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

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



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# Foreword

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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 electrofusion socket joints using phased array ultrasonic testing

## 1 Scope

This document describes the 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, cold fusion 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 method

NOTE 1 At the time of publication, experience only exists on the use of PAUT for polyethylene (PE80 and PE100) electrofusion socket joint sizes between 90 mm and 710 mm (SDR 11 and 17)[7][8][9][10][11][12][13].

NOTE 2 Round robin testing has shown that PAUT is a viable method for enhancing the integrity assessment of electrofusion joints[16].

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

## 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 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 — 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, ISO 23243 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 non-destructive testing indication(s) at the joint interface



**3.2**
**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

**3.3**
**pipe under-penetration**
incomplete penetration of the pipe into the electrofusion socket

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

Note 1 to entry: The melt fusion zone is shown in Figure 1.

**3.5**
**misalignment**
angular offset between the axis of the electrofusion socket fitting and the axis of the pipe

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

**3.8**
**wire dislocation**
displacement of heating wires from their original position in the fitting

**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 and the number of probes

**3.11**
**probe position**
axial and radial position of the probe with respect to the heating wire coil in the electrofusion socket joint

**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

**3.14**
**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



**3.15**
**electrofusion socket joint**
fused combination of one or more pipe components using an electrofusion socket fitting

**3.16**
**fusion zone**
one side of an electrofusion socket joint

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

# 4 General

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

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 is required:

a) purpose and extent of testing;

b) reference sample;

c) requirements for getting access to the electrofusion socket joints, the surface condition of the pipe and the temperature range;

d) personnel qualifications;

e) reporting requirements;

f) manufacturing or operation stage of electrofusion socket joints at which the testing is to be carried out.

## 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;

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 at least the following information:

a) purpose and extent of testing;

b) reference sample;

c) requirements for access to the electrofusion socket joints, 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 elements 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 electrofusion socket joint.

## 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

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

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

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

### 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 wave modes 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 equipment.

The most suitable ultrasonic probe frequency should 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. However, the optimal frequency can be shifted up or down depending on the attenuation and thickness of the sample to be tested.



**Table 1 — Selection of probe frequency**

| Recommended frequency<br>MHz | Fitting wall thickness<br>mm |
|---|---|
| 3,5 | 30 - 50 |
| 5,0 | 10 - 50 |
| 7,5 | 10 – 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 specialty encoded scanners to facilitate the inspection.

### 7.5 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.

NOTE Any couplant used needs to be cleaned off after testing.

## 8 Range and sensitivity settings

### 8.1 Settings

#### 8.1.1 General

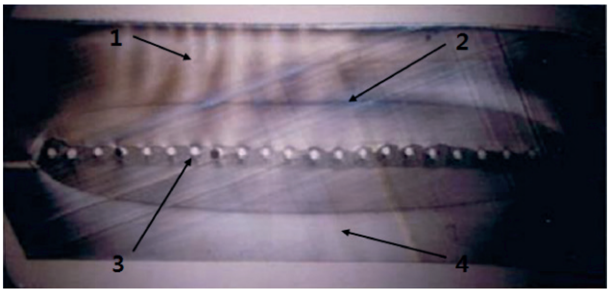
Setting of range and sensitivity shall be carried out prior to each testing period in accordance with this document. Any change of the phased array set-up (e.g. probe position and steering parameters) will require a new setting. The set-up should be optimized on the reference reflectors to give a minimum signal-to-noise ratio minimum 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). When feasible, the range monitored may be extended from the probe-fitting interface and include the inside surface of the pipe.

The range in the axial direction shall cover the nominal length of the fusion zone, which is the expected fusion length indicated by the aligned heating wires.

The range in the circumferential direction shall include the full circumference. Areas not tested due to obstacles (e.g. fusion indicators and connectors) shall be reported.

