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**Thermoplastic pipes for the  
conveyance of fluids — Inspection  
of polyethylene electrofusion socket  
joints using phased array ultrasonic  
testing**

*IT* Tubes en matières thermoplastiques pour le transport des fluides —  
Contrôle des assemblages par emboîtures électrosoudables en  
polyéthylène au moyen de la technique par ultrasons multi-éléments

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO 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](http://www.iso.org/directives)).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at [www.iso.org/patents](http://www.iso.org/patents). ISO shall not be held responsible for identifying any or all such patent rights.

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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](http://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 16943:2019), which has been technically revised.

The main changes are as follows:

- the definitions of cold fusion and lack of fusion have been clarified;
- procedure qualification has been revised.

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](http://www.iso.org/members.html).



# Thermoplastic pipes for the conveyance of fluids — Inspection of polyethylene electrofusion socket joints using phased array ultrasonic testing

## 1 Scope

This document describes phased array ultrasonic testing (PAUT) of polyethylene electrofusion (EF) socket joints used for the conveyance of fluids.

This document provides a test whereby the presence of imperfections such as voids, wire dislocation, misalignment, pipe under-penetration, particulate contamination and lack of fusion in electrofusion socket joints can be detected.

The technique is only applicable to polyethylene electrofusion socket 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 covers the test equipment, the preparation and performance of the test, the assessment of indications and the reporting for polyethylene EF joints.

Acceptance criteria are not covered in this document.

NOTE 1 At the time of publication, experience only exists in the use of PAUT for polyethylene (PE80 and PE100) electrofusion socket joint sizes between 90 mm and 710 mm (SDR 11 and 17).<sup>[1][2][3][4][5][6][7]</sup>

NOTE 2 Interlaboratory testing has shown that PAUT is a viable method for enhancing the integrity assessment of electrofusion joints.<sup>[8][15][16]</sup>

NOTE 3 This document does not apply to the detection of unscraped pipe. Such detection can be achieved by simple visual testing, provided mechanical scraping tools are employed.

NOTE 4 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 International 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 13954, *Plastics pipes and fittings — Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal outside diameter greater than or equal to 90 mm*

ISO 13955, *Plastics pipes and fittings — Crushing decohesion test for polyethylene (PE) electrofusion assemblies*

ISO 23243, *Non-destructive testing — Ultrasonic testing with arrays — Vocabulary*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577, ISO 23243 and the following apply.

ISO and IEC maintain terminology 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 pipe under-penetration

incomplete penetration of the pipe into the electrofusion socket

#### 3.5 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 electrofusion socket jointing process

Note 1 to entry: The MFZ is shown in [Figure 1](#).

#### 3.6 misalignment

angular offset between the axis of the electrofusion socket fitting and the axis of the pipe

#### 3.7 particulate contamination

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

#### 3.8 void

empty space (or air pocket) in an electrofusion socket joint

#### 3.9 wire dislocation

displacement of heating wires from their original position in the fitting

#### 3.10 phased array image

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



**3.11****phased array setup**

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

**3.12****probe position**

axial and radial position of the probe with respect to the heating wire coil in the electrofusion socket joint

**3.13****scan increment**

distance between successive data collection points in the direction of scanning

**3.14****false call**

reporting an imperfection when none exists

**3.15****electrofusion socket fitting**

part containing one or more integral heating elements that are capable of converting electrical energy to heat to make a joint between pipes

**3.16****electrofusion socket joint**

fused combination of one or more pipe components using an electrofusion socket fitting

**3.17****fusion zone**

one side of an electrofusion socket joint

Note 1 to entry: There are two fusion zones in a straight joint.

**4 General**

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This document covers the equipment, preparation and performance of the test for polyethylene electrofusion socket joints. It also covers the reporting.

This document can be used to draft a detailed procedure for phased array ultrasonic testing of polyethylene electrofusion socket joints.

**5 Information required prior to testing****5.1 Items to be defined for the procedure development**

Information on the following items shall be provided:

- a) purpose and extent of testing;
- b) manufacturing or operation stage of electrofusion socket joints at which the testing is to be carried out;
- c) reference sample;
- d) requirements for getting access to the electrofusion socket 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 an electrofusion socket 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 pipe and fitting dimensions.

## 5.3 Written test procedure

For all testing, a written test procedure is required. This test procedure shall include the information specified in [5.1](#) and the following:

- 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 electrofusion socket 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 operators shall be familiar with and have practical experience in the use of phased array systems.

Specific theoretical and practical training and examination of personnel shall be performed on representative polyethylene electrofusion socket 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.

### 7.2 Ultrasonic instrument and display

The instrument shall be capable of selecting an appropriate portion of the time base within which A-scans are digitized. It is recommended that the sampling rate of the A-scan should be at least six times the nominal probe frequency. The instrument and display shall achieve a resolution capable of identifying each heating wire individually.

### 7.3 Ultrasonic probes

Only longitudinal waves are feasible for polyethylene.

Any type of phased array probe can be used if it satisfies the requirements of [Clause 8](#) with the phased array instrument.

The most suitable ultrasonic probe frequency shall be selected in accordance with the thickness of the electrofusion socket fitting. [Table 1](#) shows recommended frequencies for each thickness range of the electrofusion socket fitting.

The optimal frequency can be shifted up or down depending on the attenuation and thickness of the EF socket fitting tested.

**Table 1 — Selection of probe frequency**

| Recommended frequency<br>MHz | Fitting wall thickness, $t$<br>mm |
|------------------------------|-----------------------------------|
| 3,5                          | $30 \leq t \leq 50$               |
| 5,0                          | $10 \leq t \leq 50$               |
| 7,5                          | $10 \leq t \leq 30$               |

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.

NOTE Space and accessibility conditions can require special encoded scanners to facilitate the inspection.

### 7.5 Couplant

[ISO/TS 16943:2023](#)

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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 to be cleaned off after testing.

## 8 Range and sensitivity settings

### 8.1 Settings

#### 8.1.1 General

The 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 setup (e.g. probe position and steering parameters) will require a new setting. The set-up shall 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 at least the melt fusion zone above the plane of the heating wires and the same distance below.

If the position of the melt fusion zone is unknown, at least half of the thickness of the electrofusion socket fitting above and below the plane of the heating wires shall be used (see [Figure 2](#)).