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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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Contents

Page

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17643 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*.

Introduction

Requests for official interpretations of any aspect of this International Standard should be directed to the Secretariat of ISO/TC 44/SC 5 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

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, parent materials).

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 for specific points in this International Standard, the general principles of EN 12084 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 referenced documents 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.

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

EN 12084, *Non-destructive testing — Eddy current testing — General principles and guidelines*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-5 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 EN 12084. 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 EN 12084:

- 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 parent 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 2 mm thick. 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 instrumentation used for eddy current testing in accordance with this International Standard shall be capable of analysis and display in the complex plane of both phase and amplitude and have at least the following features:

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 Calibration of sensitivity levels

After balance and lift-off compensation and a further adjustment of the gain and phase controls, a 1 mm deep artificial discontinuity in a calibration block (see 6.4.3.1) shall be indicated as a full screen deflection through a coating thickness corresponding to the maximum expected on the structure to be examined.

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

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

If these requirements cannot be met, eddy current testing 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 testing.

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.

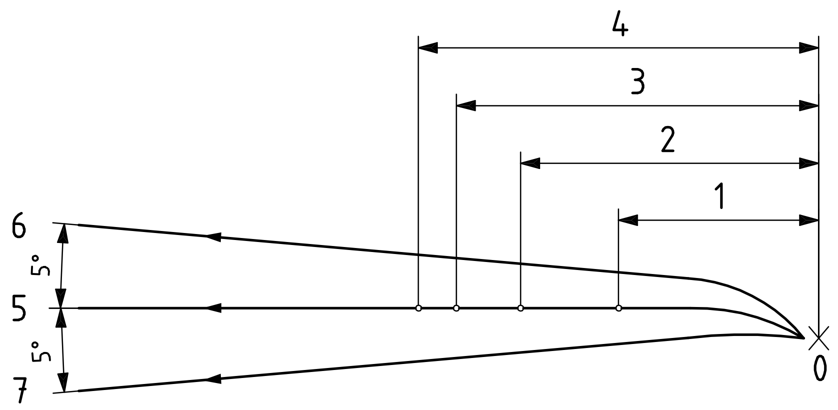
6.4.1.6 Evaluation mode

The evaluation mode 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.

6.4.2 Surface probes

6.4.2.1 Probes for measuring coating thickness 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 instrumentation 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 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. (See Figure 1.)



Key

0	balance point
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 1 — Coating thickness measurement and material sorting using absolute probe

6.4.2.2 Probes for testing of welds

For testing 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 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 ± 0,1 mm. The recommended width of the notches is ⩽ 0,2 mm. An example of a calibration block is shown in Figure 2.

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 instrumentation 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.