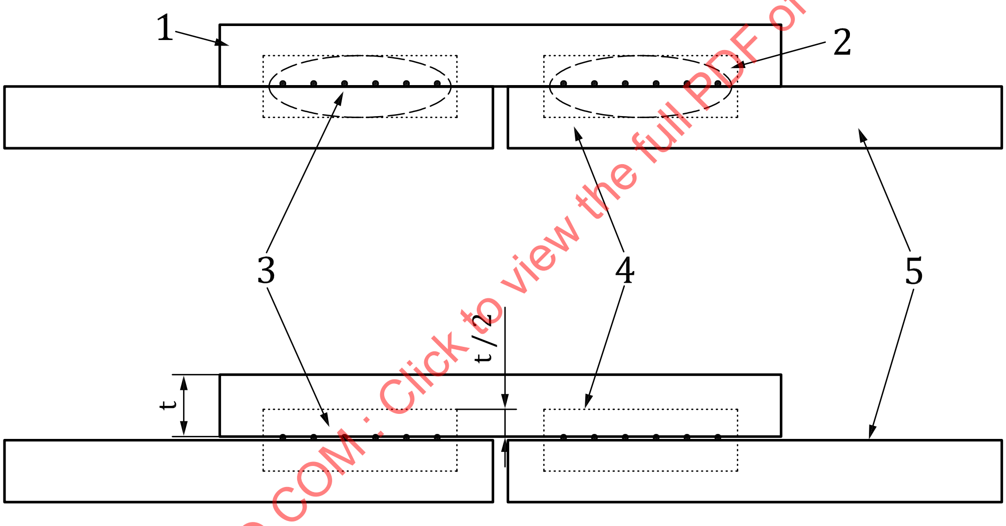



**Key**

1 electrofusion socket fitting
2 MFZ boundary
3 heating wire
4 pipe

NOTE Image source: Reference [14].

**Figure 1 — Photograph of MFZ**




**Key**

1 electrofusion socket fitting
2 MFZ boundary
3 heating wire
4 test area
5 pipe



**Figure 2 — Test area with known MFZ (top) and unknown MFZ (bottom)**

### 8.1.3 Sensitivity setting

After selection of the scanning technique, the following steps shall be taken using the same focusing, coupling and wedge or delay-line conditions for calibrating reference sensitivity as used for electrofusion socket joint testing.

a) Equalize the response for each delay law on a side-drilled hole (SDH) at the depth of interest. Ensure that the difference between each delay law shall not deviate by more than ±3 dB from the average amplitude response.

b) Set the response from the SDH to an amplitude between 40 % and 80 % screen height. This shall be considered the reference sensitivity.

c) Evaluate the scan surface interface ring time to ensure sufficient resolution exists to discern the MFZ.

d) Evaluate the resolution of adjacent turns of wire in the fitting to ensure that there is more than 12 dB drop between the peak amplitudes from adjacent turns of wire.

## 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 with SDHs satisfying the conditions in 8.2.2 or an electrofusion socket fitting satisfying the conditions in 8.2.3 shall be used as the reference sample.

### 8.2.2 Reference block

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

SDHs shall be used as reference reflectors for testing polyethylene electrofusion socket joints. The SDHs shall be located at a depth close to the thickness of the electrofusion socket fitting.

A transfer correction should be applied to account for the difference in material grade, curvature, wire diameter and surface roughness between the reference block and the test object.

An example of a reference block is given in Annex B.

### 8.2.3 Electrofusion socket fitting

The wires in an electrofusion socket fitting of the same make, geometry and size as that to be tested can be used to set the sensitivity. The probe should be placed on the outer surface of an unjoined electrofusion socket fitting. When using these reference reflectors, a transfer correction is not required if the surface roughness is similar. However, equalizing the response from each delay law is still required and shall be carried out according to 8.1.3 a).

## 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 electrofusion socket joint changes by more than 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 electrofusion socket 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 Figure B.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 electrofusion socket joints. The procedure shall be demonstrated to perform in an acceptable way on electrofusion socket joints containing representative imperfections (lack of fusion, particulate contamination, cold fusion and pipe under-penetration), which have been shown to reduce the integrity of the joint as shown by destructive testing.

The procedure qualification requires the manufacture of a series of samples of polyethylene electrofusion socket joints for each diameter range to be tested (see Table 2), some with imperfections and some without.

