- professional
- customer focused
- cost aware

New Prestandard CEN/TS 14751 :

TOFD on Weld Seams

ECNDT 2006
Berlin, 25.-29. September 2006
We.2.7.2

Dr.-Ing. Andreas Hecht
Plant Inspection / Materials Engineering

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Verbund Site

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European Prestandard CEN/TS 14751 TOFD on Weld Seams

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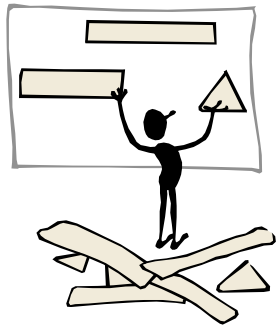
- **TOFD** Time-of-Flight Diffraction Technique
- Existing codes / recommendations / standards on TOFD
- Implementation of DIN CEN/TS 14751 within other European NDT – Standards on weld-testing
- European Prestandard **DIN CEN/TS 14751**
- Further European Activities



Principle of TOFD

Diffraction (not Reflection)

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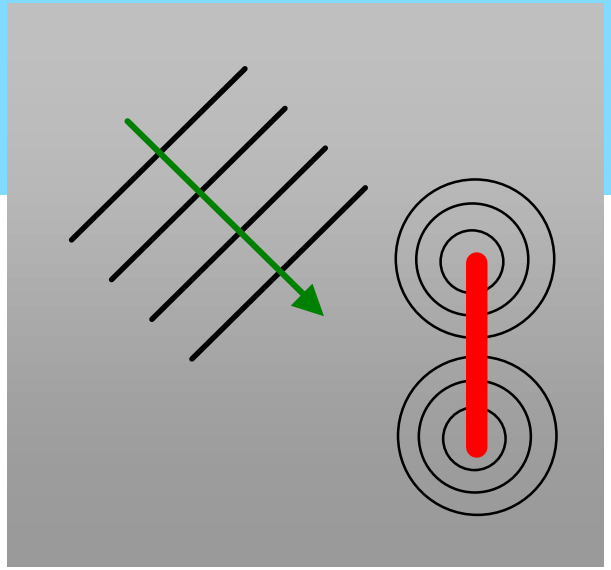
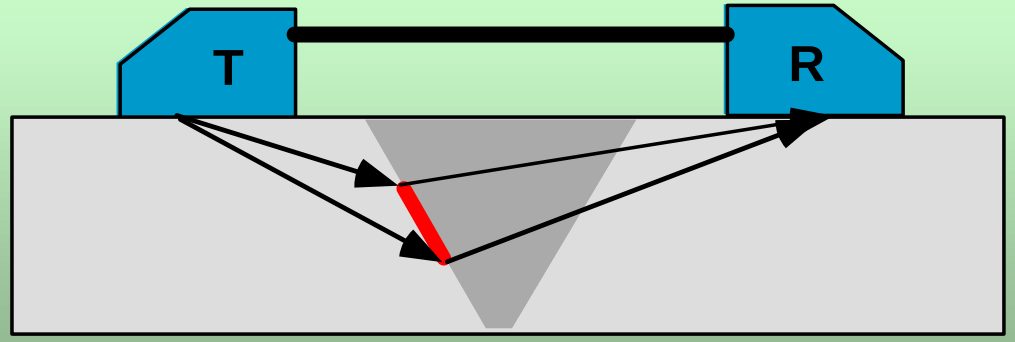


- rigid mechanical coupling
  of transmitter and receiver
- no scanning, movement only along the weld
- preferably longitudinal waves
- wide angles of divergence required
- received signals of low amplitude



diffraction of the ultrasonic wave at the edges of a defect

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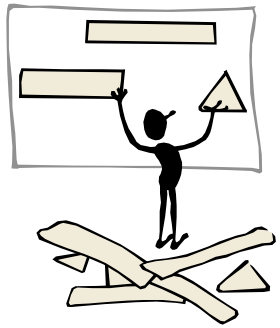

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Existing codes / recommendations / standards on TOFD

Europe

- **BS 7706** (national) December 1993
  Guide to calibration and setting-up of the ultrasonic TOFD-technique for the detection, location and sizing of flaws
- **ENV 583-6** (European pre-standard) January 1997
  TOFD as a method for defect detection and sizing
- **CEN/TS 14751** (CEN Technical specification) November 2004
  Welding – Use of TOFD for examination of welds

Other

- **ASME Code Case 2235** since 1998, at present: 2235-9 from Oct. 2005
  Use of ultrasonic examination in lieu of radiography
  (see also interpretation VIII-1-98-41)
- **ASTM E 2373-04** July 2004
  Standard practice for the ultrasonic TOFD-technique
- **2006 ASME Code, Section V** 2006
  Article 4, Mandatory Appendix III, Non-mandatory Appendix L and N

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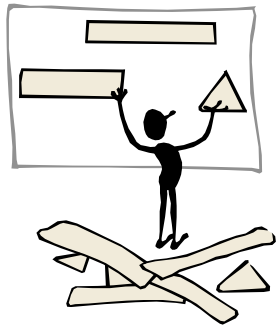

TOFD on Weld Seams

Implementation of TOFD-prestandard into European NDT-weld-testing system created by CEN/TC 121/SC 5

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EN ISO 5817 – fusion welded joints quality levels for imperfections

EN 12062 – NDE of welds

	basic standard	weld examination standard	acceptance levels
RT	EN 444	EN 1435	EN 12517
UT	EN 583-1	EN 1714	EN 1712
MT	EN ISO 9934-1	EN 1290	EN 1291
PT	EN 571-1	EN 571-1	EN 1289
VT	EN 13018	EN 970	EN ISO 5817
TOFD	ENV 583-6	CEN/TS 14751	in progress

Constraints / Explanations

- Table is valid for fabrication inspections within the EU
- Main standard EN 12062 has to be reviewed:
  - EN 25817 → EN ISO 5817
  - TOFD to be implemented
- ENV 583-6 from 1997 acts as a basic standard
- Weld testing standard CEN/TS 14751 completed
- Technical Specification (TS) means: „state-of-the-art is not yet stable enough“
- EN-standard for acceptance levels in progress

TOFD on Weld Seams

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European Working Group

- CEN/TC 121/SC 5B/WG 2 resolution from October 1999
- Formation of a working-group

