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

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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 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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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*.

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.

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 method.

This document also covers the equipment, the preparation and performance of the test, the indication assessment and the reporting for polyethylene BF joints. The assessment of ultrasonic indications and acceptance criteria are not covered in this document.

NOTE 1 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] to [5]. Recently, field experience on BF joints in PE80 and PE100 materials has been reported[6].

NOTE 2 Round robin testing has shown that PAUT is a viable method for enhancing the integrity assessment of BF joints[7].

NOTE 3 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.

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 http://www.electropedia.org/

3.1
cold fusion
insufficient joint integrity caused by the incomplete intermolecular diffusion of polymer chains for proper molecular entanglement at the joint interface due to reasons other than contamination, which does not create any PAUT indication(s) at the joint interface

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, resulting in a non-destructive testing indication at the joint interface

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 BF 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 ID or OD surface of the butt fusion joint

3.8
void
empty space (or air pocket) in a BF 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 BF centre 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 Information required prior to testing

4.1 Items required for procedure

Information on the following items is required:

— purpose and extent of testing;

— reference sample;

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

— personnel qualifications;

— reporting requirements;

— manufacturing or operation stage of BF joints at which the testing is to be carried out.

4.2 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 4.1 together with the following additional information:

a) written test procedure;

b) all relevant joint dimensions.

4.3 Written test procedure

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

a) purpose and extent of testing;

b) reference sample;

c) requirements for access to the BF joints and surface conditions and temperature;

d) personnel qualifications;

e) reporting requirements;

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

g) evaluation of indications;

h) environmental and safety issues;

i) 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 BF joint.

5 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 BF joints. Specific theoretical and practical training and examination of personnel shall be performed on representative polyethylene BF joints containing natural or artificial reflectors similar to those expected. These training and examination results shall be documented.

6 Equipment

6.1 General

For the selection of system components (hardware and software), ISO 13588[8] and ISO/TS 16829[9] give useful information.

Ultrasonic equipment used for phased array testing should comply with the requirements of ISO 18563-1[10], ISO 18563-2[11] and ISO 18563-3[12] when applicable.

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

6.2 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.

6.3 Ultrasonic probes

Only longitudinal wave mode can be used.

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 equipment.

The most suitable ultrasonic probe frequency should 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** mm
1,0 to 2,25	60 to 100
2,25 to 4,0	30 to 60
4,0 to 5,0	8 to 30

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

6.4 Scanning mechanisms

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

6.5 Couplant

In order to generate proper images, a couplant should be used which provides a constant transmission of ultrasound between the probe and the material. The same couplant used for calibration shall be used for the testing. Any couplant used should be cleaned off after testing.

7 Range and sensitivity settings

7.1 Settings

7.1.1 General

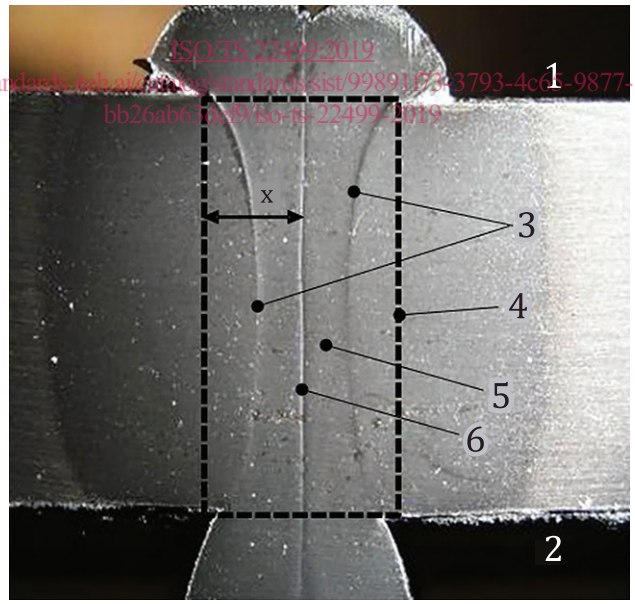
Setting of range and sensitivity shall be carried out prior to each testing period in accordance with this document. Any change of the phased array set-up, e.g. probe position and steering parameters, will require a new setting. The set-up should be optimized on the reference reflectors to give a signal-to-noise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

7.1.2 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

7.1.3 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 BF 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 BF joints[7]

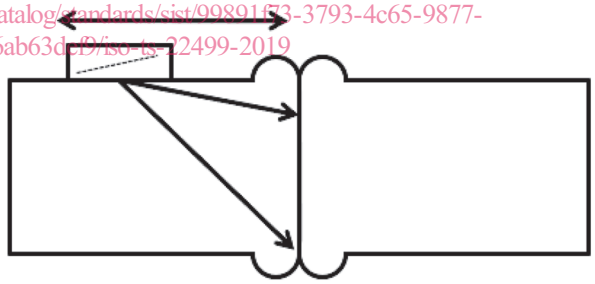
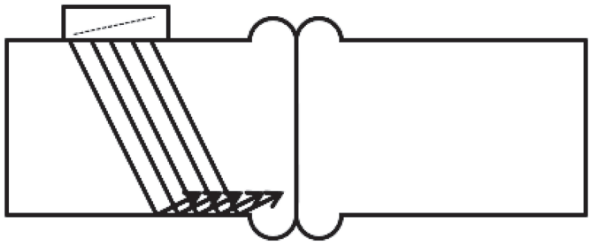
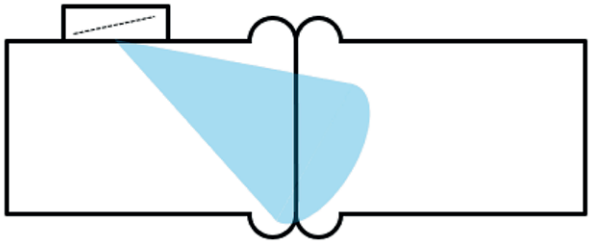
Testing technique	Test set-up	Example of sketches
Fixed angles at fixed probe position to BF joint (line scans)	Not suitable as a single technique; multiple scans at different angles are needed	
Fixed angles with raster scanning	One side	
E-scan at fixed probe position (line scan)	One side with two angles	

Table 2 *(continued)*

Testing technique	Test set-up	Example of sketches
S-scan at fixed probe position (line scan)	One side	

7.2 Reference sample

7.2.1 General

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 7.2.2 shall be used as the reference sample.

7.2.2 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.

7.2.3 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.

7.3 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. Any change in the response of the reference reflector >−4 dB from the reference sensitivity level should merit re-configuring the equipment and re-scanning all the joints since the previous acceptable calibration.

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