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

— Category A: 4 fusion zones, each containing four embedded planar imperfections (thickness of 25 µm or less) of 2 mm, 3 mm, 4 mm and 8 mm in diameter, randomly distributed around the circumference (see Annex C);

— Category B: 4 fusion zones that are cold fusions, using conditions that have been shown to generate brittle failures when tested to ISO 13954 or ISO 13955;

— Category C: 16 fusion zones, where:

  — 8 fusion zones contain no imperfections, using conditions that have been proven to generate no brittle failures when tested according to ISO 13954 or ISO 13955;

  — 4 fusion zones contain fine particulate contamination (particle size <50 µm), evenly distributed around the whole fusion joint circumference (see Annex C) and proven to generate brittle failures when tested according to ISO 13954 or ISO 13955;

  — 4 fusion zones contain under-penetrated pipe, where the end of the pipe is level with the last turn of wire on the inside edge of the fusion zone of the EF socket fitting.

For the procedure to be qualified for the imperfection detection:

— 15 or more of the 16 embedded planar imperfections (Category A) shall be detected. To be considered a detected imperfection, its reported axial position shall be within 10 mm of the true position and its reported circumferential position shall be within 20 mm of the true position, and

— 18 or more of the 20 Category B and C fusion zones shall be classified correctly, and

— For the fusion zones containing no imperfections, there shall be no false calls.

For the purposes of procedure qualification, Category B and C fusion zones shall only be classified as having imperfections or no imperfections.

NOTE 1 Indications due to voids around or between turns of heating wire are ignored during procedure qualification.

NOTE 2 Annex D provides information regarding the measurement of MFZ thickness using PAUT. MFZ thickness combined with destructive tests has been used to detect cold fusion[7][10].

Procedure qualification is only required once for each fitting diameter range (see Table 2) unless the procedure or any of the test equipment is changed.



**Table 2 — Pipe diameter ranges for the qualification of test procedures**

| Range | Nominal diameter of fitting, $d_n$<br>mm |
|---|---|
| A | $90 \leq d_n < 355$ |
| B | $355 \leq d_n < 710$ |
| C | $710 \leq d_n$ |

## 10.2 Scan increment

The scan increment setting along the circumference of the electrofusion socket joint is dependent upon the thickness of the electrofusion socket joint (fitting plus pipe) to be tested. For thicknesses up to 60 mm, the scan increment shall be no more than 1 mm. For thicknesses above 60 mm the scan increment shall be no more than 2 mm.

## 10.3 Component geometry

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, such as dirt, dust or ice. The test surface shall be examined visually and the position of any surface damage shall be reported.

## 10.5 Component temperature

The test should be conducted sufficiently after the end of the cooling time specified by the manufacturer of the fitting.

## 10.6 Testing

Before starting the test, a proper ultrasonic coupling between the probe and the electrofusion socket fitting shall be achieved and maintained throughout the scan.

The zero datum (starting position) shall be recorded and the ultrasonic probe shall be moved around the circumference of the electrofusion socket joint to test the entire circumference and width of the fusion zone. Any areas that could not be tested shall be reported.

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.

If the axial and/or circumferential length of an electrofusion socket joint is scanned in more than one section, an overlap of at least 20 mm between the adjacent scans shall be applied. The testing in the circumferential direction shall include the full joint circumference plus at least 25 mm to accommodate potential encoder error.

Reportable indications are those caused by cold fusion, voids, cracks, lack of fusion, pipe under-penetration, particulate contamination and dislocations of heating wires within the test volume.

## 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 Evaluation and analysis of test data

### 11.1 General

Evaluation 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 heating wires and cold zones in the electrofusion socket joint (see Annex A). In order to identify indications of geometric features, knowledge of the design of the electrofusion socket fitting 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 shall 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 axial 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 width of an indication is defined as the dimension along the axis of the pipe.



