INTERNATIONAL STANDARD

ISO 10893-10

First edition
2011-04-01

Non-destructive testing of 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

Essais non destructifs des tubes en acier —

Partie 10: Contrôle automatisé par ultrasons sur toute la circonférence des tubes en acier sans soudure et soudés (sauf à l'arc immergé sous flux en poudre) pour la détection des imperfections longitudinales et/ou transversales

Reference number
ISO 10893-10:2011(E)

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Published in Switzerland

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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 10893-10 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 9303:1989 and ISO 9305:1989, 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 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 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

1 Scope

This part of ISO 10893 specifies requirements for automated full peripheral ultrasonic shear wave (generated by conventional or phased array technique) testing of seamless and welded [except submerged arc-welded (SAW)] steel tubes, for the detection of longitudinal and/or transverse imperfections.

Unless otherwise specified in the purchase order, the testing method is applicable to the detection of predominantly longitudinal imperfections.

In the case of testing on longitudinal imperfections, Lamb wave testing can be applied at the discretion of the manufacturer.

For seamless tubes, by agreement between the purchaser and manufacturer, testing principles of this part of ISO 10893 can be applied to detect imperfections having other orientations.

This part of ISO 10893 is applicable to the inspection of tubes with an outside diameter greater than or equal to 10 mm, normally with an outside diameter-to-thickness ratio greater than or equal to 5.

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

NOTE For options for testing tubes with an outside diameter-to-thickness ratio less than 5 on longitudinal imperfections, see Annex A.

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 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
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

3.9
average of the specified thickness range
average of the specified thickness range given by:

$$\frac{T_{\text{max}} + T_{\text{min}}}{2}$$

where T_{max} and T_{min} are the maximum and the minimum thicknesses allowed by the standard when taking into account the wall thickness tolerances

4 General requirements

4.1 Unless otherwise specified by the product standard or agreed on by the purchaser and manufacturer, this ultrasonic testing shall be carried out on tubes after completion of all the primary production process operations (rolling, heat treating, cold and hot working, sizing and straightening, etc.).

4.2 The tubes under test 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 test shall be carried out by suitable 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 tubes shall be tested by using an ultrasonic shear wave technique for the detection of longitudinal and transverse imperfections. Lamb wave technique may be applied for the detection of longitudinal imperfections.

5.2 During testing, the tubes and the transducer assembly shall be moved relative to each other such that the whole of the tube surface 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 %. 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 (see Annex B).

5.3 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 defects and forward and backward for the detection of transversal defects.

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 U1 category tubes with an outside diameter equal to or less than 50 mm, the width of any one transducer unit shall normally be restricted to a maximum of 12,5 mm.

In the case of use of the Lamb wave technique or phased array technique, the maximum width of transducer or active aperture, measured parallel to the major axis of the tube, shall be limited to 35 mm.

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

5.5 The ultrasonic test frequency of transducers that shall be used shall be in the range 1 MHz to 15 MHz for shear wave technique and in the range 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 and/or sorting system.

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. The dimensions of these standards should not be construed as the minimum size of imperfection detectable by such equipment.

6.1.2 For the detection of longitudinal imperfections, the ultrasonic equipment shall be calibrated using longitudinal reference notches on the outside and inside surfaces of a reference tube.

For the detection of transverse imperfections, the ultrasonic equipment shall be calibrated using transverse reference notches on the outside and inside surfaces of a reference tube.

For both examination types, when the tube internal diameter is less than 15 mm, the manufacturer and purchaser may agree to waive the internal notch.

For seamless tubes, where the detection of imperfections having other orientations can be requested, relevant requirements replacing or in addition to those of this part of ISO 10893 shall be specified at the time of enquiry and order.

6.1.3 The reference tubes shall have the same nominal diameter and thickness, same surface finish and 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).

6.1.4 In order to obtain clearly distinguishable signals, the notches shall be sufficiently separated from the ends of the reference tubes and from each other.

6.2 Types of reference notches

6.2.1 The reference notches shall lie parallel (longitudinal notches) or transverse (transverse notches) to the major axis of the reference tube.

The reference notches shall be of the “N” type (N-notch); the “V” type notch (V-notch) may be used at the discretion of the manufacturer when the specified notch depth is less than 0,5 mm (see Figure 1). In the case of “N” type notch, the sides shall be nominally parallel and the bottom shall be nominally square to the sides.

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

a) “V” type notch **b) “N” type notch**

Key

w width

d depth

Figure 1 — Reference notch forms

6.2.2 In the case of transverse notches, the notch forms shown in Figure 2 shall be used, at the discretion of the manufacturer.

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

a) External partial circumferential notch **b) Internal partial circumferential notch**

Key
d depth

Figure 2 — Typical transverse notches

6.3 Dimensions of reference notches

6.3.1 Width, w (see Figure 1)

The width of the reference notch shall not be greater than 1,0 mm and should not exceed twice the depth.

6.3.2 Depth, d (see Figure 1 and 2)

6.3.2.1 The depth of the reference notch shall be as given in Table 1.

NOTE 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 can give different test results.

Table 1 — Acceptance levels and corresponding reference notch depth

Acceptance level	Notch depth of the specified thickness %
U1	3
U2	5
U3	10
U4	12,5

6.3.2.2 The minimum notch depth is related to the type of tube used for a particular application and is denoted by a subcategory as given in Table 2, unless otherwise agreed on by the purchaser and manufacturer. In the absence of specified subcategories, the minimum notch depth shall be 0,2 mm for cold-drawn, cold pilgered or machined tubes and 0,5 mm for all the other conditions.

