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

Contrôle non destructif des assemblages soudés — Contrôle par courants de Foucault des assemblages soudés avec analyse des signaux dans le plan complexe





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Foreword

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

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*.

This second edition cancels and replaces the first edition (ISO 17643:2005), which has been technically revised.

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

1 Scope

This International Standard defines eddy current testing techniques for detection of surface breaking and near surface planar discontinuities, mainly in ferritic materials (weld material, heat-affected zones, base material).

Eddy current testing can also be specified for use with non-ferritic materials, for example in an application standard.

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

Eddy current testing can be carried out on all accessible surfaces and on welds of almost any configuration.

Unless otherwise specified at specific items in this International Standard, the general principles of ISO 15549 apply.

NOTE Eddy current testing is usually performed in the as-welded condition. However, the accuracy of the results can be affected by very rough surface finishes.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 12718, *Non-destructive testing — Eddy current testing — Vocabulary*

ISO 15548-1, *Non-destructive testing — Equipment for eddy current examination — Part 1: Instrument characteristics and verification*

ISO 15548-2, *Non-destructive testing — Equipment for eddy current examination — Part 2: Probe characteristics and verification*

ISO 15548-3, *Non-destructive testing — Equipment for eddy current examination — Part 3: System characteristics and verification*

ISO 15549, *Non-destructive testing — Eddy current testing — General principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12718 apply.

4 Personnel qualification

Non-destructive testing shall be performed by qualified and capable personnel. It is recommended that personnel are qualified in accordance with ISO 9712 or an equivalent standard at an appropriate level in the relevant industry sector.

5 Written procedures

If a written procedure is required, it should be prepared in accordance with ISO 15549. Otherwise, the procedures detailed in this International Standard shall be followed.

6 General applications

6.1 Essential variables

Prior to eddy current testing, the following essential items shall be specified in accordance with ISO 15549:

- certification of testing 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 eddy current testing, the following information should be specified. Further information may be necessary for determination of the nature of the discontinuities and the composition or grade of the base material:

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

6.3 Surface conditions

Eddy current testing can be used to detect surface cracks through non-metallic coatings up to a thickness of 2 mm. For coating thicknesses greater than 2 mm, the sensitivity of the test method shall be demonstrated in advance before eddy current testing is used.

NOTE 1 Eddy current testing is dependent on close contact between the probe and the test surface. For effective eddy current testing 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.

NOTE 2 It should be noted that some types of conductive coating, such as thermally sprayed aluminium and lead, can seriously influence the results as they can deposit electrically conductive metallic material in 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 Instrumentation (excluding probe)

6.4.1.1 General

The instrument used for eddy current testing in accordance with this International Standard shall be capable of analysis and display in the complex plane. The amplitude and phase of eddy current signals shall be measurable.

6.4.1.2 Frequency

The eddy current instrumentation shall be able to operate at a selected frequency within the range 1 kHz to 1 MHz.

6.4.1.3 Signal display

The display shall include the facility to freeze eddy current signals on screen until reset by the operator. The trace shall be clearly visible under all lighting conditions expected during testing.

6.4.1.4 Phase control

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

6.4.2 Surface probes

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

The probe shall operate in the 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.

6.4.2.2 Probes for testing of welds

For testing of ferritic welds, probes specially designed for this purpose shall be used.

The coils assembly shall be orthogonal, tangential or equivalent.

The electrical connection shall enable differential measurements which are characterized by having a minimal dependency on continuous or small 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 of 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 specified, for example in an application standard. The tolerance on the notch depth shall be $\pm 0,1$ mm. The recommended width of the notches is $\leq 0,2$ mm. An example of a calibration block is shown in [Figure 1](#).

