedure qualification and guidance for personnel qualifications, which are essential for the application of this test technique.

This document also covers the equipment, the preparation and performance of the test, the indication assessment and the reporting for polyethylene BF joints.

Acceptance criteria are not covered in this document.

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 13953, *Polyethylene (PE) pipes and fittings — Determination of the tensile strength and failure mode of test pieces from a butt-fused joint*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577 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 https://www.electropedia.org/

3.1
cold fusion
incomplete intermolecular diffusion of polymer chains for proper molecular entanglement at the joint interface due to reasons other than contamination

Note 1 to entry: Cold fusion results in insufficient joint integrity including significant reduction of joint ductility.

3.2
inclusion
foreign material trapped in the fusion joint

3.3
lack of fusion
absence of intermolecular diffusion of polymer chains for molecular entanglement at the interface

Note 1 to entry: A lack of fusion flaw results in complete separation at the flaw location.

3.4
melt fusion zone
MFZ
zone containing the fusion interface and having boundaries on either side of the interface which reflect the limits of crystalline melting during the butt fusion jointing process

Note 1 to entry: The MFZ is shown in Figure 1.

3.5
misalignment
offset between the axis of the pipes/fittings to be jointed

3.6
particulate contamination
fine particles (e.g. airborne dust) or coarse particles (e.g. sand and grit) that are present at the fusion interface

3.7
surface imperfection
imperfection on the inner diameter or outer diameter surface of the butt fusion joint

3.8
void
empty space (or air pocket) in a butt fusion joint

3.9
phased array image
one-, two-, or three-dimensional display, constructed from the phased array data

3.10
phased array set-up
probe arrangement defined by probe characteristics (e.g. frequency, probe element size, beam angle, wave mode), *probe position* (3.11), and the number of probes

3.11
probe position
point between the front of the wedge (or probe) and the butt fusion center line

3.12
scan increment
distance between successive data collection points in the direction of scanning

3.13
false call
reporting an imperfection when none exists

4 General

This document covers the equipment, the preparation and performance of the test, the indication assessment and the reporting for polyethylene butt fusion joints.

This document may be used to draft a detailed procedure for phased array ultrasonic testing of polyethylene butt fusion joints.

Characterization of imperfections in the parent material adjacent to the butt fusion joint is also possible.

5 Information required prior to testing

5.1 Items required for procedure

Information on the following items shall be provided:

a) purpose and extent of testing;

b) manufacturing or operation stage of BF joints at which the testing is to be carried out;

c) reference sample;

d) requirements for getting access to the BF joints, the surface condition of the pipe; and the temperature range;

e) personnel qualifications;

f) reporting requirements.

5.2 Specific information required by the operator before testing

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

a) written test procedure, qualified in accordance with Clause 10;

b) all relevant joint dimensions.

5.3 Written test procedure

For all testing, a written test procedure is required. This test procedure shall include the following information:

a) documented testing strategy or scan plan.

NOTE The testing strategy gives information on the probe placement, movement and component coverage that provides a standardized and repeatable methodology for fusion joint testing. The scan plan gives information on the volume tested for each butt fusion joint.

b) equipment requirements and settings (including but not limited to frequency, sampling rate, pitch between elements and elements size);

c) evaluation of indications;

d) environmental and safety issues.

6 Personnel qualifications

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

In addition to a general knowledge of ultrasonic testing, the operator shall be familiar with and have practical experience in the use of phased array systems on polyethylene butt fusion joints.

Specific theoretical and practical training and examination of personnel shall be performed on representative polyethylene butt fusion joints containing natural or artificial reflectors similar to those expected in the field.

These training and examination results shall be documented.

7 Equipment

7.1 General

The complete equipment (i.e. ultrasonic instrument, probe, cables and display monitor) shall be capable of the repetition of test results.

For selecting the system components (hardware and software), ISO 13588 and ISO/TS 16829 provide useful information.

Equipment used for phased array testing is described in ISO 18563-1, ISO 18563-2 and ISO 18563-3 and contains some useful information.

7.2 Ultrasonic instrument and display

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 should be at least six times the nominal probe frequency.

