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**Thermoplastic pipes for the conveyance of fluids – Inspection of polyethylene butt fusion joints using time of flight diffraction testing**

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~~In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard (“state of the art”, for example), it may decide by a simple majority vote of its participating members to publish a Technical Specification.~~

~~The committee responsible for this document is~~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.



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# Thermoplastic pipes for the conveyance of fluids — Inspection of polyethylene butt fusion joints using time of flight diffraction testing

## 1 Scope

This document describes the time of flight diffraction (TOFD) testing 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 requirement 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 acceptance criteria are not covered in this document.

NOTE\_1 At the present time laboratory experiences exist on the use of TOFD for polyethylene butt fusion joints and/or reference blocks of wall thickness between 8 mm to 100 mm [1+02+03+04+05+06]. Recently field experience on butt fusion joints in HDPE pipes has been reported [7].

NOTE\_2 Round robin testing has shown that TOFD is a viable method for enhancing the integrity assessment of butt-fusion joints [14].

NOTE\_3 TOFD 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 [14].

## 2 Normative references

The following referenced standards are indispensable for the application 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 inspection — 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 terms and definitions apply.

ISO and IEC maintain **terminological 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 <http://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 ID or OD surface of the butt fusion joint

#### **3.8**

##### **void**

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

#### **3.9**

##### **time-of-flight diffraction image / TOFD- image**

two-dimensional image, constructed by collecting adjacent A-scans while moving the time-of-flight diffraction setup

NOTE 1 to entry: The signal amplitude of the A-scan is typically represented by grey-scale values

### **3.10**

#### **time-of flight diffraction set-up/ TOFD setup**

probe arrangement defined by probe characteristics (e.g. frequency, probe element size, beam angle, wave mode), probe position, *probe centre separation* (3.11) and the number of probe pairs

### **3.11**

#### **probe centre separation**

distance between the index points of the two probes

**NOTE-Note 1 to entry**:- The probe centre separation for two probes located on a curved surface is the straight-line, geometric separation between the two probe indexes and not distance measured along the surface.

### **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 TOFD equipment, the preparation and performance of the test, the indication assessment and the reporting for polyethylene butt fusion joints. The acceptance criteria are not covered in this document.

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

Characterisation 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 test procedure development**

Information on the following items is required:

- purpose and extent of testing;
- reference sample;
- requirements for getting access to the butt fusion joints, the surface condition of the pipe; and the temperature range
- personnel qualifications;

- reporting requirements;
- manufacturing or operation stage of butt fusion joints at which the testing is to be carried out.

## **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) a) written test procedure, qualified in accordance with Clause 10;
- b) b) all relevant joint dimensions.

## **5.3 Written qualified test procedure**

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

- a) a) purpose and extent of testing;
- b) b) reference sample;
- c) c) requirements for access to the butt fusion joints and surface conditions and temperature;
- d) d) personnel qualifications;
- e) e) reporting requirements;
- f) f) equipment requirements and settings (including but not limited to frequency, sampling rate and element size, probe centre separation);
- g) g) evaluation of indications;
- h) h) environmental and safety issues;
- i) 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 butt fusion 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 operator shall be familiar with and have practical experience in the use of TOFD 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. 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.

**Note-NOTE 1:** In selecting the system components (hardware and software) ISO TS 16829<sup>[8]</sup> give useful information.

**Note-NOTE 2:** Ultrasonic equipment used for TOFD testing should comply with the requirements of ISO 15626<sup>[9]</sup> EN-12668 <sup>[10]</sup> when applicable.

### 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 wave mode can be used.

#### 7.3.1 Probe selection

Any type of ultrasonic TOFD probe can be used if it satisfies the requirement of **Section-Clause 8** (Range and sensitivity settings) with the ultrasonic equipment.

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.

For thicknesses greater than 30 mm the wall thickness shall be divided into more than one inspection zone, each zone covering a different depth region. Probe angle and frequencies shall be chosen to cover full volume. These zones can be inspected simultaneously or separately. Table-2 shows the examples of single and multiple inspection zone probe setup.

**Table-1— Selection of probe frequency**

Wall Thickness (t) mm	Number of TOFD setups	Centre Frequency MHz	Recommended Beam angle (longitudinal waves)	Element size mm
8 ≤ t < 30	1 or 2	5 to ≤ 10	60 to ≤ 70	3 to ≤ 6