Hecht (chairman)	D	BASF
Chardome	B	AIB Vincotte
Chauveau	F	Institute de Soudure (IS)
Hughes	GB	Health & Safety Executive (HSE)
Kenzie	GB	The Welding Institute (TWI)
Pers-Anderson	S	Westinghouse TRC
Rasmussen	DK	FORCE
Schlengermann	D	GE Inspection
Vandriessche	B	AIB Vincotte
Verkooijen	NL	Sonovation
Walaszek	F	CETIM

- 9 meetings from August 2000 up to October 2002

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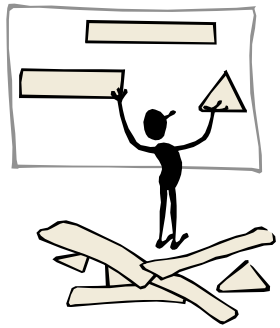

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European Frontpage

TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

TECHNISCHE SPEZIFIKATION

CEN/TS 14751

November 2004

ICS 25.160.40

English version

Welding - Use of time-of-flight diffraction technique (TOFD) for examination of welds

Soudage - Utilisation de la technique de diffraction des temps de vol (méthode TOFD) pour le contrôle des soudures

Schweißverbindungen - Anwendung der Beugungslaufzeittechnik (TOFD) für die Prüfung von Schweißverbindungen

This Technical Specification (CEN/TS) was approved by CEN on 11 July 2004 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

CEN members are required to announce the existence of this CEN/TS in the same way as for an EN and to make the CEN/TS available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the CEN/TS) until the final decision about the possible conversion of the CEN/TS into an EN is reached.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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1 Scope

This document specifies the application of the time-of-flight diffraction (TOFD) technique for the semi-, or fully-automated ultrasonic testing of fusion welded joints in metallic materials equal to and above 6 mm thickness. It is primarily intended for use on full penetration welded joints of simple geometry in plates, pipes, and vessels, where both the weld and parent material are low alloyed carbon steel. Where specified and appropriate, TOFD may also be used on other types of materials that exhibit low ultrasonic attenuation (especially that due to scatter).

Where material dependent ultrasonic parameters are specified in this document, they are based on steels having a sound velocity of (5920 ± 50) m/s for longitudinal waves, and (3255 ± 30) m/s for transverse waves. This has to be taken into account when examining materials with a different velocity.

This document makes reference to the basic pre-standard ENV 583-6 and provides guidance on the specific capabilities and limitations of TOFD for the detection, location, sizing and characterisation of discontinuities in fusion welded joints. TOFD may be used as a stand-alone method or in combination with other NDT methods or techniques, both for manufacturing inspection (pre-service) and for in-service inspection.

This document specifies four examination levels (A, B, C, D) corresponding to an increasing level of inspection reliability. Guidance on the selection of examination levels is provided.

This document permits assessment of indications for acceptance purposes. This assessment is based on the evaluation of transmitted, reflected and diffracted ultrasonic signals within a generated TOFD image.

This document does not include acceptance levels for discontinuities.

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Capabilities and Limitations

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4 General remarks on the capabilities of the technique

General principles of the TOFD-technique are described in ENV 583-6. For the testing of fusion welded joints some specific capabilities and limitations of the technique have to be considered.

The TOFD technique is an ultrasonic image-generating technique, which offers the capability of detection, location and sizing. To a certain extent characterisation of discontinuities in the weld material as well as in the adjacent parent material is also possible.

Compared with purely reflection-based techniques, the TOFD technique, which is based upon diffraction as well as reflection, is less sensitive to the orientation of the discontinuity. Discontinuities oriented perpendicular to the surface, and at intermediate angles of tilt, are detectable as well as discontinuities in the weld fusion faces.

There is a reduced capability for the detection of discontinuities close to or connected with the scanning surface or with the opposite surface. This has to be considered especially for crack-sensitive steels or at in-service inspections. In cases where full coverage of these zones is required, additional measures shall be taken. By example, TOFD can be accompanied by other NDT-methods or -techniques, e.g. conventional pulse-echo testing, see EN 1714.

Diffracted signals from weld-discontinuities have small amplitudes comparable to grain-scatter signals from coarse-grained materials which may hinder the detection and evaluation of discontinuities.

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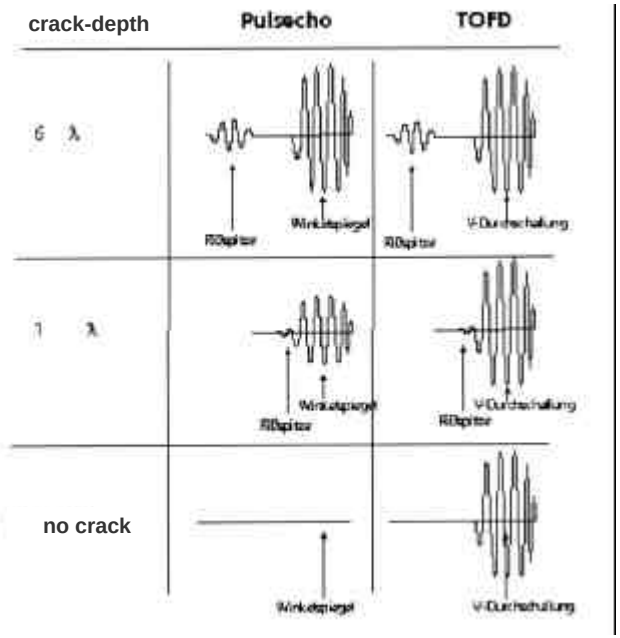
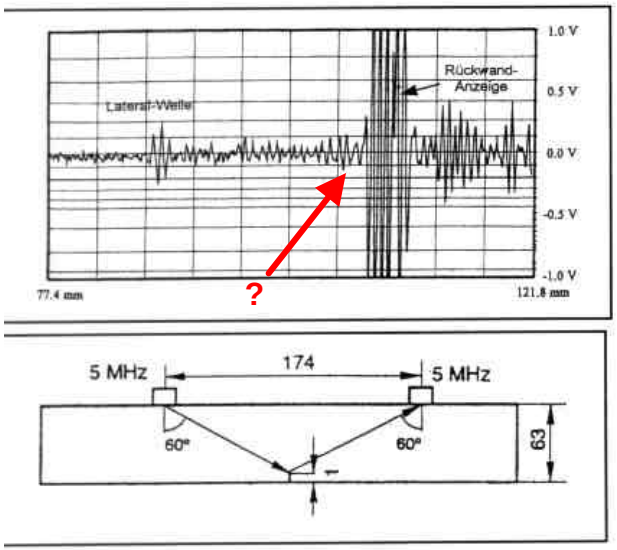
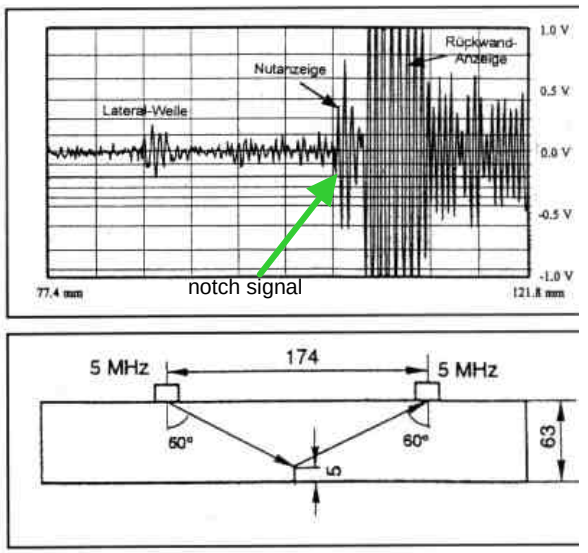
Limited capability of detection at surfaces