When an indication starts behind the indication of a heating wire, the measurement of the indication shall include the dimension of the heating wire indication. When an indication is located underneath consecutive heating wire indications, it shall be assumed that the indication is connected through the masked areas and the measurement of an indication shall include the dimensions of the heating wire indications.

### 11.6 Assessment of indications

The assessment of indications can be based on signal amplitude, equivalent reflector size, signal pattern, or other features. The amplitude drop can be used to determine the size of an indication. The width of an indication in the axial direction should be determined at the scan position of maximum extent.

NOTE The maximum amplitude and size of each indication need to 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) reference to this document;

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 test object:

   1) identification of the test object;

   2) electrofusion socket fitting dimensions (nominal pipe outside diameter, thickness of fitting, fusion zone axial length);

   3) electrofusion socket fitting identification or manufacturer's serial number;

   4) polyethylene material classification;

   5) location of fusion joint(s) examined;

   6) condition and temperature of surface;

d) information relating to equipment:

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

   2) 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) 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) electronic 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) 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.



# Annex A
(informative)

# Examples of phased array images

This annex provides examples of phased array images.

The phased array image in Figure A.1 shows clear indications from the heating wire coil along the fusion interface.

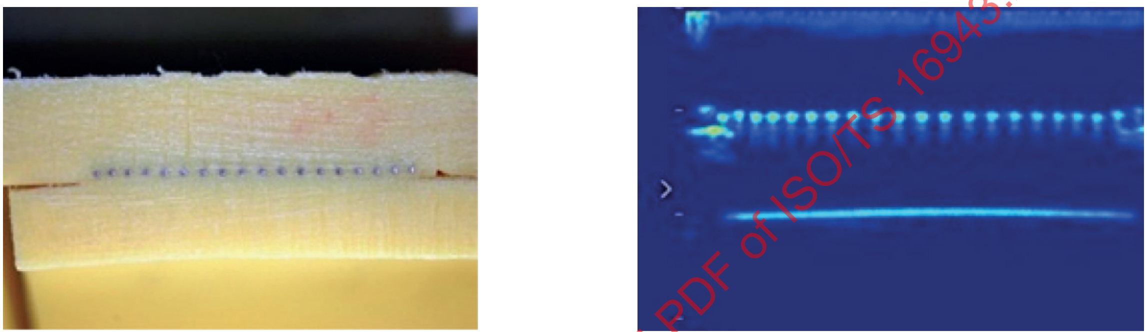


**Figure A.1 — EF socket joint without indications of imperfections**

In Figure A.2 the white line located underneath the wires indicates an imperfection at the fusion interface.

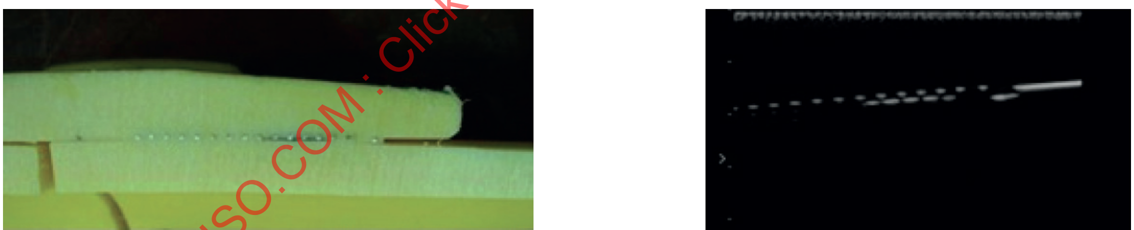


**Figure A.2 — Indication of imperfection in an EF socket joint**

The phased array image in Figure A.3 shows the dislocation of heating wires due to overheating.