7.3 Ultrasonic probes

Only longitudinal waves are feasible for polyethylene.

Any type of phased array probe can be used if it satisfies the range and sensitivity setting requirements of Clause 7 with the phased array instrument.

The most suitable ultrasonic probe frequency shall be selected in accordance with the pipe wall thickness. Table 1 shows the recommended frequencies for each thickness range. However, the optimal frequency can deviate from these values depending on the attenuation and thickness of the sample to be tested.

The gap between the test surface and the bottom of the wedge shall not be greater than 0,5 mm.

Table 1 — Selection of probe frequency

Recommended frequency MHz	**Wall thickness, *t*** mm
1,0 to 2,25	$60 \le t \le 100$
2,25 to 4,0	$30 \le t < 60$
4,0 to 5,0	$8 \le t < 30$

NOTE In general, higher frequencies provide better resolution and lower frequencies provide better penetration.

7.4 Scanning mechanisms

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

7.5 Couplant

In order to generate proper images, a couplant shall be used which provides a constant transmission of ultrasound between the probe and the fusion joint tested.

The same couplant used for calibration shall be used for the testing.

Any couplant used should be cleaned off after testing.

8 Range and sensitivity settings

8.1 Settings

8.1.1 General

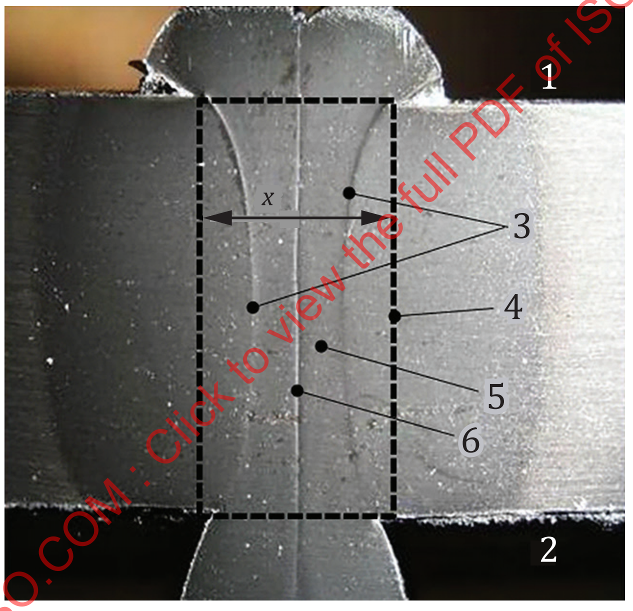
Setting of range and sensitivity shall be carried out prior to each testing period in accordance with this document. Any change of the phased array set-up, e.g. probe position and steering parameters, will require a new setting. The set-up should be optimized on the reference reflectors to give a minimum signal-to-noise ratio of 6 dB.

8.1.2 Range setting — Test volume

The range in the depth direction shall cover the full joint thickness in the fusion zone.

The range in the axial direction shall cover the MFZ on both sides of the BF centre line. As a general guidance, for wall thicknesses <100 mm, the test area width is 10 mm or 1/5 of the wall thickness from either side of the fusion zone, whichever is smaller (see Figure 1).

The range in the circumferential direction shall include the full circumference.



Key

1 outside of joint

2 inside of joint

3 MFZ boundary

4 test area

5 MFZ

6 fusion interface

x width of test area

Figure 1 — Test area

8.1.3 Sensitivity setting

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

a) sensitivity shall be set for each beam generated by the phased array probe;