- Dead zone at scanning-surface, caused by pulse-length
- Zone of limited sensitivity at opposite-surface, caused by interference between tip-diffraction and backwall; depends of wave-length and pulse-length

Comparison pulse-echo / TOFD acc. to Schmitz and Müller (IZfP-Saarbrücken)







- Measurements of Kreier (Innotest) and Brekow (BAM) published at ECNDT 1998
- notch 5 mm deep: diffraction signal of notch tip clearly visible
  notch 1 mm deep: no definite diffraction signal

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5 Examination levels

This document specifies four examination levels (A, B, C and D). From examination level A to examination level C an increasing reliability will be achieved.

Table 1 — Examination levels

examination level	TOFD set-up	reference block for set-up verification (see 8.2)	reference block for sensitivity settings (see 10.1.4)	offset-scan	Written test instruction
A	acc. to Table 2	no	No	no	this TS
B	acc. to Table 2	no	Yes	no	this TS
C	acc. to Table 2	yes	Yes	a	yes
D	as specified	yes	Yes	a	yes

[a] the necessity, number of and position of offset scans has to be determined

For pre-service inspections (see also EN 12062) all examination levels are applicable. Level A is only applicable for wall-thickness up to 50 mm. For in-service inspections only examination level D shall be applied.

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proposed table for EN 12062 - revision

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- **Proposal** made by German experts of CEN/TC 121/SC 5B/WG 2 (UT)
- Has to be accepted by CEN/TC 121/SC 5B (NDT of welds) and CEN/TC 121 (Welding)

Table A7: time-of-flight diffraction technique (TOFD)

Quality class according to EN ISO 5817	Examination level according to CEN/TS 14751	Acceptance level according to EN xxxxx (actually doc. N377)
B	C	1
C	B	2
D	A	3

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8.2 Set-up of Probes

Table 2 — Recommended TOFD set-ups for simple butt-welds dependent on wall-thickness

Thickness t / mm	Number of TOFD set-ups	Depth-range Δt / mm	Centre-frequency f / MHz	Beam-angle α / ° (long.-waves)	Element – size / mm	Beam intersection
6-10	1	0-t	15	70	2-3	2/3 of t
10-15	1	0-t	15-10	70	2-3	2/3 of t
15-35	1	0-t	10-5	70-60	2-6	2/3 of t
35-50	1	0-t	5-3	70-60	3-6	2/3 of t
50-100	2	0-t/2	5-3	70-60	3-6	1/3 of t
		t/2-t	5-3	60-45	6-12	5/6 of t; or t for $\alpha \leq 45°$
100-200	3	0-t/3	5-3	70-60	3-6	2/9 of t
		t/3-2t/3	5-3	60-45	6-12	5/9 of t
		2/3t-t	5-2	60-45	6-20	8/9 of t; or t for $\alpha \leq 45°$
200-300	4	0-t/4	5-3	70-60	3-6	1/12 of t
		t/4-t/2	5-3	60-45	6-12	5/12 of t
		t/2-3t/4	5-2	60-45	6-20	8/12 of t
		3t/4-t	3-1	50-40	10-20	11/12 of t; or t for $\alpha \leq 45°$

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12 Interpretation and analysis of TOFD images

similar to
RT - film interpretation

12.1 General

Interpretation and analysis of TOFD images is generally performed as follows:

- Assessing the quality of the TOFD-image;
- Identification of relevant indications and discrimination of non-relevant indications;
- Classification of relevant indications in terms of:
  — embedded (linear, point-like);
  — surface breaking;
- Determination of location (typically position in x- and z-direction) and size (length and through-wall extent);
- Evaluation against acceptance criteria.

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12.2 Assessing the quality of the TOFD image

A TOFD-testing has to be carried out such that satisfactory images are generated which can be evaluated with confidence. Satisfactory images are defined by appropriate:

— coupling, see 8.7 and Clause 11;
— data acquisition, see Clause 11;
— sensitivity setting, see 10.1.4;
— time-base setting, see 10.1.2.

Assessing the quality of TOFD-images requires skilled and experienced operators, see 7.1. The operator has to decide whether non-satisfactory images require new data acquisition (rescanning).

Examples of non-satisfactory images are given in Annex B.1.

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What is a relevant TOFD-indication ?

12.3 Identification of relevant indications

Satisfactory TOFD images shall be assessed for the presence of indications. Indications are identified by patterns or disturbances within the image.

TOFD is able to image discontinuities in the weld as well as geometric features of the test object. In order to identify indications of geometric features, detailed knowledge of the test object is necessary. Those indications arising from the intended or actual shape of the test object are considered as non-relevant. Examples of geometric indications are given in Annex B.3.