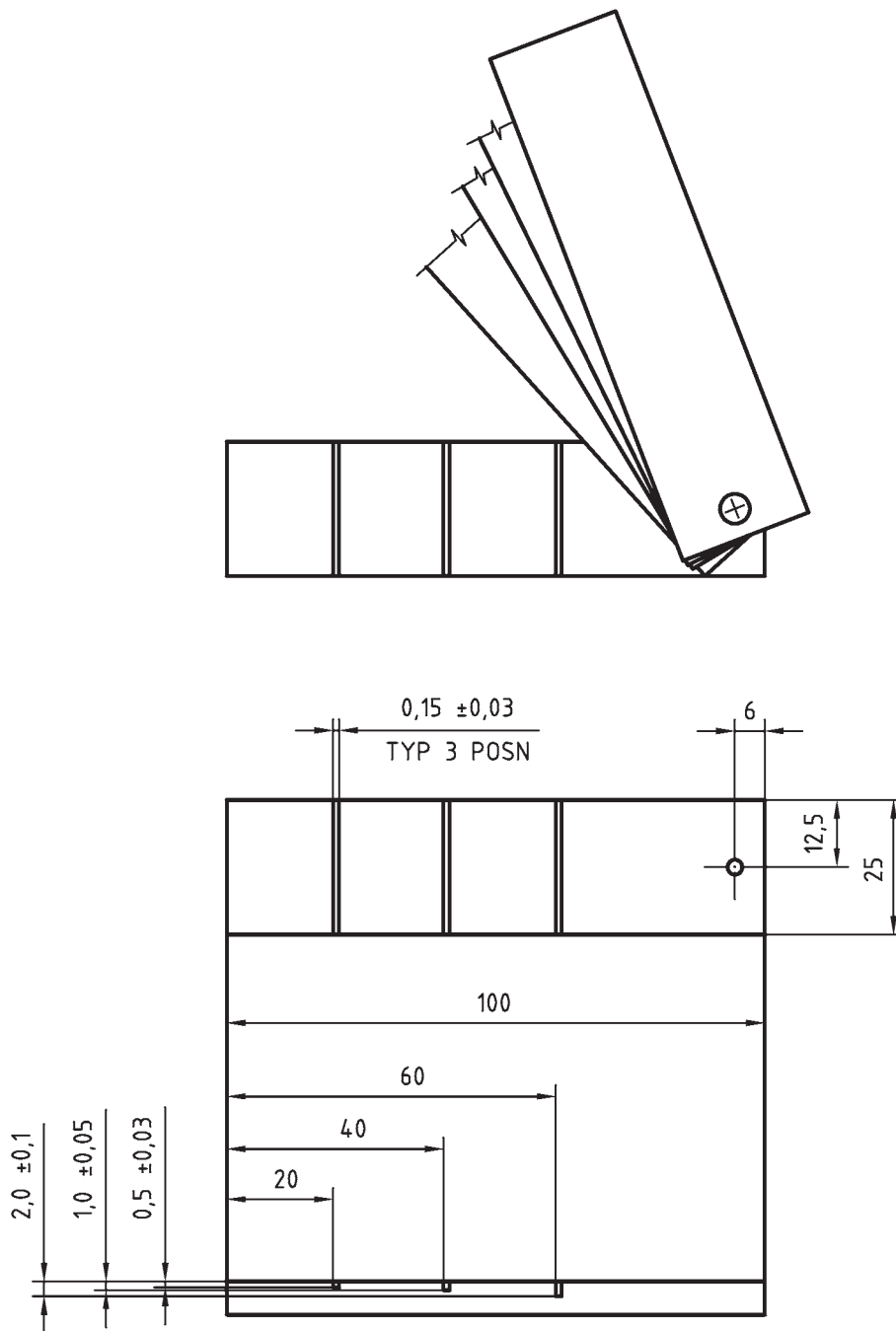


Figure 1 — Example of a calibration block

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.

The thickness of the non-conductive flexible strips should be multiple of 0,5 mm.

6.4.3.3 Probe extension cables

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

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 (instrument and probes) shall have a currently valid calibration certificate. This may be issued by the manufacturer, (in accordance with ISO 15548-1 and ISO 15548-2) a recognized calibration laboratory or an authorized agency.

6.4.4.2 Functional check

Maintenance shall follow ISO 15548-3 or a written procedure. The results of maintenance checks shall be recorded.

6.5 Test procedure

6.5.1 Evaluation mode

The evaluation mode shall use 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.

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

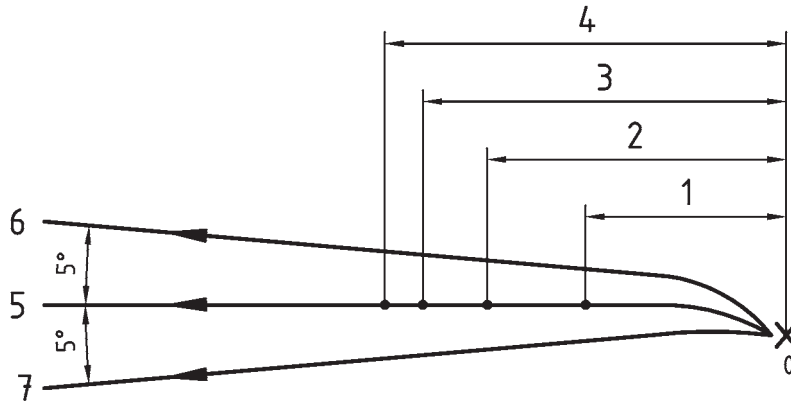
Connect the probe for absolute measurements to the instrument. Select the appropriate frequency

Set the gain of the instrument in order to obtain a full screen deflection lift-off signal when the probe is moved from an uncoated spot on the calibration block to a spot covered with the maximum coating thickness expected on the structure to be tested.

