INTERNATIONAL STANDARD

ISO 10893-2

First edition
2011-04-01

Non-destructive testing of steel tubes —

Part 2: Automated eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of imperfections

Essais non destructifs des tubes en acier —

Partie 2: Contrôle automatisé par courants de Foucault pour la détection des imperfections des tubes en acier sans soudure et soudés (sauf à l'arc immergé sous flux en poudre)

Reference number
ISO 10893-2:2011(E)

Contents

Page

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.

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 10893-2 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 19, *Technical delivery conditions for steel tubes for pressure purposes*.

This first edition cancels and replaces ISO 9304:1989, which has been technically revised.

ISO 10893 consists of the following parts, under the general title *Non-destructive testing of steel tubes*:

— *Part 1: Automated electromagnetic testing of seamless and welded (except submerged arc-welded) steel tubes for the verification of hydraulic leaktightness*

— *Part 2: Automated eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of imperfections*

— *Part 3: Automated full peripheral flux leakage testing of seamless and welded (except submerged arc-welded) ferromagnetic steel tubes for the detection of longitudinal and/or transverse imperfections*

— *Part 4: Liquid penetrant inspection of seamless and welded steel tubes for the detection of surface imperfections*

— *Part 5: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections*

— *Part 6: Radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*

— *Part 7: Digital radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*

— *Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections*

— *Part 9: Automated ultrasonic testing for the detection of laminar imperfections in strip/plate used for the manufacture of welded steel tubes*

— *Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections*

— *Part 11: Automated ultrasonic testing of the weld seam of welded steel tubes for the detection of longitudinal and/or transverse imperfections*

— *Part 12: Automated full peripheral ultrasonic thickness testing of seamless and welded (except submerged arc-welded) steel tubes*

Non-destructive testing of steel tubes —

Part 2:
Automated eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of imperfections

1 Scope

This part of ISO 10893 specifies requirements for automated eddy current testing of seamless and welded tubes with the exception of submerged arc-welded (SAW) tubes, for the detection of imperfections according to the different acceptance levels as shown in Tables 1 and 2. It is applicable to the inspection of tubes with an outside diameter greater than or equal to 4 mm.

This part of ISO 10893 can also be applicable to the testing of hollow sections.

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.

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

ISO 11484, *Steel products — Employer's qualification system for non-destructive testing (NDT) personnel*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11484 and the following apply.

3.1
reference standard
standard for the calibration of non-destructive testing equipment (e.g. drill holes, notches and recesses)

3.2
reference tube
tube or length of tube containing the reference standard(s)

3.3
reference sample
sample (e.g. segment of tube, plate or strip) containing the reference standard(s)

NOTE Only the term “reference tube” is used in this part of ISO 10893, also covering the term “reference sample”.

3.4
tube
hollow long product open at both ends, of any cross-sectional shape

3.5
seamless tube
tube made by piercing a solid product to obtain a tube hollow, which is further processed, either hot or cold, into its final dimensions

3.6
welded tube
tube made by forming a hollow profile from a flat product and welding adjacent edges together, and which after welding can be further processed, either hot or cold, into its final dimensions

3.7
manufacturer
organization that manufactures products in accordance with the relevant standard(s) and declares the compliance of the delivered products with all applicable provisions of the relevant standard(s)

3.8
agreement
contractual arrangement between the manufacturer and purchaser at the time of enquiry and order

4 General requirements

4.1 Unless otherwise specified by the product standard or agreed on by the purchaser and manufacturer, this eddy current inspection shall be carried out on tubes after completion of all the production process operations, such as rolling, heat treating, cold forming and hot working, sizing and primary straightening.

4.2 The tubes being tested shall be sufficiently straight to ensure the validity of the test. The surfaces shall be sufficiently free of foreign matter which can interfere with the validity of the test.

4.3 This inspection shall be carried out by trained operators qualified in accordance with ISO 9712, ISO 11484 or equivalent and supervised by competent personnel nominated by the manufacturer. In the case of third-party inspection, this shall be agreed on between the purchaser and manufacturer.

The operating authorization issued by the employer shall be according to a written procedure. NDT operations shall be authorized by a level 3 NDT individual approved by the employer.

NOTE The definition of levels 1, 2 and 3 can be found in appropriate International Standards, e.g. ISO 9712 and ISO 11484.