To decide whether an indication is relevant (caused by a discontinuity), patterns or disturbances have to be evaluated considering shape and signal amplitude relative to general noise level. The extent of an indication may need to take account of grey level values or patterns of neighbouring sections.

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12.4 Classification of relevant indications

12.4.1 General

Amplitude, phase, location and pattern of relevant indications may contain information on the type of discontinuity.

Relevant indications are classified either as indications from surface-breaking or embedded discontinuities by analysing the following features:

a) disturbance of the lateral wave;
b) disturbance of the backwall reflection;
c) indications between lateral wave and backwall reflection;
d) phase of indications between lateral wave and backwall reflection;
e) mode converted signals after the first backwall reflection.

Some typical TOFD-images of discontinuities in fusion welded joints are provided in Annex B.2.

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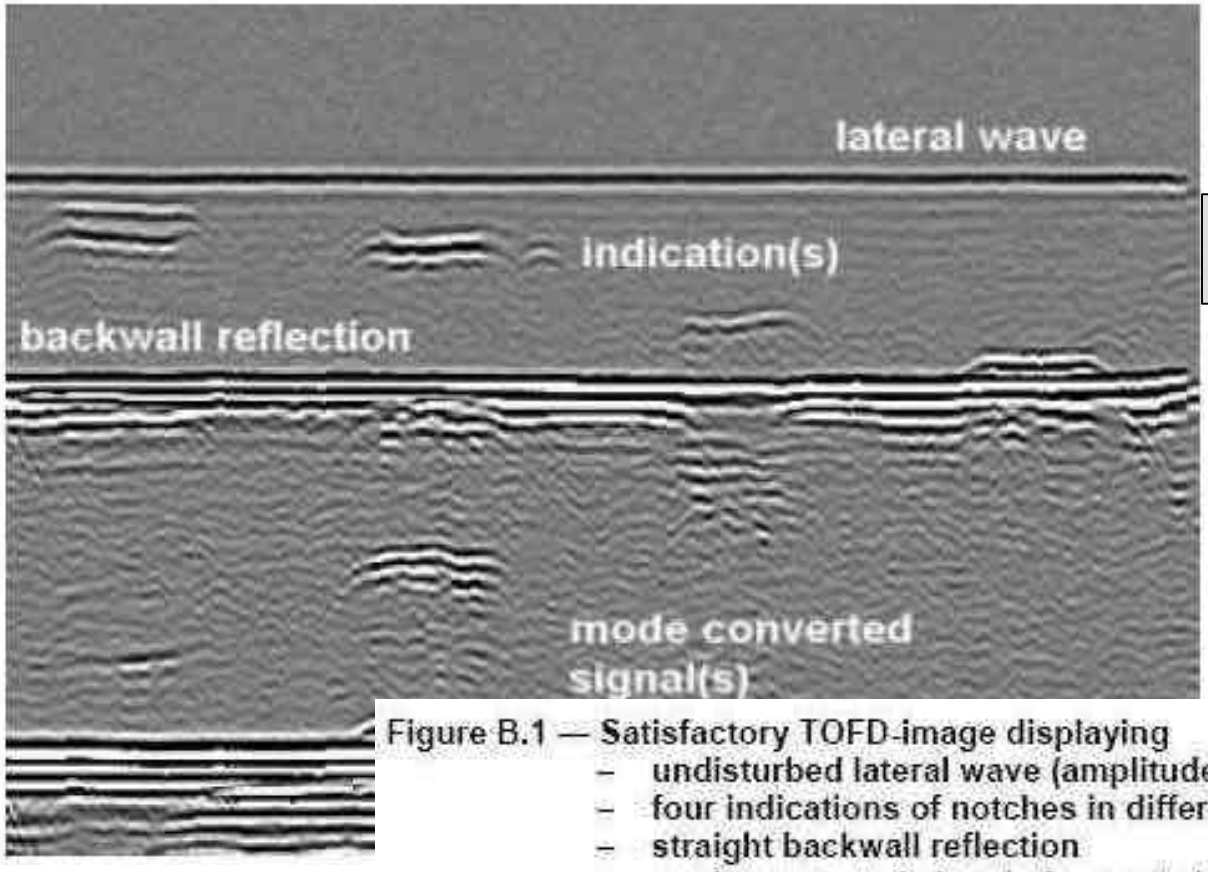
Annex B1: Satisfactory Image

B.1 Satisfactory and unsatisfactory TOFD-images



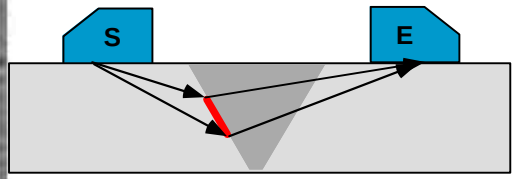


Figure B.1 — Satisfactory TOFD-image displaying
- undisturbed lateral wave (amplitude between 40 % and 80 % FSH)
- four indications of notches in different depths
- straight backwall reflection
- mode converted signals from notches and backwall

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Annex B1: Gain Setting too low