Set the phase of the lift-off signals to display them as shown on [Figure 2](#).

The coating thickness on the raw surface of a weld is never constant. 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 eddy current testing of the weld.

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 [Figure 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.



Key

- 0 balance point on the calibration block
- 1, 2, 3, 4 deflections representing variations in 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

Figure 2 — Coating thickness measurement and material sorting using absolute probe

6.5.3 Procedure for testing welds in ferritic materials

6.5.3.1 Frequency

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

6.5.3.2 Calibration

Calibration is performed by moving the probe over the notches of 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.

Position the probe on a zone of the block free from notches. Balance and if necessary compensate the lift-off. Adjust the balance point in the centre of the display.

Adjust the gain of the instrument to give increasing signals from increasing notch depths. The 1 mm deep notch shall give a signal amplitude of approximately 80 % of the full screen height. The sensitivity levels shall then be adjusted to compensate for component geometry. A 0,5 mm deep notch in the same calibration block shall be indicated as a minimum of 50 % of the signal obtained from the 1 mm deep notch indication through the same coating thickness.

When calibration is completed, verify that the balance point is still in the centre of the display and if necessary refine the adjustment.

A verification shall be performed periodically and as a minimum at the beginning and the end of testing and after every change in working conditions. Every verification shall be recorded.

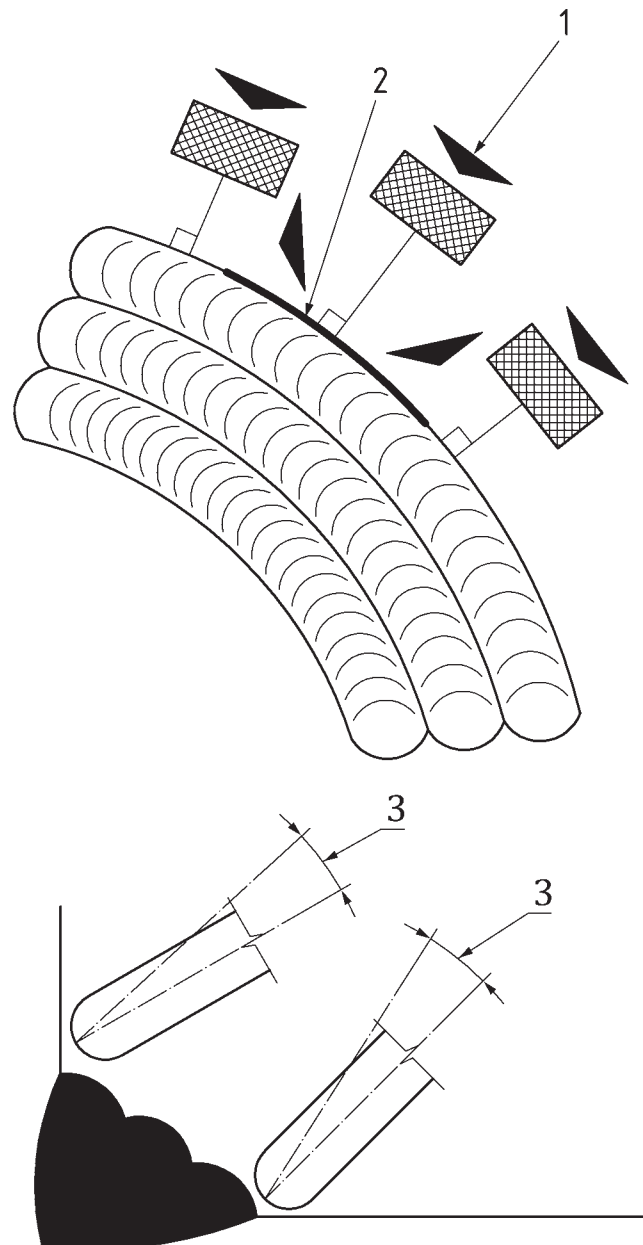
6.5.3.3 Scanning

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

Eddy current testing can be split into two parts: the heat-affected zones (see [Figures 3, 4, and 5](#)) and the weld surface (see [Figures 6 and 7](#)).