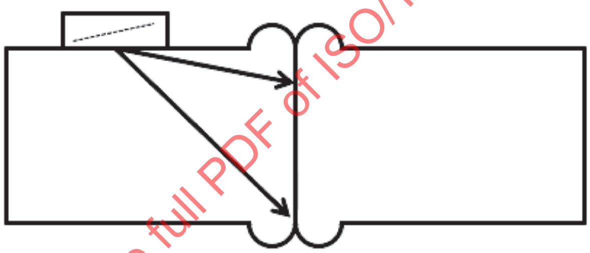
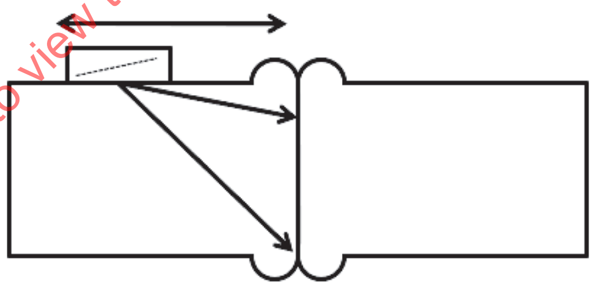
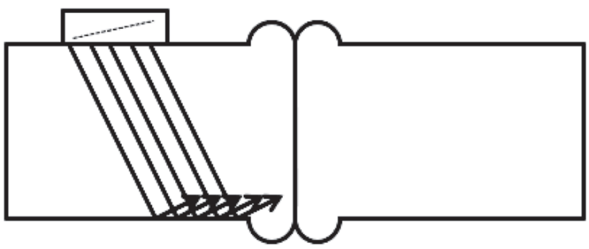
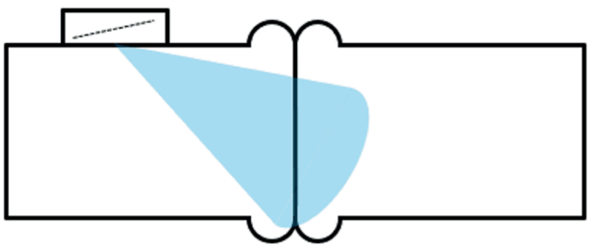
  1) when a probe with wedge is used, the sensitivity shall be set with the wedge in place,

  2) when beam focussing is used, the sensitivity shall be set for each focused beam;

b) use of angle-corrected gain (ACG) or time-corrected gain (TCG) shall be applied to enable the display of signals for all beam angles and all distances with the same amplitude.

NOTE Different testing techniques of PAUT for butt fusion joints (e.g. fixed angles, E-scans and S-scans at fixed probe position) can be employed as shown in Table 2.

Table 2 — Description of testing techniques for butt fusion joints[7]

Testing technique	Test set-up	Example of sketches
Fixed angles at fixed probe position to BF joint (line scans)	Not suitable as a single technique; multiple scans at different angles are needed	
Fixed angles with raster scanning	One side	
E-scan at fixed probe position (line scan)	One side with two angles	
S-scan at fixed probe position (line scan)	One side	

8.2 Reference sample

8.2.1 General

A reference sample shall be used to determine the adequacy of the setting (e.g. coverage, sensitivity).

The temperature of the reference sample shall be the same as the temperature ±5 °C of the test object at the time of testing and shall be kept in the same environment as the test object throughout the test. A reference block satisfying the conditions in 8.2.2 shall be used as the reference sample.

8.2.2 Reference block

Reference blocks shall be used to determine the adequacy of the settings (e.g. coverage, sensitivity). Recommendations for reference blocks are shown in Annex A.

A transfer correction should be applied to cover the difference in curvature and surface roughness of the reference block and the test object.

The reference block used shall be of the same material classification as the pipe/fitting being inspected. The thickness of the reference block shall be at least equal to the thickness of the joint to be tested. The length and width of the reference block shall be chosen such that all relevant reflectors can be properly scanned.

8.2.3 Reference reflectors

Side-drilled holes (SDHs) and surface notches shall be used as reference reflectors for the testing of polyethylene BF joints.

For a thickness ≤30 mm, at least three reflectors are recommended; for a thickness >30 mm, at least five reflectors are recommended.

8.3 Checking of the settings

The range and sensitivity shall be checked prior to testing, every 4 h of testing and at the end of the testing period, or if the temperature of the joint changes by >10 °C.

If there is any change in the response of the reference reflector greater than −4 dB from the Reference Sensitivity Level, the equipment should be re-configured and all the butt fusion joints since the previous acceptable calibration should be re-scanned.

The reference sensitivity level shall be established over the range of interest using SDHs as shown in Table A.1.