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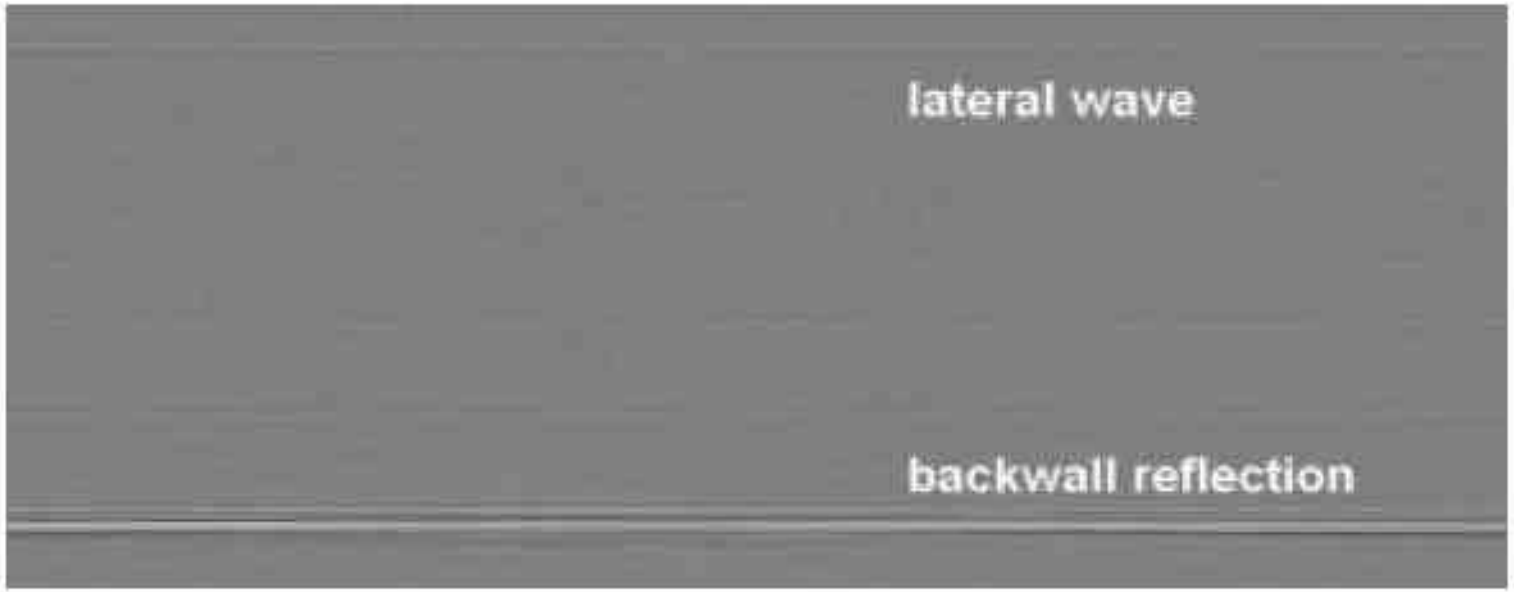

Figure B.2 — Gain setting too low
Amplitude of lateral wave << 40 % FSH

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Ánnex B1: Gain Setting too High

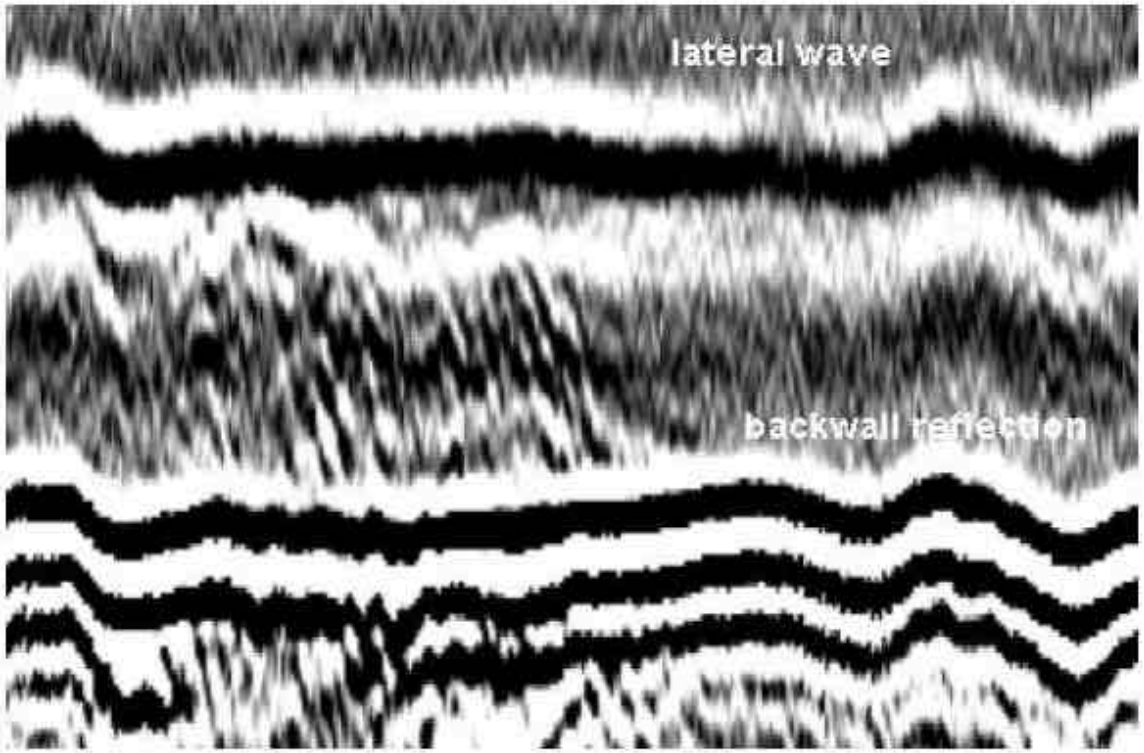

Figure B.3 — Gain setting too high
Amplitude of lateral wave >> 80 % FSH (saturated)

