BS EN 1711:2000
Incorporating Amendment No. 1

Non-destructive examination of welds — Eddy current examination of welds by complex plane analysis

焊接的无损检验——通过综合平面分析对焊接的电流检验

The European Standard EN 1711:2000, with the incorporation of amendment A1:2003 has the status of a British Standard

ICS 25.160.40

British Standards

National foreword

This British Standard is the official English language version of EN 1711:2000, including amendment A1:2003.

The UK participation in its preparation was entrusted to Technical Committee WEE/46, Non-destructive testing, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

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This British Standard, having been prepared under the direction of the Engineering Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 May 2000

Summary of pages

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Amendments issued since publication

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ICS 25.160.40

English version

Non-destructive examination of welds – Eddy current examination of welds by complex plane analysis

(includes amendment A1:2003)

Contrôle non destructif des assemblages soudés – Contrôle par courants de Foucault des assemblages soudés par analyse des signaux dans le plan complexe (inclut l'amendement A1:2003)

Zerstörungsfreie Prüfung von Schweißverbindungen – Wirbelstromprüfung von Schweißverbindungen durch Vektorauswertung (enthält Änderung A1:2003)

This European Standard was approved by CEN on 11 December 1999, and amendment A1 was approved by CEN on 20 November 2003.

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Central Secretariat: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 1711:2000 + A1:2003 E

Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 121, Welding, the Secretariat of which is held by DS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2000, and conflicting national standards shall be withdrawn at the latest by August 2000.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Foreword to amendment A1

This document EN 1711:2000/A1:2003 has been prepared by Technical Committee CEN/TC 121 “Welding”, the secretariat of which is held by DS.

This Amendment to the European Standard EN 1711:2000 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2004, and conflicting national standards shall be withdrawn at the latest by June 2004.

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1 Scope

This standard defines eddy current examination techniques for detection of surface breaking and near surface planar imperfections, mainly in ferritic materials (weld material, heat affected zones, parent materials).

This eddy current technique can also be applied to other metallic construction materials (e.g. stainless steels) if required by the design specification.

The techniques can be applied to coated and uncoated objects during fabrication and in service, onshore and offshore.

The examination can be carried out on all accessible surfaces and on welds of almost any configuration.

Usually, it can be applied in the as-welded condition. However, a very rough surface can prevent an efficient examination.

Unless otherwise specified for specific points in this standard, the general principles of prEN 12084:1995 apply.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 473, *Qualification and certification of NDT personnel — General principles.*

EN 1289, *Non-destructive examination of welds — Penetrant testing of welds - Acceptance levels*.

EN 1291, *Non-destructive examination of welds — Magnetic particle testing of welds - Acceptance levels.*

EN 1330-5, *Non-destructive testing — Terminology — Part 5 : Terms used in Eddy current testing.*

EN 12062, *Non-destructive examination of welds — General rules for metallic materials*.

prEN 12084 :1995, *Non-destructive testing — Eddy current examination — General principles and basic guidelines*.

EN 25817, *Arc-welded joints in steels — Guidance on quality levels for imperfections (ISO 5817 :1992).*

EN 30042, *Arc-welded joints in aluminium and its weldable alloys — Guidance on quality levels for imperfections (ISO 10042 :1992).*

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in EN 1330-5 apply.

4 Personnel requirements

Personnel conducting the examinations in accordance with this standard shall be qualified and certified to an appropriate level in accordance with EN 473.

5 Procedure

For general applications, this standard shall be considered as a sufficient procedure. If required by the design specification, a written procedure shall be produced using the guidance given in prEN 12084:1995.

6 General applications

6.1 Essential information

Before performing an eddy current examination the necessary information shall be specified using prEN 12084:1995 for guidance and including at least:

- certification of examination personnel;
- testing plan;
- testing equipment;
- calibration of the equipment;
- calibration blocks;
- acceptance criteria;
- recording of indications;
- reporting format;
- actions necessary for non acceptable indications.

6.2 Additional information

Prior to testing, the following information is required:

- composition or grade of parent material;
- type of filler metal;
- location and extent of welds to be tested;
- weld surface geometry;
- surface conditions;
- coating type and thickness.

Operators shall ask for further information that will be helpful in determining the nature of discontinuities.

6.3 Surface conditions

Depending on the sensitivity requirements, the eddy current method is able to indicate surface cracks through non-metallic coatings of up to 2 mm thickness. Coating thicknesses greater than this may be considered if the relevant sensitivity can be demonstrated.

Eddy current examination is dependent on close contact between the probe and the test surface. For effective eddy current examination of welds, it should be noted that local adverse weld form, excessive weld spatter, scale, rust and loose paint can influence sensitivity by separating the probe from the test object and by inducing noisy responses.

It shall also be noted that some types of conductive coating, such as thermally spray aluminium and lead, could seriously influence the results as they can deposit electrically conductive metallic material in all cracks open to the surface. Cracks covered with such a metallic deposit are not always indicated by this method.

6.4 Equipment

6.4.1 Instrument

6.4.1.1 General

The instrument used for the examinations described in this standard shall be capable of analysis and display in the complex plane of both phase and amplitude and at least have the following features.

6.4.1.2 Frequency

The eddy current instrument shall be operated at a selected frequency in the range from 1 kHz to 1 MHz.

6.4.1.3 Sensitivity levels

After balance and lift off compensation and a further adjustment of the gain and phase controls, the 1 mm deep artificial imperfection in a relevant calibration block shall be indicated as a full screen deflection through a coating thickness corresponding to the maximum expected on the structure to be examined.

Further, a 0,5 mm deep artificial imperfection in the same calibration block shall be a minimum of 50 % of the signal obtained from the 1 mm deep artificial imperfection indicated through the same coating thickness.

Both requirements shall apply to the chosen probe and shall be verified on a relevant calibration block (according to 6.4.3.1).

If these requirements cannot be met examination is not possible.

6.4.1.4 Signal display

As a minimum, the signal display shall be a complex plane display with the facility to freeze data on screen until reset by the operator. The trace shall be clearly visible under all lighting conditions expected during the examination.

6.4.1.5 Phase control

The phase control shall be able to give complete rotation (360°) in steps of no more than 10° each.