5 Test method

5.1 Test techniques

5.1.1 The tubes shall be tested by the eddy current method for the detection of imperfections using in “absolute mode” and/or in “differential mode” one of the following alternative automated or semi-automated techniques:

a) concentric coil technique — full peripheral (see Figure 1);

b) fixed or rotating probe/pancake coil technique — full peripheral (see Figure 2);

c) segment coil technique — weld seam only (see Figure 3) or full body (see Figure 4).

For all techniques, the chosen relative speed of movement during the testing shall not vary by more than ±10 %.

It is recognized that there may be a short length at both tube ends which cannot be tested. Any untested ends shall be dealt with in accordance with the requirements of the appropriate product standards.

NOTE See Annex A for guidelines on the limitations of the eddy current test method.

5.1.2 When testing tubes using the concentric coil technique, the maximum tube outside diameter that shall be tested shall be restricted to 180 mm (250 mm for E4H).

Square and rectangular tubes, used for structural purposes, with a maximum dimension across the diagonal of 180 mm may also be tested using this technique with adequately shaped coils.

5.1.3 When testing tubes using the rotating or fixed probe/pancake coil technique, the tube and the probe/pancake coil shall be moved relative to each other or the movement shall be simulated by electronic commutation through the individual probes composing the pancake, such that the whole of the tube surface is scanned. There is no restriction on the maximum tube outside diameter using this technique.

NOTE It is emphasized that only external surface breaking imperfections can be detected using this technique.

5.1.4 When testing the weld of welded tubes using the segment coil technique, there is no restriction on the maximum tube outside diameter. The test coil shall be maintained in proper alignment with the weld, such as that the whole of the weld is scanned.

5.1.5 When testing the full body of tubes using the segment coils technique, the maximum tube outside diameter that shall be tested shall be limited to:

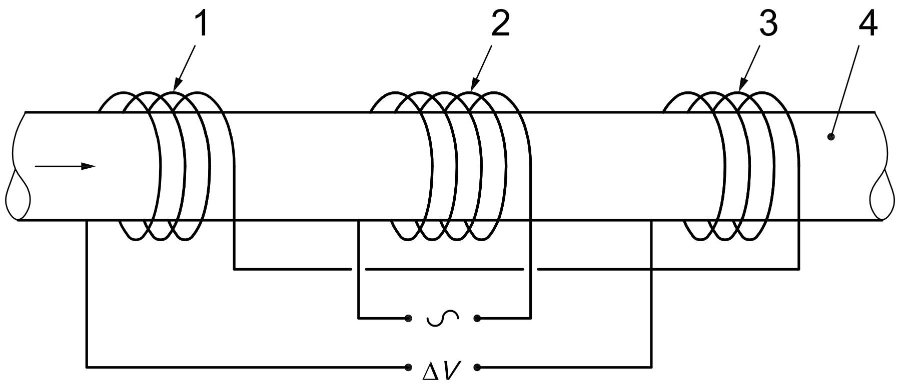
— ∅ 219,1 mm for 2 × 180° coils,

— ∅ 508,0 mm for 4 × 100° coils.

NOTE It is emphasized that the test sensitivity is at a maximum at the tube surface adjacent to the test coil and decreases with increasing thickness (see Annex A).

5.2 Test equipment

The equipment shall be capable of classifying tubes as either acceptable or suspect tubes by means of an automated trigger/alarm level combined with a marking and/or sorting system.