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

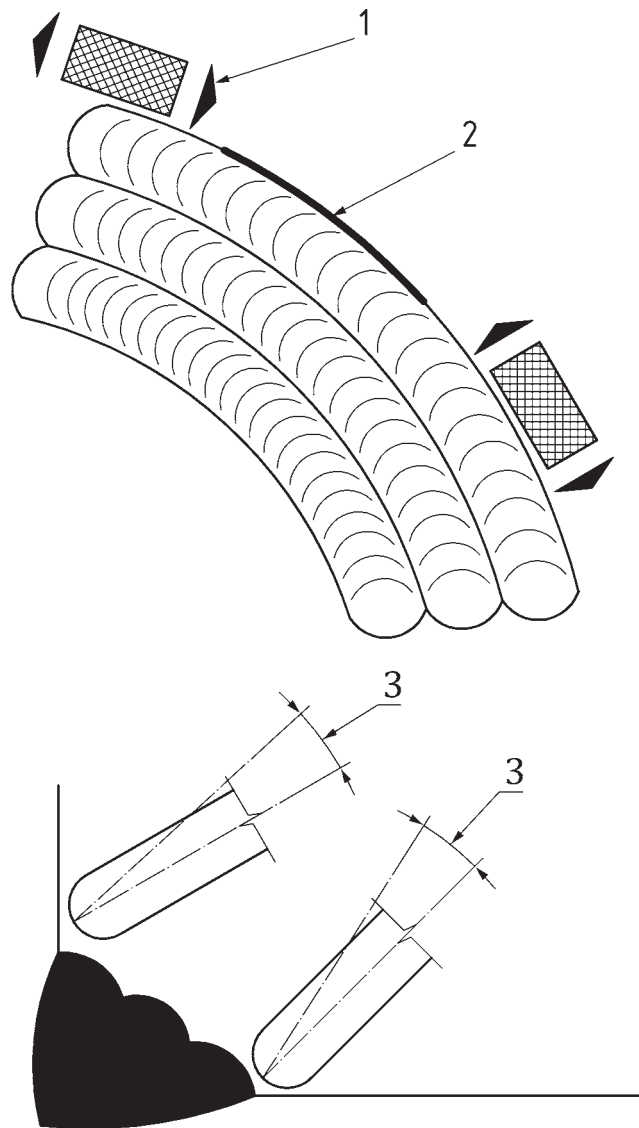
For differential probes, the sensitivity is affected by the orientation of the discontinuity relative to the coils. Therefore, care shall be taken that this is also controlled during testing.



Key

- 1 probe direction
- 2 discontinuity
- 3 optimum angle to accommodate the varying surface conditions

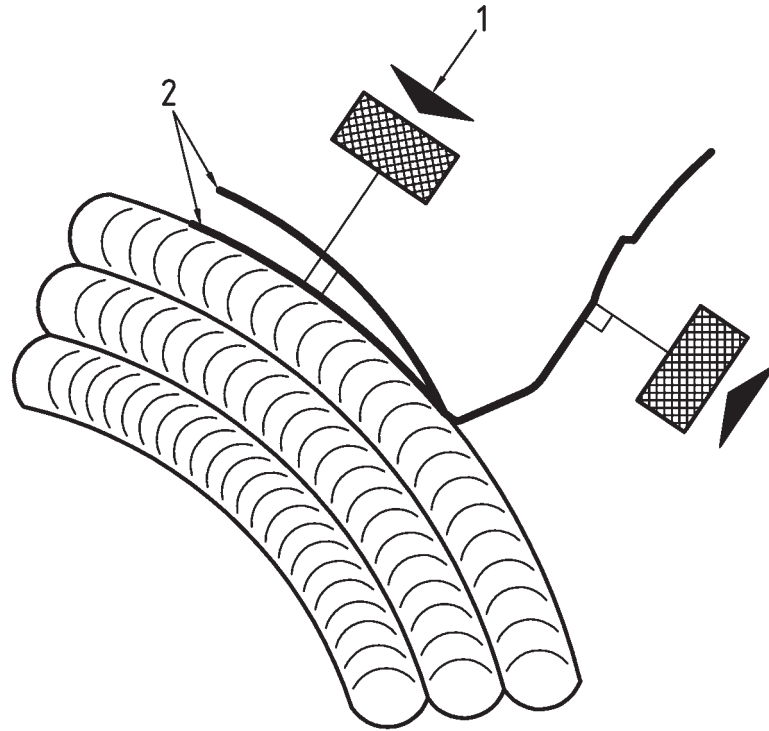
Figure 3 — Base material and heat-affected zone testing