from CEN/TS 14751

from ASME V 2006

FIG. N-483(c) TOFD IMAGE WITH GAIN SET TOO HIGH

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Annex B1: Coupling Losses

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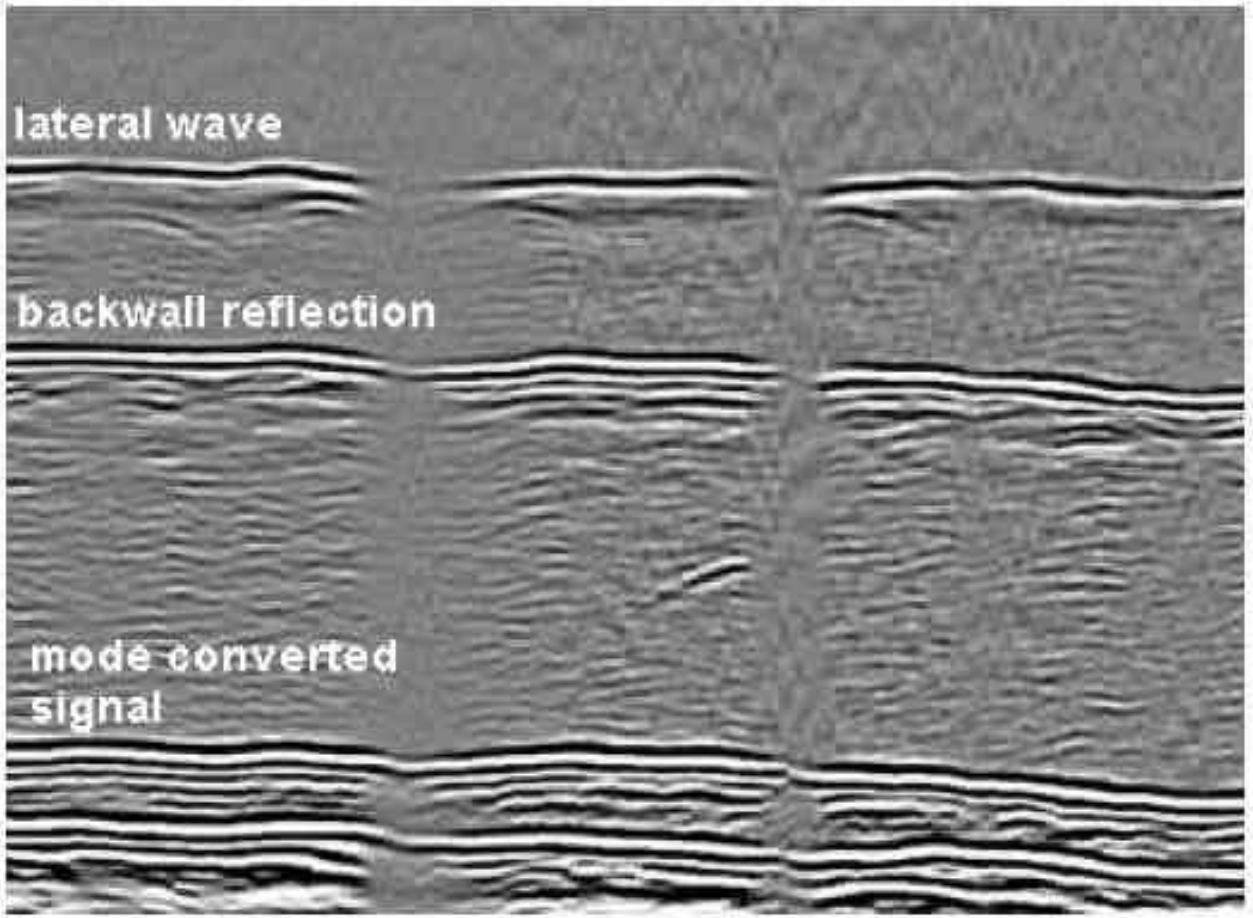

Figure B.7 — Loss of signals due to lack of couplant

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Unsatisfactory Image from On-Site-Inspection (not included)

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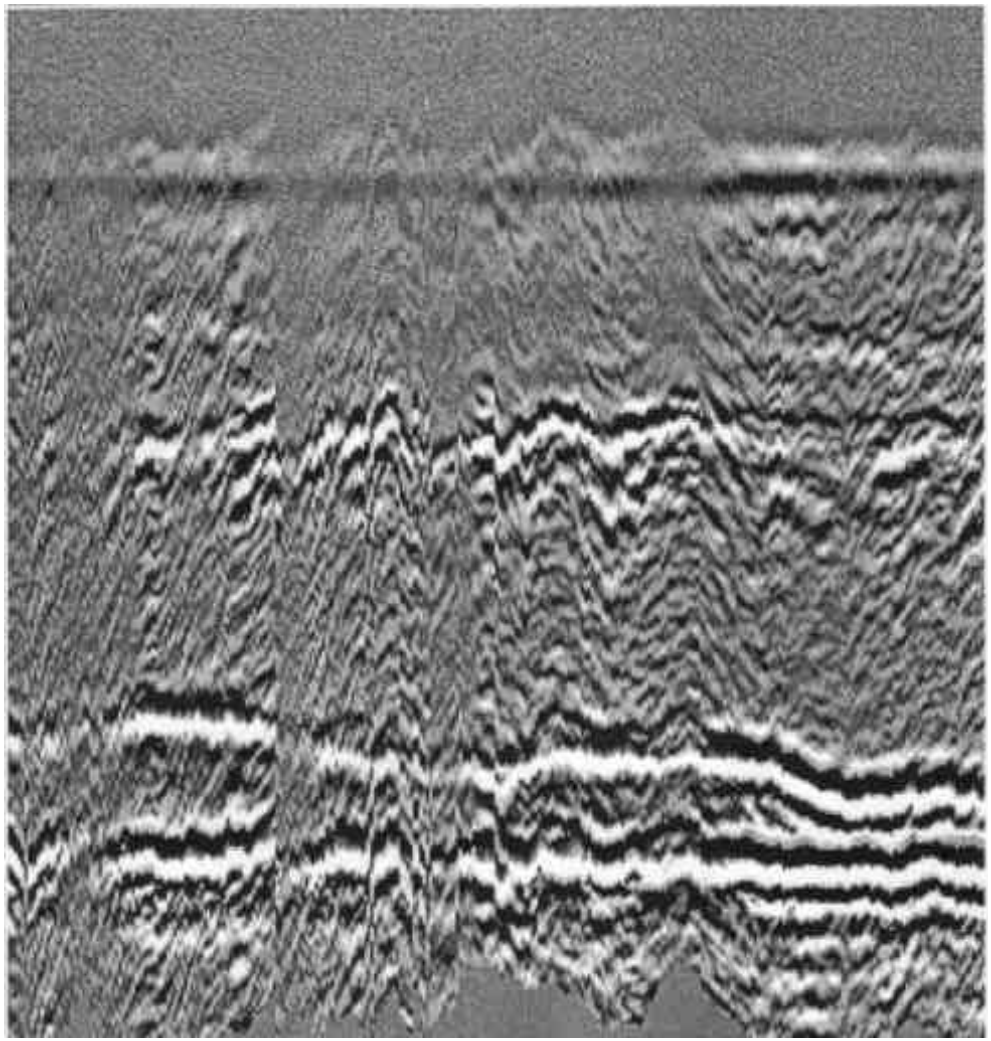

- gain-setting slightly to high
- coupling losses
- electronic trigger-problems

- **result**:
  „no relevant indications“

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Annex B2: Indication from Opposite Surface