Dimensions in millimetres

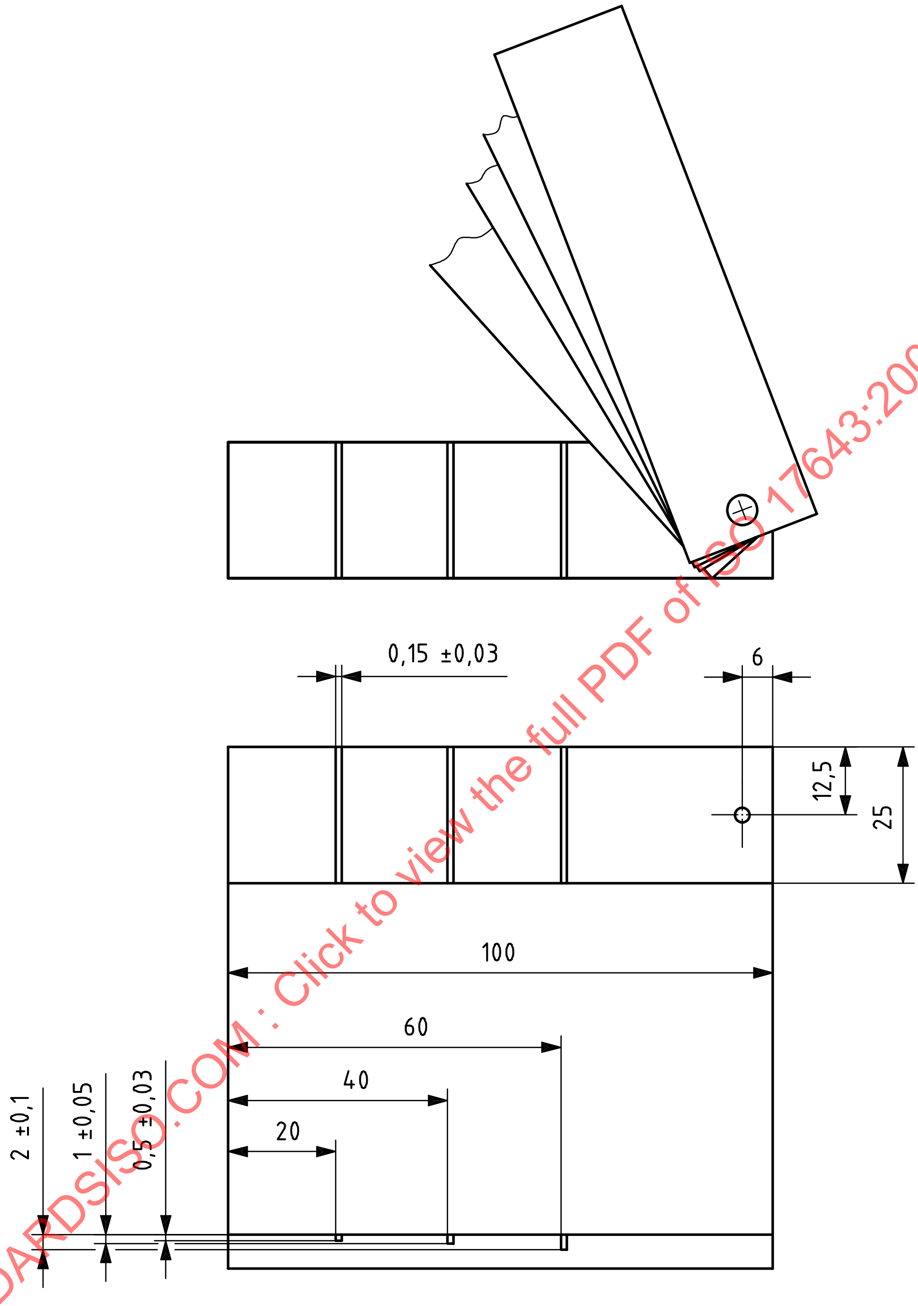


Figure 2 — Example of a calibration block

6.4.4 Systematic equipment maintenance

6.4.4.1 Calibration certificate

The equipment (instrumentation and probe) shall have a currently valid calibration certificate. This may be issued by the manufacturer, a recognized calibration laboratory or an authorized agency. The equipment shall be re-calibrated at least annually.

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.

Maintenance shall follow a written procedure. The results of maintenance checks shall be recorded.

6.5 Test 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. 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 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 testing welds in ferritic materials

6.5.2.1 Frequency

The frequency shall be optimized with respect to the sensitivity, lift-off and other unwanted signals. For 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 approximately 80 % of the full screen height. The sensitivity levels shall then be adjusted to compensate for component geometry.