9 Equipment checks

A check of the equipment shall be performed daily before and after testing to verify that all relevant channels, probes, and cables of the ultrasonic phased array system are functional. If any item of the system fails, corrective action shall be carried out and the system shall be retested.

10 Test procedure

10.1 Procedure qualification

Procedure qualification is required for testing polyethylene BF joints. The procedure shall be demonstrated to perform in an acceptable way on butt fusion joints containing representative imperfections (lack of fusion, particulate contamination), which have been shown to reduce the integrity of the joint as shown by destructive testing.

NOTE The production of cold fused (CF) joints in field applications does exist. However, it has been found that it is not possible to create a CF joint reliably in the laboratory and thus CF joints are currently excluded from the procedure qualification of this document. This does not imply that detection of CF joints by NDT is not possible. In fact, interlaboratory tests carried out by ISO/TC 138/SC 5 show that true CF joints can be detected by PAUT[16]. Individual organizations can include CF joints in their qualification process upon agreement with the parties involved.

Procedure qualification is intended to provide confidence that the inspection procedure can provide a minimum ability to detect flaws. It is recommended that acceptance criteria be agreed upon by the parties involved.

The procedure qualification requires the manufacturing of a series of samples of polyethylene BF joints for each pipe wall thickness range to be tested, some with imperfection and some without (see Table 3). Some examples for implanting imperfections to BF joints are given in Annex B.

The following categorized sample joints shall be tested in a blind fashion:

— **Category I**: 2 fusion joints, each containing 8 embedded planar lack of fusion imperfections (thickness of 25 µm or less), randomly distributed around the circumference. For each pipe wall thickness range, 2 planar imperfections for each size given in Table 3 shall be used.

— **Category II**: 14 fusion joints where:

  a) 8 fusion joints contain no imperfections, using conditions that have been proven to generate no brittle failures when tested to ISO 13953;

  b) 6 fusion joints contain fine particulate contamination (particle size <50 µm) evenly distributed and dispersed around the whole fusion joint circumference and proven to generate only brittle failures when tested according to ISO 13953.

Before blind testing, up to 5 fusion joints containing no imperfections can be inspected in order to set up the PAUT equipment.

For the procedure to be qualified for the detection of imperfections:

a) 13 or more of the 16 embedded planar lack of fusion imperfections (Category I) shall be detected, and classified correctly as planar lack of fusion imperfections;

b) To be considered a detected imperfection, the reported circumferential position of the imperfection shall be within ±5 % of the joint circumference from the true circumferential position. All other reported indications shall be considered false calls, and there shall be no more than 2 false calls in the Category I joints;

c) 5 or more of the 6 fusion joints containing fine particulate contamination (Category II b)) shall be classified correctly as having imperfections; and

d) For the fusion joints containing no imperfections (Category II a)), 7 or more of the 8 fusion joints shall be classified correctly as having no imperfections. There shall be no more than 1 false call.

Procedure qualification is only required once for each pipe wall thickness range (see Table 3) unless the procedure or any of the test equipment is changed.

Table 3 — Pipe wall thickness ranges and associated sizes of embedded planar imperfections for the qualification of test procedures

Range	Wall thickness of pipe/fitting, *t* mm	Imperfection diameters mm
A	$8 \leq t < 15$	1, 1,5, 2,5, 4
B	$15 \leq t < 30$	1,5, 2,5, 4, 6
C	$30 \leq t < 60$	2,5, 4, 6, 9
D	$60 \leq t \leq 100$	4, 6, 9, 13,5

10.2 Scan increment

The scan increment setting along the circumference of the joint is dependent upon the wall thickness of the BF joint to be tested.

a) For thicknesses up to 60 mm, the scan increment shall be no more than 1 mm.

b) For thicknesses above 60 mm the scan increment shall be no more than 2 mm.

10.3 Geometry of the fusion joint tested

If parts of the fusion zone cannot be tested in the axial or circumferential direction due to complex geometry, these areas shall be reported.

10.4 Preparation of scanning surfaces

The test surface shall be prepared so that it is free from contamination, e.g. dirt, dust, or ice. Then the test surface shall be examined visually and the position of any surface damage shall be reported.