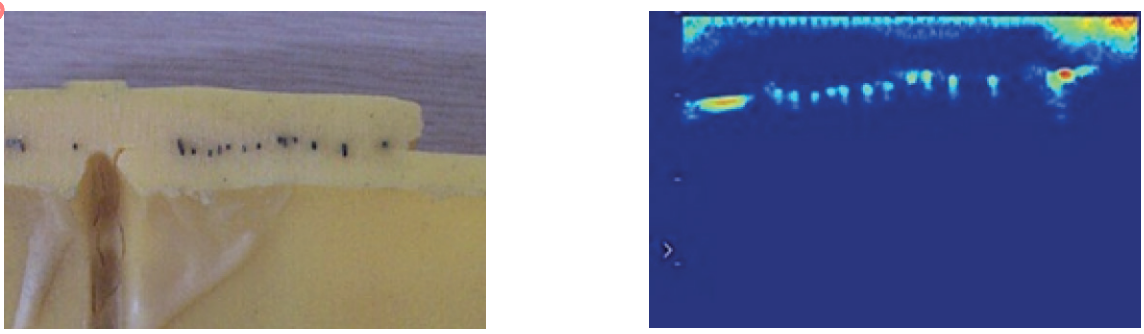


**Figure A.3 — Dislocation of heating wires**

In Figure A.4, if an imperfection is located in the plane of the wires or just above, it is a void.

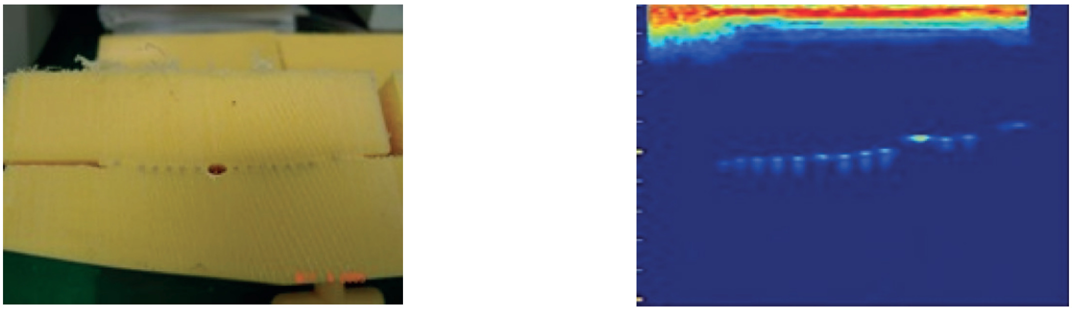


**Figure A.4 — Voids in EF joint**

Figure A.5 is a phased array image from soil embedment at the fusion interface.

**Figure A.5 — Soil in an EF socket joint**

Figure A.6 is a phased array image from pipe under-penetration.