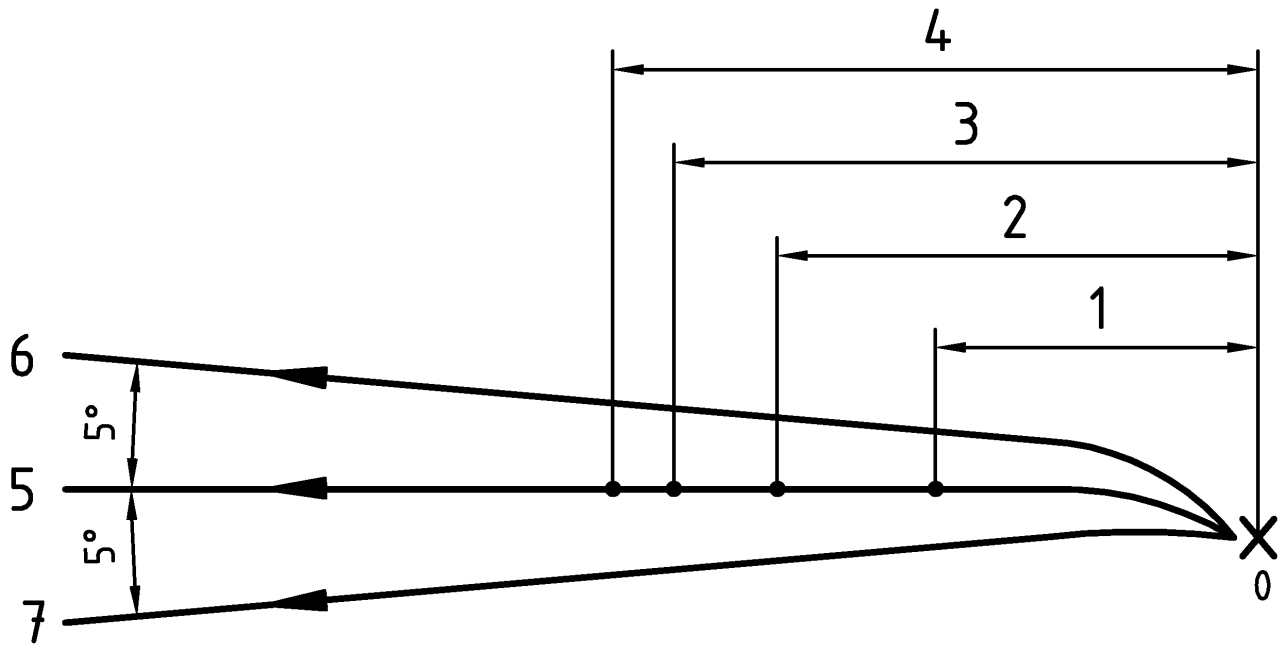
6.4.1.6 Evaluation mode

The evaluation mode uses both phase analysis and amplitude analysis of a vector traced to the complex plane display. Evaluation may be by comparison of this display with the reference data previously stored.

6.4.2 Surface probes

6.4.2.1 Probes for measuring thickness of coating and material evaluation relative to calibration block

To be acceptable for this purpose, the probe shall be capable of providing a full screen deflection lift off signal on the instrument when moved from an uncoated spot on a calibration block to a spot covered with the maximum coating thickness expected on the structure to be tested. The probe shall operate in absolute mode at a selected frequency in the range from 1 kHz to 1 MHz. All the probes shall be clearly marked with their operating frequency range. (See Figure 1).



Key

1,2,3,4 Deflections representing variations of thickness of simulated coatings on calibration block
5 Deflection representing material of calibration block
6,7 Deflection representing range of material to be examined using calibration block
0 Balance

Figure 1 — Coating thickness measurement and material sorting using absolute probe

6.4.2.2 Probes for weld examination

For examination of ferritic welds, probes specially designed for this purpose shall be used. The probe assembly shall be differential, orthogonal, tangential or equivalent which is characterized by having a minimal dependency on variations in conductivity, permeability and lift off in the welded and heat-affected zones.

The diameter of the probe shall be selected relative to the geometry of the component under test. Such probes shall be able to operate when covered by a thin layer on non-metallic wear-resistant material over the active face. If the probe is used with a cover, then the cover shall always be in place during calibration. The probe shall operate at a selected frequency in the range from 100 kHz to 1 MHz.

6.4.3 Accessories

6.4.3.1 Calibration block

A calibration block, of the same type of material as the component to be examined shall be used. It shall have EDM (Electric Discharge Machined) notches of 0,5 mm, 1,0 mm and 2,0 mm depth, unless otherwise agreed between contracting parties. The tolerance on the notch depth shall be ±0,1 mm. The recommended width of the notches shall be ≤ 0,2 mm. (See Figure 2).