Key

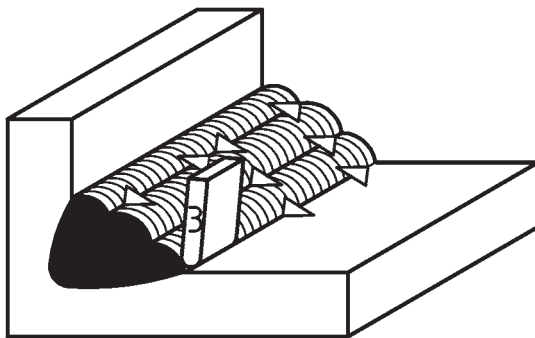
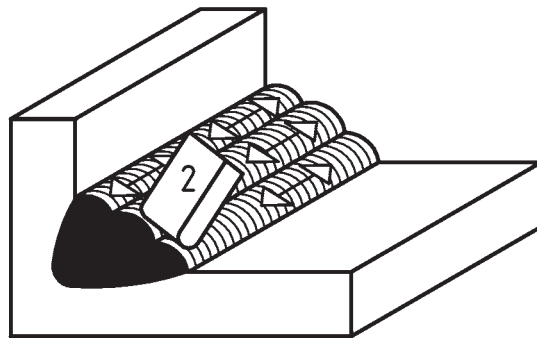
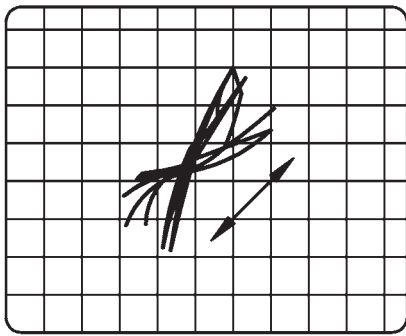
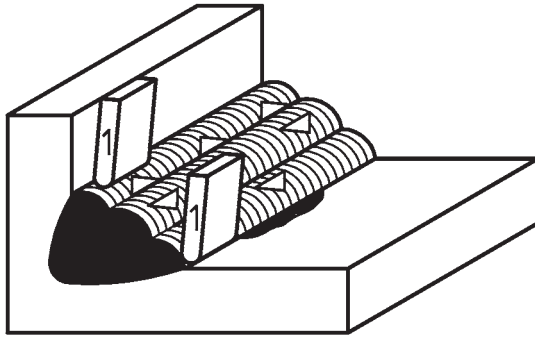
- 1 probe direction
- 2 discontinuity
- 3 optimum angle to accommodate the varying surface conditions