Table 2 — Subcategories and minimum notch depth

Subcategory	Minimum notch depth[a] mm	Typical tube condition
A	0,1	Cold-drawn, cold pilgered or machined tubes
B	0,2	
C	0,3	All conditions
D	0,5	

[a] The minimum notch depth that may be used is related to specific tube manufacturing methods where the surface finish plays a dominant role in the minimum notch depth that can be adopted for ultrasonic equipment calibration in order to achieve an acceptable signal-to-noise ratio.

6.3.2.3 The maximum depth of notch for all acceptance levels and subcategories shall be 1,5 mm, except for tubes with a wall thickness greater than 50 mm, for which it can be increased to 3,0 mm, unless otherwise agreed on.

6.3.2.4 The tolerance on notch depth shall be ±15 % of reference 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 shall be ±0,03 mm.

6.3.3 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 single virtual transducer, with the following limitation:

— maximum of 25 mm for cold-drawn, cold pilgered or machined tubes;

— maximum of 50 mm for all other conditions.

6.3.4 Verification of the reference standards

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

7 Equipment calibration and checking

7.1 General

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

7.2 Adjustment of trigger/alarm level

7.2.1 Where a single trigger/alarm level is used, the probes shall be adjusted such that the signals from the internal and external reference notches are equal, as far as possible, and the full signal amplitude of the lesser of the two signals shall be used to set 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 position and width of the gates shall be adjusted in such a way that the entire wall thickness of the tube is tested.

7.2.3 When only the external notch is used, the full signal amplitude from the external notch occurring immediately after the internal gated time period shall be used as the internal notch signal amplitude.

7.3 Calibration check and recalibration

7.3.1 The calibration of the equipment shall be dynamically 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 testing installation.

The frequency of checking the calibration shall be at least every 4 h, but also whenever there is a testing installation 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 probe assembly shall be the same as that used during the production test. Other calibration conditions may be 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 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 retested 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.

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

b) the suspect area shall be cropped off;

c) 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 10893-10;

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)

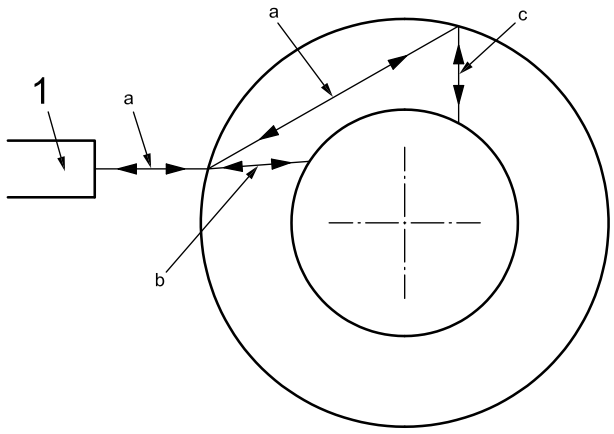
Testing on longitudinal imperfections of tubes with a ratio of the specified outside diameter to the average of the specified thickness range less than 5

A.1 General

A.1.1 When the diameter-to-thickness ratio (D:T) of the tube is less than 5, either A.1.2 or A.1.3 shall be applied by agreement between the purchaser and manufacturer.

A.1.2 When the diameter-to-thickness ratio (D:T) of the tube is less than 5, but greater than or equal to 4, the internal longitudinal notch depth shall be increased in relation to the external notch depth, as given in Table A.1.

A.1.3 When the diameter-to-thickness ratio (D:T) of the tube is less than 5, but greater than or equal to 3, the incidence angle shall be decreased. Then, in addition to the direct converted shear wave, a shear wave generated by the refracted compression wave shall be used (see Figure A.1). In this case, the ratio of internal to external notch depth may be by agreement between the purchaser and manufacturer, but shall under no circumstance be less than 1,0 or greater than the relevant ratios given in Table A.1.



Key

1 single transducer probe, emitting and receiving, or dual transducer probe with separate transmitting and receiving transducers

a Compression (longitudinal) wave.

b Direct shear wave.

c Mode-converted shear wave.

Figure A.1 — Immersion testing using compression wave to shear wave conversion

A.2 Ratio

See Table A.1.

Table A.1

Ratio	
Diameter-to-thickness ratio	**Internal reference notch depth/ external reference notch depth**
$< 5{,}00$ and $\geqslant 4{,}75$	1,6
$< 4{,}75$ and $\geqslant 4{,}50$	1,9
$< 4{,}50$ and $\geqslant 4{,}25$	2,2
$< 4{,}25$ and $\geqslant 4{,}00$	2,5

Annex B
(normative)

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

B.1 Untested tube ends

When specified by the relevant product standard, tube end zones which cannot be tested by the automated ultrasonic test equipment shall be subjected to a manual/semi-automated test around the full periphery of the tube, 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 surface of the untested end is scanned with a 10 % overlap of adjacent scanning paths, 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 B.3.

B.2 Local suspect areas

Where 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 B.3, such that the whole of the local suspect area is scanned.

B.3 Manual/semi-automated ultrasonic test restrictions

The following restrictions apply to the application of a manual/semi-automated ultrasonic shear wave test to untested end zones or local suspect areas (or both).

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 sound propagation in both circumferential and/or longitudinal directions;

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

d) the type of ultrasonic transducer that shall be 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 transducer is held at the correct distance in relation to the tube surface, e.g. for contact type transducers, the “wear face” at the front face of the transducer 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.

ICS 23.040.10; 77.040.20; 77.140.75

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