Dimensions in millimetres

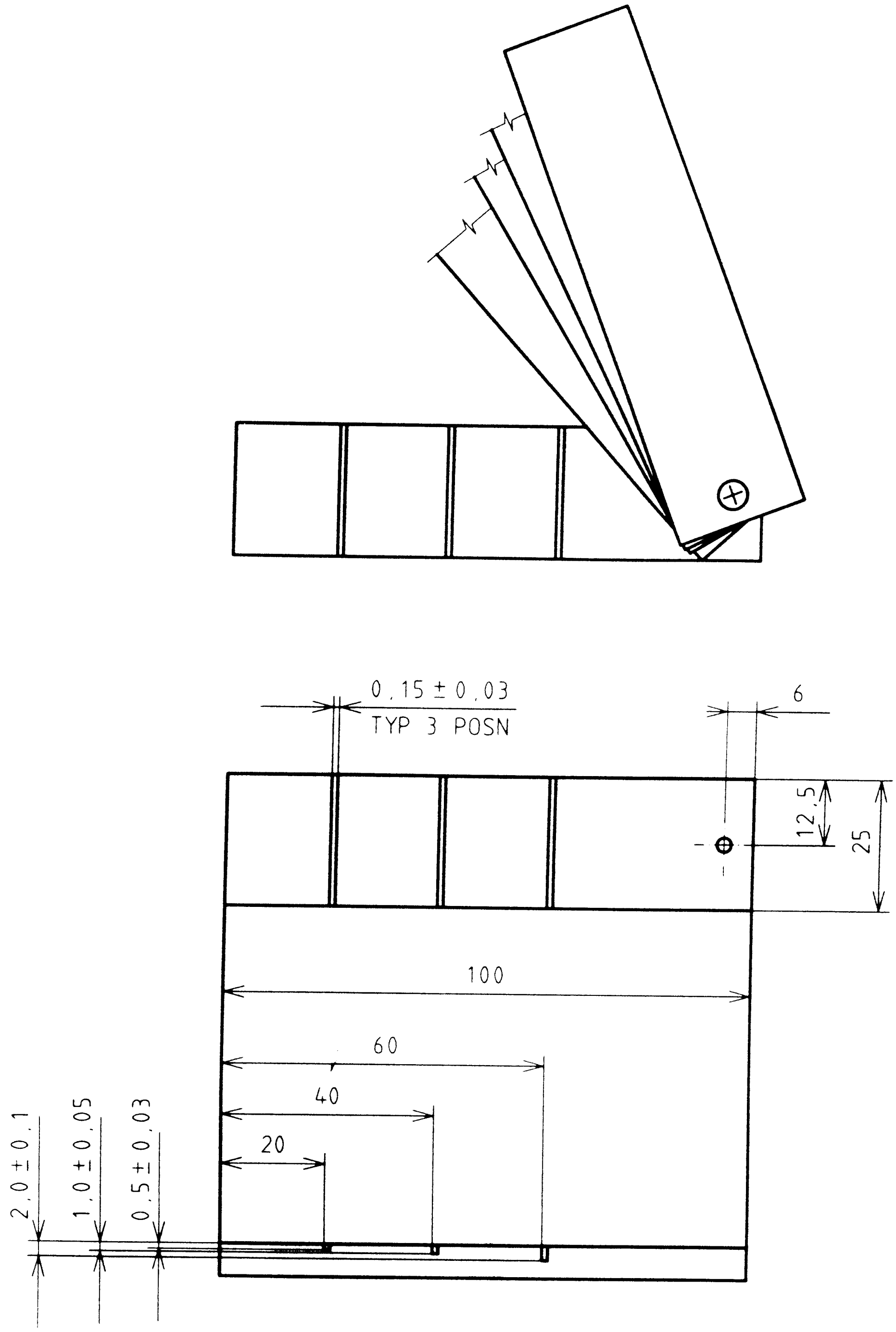


Figure 2 — Typical calibration block

6.4.3.2 Non-conductive flexible strips

Non-conductive flexible strips of a known thickness to simulate the coating or actual coatings on the calibration block shall be used.

It is recommended that non-conductive flexible strips be multiples of 0,5 mm thickness.

6.4.3.3 Probe extension cables

Extension cables may only be used between the probe and the instrument if the function, sensitivity and the resolution of the whole system can be maintained.

6.4.3.4 Remote display and control

For operation with long extension cables, the equipment shall include a device for remote signal display at the operator's location.

6.4.4 Systematic equipment maintenance

6.4.4.1 Calibration certificate

The equipment shall have a current, valid calibration certificate issued by the manufacturers and/or their official agent(s). This calibration process shall be carried out on an annual basis as a minimum.

6.4.4.2 Functional check

The equipment shall be checked and adjusted on a periodic basis for correct functioning. This shall only include measurements or adjustments that can be made from outside the equipment. Such adjustments shall be carried out in case of device faults or partial deterioration. The maintenance shall follow a written procedure. The results of maintenance checks shall be recorded.

6.5 Examination procedure

6.5.1 Procedure for measuring coating thickness and material comparison relative to calibration block

The coating thickness on the unmachined surface of a weld is never constant. However, as it will influence the sensitivity of crack detection, it is necessary to get an estimate of the maximum coating thickness in the Heat Affected Zone prior to the examination of the weld probe.

The lift off signal obtained from the component to be tested shall be similar to the signal obtained from the calibration block, i.e. it shall be within 5° either side of the reference signal (see Figures 1 and 2). In the event that the signal is out of this range, a calibration block more representative of the material to be examined shall be produced/manufactured.

6.5.2 Procedure for examination of welds in ferritic materials

6.5.2.1 Frequency

The frequency shall be optimized with respect to the sensitivity, the lift off and other unwanted signals. Under usual conditions a frequency of about 100 kHz is recommended.

6.5.2.2 Calibration

Calibration is performed by passing the probe over the notches in the calibration block. The notched surface shall first be covered by non-conductive flexible strips having a thickness equal to or greater than the measured coating thickness.

The equipment sensitivity is adjusted to give increasing signals from increasing notch depths. The 1 mm deep notch shall give a signal amplitude of approximatively 80 % of the full screen height. The sensitivity levels shall then be adjusted to compensate for component geometry.

Calibration check shall be performed periodically and as a minimum at the beginning and the end of the examination and after every change in working conditions. Every calibration shall be recorded.

When the calibration is complete it is recommended the balance be adjusted to the centre of the display.

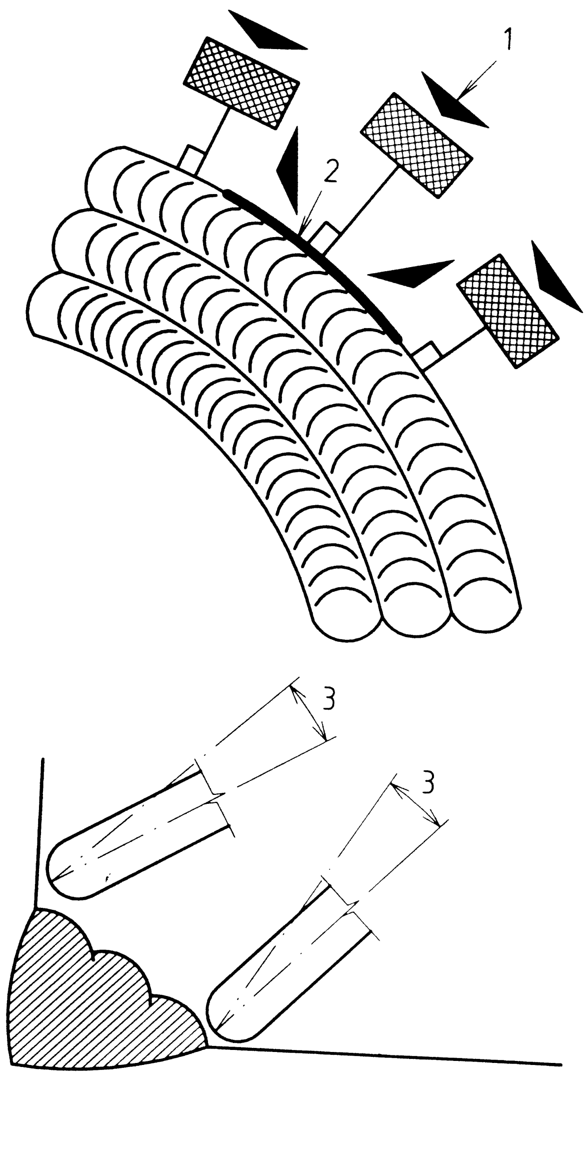
6.5.2.3 Scanning

The weld surface and the heat affected zones shall be scanned with the chosen probe(s). As far as the geometry of the test objects permits, the probe shall be moved in the directions perpendicular to the main direction of the expected imperfections. If this is unknown, or if imperfections in different directions are expected, at least two probe runs shall be carried out, one perpendicular to the other.