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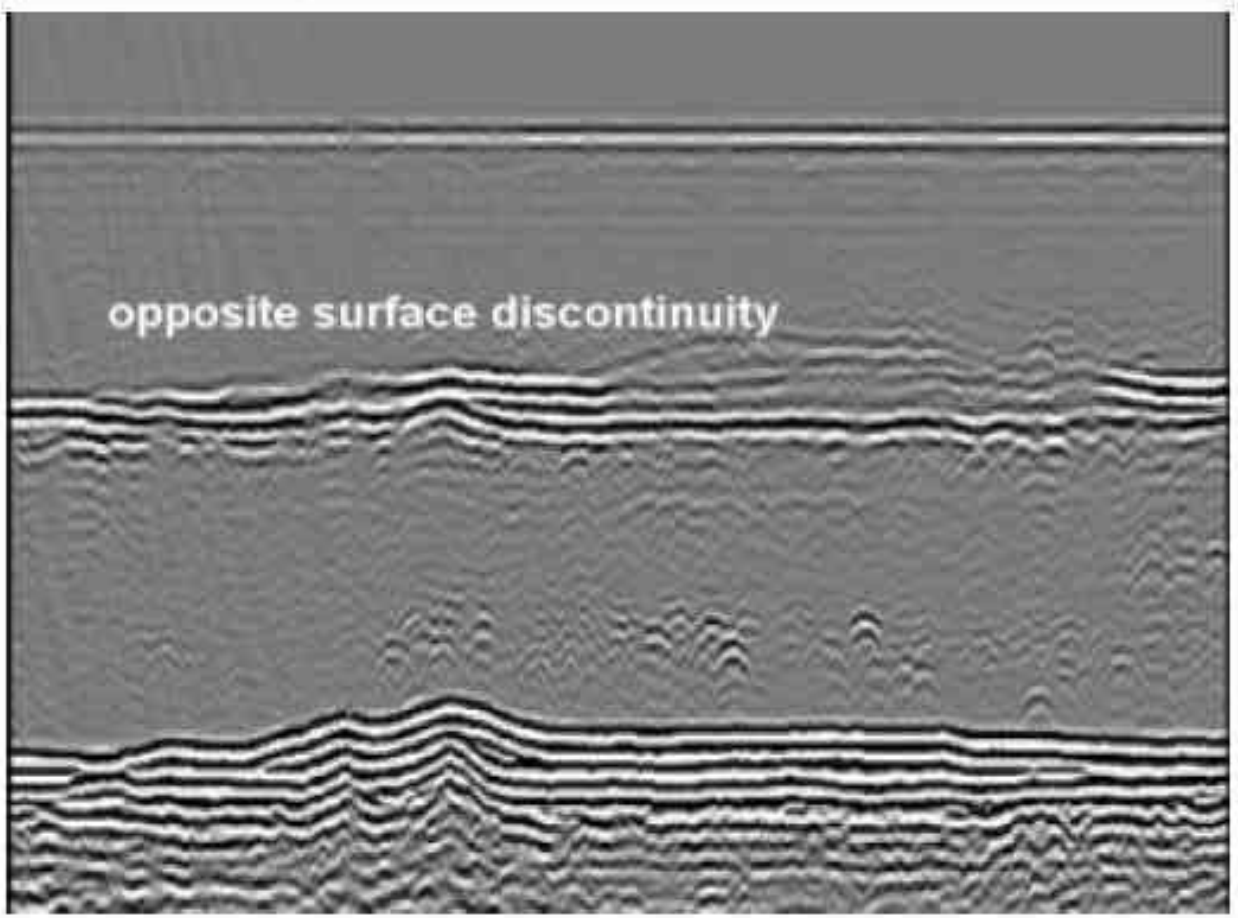

Figure B.10 — Elongated indication of an opposite surface breaking discontinuity

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Annex B3: Indication with measurable length and height