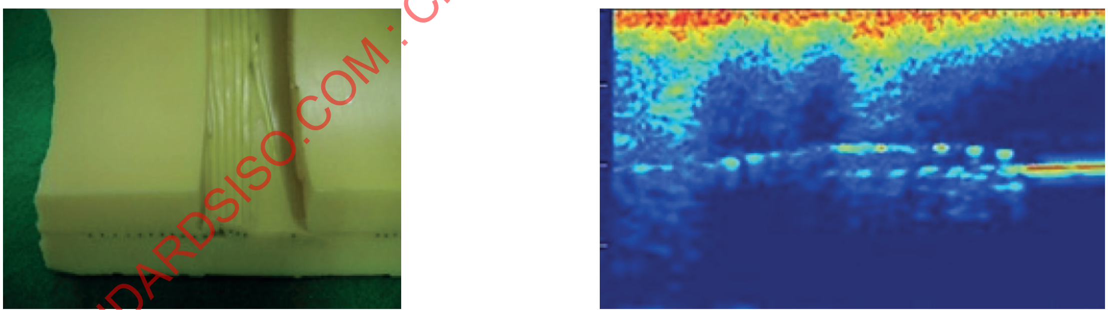


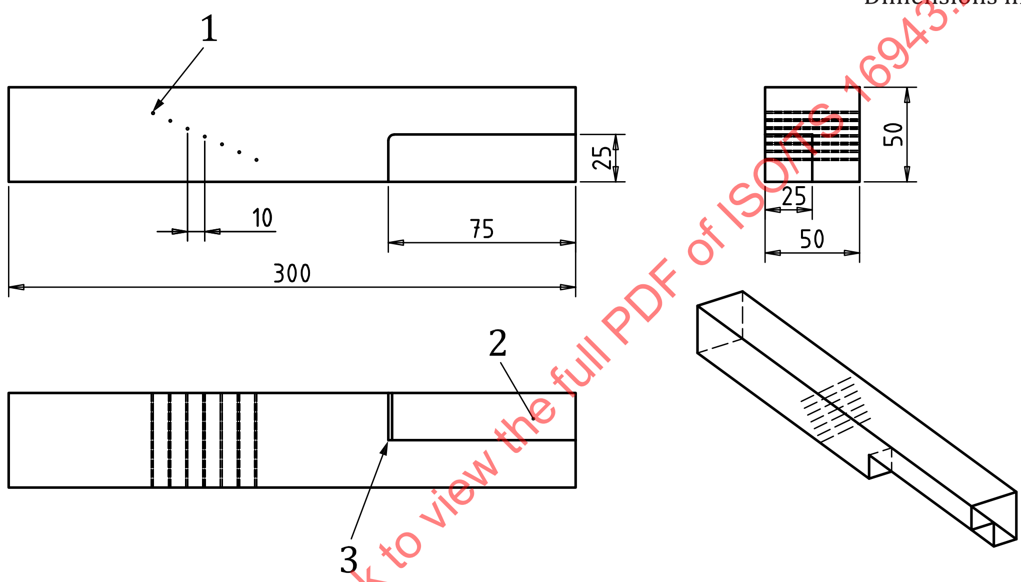
**Figure A.6 — Pipe under-penetration in an EF socket joint**

# Annex B
(informative)

## Example of a reference block

To set up the test sensitivity, a reference block can be used. The reference block should be made of the same, or acoustically equivalent, material as that to be tested. The shape and dimensions of a possible reference block are illustrated in Figure B.1.

Dimensions in millimetres




**Key**

1 7 × Ø 3,0 mm SDHs at depths between 10 mm and 40 mm in 5 mm steps

2 velocity calibration step

3 radius ≤ 3 mm

**Figure B.1 — Example of a reference block**

Holes should be drilled and reamed, and they should be essentially parallel to the test surface. The diameter of the holes should be similar to the diameter of the heating wire in the electrofusion socket joint being tested.

Choose the SDH whose depth position (hole to surface) is closest to the thickness of the electrofusion socket fitting to be tested. Maximize the signal from the SDH and adjust the gain to give 80 % of full screen height.

Where there is a difference in sound attenuation between the reference block and the test object, a transfer correction is required to compensate for the difference. The correction is accomplished by noting the difference between signals received from the back surfaces of the reference block and the test object having equal thickness and correcting for this difference.

Where there is a difference in sound velocity between the reference block and the test object, the compensation of length measurement error should be corrected by measuring the horizontal and vertical length of two points in the reference block and in the test object.



# Annex C
(informative)

# Example procedures for producing imperfections in electrofusion socket joints

## C.1 Planar lack of fusion

a) Clean the pipe ends using water and a lint-free cloth.

b) Use another lint-free cloth to dry the pipe ends.

c) Mark the end of the pipe to the insertion depth of the fitting.

d) Scrape the surface of the pipe using a suitable mechanical scraping tool (see Figure C.1).

**Figure C.1 — Mechanical scraping of pipe prior to applying artificial imperfections**

e) Place an aluminium disc (25 µm thick) on to the scraped surface of the pipe using static-free tweezers and use a soldering iron to heat-stake the aluminium disc on to the scraped pipe surface (see Figure C.2), being careful to avoid using too much pressure, which could distort the disc.

NOTE For discs above 4 mm in diameter, ideally the discs are heat-staked in several locations.