Key

1 secondary coil 1

2 primary coil

3 secondary coil 2

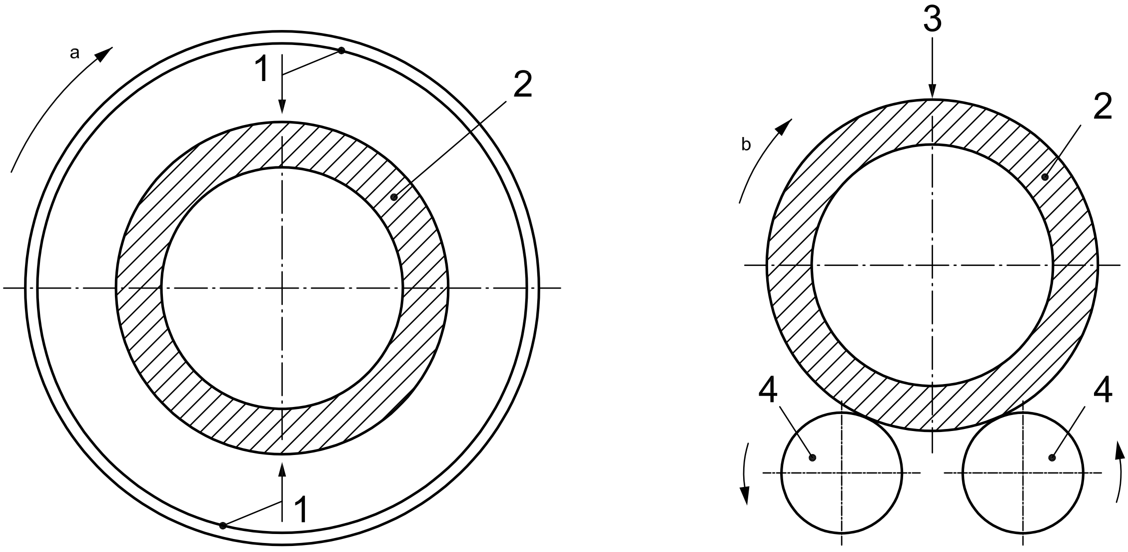
4 tube

~ alternate energizing current

ΔV signal output

NOTE The above diagram is a simplified form of a multi-coil arrangement which can contain, for example split primary coils, twin differential coils and calibrator coil.

Figure 1 — Simplified diagram of the concentric coil technique



a) Rotating probe/pancake coil technique — Linear movement of the tube

b) Fixed probe/pancake coil technique — Linear and rotary movement of the tube

Key

1 position of probe/pancake coil

2 tube

3 position of fixed pancake coil

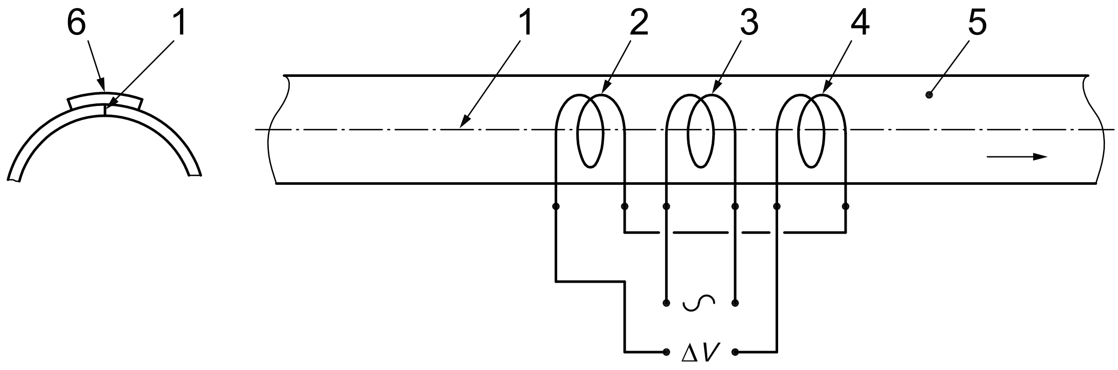
4 rollers

[a] Direction of probe rotation.

[b] Direction of tube rotation.

NOTE The pancake coils in a) and b) can have different forms, e.g. single-coils, multiple coils of different configurations, depending on the equipment used and other factors.

