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Non-destructive testing of steel tubes —

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

Essais non destructifs des tubes en acier —

Partie 11: Contrôle automatisé par ultrasons du cordon de soudure des tubes en acier soudés pour la détection des imperfections longitudinales et/ou transversales

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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.

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 10893-11 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 9764:1989 and ISO 9765:1990, which have 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 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 11:
Automated ultrasonic testing of the weld seam of welded steel tubes for the detection of longitudinal and/or transverse imperfections

1 Scope

This part of ISO 10893 specifies requirements for the automated ultrasonic shear wave (generated by conventional or phased array technique) testing of the weld seam of submerged arc-welded (SAW) or electric resistance and induction-welded (EW) steel tubes.

For SAW tubes, the test covers the detection of imperfections oriented predominantly parallel to or, by agreement, perpendicular to the weld seam or both.

For EW tubes, the test covers the detection of imperfections oriented predominantly parallel to the weld seam. In the case of testing on longitudinal imperfections, Lamb wave testing can be applied at the discretion of the manufacturer.

For the detection of imperfections at the weld seam of EW tubes, full peripheral ultrasonic testing is possible.

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

NOTE For full peripheral ultrasonic testing of seamless and welded (except SAW) tubes, see ISO 10893-10.

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 5577, *Non-destructive testing — Ultrasonic inspection — Vocabulary*

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

ISO 10893-6, *Non-destructive testing of steel tubes — Part 6: Radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*

ISO 10893-7, *Non-destructive testing of steel tubes — Part 7: Digital radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*

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 5577 and ISO 11484 and the following apply.

3.1
reference standard
standard for the calibration of non-destructive testing equipment (e.g. drill holes, notches, 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
welded tube
ttube made by forming a hollow profile from a flat product and welding adjacent edges together. After welding the tube may be further processed, either hot or cold, into its final dimensions

3.6
electric welded tube
tube made by pressure welding, in a continuous or non-continuous process, in which strip is formed cold into a hollow profile and the seam weld made by heating the adjacent edges through the resistance to the passage of high- or low-frequency current, and pressing the edges together

NOTE The electric current can be applied either by direct electrode contact or by induction.

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 standards or agreed on by the purchaser and manufacturer, an ultrasonic test shall be carried out on tubes after completion of all the primary production process operations (rolling, heat treating, cold and hot working, sizing and primary straightening, etc.).

For cold-expanded tubes, the ultrasonic testing of the weld shall be carried out after expansion. In case of spirally welded tubes, where the tube is not subsequently subjected to a hydrostatic test at the tube mill, the acceptance test may be carried out online.

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

4.3 This test shall be carried out by suitably 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 by the purchaser and manufacturer.

The operating authorization issued by the employer shall be according to a written procedure. Non-destructive testing (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 The weld seam of the tube shall be tested using an ultrasonic shear wave technique for the detection of longitudinal and/or transverse imperfections. Lamb wave technique may be applied for the detection of longitudinal imperfections of EW tubes.

Unless otherwise agreed on by the purchaser and manufacturer, testing shall be carried out in two opposite directions of sound propagation for the requested type of inspection, clockwise and anticlockwise for the detection of longitudinal imperfections and forward and backward for the detection of transverse imperfections.

5.2 During testing, the tubes and the probe assembly shall be moved relative to each other such that the whole area under inspection is scanned with coverage calculated on the dimension of the transducer(s).

The relative speed of movement during testing shall not vary by more than 10 %.

5.3 There can 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 standard.

In the case of SAW tubes, the untested ends may, at the manufacturer's discretion, be checked either by a manual ultrasonic test in accordance with this part of ISO 10893 or by a radiographic test in accordance with ISO 10893-6 or ISO 10893-7.

In the case of EW tube, the untested ends may be tested in accordance with Annex A.

5.4 For the detection of longitudinal imperfections, the maximum width of each individual transducer, measured parallel to the major axis of the tube, shall be 25 mm. For the detection of transverse imperfections, the maximum width of each individual transducer, measured perpendicular to the major axis of the tube, shall be 25 mm.

In case of the use of Lamb wave technique or phased array technique, the maximum length of transducer or active aperture shall be limited to 35 mm.

5.5 The ultrasonic test frequency of transducers shall be in the range 1 MHz to 15 MHz for shear wave technique and in the range of 0,3 MHz to 1 MHz for Lamb wave technique, depending on the product condition and properties, the thickness and surface finishing of tubes under examination.