The examination can be split into two parts; the heat affected zones (see Figures 3, 4, 5) and the weld surface (see Figures 6, 7).

It shall be noted that the reliability of the examination is highly dependent on the orientation of the coils relative to the surface under test. Care shall also be taken to ensure that the probe is at the optimum angle to meet the varying surface conditions in the heat affected zone.

For differential probes, the sensitivity is affected by the orientation of the imperfection relative to the coil. Therefore, care shall be taken that this is also controlled during the examination.



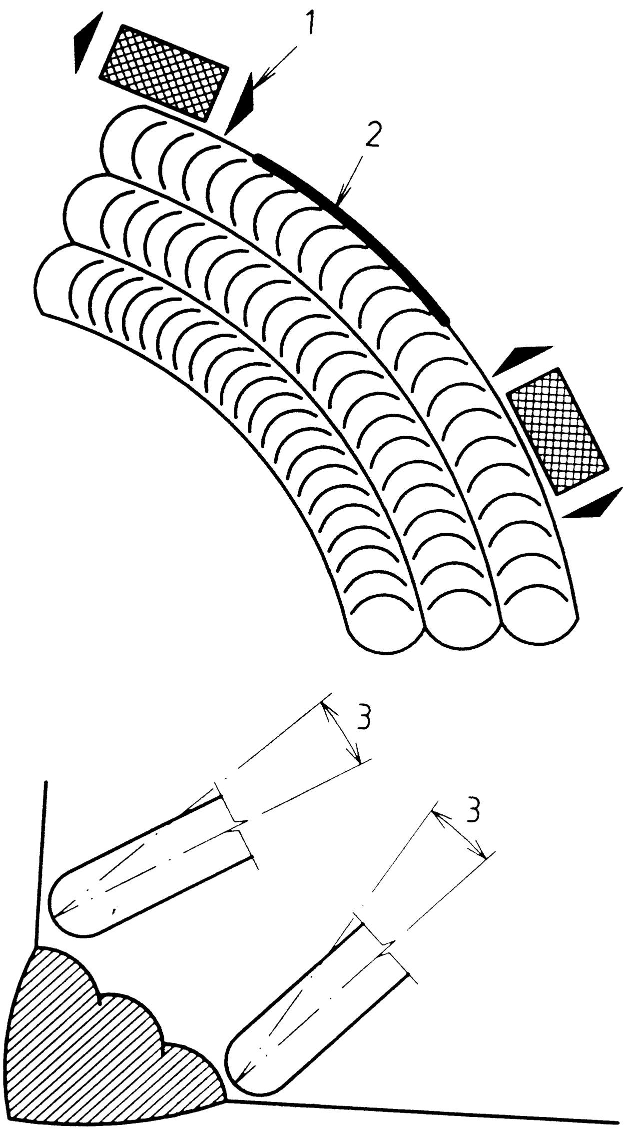
Key

1 Probe direction

2 Imperfection

3 Optimum angle to meet the varying surface conditions

Figure 3 — Material and Heat Affected Zone examination



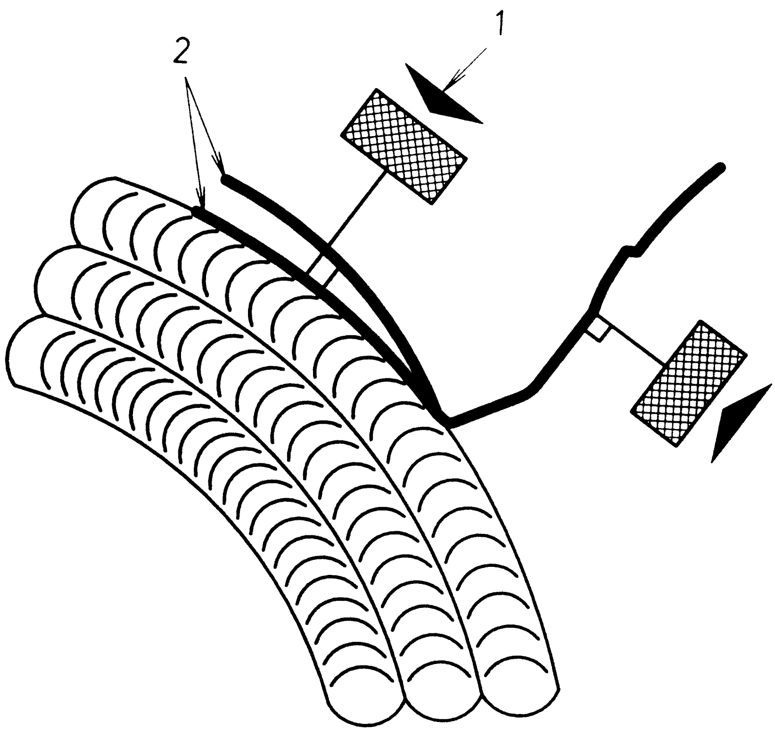
Key

1 Probe direction

2 Imperfection

3 Optimum angle to meet the varying surface conditions

Figure 4 — Single pass scan in toe of the weld

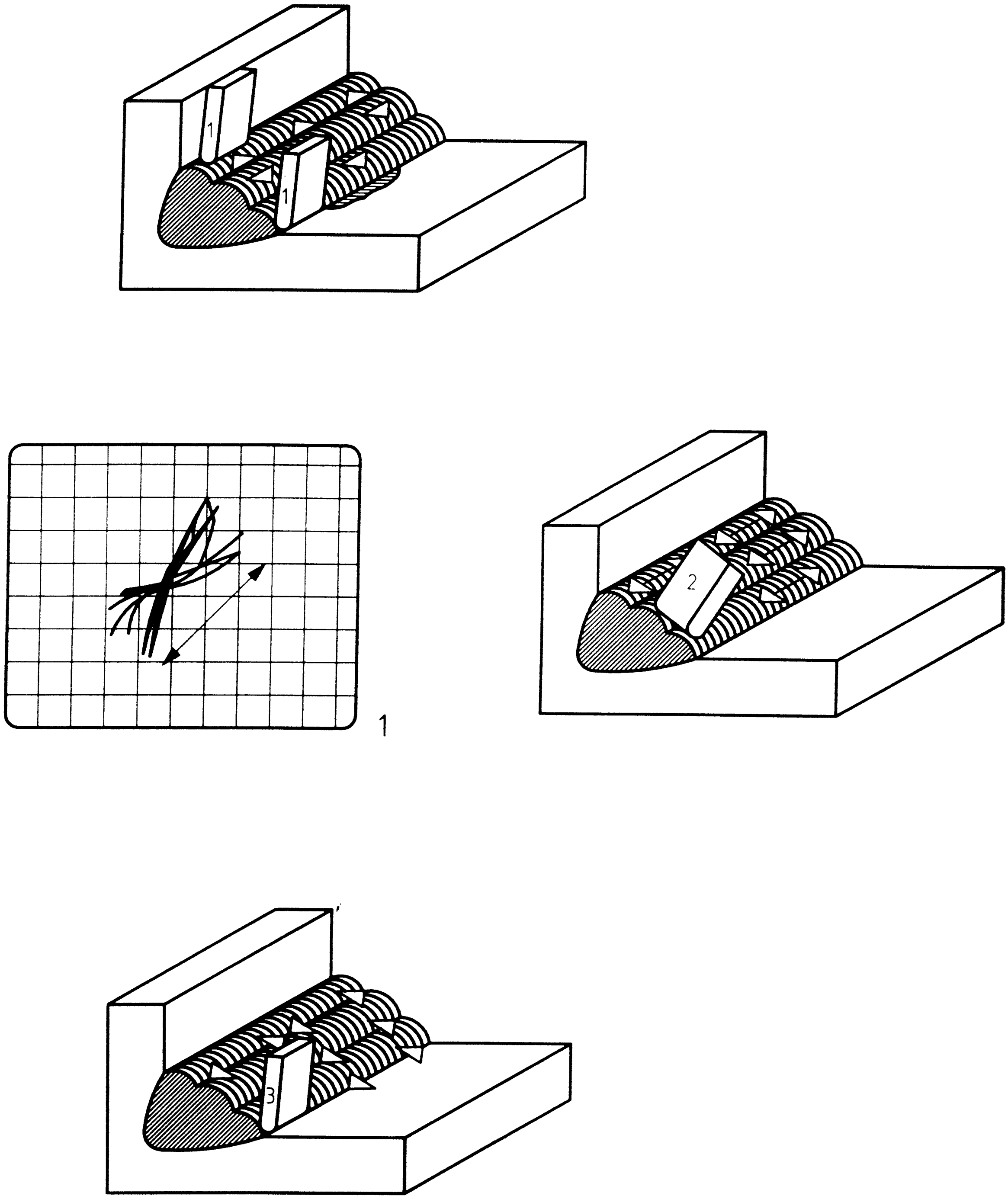


Key

1 Probe direction

2 Imperfection

Figure 5 — Additional scans in the Heat Affected Zone

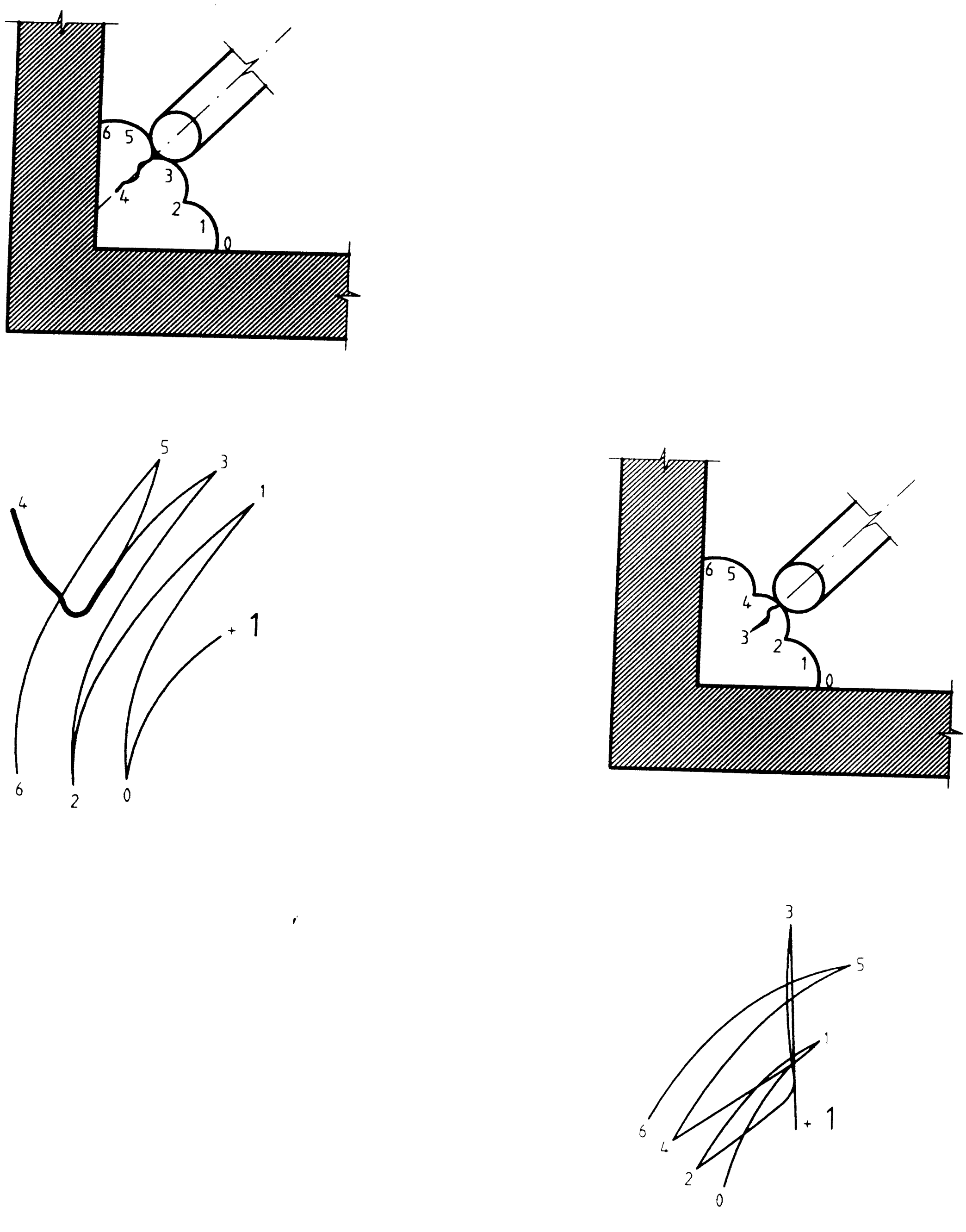


Key

1 Signal “envelope” from traversing weld cap

1,2,3 Different positions of the probe