Figure 2 — Simplified diagram of probe/pancake coil technique

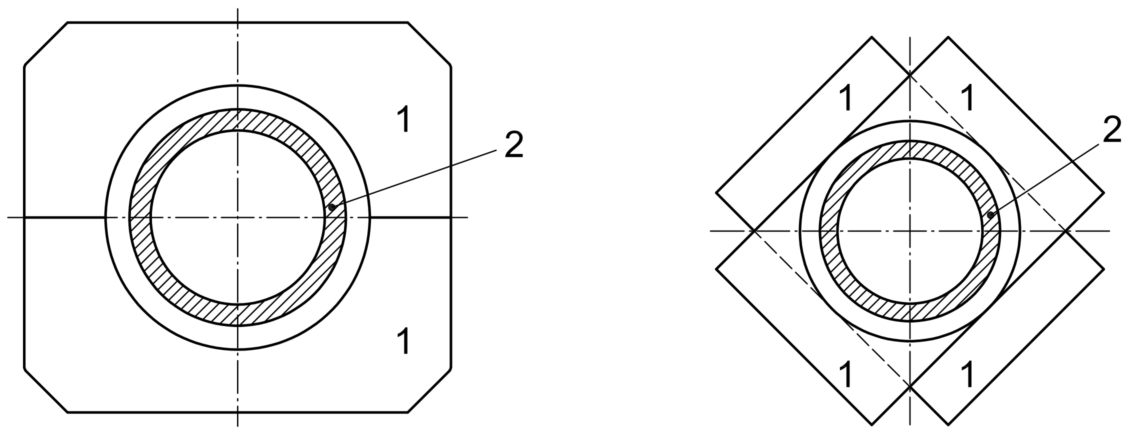


Key

1 weld seam
2 secondary coil 1
3 primary coil
4 secondary coil 2
5 tube
6 coil
~ alternate energizing current
ΔV signal output

NOTE The segment coil arrangement in this figure can take many forms depending, for example on the equipment used and the product being inspected.

Figure 3 — Simplified diagram of segment coil testing method of the weld seam



a) 2 × 180° **segment coils** **b)** 4 × 100° **segment coils**

Key

1 segment coil
2 tube

Figure 4 — Simplified diagram of eddy current segment coil technique

6 Reference tube

6.1 General

6.1.1 The reference standards defined in this part of ISO 10893 are convenient standards for calibration of non-destructive testing equipment. Their dimensions should not be considered as the minimum size of imperfections detectable by such equipment.

6.1.2 The reference tubes shall have the same specified diameter and thickness, same surface finish, and delivery condition (e.g. as-rolled, normalized, quenched and tempered) and similar steel grade as the tubes being tested. For specified wall thickness exceeding 5 mm, the wall thickness of the reference tubes may be greater than the specified wall thickness of the pipe under inspection, provided the notch depth is calculated on the specified wall thickness of the pipe being inspected. The manufacturer shall demonstrate, on request, the effectiveness of the adopted solution.

6.1.3 The reference standards for the various testing techniques shall be as follows:

a) a reference hole or holes as defined in 6.2 and 6.5.1, when using the concentric coil technique;

b) a reference hole or holes as defined in 6.3 and 6.5.1, when using the segment coil technique;

c) a reference notch as defined in 6.4 and 6.5.2, when using the fixed or rotating probe/pancake coil technique.

NOTE 1 In special cases, for example when testing hot tubes or using equipment contained within a continuous tube mill, a modified calibration or calibration checking procedure can be used, by agreement.

NOTE 2 When using the concentric coil technique a longitudinal notch can be used, by agreement, as the reference standard.

6.1.4 The reference standards (see 6.2 to 6.4) shall be sufficiently separated longitudinally (in the case of reference holes) and from the ends of the reference tube such that clearly distinguishable signal indications are obtained.

6.2 Concentric coil technique

6.2.1 When using the eddy current concentric coil technique, the reference tube shall contain three or four circular holes, drilled radially through the full thickness of the reference tube. The holes shall be circumferentially displaced respectively at 120° or 90° from each other.

6.2.2 Alternatively, only one hole shall be drilled through the full thickness of the reference tube and during calibration and calibration checking the reference tube shall be passed through the equipment with the hole positioned at 0°, 90°, 180° and 270°.

6.3 Segment coil technique

6.3.1 When using the segment coil technique, the reference tube shall contain a single circular hole, drilled radially through the full thickness of the reference tube and located adjacent or directly in the weld seam.

6.3.2 When using the segment coil technique, for full body inspection, the reference tube shall contain three circular holes, drilled radially through the full thickness of the reference tube. Each segment coil shall be checked with the reference tube, and the three holes shall be displaced as follows:

— 180° segment coils: 0°, +90° and −90° from the centre of the coil;

— 100° segment coils: 0°, +45° and −45° from the centre of the coil.

6.3.3 Alternatively, only one hole shall be drilled through the full thickness of the reference tube and during calibration and calibration checking the reference tube shall be passed through the equipment with the hole positioned at 0°, +90° and −90° for the 180° segment coil and at 0°, +45° and −45° for the 100° segment coil. These operations shall be repeated for each segment coil.

6.4 Fixed and rotating coil/pancake technique

When using the fixed or rotating coil/pancake technique, the reference tube shall contain a longitudinal reference notch on the external surface.

6.5 Dimensions of the reference standards

6.5.1 Reference hole

The diameter of the reference holes related to the tube outside diameter shall not exceed the requirements of Table 1; the holes shall be formed by machining, spark erosion or other methods.