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

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

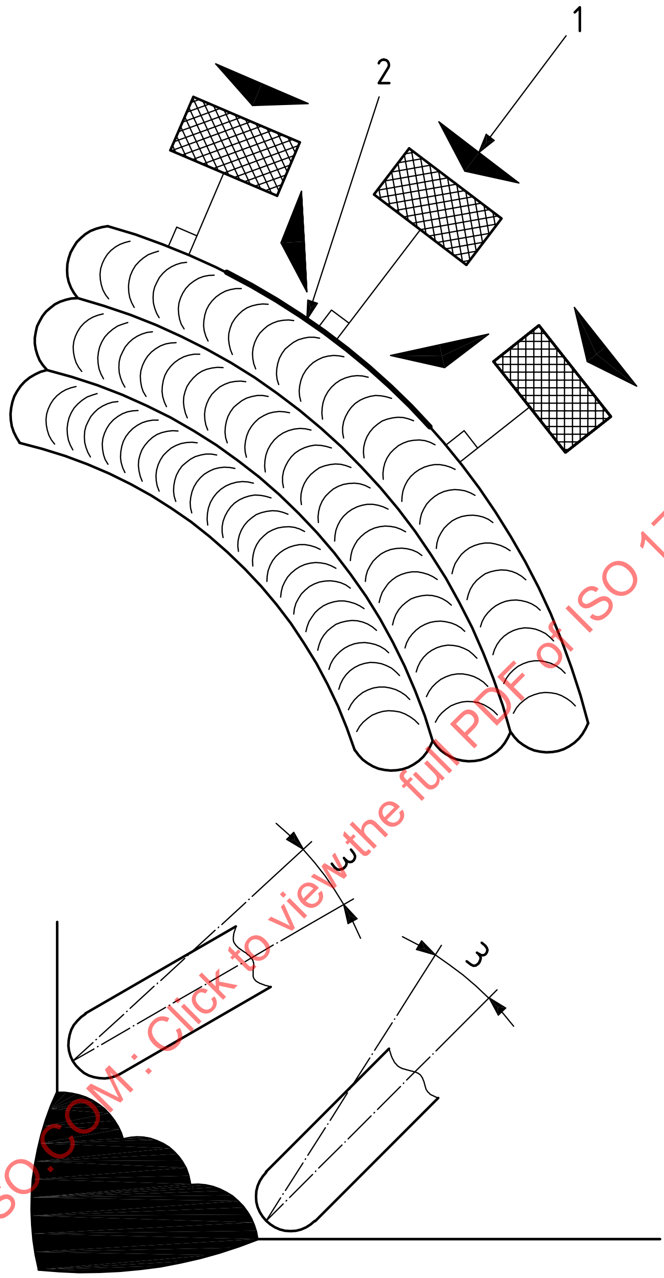
6.5.2.3 Scanning

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 discontinuities. If this is unknown, or if discontinuities in different directions are expected, at least two probe runs 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 coil. Therefore, care shall be taken that this is also controlled during testing.