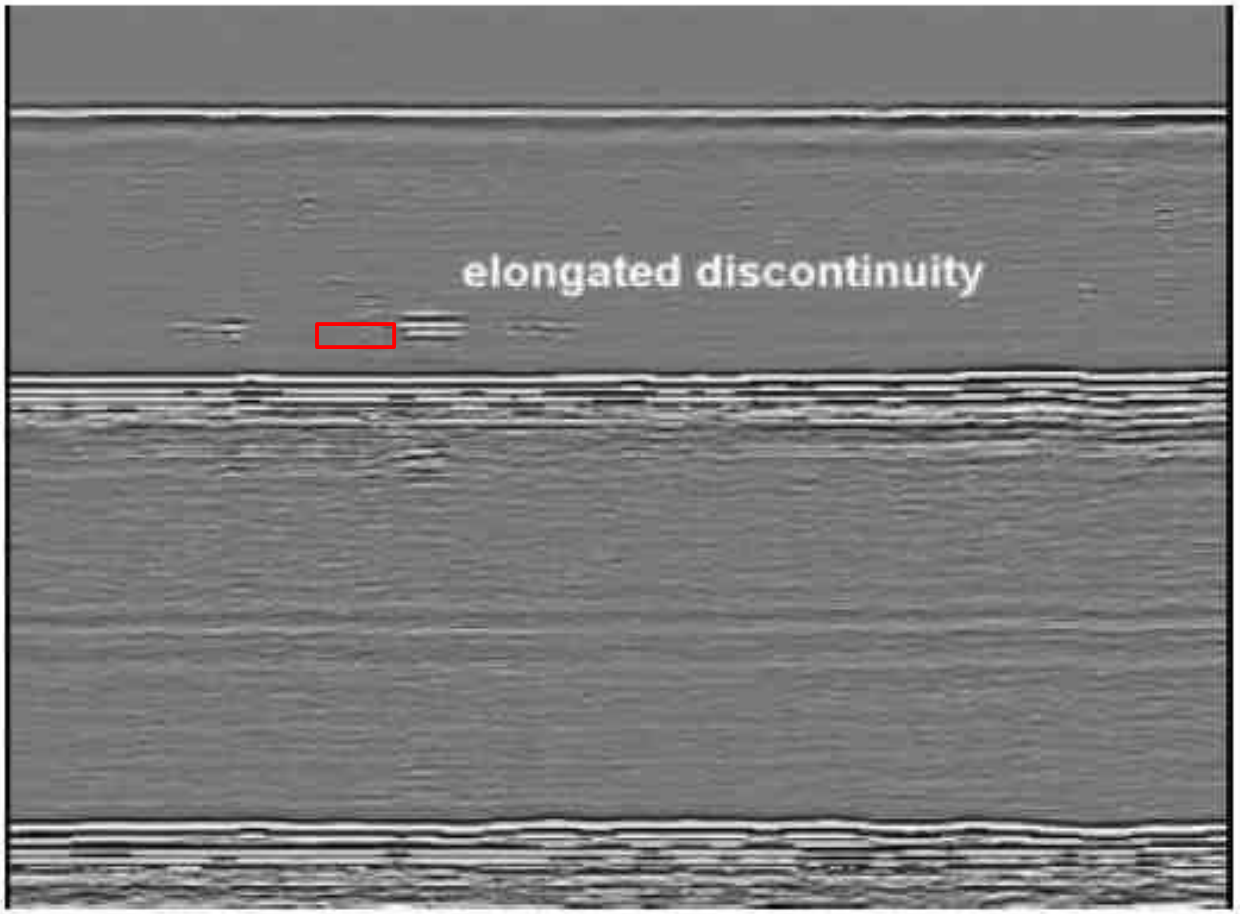

Figure B.14 — Indication of an elongated discontinuity with measurable height

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Annex B3: Geometrical Indication

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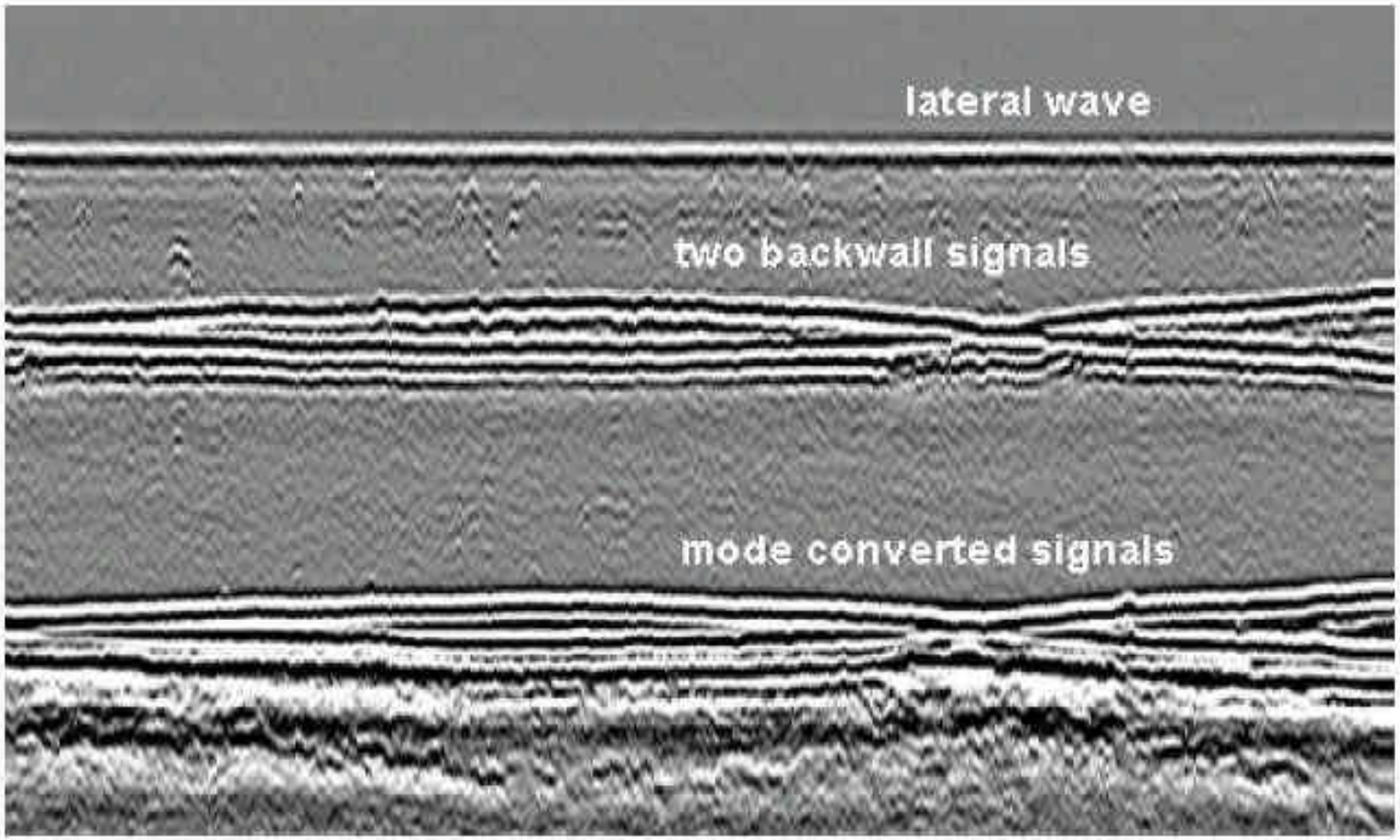

Figure B.17 — Image of misalignment in circumferentially welded pipes

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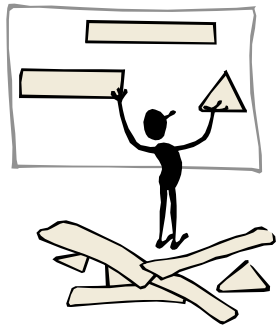

Further European Activities

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- practical use of CEN/TS 14751 on-site:
  - get experienced with the provisions of the TS
  - review after 3 years and decision taken of transfer of TS into an EN or not
  - DIN EN ISO 17025: „there is no need to qualify / validate standardized techniques“
- preparation of an European standard on TOFD – acceptance levels
  - draft prepared by CEN/TC 121/SC 5B/WG 2
  - ready for 5-months inquiry at CEN/TC 121
- review of EN 12062 necessary
  - implementation of TOFD (CEN/TS 14751 + accept.lev.)
- European TOFDPROOF – project
  - http://www.mpa-lifetech.de/TOFD/
  - organized by EPERC

A Christmas Card from Bjarne Larsen in good fun

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All the best wishes
for a merry Christmas
and a happy and
prosperous New Year

Bjarne

Für ein frohes und
TOFD-freies Neujahr !

For a happy and TOFD-free new year !