Figure 6 — Scanning procedure for weld cap examination



Key

1	Balance
0,1,2,3,4,5,6	Different positions of the probe

Figure 7 — Typical imperfection signals generated during weld cap scanning

6.6 Detectability of imperfections

The ability to detect imperfections depends on many factors and the present knowledge of the application of the eddy current method to welded components does not permit the proposal of precise criteria. The criteria shall be established, as defined in EN 12062. Some recommendations are made below to take account of the limiting factors which affect imperfection detectability.

a) Material of calibration block

the material of the calibration block shall be similar to that of the component under test (6.5.1);

b) conductive coatings

conductive coatings reduce the sensitivity of the test. The maximum coating thickness shall also be reduced and depending on the conductivity;

c) non-conductive coatings

non-conductive coatings reduce the sensitivity of the test depending on the distance between the probe and the component under test;

d) geometry of the component

the shape of the component and the access of the probe to the area under test reduce the sensitivity of the test;

complex weld geometries such as cruciforms and gusset plates shall be examined relative to the complex geometry and possible orientation of the imperfections;

e) orientation of coils to the imperfection

1) inclination

care shall be taken to ensure the optimum angle of the coils relative to the area under test is maintained;

2) directional induced current

the induced current is directional, therefore care shall be taken to ensure that the orientation of current is perpendicular and/or parallel to the expected imperfection position;

f) minimum size of imperfection

the mimimum size of imperfection that the eddy current method is capable to detect in a ferritic steel weld in the “as welded” condition is 1 mm deep × 5 mm long.

A recommended flow diagram for performing an eddy current examination is shown in Figure 8.

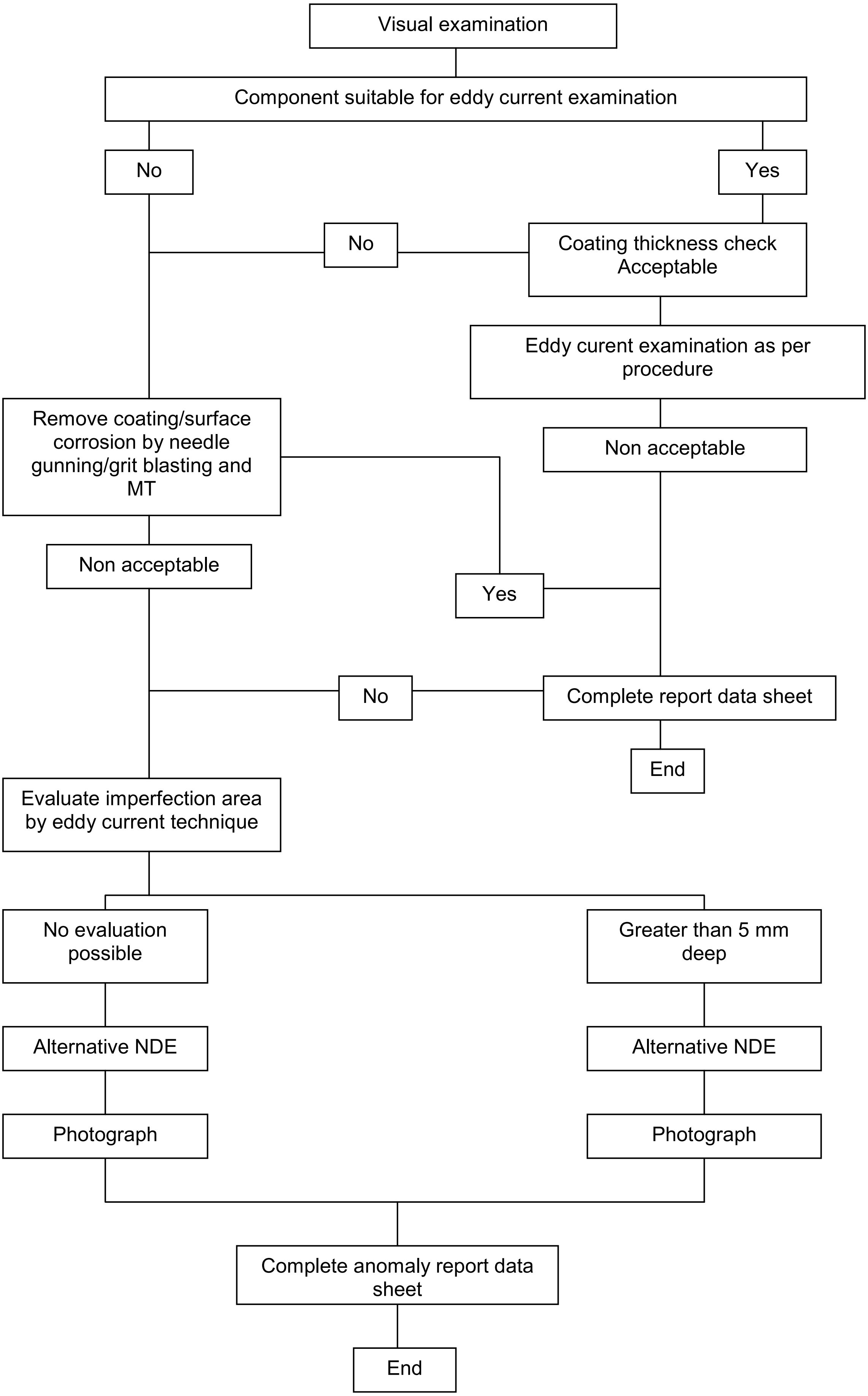


Figure 8 — Recommended eddy current method flow diagram

6.7 Evaluation of non acceptable indication

A non acceptable indication is defined as an area displaying an abnormal signal compared to that expected from that area of the component under test.

In the event of a non acceptable indication being noted (see Figure 9), a further investigation of the area is recommended.

A longitudinal scan shall be employed and the length of the indication noted (see Figure 4).