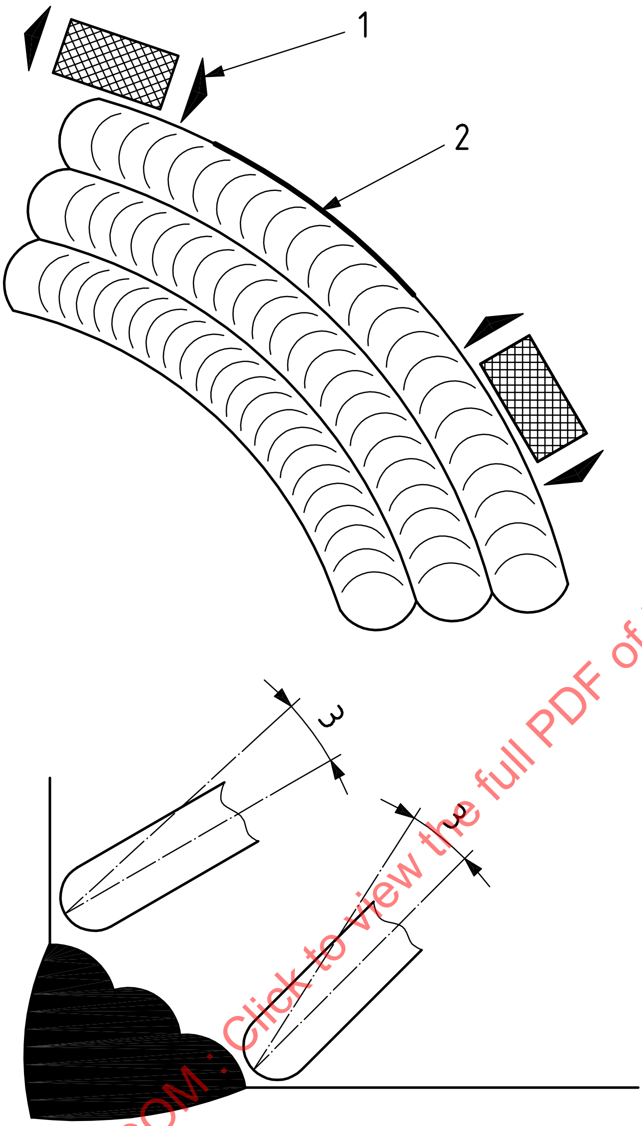
Key

1 probe direction

2 discontinuity

3 optimum angle to accommodate the varying surface conditions

Figure 3 — Parent material and heat-affected zone testing



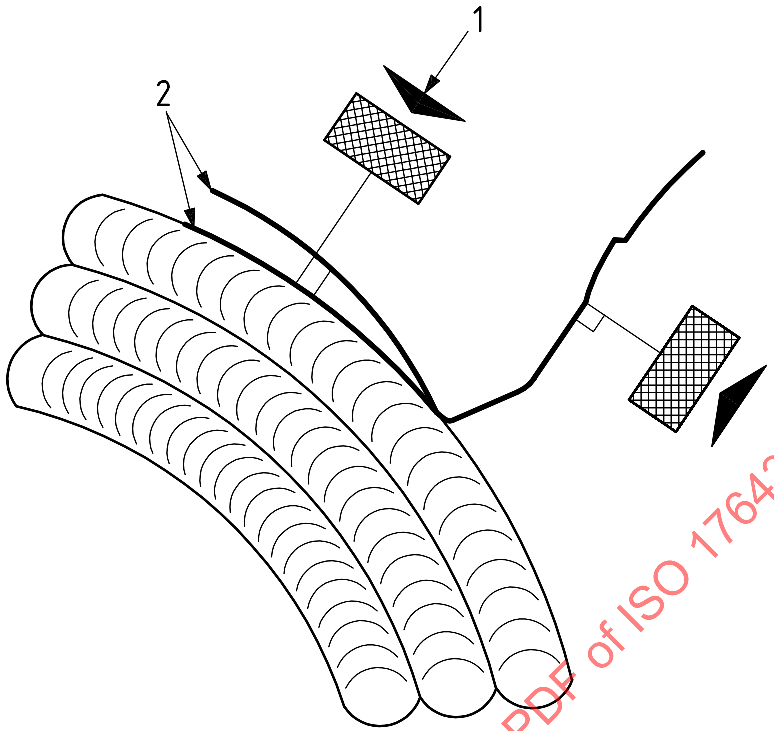
Key

1 probe direction

2 discontinuity