Table 1 — Specified tube outside diameter and corresponding diameters of the reference holes for possible acceptance levels

Specified tube outside diameter D mm	Acceptance level hole diameter mm			Specified tube outside diameter D mm	Acceptance level hole diameter mm
	E1H	E2H	E3H		E4H
$4 \leqslant D \leqslant 10$	0,60	0,70	0,80	$4 \leqslant D \leqslant 15{,}8$	1,20
$10 < D \leqslant 20$	0,70	0,80	1,00	$15{,}8 < D \leqslant 26{,}9$	1,40
$20 < D \leqslant 44{,}5$	0,80	1,00	1,30	$26{,}9 < D \leqslant 48{,}3$	1,70
$44{,}5 < D \leqslant 76{,}1$	1,00	1,20	1,60	$48{,}3 < D \leqslant 63{,}5$	2,20
$76{,}1 < D \leqslant 180$	1,20	1,40	2,00	$63{,}5 < D \leqslant 114{,}3$	2,70
$180 < D$	1,40	1,80	2,20	$114{,}3 < D \leqslant 139{,}7$	3,20
				$139{,}7 < D$	3,70

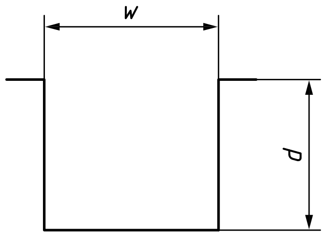
6.5.2 Reference notch

6.5.2.1 General

a) The reference notch shall be of the “N” type (see Figure 5) and shall lie parallel to the major axis of the tube. The sides shall be nominally parallel and the bottom shall be nominally square to the sides.

b) The reference notch shall be formed by machining, spark erosion or other methods.

NOTE The bottom or the bottom corners of the notch can be rounded.



Key

w width

d depth

Figure 5 — "N" type notch

6.5.2.2 Dimensions of the reference notch

a) Width, *w* (see Figure 5)

The width of the reference notch shall not be greater than the reference notch depth or 1 mm whichever is greater.

b) Depth, *d* (see Figure 5)

The depth of the reference notch shall be as given in Table 2, with the following limitations:

— minimum notch depth: 0,3 mm;

— maximum notch depth: 1,5 mm.

The tolerance on notch depth shall be ±15 % of reference notch depth.

c) Length

Unless otherwise specified by product standard or agreed between purchaser and manufacturer, the length of the reference notch(es) shall be greater than twice the width of each individual probe/pankace coil or transducer. In any case, the length of reference notch shall not exceed 50 mm.

6.5.3 Verification of the reference standards

6.5.3.1 The diameter of the reference hole(s) (see Table 1), when used, shall be verified and shall not exceed the value reported in Table 1.

6.5.3.2 The reference notch dimensions and shape shall be verified by a suitable technique.

Table 2 — Acceptance level and corresponding external reference notch depth (for fixed and rotating probe/pancake coil technique)

Acceptance level	Notch depth of the specified thickness %
E2	5
E3	10
E4	12,5
E5	15

NOTE The values of notch depth specified in this table are the same for the corresponding categories, in all International Standards concerning non-destructive testing of steel tubes where reference is made to different acceptance levels. Although the reference standards are identical, the various test methods involved can give different test results. Accordingly, the acceptance level designation prefix E (eddy current) has been adopted to avoid any inferred direct equivalence with other test methods.

7 Equipment calibration and checking

7.1 At the start of each inspection cycle, the equipment shall be calibrated to produce consistently, (e.g. from three consecutive passes of the reference tube through the equipment), clearly identifiable signals from the reference standard(s). These signals shall be used to activate their respective trigger alarm of the equipment as follows:

a) when using multiple reference holes in the reference tube (concentric coil techniques or segment coil technique for testing full surface), the full amplitude obtained from the reference hole giving the smallest signal shall be used to set trigger/alarm level of the equipment. When using a single reference hole in the reference tube, the reference tube shall be passed through the inspection equipment with the reference hole, on successive runs, positioned as specified in 6.2.2, and the full amplitude obtained from the reference hole run giving the smallest signal shall be used to set trigger/alarm level of the equipment;

b) when using a single reference hole (segment coil technique for testing the weld of welded tubes), the full amplitude obtained from the reference hole run giving the smallest signal shall be used to set the trigger/alarm level of the equipment;

c) when using the reference notch (fixed or rotating probe/pancake coil technique), the full signal amplitude obtained from the reference notch shall be used to set the trigger/alarm level of the equipment.