10.5 Temperature of fusion joint tested

The test shall be conducted sufficiently after the end of the cooling time specified in the jointing procedure such that temperature equilibrium is assured throughout the joint thickness. The temperature of the joint shall be reported.

10.6 Testing

a) Before starting the test, a proper ultrasonic coupling between the probe and the pipe surface shall be achieved and maintained throughout the scan.

b) The zero datum (starting position) shall be recorded and the ultrasonic probe shall be moved around the circumference of the butt fusion joint to test the entire circumference and depth of the fusion zone.

c) Any areas that could not be tested shall be reported.

d) The scanning speed shall be chosen such that satisfactory images are generated. The scanning speed is dependent on factors such as number of delay laws, scan resolution, signal averaging, pulse-repetition frequency, data acquisition frequency, and volume to be tested. Missing data 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.

e) If the axial and/or circumferential length of a butt fusion joint is scanned in more than one section, an overlap of at least 20 mm between the adjacent scans shall be applied.

f) The testing in the circumferential direction shall include the full joint circumference plus at least 25 mm to accommodate potential encoder error.

g) Indications caused by imperfections such as voids, lack of fusion, inclusions, surface imperfections, misalignment and particulate contamination within the test volume shall be reported.

10.7 Data storage

Ultrasonic testing shall be performed using a device employing computer-based data acquisition. All A-scan data covering the test volume shall be stored for a period as agreed by the parties involved.

11 Interpretation and analysis of test data

11.1 General

Interpretation and analysis of the test data are typically performed as follows:

a) assess the quality of the test data (see 11.2);

b) identify relevant indications (see 11.3);

c) classify relevant indications (see 11.4);

d) determine location and size of the indications (see 11.5);

e) assess the indications (see 11.6).

11.2 Assessing the quality of the test data

The phased array test shall be performed such that satisfactory images are generated which can be evaluated. Satisfactory images are defined by appropriate:

a) coupling;

b) range setting;

c) sensitivity setting;

d) signal-to-noise ratio;

e) data acquisition (scan length, missed lines, coverage).

It shall be ensured that the signal is not saturated within the test volume.

Assessing the quality of phased array images requires skilled and experienced operators (see Clause 6). If the operator decides that the scan data quality does not meet the requirements of the procedure, a rescan shall be carried out.

11.3 Identification of relevant indications

The phased array technique provides images of both imperfections in the fusion zone and geometric features such as BF beads and pipe/fitting walls.

In order to identify indications of geometric features, knowledge of the joint dimensions is necessary.

To decide whether an indication is relevant (caused by an imperfection), patterns or disturbances shall be evaluated considering the shape and signal amplitude relative to the noise level.

11.4 Classification of relevant indications

Amplitude, location and pattern of relevant indications may contain information on the type of imperfection. Relevant indications should be classified as agreed by the parties involved.

11.5 Determination of location and size of indications

The location of an indication in the circumferential and depth directions in the fusion zone shall be determined from the acquired data.

The length of an indication is defined as the dimension along the circumference of the joint and the height of an indication is defined as the dimension in the through wall direction.

11.6 Assessment of indications

The assessment of indication can be based on signal amplitude, equivalent reflector size or reflector pattern, or on other features.

The amplitude drop can be used to determine the size of an indication.

The height of an indication in the through-wall direction should be determined at the scan position of maximum extent.

The maximum amplitude and size of each indication should be evaluated according to the specified acceptance criteria agreed by the parties involved.

12 Test report

The test report shall include all specific test requirements, procedural details and results for a particular test. The test report shall include at least the following information.

a) a reference to this document, i.e. ISO/TS 22499:2024;

b) information relating to the inspection:

   1) test report number;

   2) names, signatures and qualifications of personnel;

   3) date of test.

c) information relating to the fusion joint(s) tested:

   1) identification of the fusion joint(s) tested (e.g. pipe-to-pipe, pipe-to-fitting or fitting-to-fitting);

   2) joint dimensions (nominal OD, thickness);

   3) classification of the material (e.g. PE80, PE100, etc.);

   4) location of fusion joint(s) tested;