Figure 4 — Single pass scan in toe of the weld

**Key**

- 1 probe direction
- 2 discontinuity

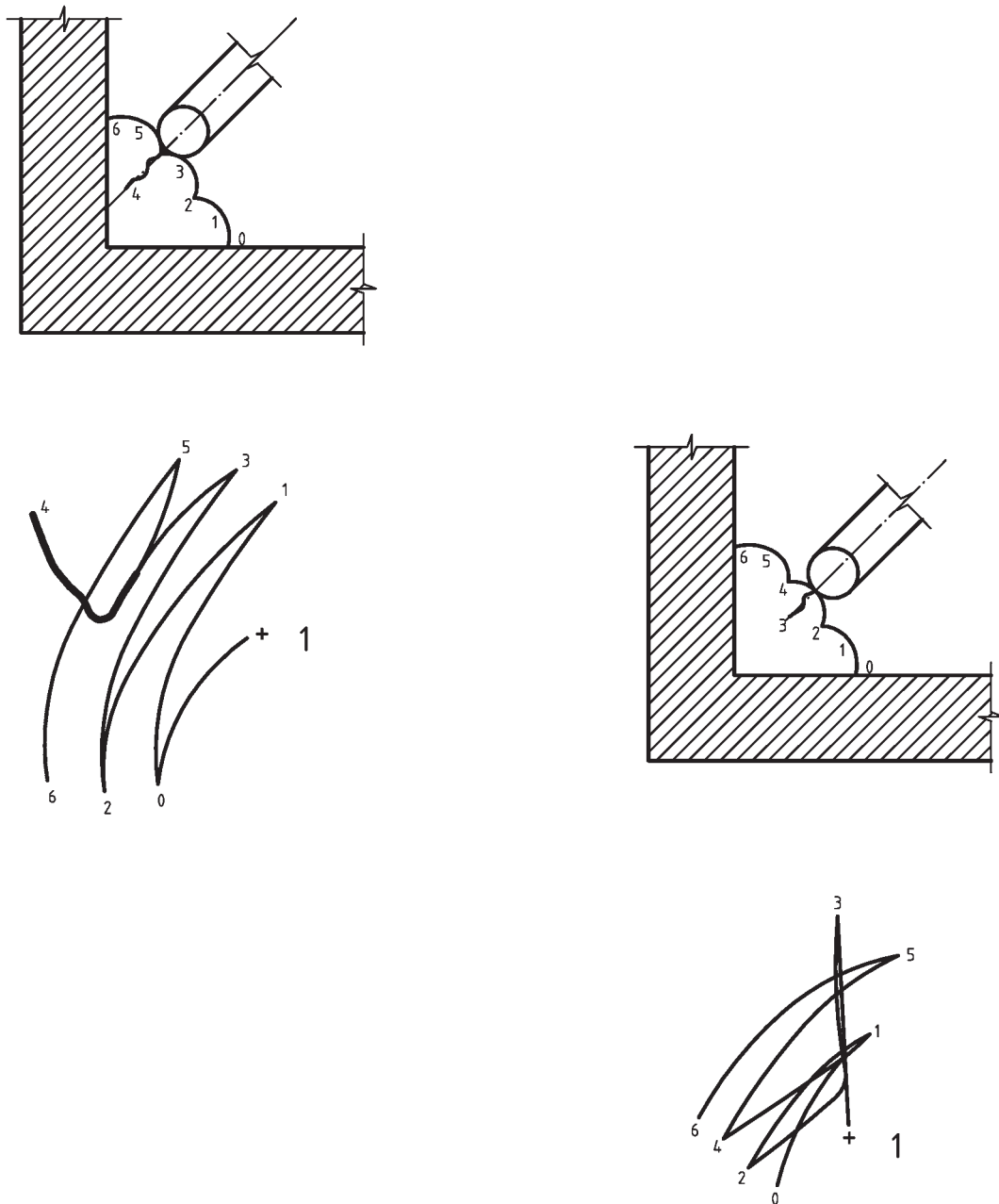
Figure 5 — Additional scans in the heat-affected zone



Key

- 1, 2, 3 different positions of the probe
- 4 signal "envelope" from traversing weld cap

Figure 6 — Scanning procedure for weld cap testing



Key

- 0 balance point
- 1, 2, 3, 4, 5, 6 different positions of the probe

Figure 7 — Typical discontinuity signals generated during weld cap scanning

6.6 Detectability of discontinuities

The following items which may affect discontinuity detectability shall be taken into account.

- a) Material of calibration block:

The material of the calibration block shall be similar to that of the component under test (see 6.5.2).

- b) Conductive coatings:

Conductive coatings reduce the sensitivity of the test.

c) Non-conductive coatings:

Non-conductive coatings reduce the sensitivity of the test depending on the distance between the probe and the conducting base material of 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 may influence the sensitivity of the test.

Complex weld geometries such as cruciform joints or gusset plates shall be examined relative to the complex geometry and possible orientation of the discontinuities.

e) Orientation of coils to the discontinuity:

1) Inclination:

Care shall be taken to ensure that 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 the current is non-parallel to the expected orientation of the discontinuity.

A recommended flow diagram for performing an eddy current examination is shown in [Annex A](#).

6.7 Procedure for testing welds in other materials

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

The procedure for testing such welds shall generally include the same items as in [6.5.3](#), 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 test 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 eddy current testing, the content of the test report shall be specified using the requirements of ISO 15549 for guidance.

The test report shall include as a minimum

- name of the testing company (if relevant),
- component identification,
- material,
- coating type and nominal thickness (if relevant),
- heat treatment,
- type of joint,
- material thickness,
- welding process,

- procedure number,
- acceptance criteria,
- surface preparation,
- the extent of testing 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 testing,
- name of inspector and date of testing, and
- Customer's signature and relevant certifying authority's signature (if relevant).

Annex A (informative)

Recommended eddy current method flow diagram