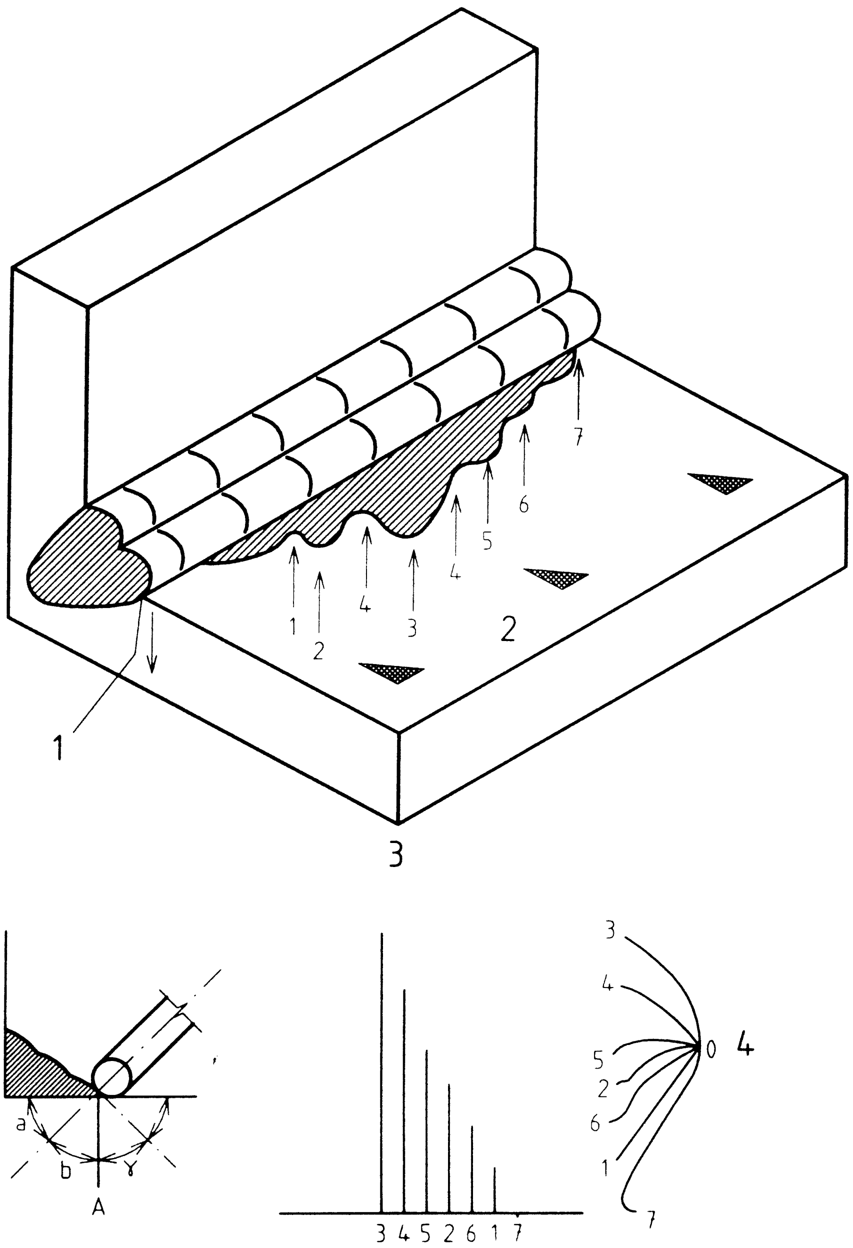
Where possible a single pass scan along the length of the indication shall be employed to obtain the signal amplitude. The maximum amplitude shall be noted (see Figure 10).

If further clarification is still needed, or when the removal of a imperfection shall be verified, it is recommended that the examination is supplemented with other non-destructive examinations, e.g. magnetic particle testing (MT) or penetrant testing (PT).

The relevant acceptance for MT (according to EN 1291) or PT (according to EN 1289) associated to EN 25817 or EN 30042 apply.

Where a non acceptable indication is noted, but no depth information is possible (see Figure 11) alternative NDE such as ultrasonic and/or Alternating Current Potential Drop techniques shall be used to determine the depth and orientation of the indication.

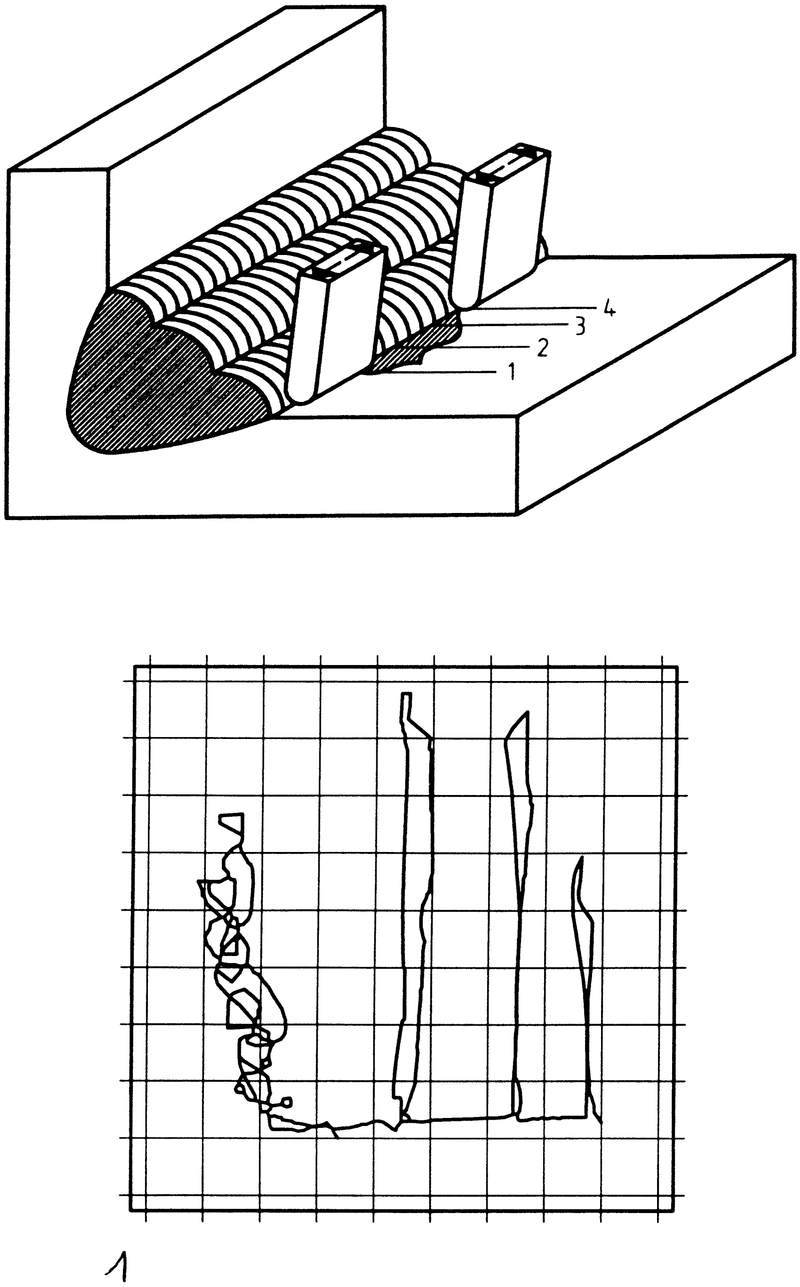
When an indication has been designated as non acceptable and an eddy current evaluation has deemed the area to be exceeding 5 mm in depth, the area shall be further investigated using ultrasonic and/or Alternating Current Potential Drop techniques in order that the full extent and orientation of the indication be determined.