   5) condition and temperature of surface.

d) information relating to equipment:

   1) the manufacturer and type of phased array instrument and software revision, including scanning mechanism with identification numbers if required;

   2) the manufacturer, type and frequency of phased array probes, including number and size of elements, pitch and gap between elements, material and angle(s) of wedges (if any), with identification numbers if required;

   3) details of reference block(s) with identification numbers if required;

   4) type of couplant used.

e) information relating to test technique:

   1) a reference to a written qualified procedure;

   2) purpose and extent of test;

   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 settings;

   6) scan plan;

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

f) information relating to phased array settings:

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

   2) focus;

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

   4) element numbers used for focal laws;

g) information relating to test results:

   1) a reference to the phased array raw data file(s);

   2) phased array images of at least those locations where relevant indications have been detected on hard copy, all images or data available in soft copy;

   3) tabulated data recording the classification, location and size of relevant indications and results of evaluation;

   4) record of all areas not tested.

Annexe A
(informative)

Example of reference reflectors and reference blocks

A.1 Reference reflectors

For a thickness *t* ≤30 mm, at least three reference reflectors are recommended. The reflectors may be machined in one or more blocks (see Figures A.1 and A.2).

For a thickness *t* >30 mm, at least five reference reflectors are recommended. The reflectors may be machined in one or more blocks (see Figures A.1 and A.2).

The tolerances for all the dimensions of the reference reflectors are as follows:

— side-drilled hole (SDH):

  — diameter: ±0,5 mm

  — length: ±5 mm

  — angle: ±2°

  — depth: ±1,0 mm

— surface notch (rectangular):

  — depth: ±0,2 mm

  — width: ±0,2 mm

  — length: ±5 mm

The recommended reference reflectors for different wall thicknesses are described in Table A.1.

NOTE Other types of reference blocks are available, e.g. in ASTM E3044M.[13]

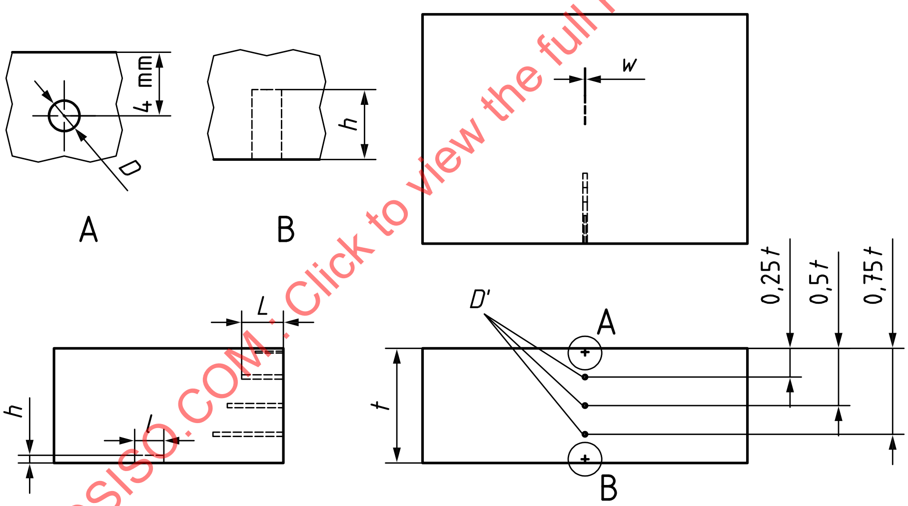
Table A.1 — Dimensions and positions of SDH and notch reflectors on the reference block