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

5.7 Where manual ultrasonic testing of untested tube ends and/or local suspect areas is required (see 5.3), use Annex A.

6 Reference tube

6.1 General

6.1.1 The reference standards defined in this part of ISO 10893 are convenient standards for establishing the sensitivity of non-destructive testing equipment. The dimensions of these standards should not be construed as the minimum size of imperfection detectable by such equipment.

6.1.2 For SAW tubes, for the detection of longitudinal imperfections, the equipment shall be calibrated using four longitudinal reference notches, two on the outside surface and two on the inside surface, in the parent material close to the weld seam of a reference tube, and/or a reference hole located in the centre of the weld (see Figure 1).

Alternatively, by agreement between the purchaser and manufacturer, the equipment may be calibrated using internal and external notches located on the centre of the weld seam. In this case, the depth of the notches shall be agreed on by the purchaser and manufacturer, and the manufacturer shall demonstrate that the sensitivity is equivalent to that obtained from the edge notches.

For the detection of transverse imperfections, if requested, the equipment shall be calibrated using two transverse notches in the weld seam, one on the external and one on the internal surface of reference tube, and/or a reference hole located in the centre of the weld.

The selection of the notches or the hole is left to the discretion of the manufacturer.

6.1.3 For EW tubes, the ultrasonic equipment shall be calibrated using a longitudinal reference notch on the outside and inside surfaces of a reference tube.

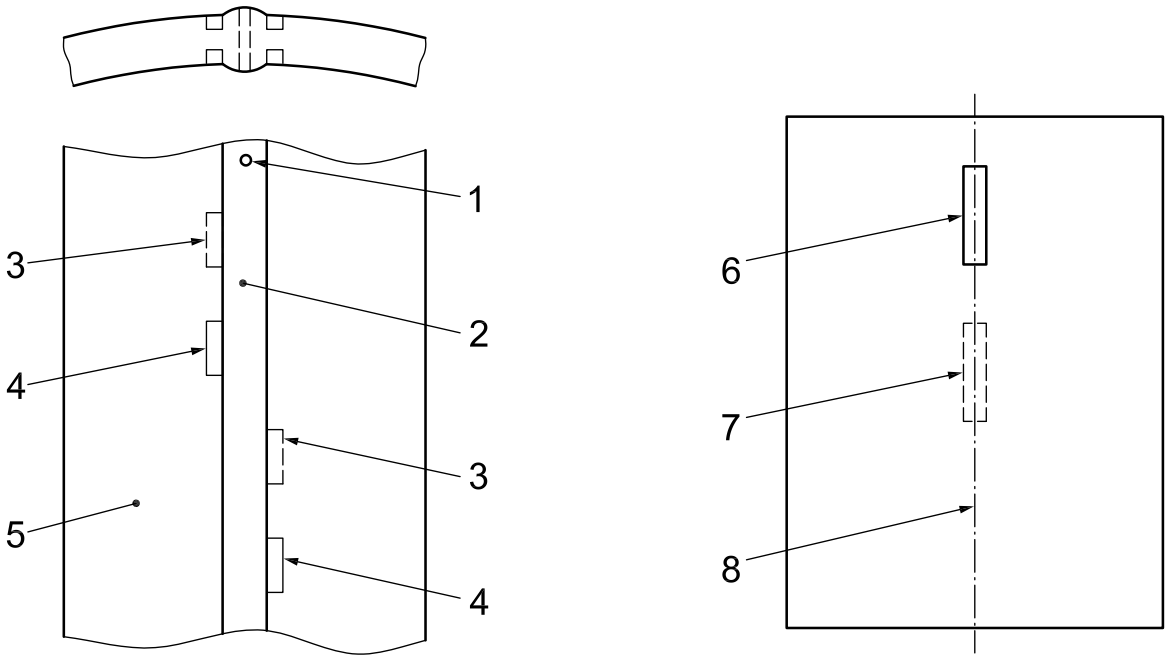
When the tube internal diameter is less than 15 mm, the manufacturer and purchaser may agree to waive the internal notch.

Alternatively, a reference hole drilled through the wall of the reference tube may be used for equipment calibration, by agreement between the purchaser and manufacturer. In this case, the diameter of the drill required to produce the reference hole for a specific acceptance level shall also be agreed on and the manufacturer shall demonstrate to the satisfaction of the purchaser that the test sensitivity achieved using the reference hole is essentially equivalent to that obtained when using the specified reference notch(es).