7.2 During the calibration check, the relative speed of movement between the reference tube and the test coils/probes shall be the same as that used during the production test (see also 5.1.2, 5.1.3 and 5.1.4). The same equipment settings, for instance frequency, sensitivity, phase discrimination, filtering and eventual magnetic saturation, shall be employed.

7.3 The calibration of the equipment shall be checked at regular intervals during the production testing of tubes of the same specified diameter, thickness and grade by passing the reference tube through the test equipment.

The frequency of checking the calibration shall be at least every 4 h, but also whenever there is an equipment operator team changeover and at the start and end of production.

7.4 The equipment shall be recalibrated if any of the parameters which were used during the initial calibration are changed.

7.5 If on checking during production testing, the calibration requirements are not satisfied then all tubes tested since the previous acceptable equipment calibration shall be retested after the equipment has been recalibrated.

8 Acceptance

8.1 Any tube producing signals lower than the trigger/alarm level shall be deemed to have passed this test.

8.2 Any tube producing signals equal to or greater than the trigger/alarm level shall be designated suspect, or at the discretion of the manufacturer, may be retested. If, after two consecutive retests, all signals are lower than the trigger/alarm level, the tube shall be deemed to have passed this test otherwise the tube shall be designated as suspect.

8.3 For suspect tubes, one or more of the following actions shall be taken subject to the requirements of the product standard.

a) The suspect area shall be dressed or explored by a suitable method. After checking that the remaining thickness is within tolerance, the tube shall be tested as previously specified. If no signals are obtained equal to or greater than trigger/alarm level, the tube shall be deemed to have passed this test.

   By agreement between the purchaser and manufacturer the suspect area may be retested by other non-destructive techniques and test methods, to agreed acceptance levels.

b) The suspect area shall be cropped off. The manufacturer shall ensure that all the suspect area has been removed.

c) The tube shall be deemed not to have passed the test.

9 Test report

When specified, the manufacturer shall submit to the purchaser a test report including at least the following information:

a) reference to this part of ISO 10893, i.e. ISO 10893-2;

b) statement of conformity;

c) any deviation, by agreement or otherwise, from the procedures specified;

d) product designation by steel grade and size;

e) type and details of inspection technique(s);

f) equipment calibration method used;

g) description of the reference standard acceptance level;

h) date of test;

i) operator identification.

Annex A
(informative)

Guidance notes on limitations of eddy current test method

A.1 Eddy current depth of penetration

During the eddy current testing of tubes, the sensitivity of the test is at a maximum at the tube surface adjacent to the test coil and decreases with increasing distance from the test coil. The signal response from a subsurface or internal surface imperfection is thus smaller than that from an external surface imperfection of the same size. The capacity of the test equipment to detect subsurface or internal surface imperfections is determined by various factors, but predominantly by the thickness of the tube under test and the eddy current excitation frequency.

The excitation frequency applied to the test coil determines the extent to which the induced eddy current intensity penetrates the tube wall. The higher the excitation frequency, the lower the penetration and conversely, the lower the excitation frequency, the higher the penetration. In particular, the physical parameters of the tube (conductivity, permeability, etc.) should be taken into account.

A.2 Concentric coil/segment coil technique

These test techniques are preferred since they can detect short longitudinal imperfections and transverse imperfections, both of which break, or lie below, the surface adjacent to the test coil.

The minimum length of the longitudinal imperfection which is detectable is principally determined by the search coil arrangement and by the rate of change of section along the length of the imperfection.

When using these techniques on ferromagnetic steel, the products being inspected shall be magnetically saturated, inserting them into an external strong magnetic field. The intention of this saturation is to normalize and reduce the magnetic permeability of the material in order to increase the penetration capability of eddy current and to reduce possible magnetic noises from material itself.

A.3 Fixed or rotating probe/pancake coil technique

This test technique uses one or more probes/coils to describe a helical path over the tube surface. For this reason, this technique detects longitudinal imperfections with a minimum length dependent on the width of the test coil and the inspection helical pitch. It is recognized that transverse imperfections are not normally detectable.

Since the excitation frequency is significantly higher than that using concentric coil/segment coil, only imperfections which break the tube surface adjacent to the test coil are detectable.

ICS 23.040.10; 77.040.20; 77.140.75

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