3 optimum angle to accommodate the varying surface conditions

Figure 4 — Single pass scan in toe of the weld

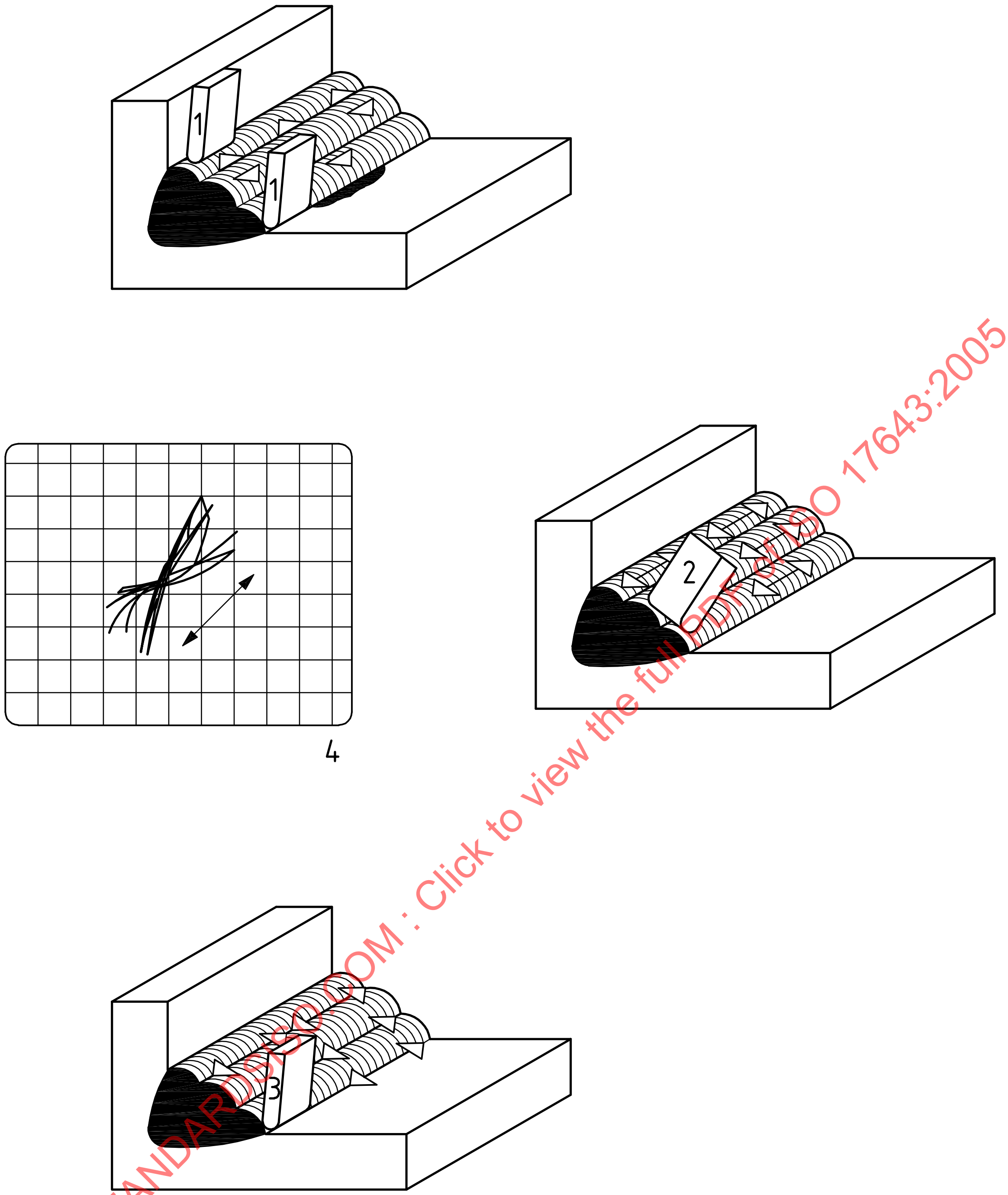


Key

1 probe direction

2 discontinuity

Figure 5 — Additional scans in the heat-affected zone

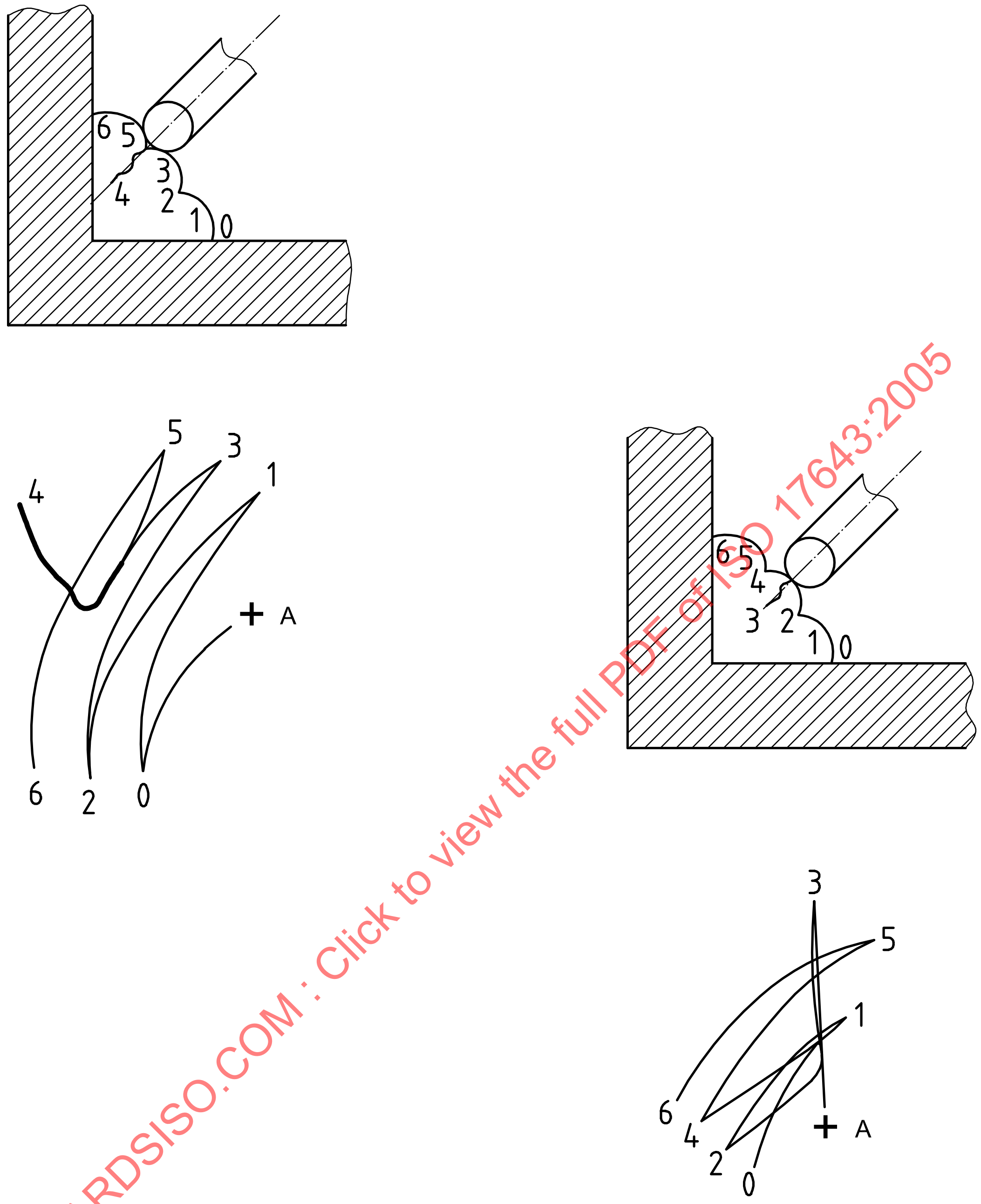


Key

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