Such notches and drill holes shall be located in the centre of the weld line, unless otherwise agreed on by the purchaser and manufacturer.

6.1.4 The reference tubes shall have the same nominal diameter and thickness, same surface finish and same heat treatment delivery condition (e.g. as-rolled, normalized, quenched and tempered) as the tubes under test, and shall have similar acoustic properties (e.g. sound velocity and attenuation coefficient). The manufacturer shall have the option of removing the weld bead of SAW tubes inside and outside such that it is in alignment with the curvature of the tube body.

6.1.5 In order to obtain clearly distinguishable signals, the external and internal notches and the hole shall be sufficiently separated from the ends of the reference tube/sample and from each other.



a) Submerged arc-welded (SAW) tube **b) Electric resistance and induction-welded (EW) tube**

Key

1	through hole	3 and 7	longitudinal internal notches	5	reference tube
2	submerged arc-weld seam	4 and 6	longitudinal external notches	8	centreline of weld

Figure 1 — Simplified representation of reference tube

6.2 Reference notches

6.2.1 Types and preparation of notch

6.2.1.1 The reference notches shall be of the "N" type (N-notch) (see Figure 2); for EW tubes the "V" type notch (V-notch) may be used at the discretion of the manufacturer, if specified notch depth is less than or equal to 0,5 mm (see Figure 2). In the case of the "N" type notch, the sides shall be nominally parallel and the bottom shall be nominally square to the sides.

a) "V" type notch **b) "N" type notch**

Key

w width *d* depth

Figure 2 — Types "V" and "N" reference notch

6.2.1.2 For SAW tubes, the reference notches shall be located in the parent material close to the weld edges and shall lie parallel to the weld seam (see Figure 1).

6.2.1.3 The reference notch shall be formed by machining, spark erosion, etc.

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

6.2.2 Dimension of reference notches

6.2.2.1 Width and depth

6.2.2.1.1 For width, w, see Figure 2. The width of the "N" type reference notch shall be not greater than 1,0 mm except for spirally welded tubes having the diameter equal to or greater than 406 mm where the width shall not exceed 1,5 mm. In any case, the width should not exceed twice the depth.

6.2.2.1.2 For depth, d, see Figure 2. The depth of the reference notch shall be as given in Table 1.

The values of notch depth specified in Table 1 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 may give different test results. Accordingly, the acceptance level designation prefix U (ultrasonic) has been adopted to avoid any inferred direct equivalence with other test methods.

The minimum notch depth shall be 0,3 mm for U2 and U3 category tubes and 0,5 mm for U4 category tubes.

The maximum notch depth shall be 1,5 mm for U2 and U3 category tubes and 3 mm for U4 category tubes.

Table 1 — Acceptance levels and corresponding reference notch depth

Acceptance level	Notch depth of the specified thickness %
U2	5
U3	10
U4	12,5
U5	15

The tolerance of notch depth shall be ±15 % of requested notch depth or ±0,05 mm, whichever is the greater, with the exception that when the notch depth is less than 0,3 mm, the tolerance on the depth shall be ±0,03 mm.

6.2.2.2 Notch length

Unless otherwise specified by the product standard or agreed on by the purchaser and manufacturer, the length of the reference notch(es) shall be greater than the width of the single transducer or active aperture. In any case, the length of reference notch shall not exceed 50 mm.

6.2.2.3 Verification

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

6.3 Reference hole

6.3.1 The reference hole shall be drilled through the wall at the centre of the weld, perpendicular to the surface of the reference tube (see Figure 1).

6.3.2 For SAW tubes, the diameter of the drill shall be selected to produce a hole no larger than that specified in Table 2. The diameter of the reference hole shall be verified.

For EW tubes, see 6.1.3.

Accordingly the acceptance level designation prefix U (ultrasonic) has been adopted to avoid any inferred direct equivalence with other test methods.

Table 2 — Acceptance levels and corresponding reference drilled hole diameter

Acceptance level	Maximum drilled hole diameter mm
U2H	1,6
U3H	3,2
U4H	4,0

7 Equipment calibration and checking

7.1 General

At the start of each test cycle, the equipment, independently of the applied type of waves, shall be calibrated to produce consistently clearly identifiable signals from the used reference notches. These signals shall be used to activate the respective trigger/alarm level(s) of the equipment.