Dimensions in millimetres

<table>
<tr><th rowspan="2">Thickness
t</th><th colspan="3">SDH</th><th colspan="3">Notch (bottom surface)</th></tr>
<tr><th>Depth to hole centre</th><th>Diameter
D</th><th>Length
L</th><th>Depth
h</th><th>Length
l</th><th>Width
w</th></tr>
<tr><td rowspan="2">8 < *t* < 30</td><td>4</td><td>2</td><td>30</td><td rowspan="2">1</td><td rowspan="10">30</td><td rowspan="10">1</td></tr>
<tr><td>0,5 *t*</td><td>2,5</td><td>60</td></tr>
<tr><td rowspan="4">30 ≤ *t* < 60</td><td>4</td><td>2</td><td>30</td><td rowspan="4">2</td></tr>
<tr><td>0,25 *t*</td><td rowspan="3">3</td><td>45</td></tr>
<tr><td>0,5 *t*</td><td>60</td></tr>
<tr><td>0,75 *t*</td><td>75</td></tr>
<tr><td rowspan="4">60 ≤ *t* ≤100</td><td>4</td><td>2</td><td>30</td><td rowspan="4">2</td></tr>
<tr><td>0,25 *t*</td><td rowspan="3">4,5</td><td>45</td></tr>
<tr><td>0,5 *t*</td><td>60</td></tr>
<tr><td>0,75 *t*</td><td>75</td></tr>
<tr><td colspan="7">NOTE The depth refers to a distance from the surface.</td></tr>
</table>

A.2 Reference blocks

A.2.1 Reference block with SDHs and a surface notch — Single block use



Key

D' diameter of SDHs at positions 0,25 *t*, 0,5 *t* and 0,75 *t*

D diameter of SDH 4 mm below the surface

L length of SDH

h depth of notch from the bottom surface

l length of notch at the bottom surface

t thickness

w width of notch at the bottom surface

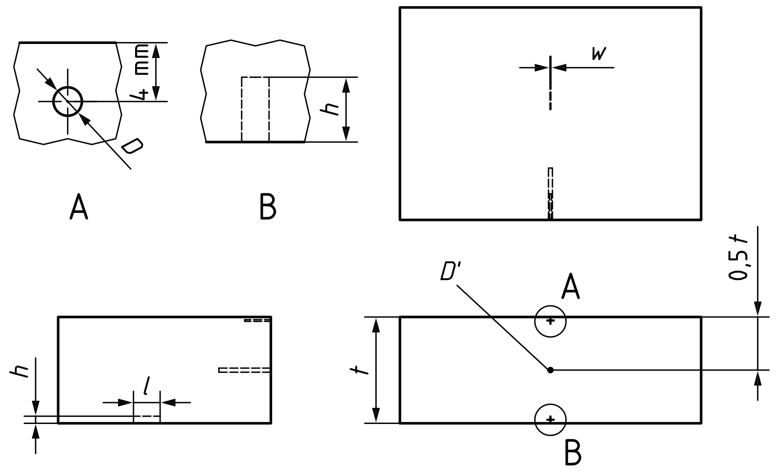
A details of "A"

B details of "B"

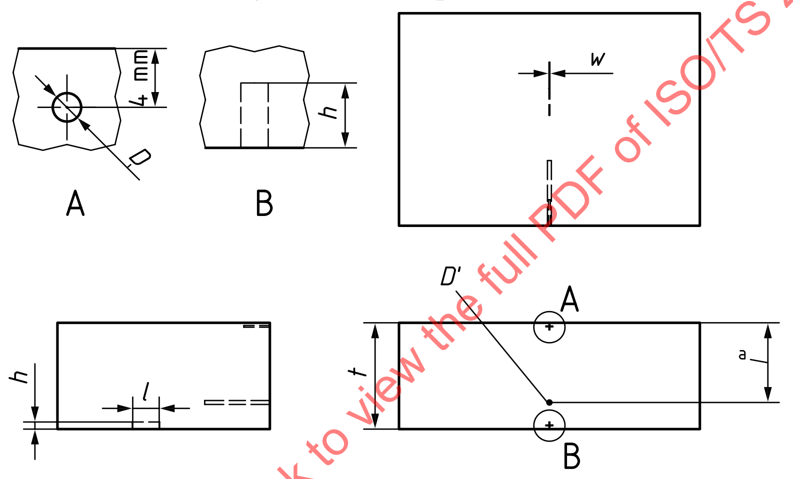
NOTE The top SDH, 4 mm below the surface, can be replaced by a surface notch of dimensions given in Table A.1.