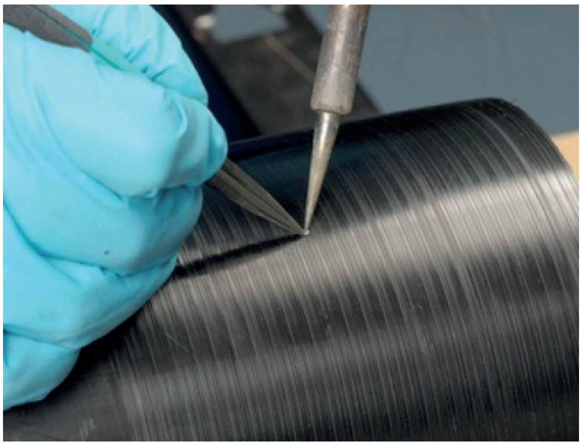


**Figure C.2 — Heat-staking of the aluminum disc on to the pipe**

Pin-staking[15] has also been successfully used for attaching the aluminium discs to the pipe surface.

f) Repeat this procedure for all of the discs.

g) Remove the pipe from the clamps and carefully insert into the bore of the electrofusion socket fitting, making sure not to displace the aluminium discs.

h) Repeat steps a) to g) for the second pipe and carry out the fusion joining operation.

## C.2 Fine particulates

a) Clean the pipe end using water and a lint-free cloth.

b) Dry the pipe using another clean lint-free cloth.

c) Mark the end of the pipe to the insertion depth of the electrofusion socket fitting.

d) Scrape the surface of the pipe using a suitable mechanical scraping tool (see Figure C.1) and place on a support.

e) Pour a small amount of micronized talc (particle size <50 µm) on a flat metal surface and spread evenly.

f) Roll a soft rubber roller back and forth over the talc to pick up an even layer of contamination and use a soft-haired brush to remove excess talc from the roller (see Figure C.3).

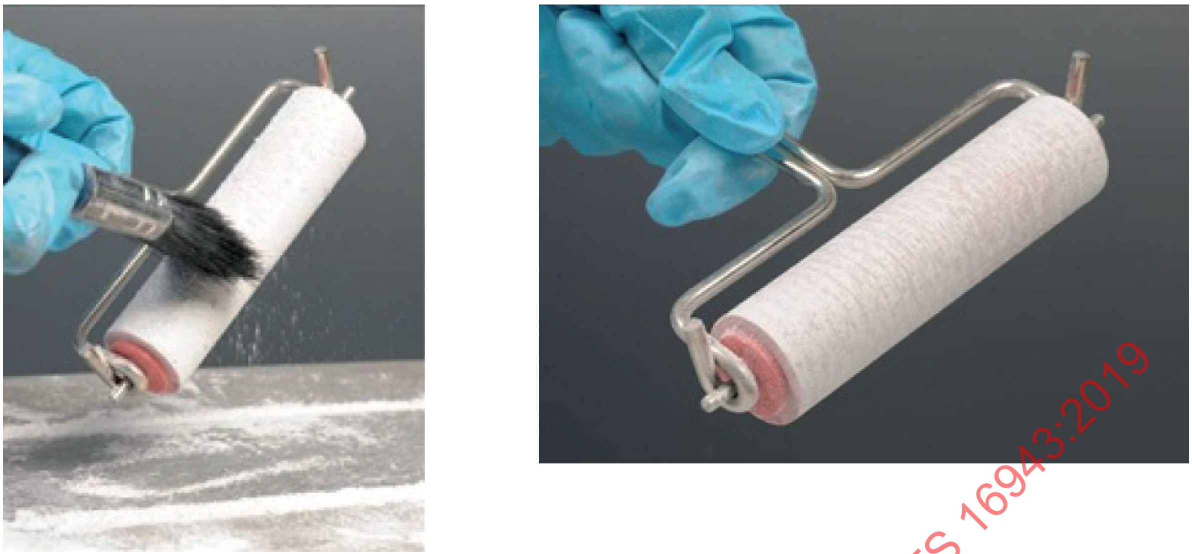


**Figure C.3 — Preparation of the roller with talc contamination**

g) Hold the roller against the scraped pipe surface and slowly rotate the pipe until the roller has completed one revolution (see Figure C.4).

**Figure C.4 — Application of talc contamination**

h) Use a soft-haired brush to even out the distribution of particulate contamination (see Figure C.5) until a visually uniform level of contamination is achieved (see Figure C.6).