Key

1	Orientation
2	Scanning direction
3	Imperfection A
4	Balance
1,2,3,4,5,6,7	Different positions of the probe

Figure 9 — Typical responses from "through wall" imperfection

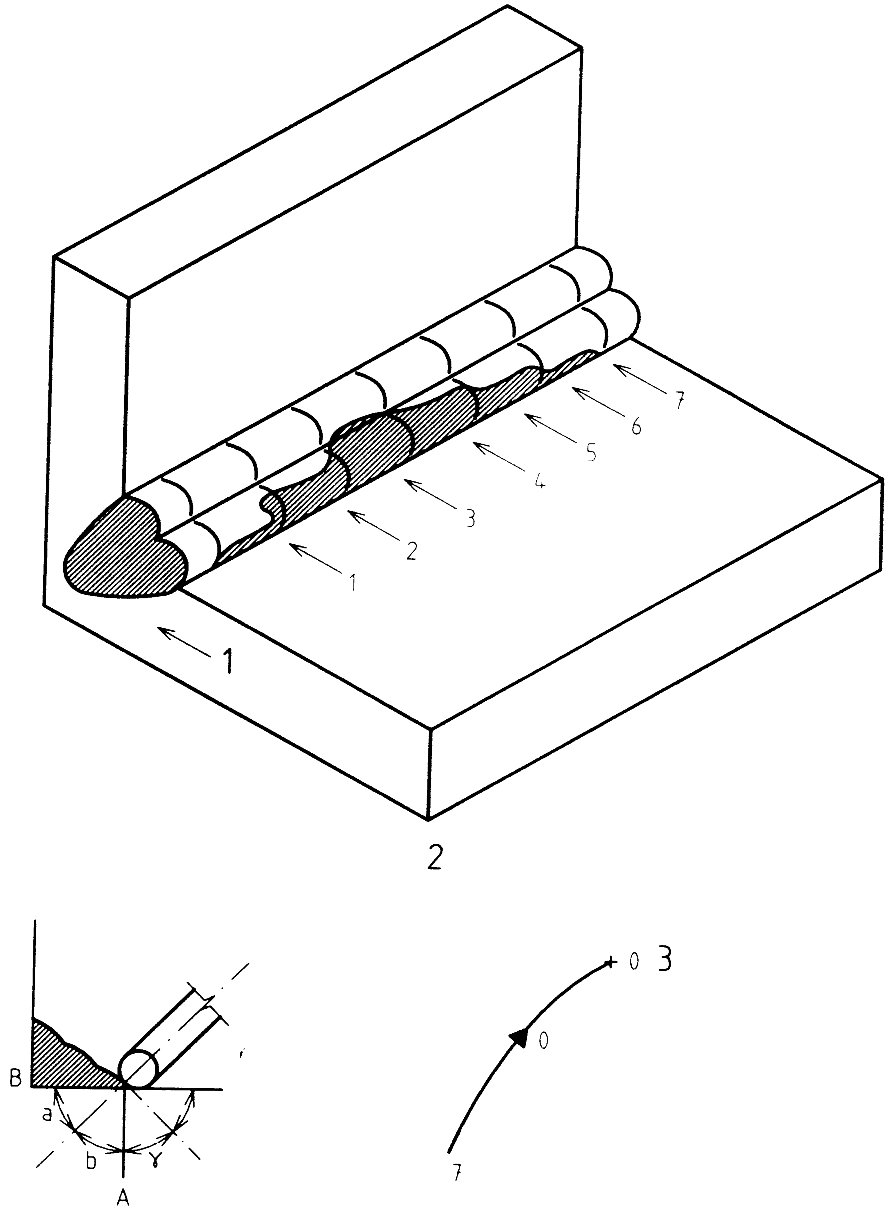


Key

1,2,3,4 Different positions of the probe

1 Crack

Figure 10 — Typical responses from fatigue and lack of fusion imperfections using a longitudinal scan



Key

1	Orientation
2	Imperfection
3	Balance
1,2,3,4,5,6,7	Different positions of the probe

Figure 11 — Typical response from "partial penetration" imperfection

6.8 Procedure for examination of welds in other materials

As previously stated, the eddy current method is also applicable to welds in other metallic construction materials such as aluminium and stainless steels.

The procedure for examination of such welds shall generally include the same items as in 6.5.2, but the choice of frequency, probes, calibration and scanning patterns shall be optimized to the actual material, and may deviate considerably from that recommended for ferritic materials.

Therefore, the examination procedure shall be based on practical experience with suitable equipment, probes and calibration blocks and shall be detailed in a specific procedure.

The limiting factors shall be clearly defined in each case.

7 Test report

Before performing an eddy current examination the content of the test report shall be specified using the requirements of prEN 12084:1995 for guidance.

The test report shall include as a minimum the following information:

- name of the testing company (if relevant);
- component identification;
- material;
- heat treatment;
- type of joint;
- material thickness;
- welding process;
- procedure number;
- acceptance criteria;
- surface preparation;
- the extent of examination with e.g. references to drawings;
- calibration block description;
- test equipment;
- test conditions (e.g. frequency, sensitivity and phase);
- calibration report;
- description and location of non acceptable indications exceeding the acceptance criteria (e.g. by sketching, photographing);
- results of examination;
- name of inspector and date of examination;
- customer signature and relevant certifying authority signature (if relevant).

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