Figure A.1 — Diagram of a single reference block containing SDHs at positions 0,25 *t*, 0,5 *t*, 0,75 *t* and a notch at the bottom surface

A.2.2 Reference block with SDHs and a surface notch — Multiblock use



a) SDH at 0,5 *t* position



b) SDH at 0,25 *t* (or 0,75 *t*) position

Key

D' diameter of SDHs at positions 0,25 *t*, 0,5 *t* and 0,75 *t*

D diameter of SDH 4 mm below the surface

L length of SDH

h depth of notch from the bottom surface

l length of notch at the bottom surface

t thickness

w width of notch at the bottom surface

A details of "A"

B details of "B"

[a] 0,25 *t* or 0,75 *t*.

NOTE 1 Detail A shows an SDH located 4 mm below the test surface, with a diameter of 2 mm and a length of 30 mm.

NOTE 2 Detail B shows a notch at the bottom of the reference block (see Table A.1 for dimensions).

NOTE 3 The top SDH, 4 mm below the surface, can be replaced by a surface notch of dimensions given in Table A.1.

Figure A.2 — Diagram of multi-reference blocks containing SDHs and a bottom surface notch

Annexe B
(informative)

Example procedures for producing imperfections in butt fusion joints[17]

B.1 Planar lack of fusion

The following is an example of the use of a heat-staking procedure.

a) Clean the pipe ends using water and a lint-free cloth. Use another lint-free cloth to dry the pipe ends.

b) Position the pipes in the clamps of the BF machine. Mark on both pipes where they are placed in relation to the clamps (mark on clamp and pipes), so that the pipes can be put back exactly in the same place later. Mark the 0° position on the top of the pipe. Trim the ends of the pipes using the trimming tool, until a continuous ribbon of swarf is obtained.

c) Wearing powder-free gloves, remove one of the pipes from the clamps while being careful not to touch the trimmed end. Place the pipe in the upright position with the trimmed end uppermost.

d) Using a ruler or callipers, measure the actual pipe wall thickness at each of the eight random positions where the planar lack of fusion imperfections will be placed around the circumference and then mark the mid-wall position with the sharp point of a compass (see Figure B.1), which should be visible without causing a significant indentation. Positioning of the imperfections should not have any interfering effects during measurement.

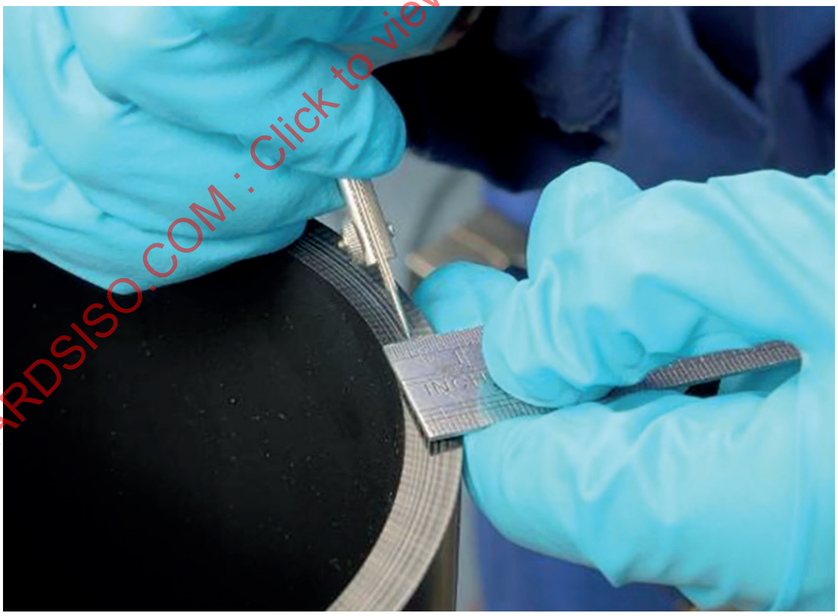


Figure B.1 — Marking the position for the planar lack of fusion imperfections

e) Place an aluminium disc (25 µm thick) on to the pipe end at each of the eight mid-wall positions using static-free tweezers such that the centre of the disc coincides with the mid-wall position on the pipe. Use