7.2 Adjustment of the trigger/alarm level

7.2.1 Where a single trigger/alarm level is used, the probe(s) shall be adjusted such that the signals from the internal and external reference notches are as equal as possible, and the full signal amplitude of the lesser of the two signals shall be used to activate the trigger/alarm level of the equipment.

7.2.2 Where separate trigger/alarm levels are used for internal and external reference notches, the full signal amplitude from each notch shall be used to set the relevant trigger/alarm level of the equipment. The positions and widths of the gates shall be adjusted in such a way that the entire wall thickness of the tube is tested.

7.2.3 When using the reference hole, the manufacturer shall demonstrate that the sensitivity achieved at the inner and outer surfaces is essentially equivalent to that achieved when using the specified reference notches.

7.3 Calibration check and recalibration

7.3.1 The calibration of the equipment shall be checked at regular intervals during the production testing of tubes of the same diameter, thickness and grade, by passing the tube through the inspection installation. The frequency of checking the calibration shall be at least every 4 h, but also whenever there is an equipment operator changeover and at the start and end of the production run.

7.3.2 During a dynamic check of the calibration, the relative speed of movement between the reference tube and the transducer assembly shall be the same as that used during the production test. Other calibration conditions are allowed, provided the manufacturer can demonstrate that the same results as the dynamic check of the calibration are obtained.

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

7.3.4 If, on checking during production testing, the calibration requirements are not satisfied, 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 as suspect or, at the manufacturer's discretion, 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) by agreement between the purchaser and manufacturer, the suspect area may be explored by a suitable method or may be retested by other non-destructive techniques and test methods, to agreed acceptance levels. Retesting shall be carried out in accordance with documented procedure;

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

c) the suspect area shall be cropped off;

d) the tube shall be deemed not to have passed this test.

9 Test report

If specified, the manufacturer shall submit to the purchaser a test report that includes at least the following information:

a) reference to this part of ISO 10893, i.e. ISO 10893-11;

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 test technique(s);

f) equipment calibration method used;

g) description of the reference standard acceptance level;

h) date of test

i) operator identification.

Annex A
(normative)

Manual/semi-automated testing of untested ends and suspect areas

A.1 Untested tube ends

If specified by the relevant product standard, the weld seam at the tube end zone which cannot be tested by the automated ultrasonic equipment shall be subjected to a manual/semi-automated test, from the ultimate tube ends and over the length of the original untested zone plus 10 %.

The manual/semi-automated ultrasonic test shall be carried out such that the whole length of the untested end is scanned with a 10 % overlap, with reference to the ultrasonic transducer width used, measured in the direction parallel to the major axis of the tube.

The manual/semi-automated ultrasonic test shall be carried out using the ultrasonic shear wave technique or Lamb wave technique, test sensitivity (reference notch depth) and general test parameters, as used during the original automated test on the main tube length, with the restrictions given in A.3.

A.2 Local suspect areas

If appropriate, local areas on the tube deemed suspect by the automated ultrasonic equipment shall be subjected to a test by manual ultrasonic shear wave technique or Lamb wave technique, test sensitivity (reference notch depth) and general test parameters, as used during the original automated test, with the restrictions given in A.3, so that the whole of the local suspect area is scanned.

A.3 Manual/semi-automated ultrasonic test restrictions

The following restrictions apply to the application of a manual/semi-automated ultrasonic test to untested end zones and/or local suspect areas:

a) the beam angle in steel used for manual ultrasonic testing with shear waves shall be nominally the same as that used during the original automated test;

b) scanning shall be carried out with ultrasonic beam propagation in circumferential or longitudinal directions (or both);

c) scanning speed over the tube surface shall not exceed 150 mm/s;

d) the ultrasonic probe type used during manual ultrasonic testing with shear waves shall be of the contact, gap-scan or immersion type. Means shall be provided to ensure that the probe is held at the correct distance in relation to the tube surface, e.g. for contact type probes, the “wear face” at the front face of the probe shall be fitted to the curvature of the tube under test;

e) the width of the transducer, measured parallel to the major axis of the tube, used in the manual ultrasonic test shall not exceed that used during the original automated test;

f) the nominal frequency of the transducer used in manual testing shall not vary from that used during the original automated test by more than ±1 MHz. Where Lamb waves have been used in the original automated test, the frequency of shear wave transducers, if used for manual testing, shall be in the range of 4 MHz to 5 MHz.

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