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Non-destructive testing of steel tubes —

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

Essais non destructifs des tubes en acier —

Partie 4: Contrôle par ressuage des tubes en acier sans soudure et soudés pour la détection des imperfections de surface

Reference number
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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 10893-4 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 12095:1994, 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 4:
Liquid penetrant inspection of seamless and welded steel tubes for the detection of surface imperfections

1 Scope

This part of ISO 10893 specifies requirements applicable to liquid penetrant testing of seamless and welded tubes for the detection of surface imperfections.

It is applicable to all or any part of the tube surface as required by the relevant product standards.

It 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 3059, *Non-destructive testing — Penetrant testing and magnetic particle testing — Viewing conditions*

ISO 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

ISO 3452-2, *Non-destructive testing — Penetrant testing — Part 2: Testing of penetrant materials*

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 3452-1 and ISO 11484 and the following apply.

3.1
tube
hollow long product open at both ends, of any cross-sectional shape

3.2
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

3.3
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

3.4
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)

3.5
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 liquid penetrant inspection shall be carried out on tubes after completion of all the primary production process operations (rolling, heat treating, cold and hot working, sizing, primary straightening, etc.).

4.2 The surface of the tube being tested shall be sufficiently clean and free of oil, grease, sand, scale or any other foreign matter which can potentially interfere with the correct interpretation of the indications obtained from liquid penetrant testing. The type of indications, as well as the minimum dimension of the surface imperfections detected, depends on the specific tube manufacturing process and the surface finish.

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 General

5.1.1 A liquid penetrant is applied to the surface being examined and allowed to enter the surface imperfections. All excess penetrant is then removed; the surface of the part is dried and a developer is applied. The developer functions both as a blotter to absorb penetrant that has been trapped in imperfections and as a contrasting background to enhance the visibility of penetrant indications. The dyestuffs in penetrants are either colour-contrast (visible under white light) or fluorescent (visible under ultraviolet light). For both penetrant techniques, the following three types of penetrant systems can be used:

a) water washable;

b) post emulsifying;

c) solvent removable.

Where the term “penetrant materials” is used in this part of ISO 10893, it is intended to include all penetrants, solvents or cleaning agents, developers, etc., used in the testing process.

5.1.2 For each tube or each part of the tube under test, either a colour-contrast penetrant technique or a fluorescent penetrant technique, both techniques with one of the three types of penetrant systems, shall be used.

The general principles and the methods of verification of liquid penetrant testing as described in ISO 3059, ISO 3452-1 and ISO 3452-2 shall be applied (see 5.3).

5.2 Detection of imperfections and their classification

The liquid penetrant method is an effective means of detecting imperfections which are open to the surface (called surface imperfections in this part of ISO 10893). Typical surface imperfections detectable by this method are cracks, seams, laps, cold shuts, laminations and porosity.

The liquid penetrant method does not make it possible to determine the nature, shape and, more generally, the dimensions of the surface imperfections revealed. The dimensions of the penetrant indication do not directly represent the actual dimensions of the surface imperfection causing this indication. That is why the classification of liquid penetrant indications shall be the following:

a) linear indications — indications where the length of the indication is equal to or more than three times the width of the indication;

b) rounded indications — indications which are circular or elliptical in shape, where the length of the indication is less than three times the width of the indication;

c) accumulated indications — indications which are linear or rounded and are aligned or clustered with a separation of not more than the length of the smallest indication and consisting of at least three indications;

d) non-relevant indications — indications which may result from localized surface irregularities to a particular tube-making process, for example machining marks, scratches and sizing/straightening marks.

The minimum dimension of indications that shall be considered during the evaluation shall be as given in Table 1, in relation to the acceptance level specified.

Table 1 — Minimum dimension of indications that shall be considered for evaluation

Acceptance level	Diameter, D, or length, L, of the smallest indication that shall be considered mm
P1	1,5
P2	2,0
P3	3,0
P4	5,0

5.3 Procedure

The liquid penetrant testing shall be in accordance with the following operational conditions:

a) for the choice of the penetrant system, the tube surface condition as well as the test category shall be taken into account;

b) for stainless steel tubes, low halogen (chlorine/fluorine) and low sulphur penetrant materials shall be applied;

c) the temperature of application shall be between 10 °C and 50 °C. When it is not practicable to conduct the liquid penetrant testing within the given temperature range, the testing procedure shall be qualified at the proposed temperature using the liquid penetrant comparator block (e.g. a quench-cracked aluminium block);

d) the penetrant should be applied by brushing or spraying. For parts of tubes, dipping or flooding is less effective but not prohibited;

e) the dwell time shall be not less than that recommended by the manufacturer of the penetrant system; usually it is between 3 min and 30 min;

f) the removal of excess water-washable or post-emulsified penetrant shall be performed with rinsing by water, under black light conditions where appropriate, at a pressure around 200 kPa (2 bar) with a maximum of 350 kPa (3,5 bar). The temperature of the water used for rinsing shall be less than 40 °C. The excess solvent-removable penetrant shall be removed insofar as possible by using wipes of white, lint-free material that is clean and dry, until most traces of penetrant have been removed. Then the surface shall be lightly wiped with a lint-free material that has been slightly moistened with solvent, until all remaining traces of excess penetrant have been removed. Flushing the surface with solvent following the application of the penetrant and prior to developing is prohibited;

g) drying of the surface subsequent to washing with water can be assisted by using wipes of white, lint-free material that is clean and dry or by using a hot-air blast at a pressure below 200 kPa (2 bar) and a temperature below 70 °C. Drying after the solvent-removing process is generally by normal evaporation, therefore no other drying techniques are necessary. The temperature of the tube shall not exceed 50 °C, unless otherwise agreed on by the purchaser and manufacturer;

h) the wet developer shall be applied by spraying, in such a manner as to assure complete coverage of the area being tested with a thin, even film of developer. The dry-powder developer shall be applied either by dipping the tube, or the parts of the tube being tested, into a fluid bed of dry developer or by dusting it with the dry-powder developer through a manual powder bulb or a spray powder gun (conventional or electrostatic), provided the powder is dusted evenly over the entire surface being tested;

i) the development time begins as soon as the wet-developer coating is dry or immediately after the application of the dry-powder developer. Generally, the development time is equal to the penetration time and varies from 5 min to 30 min, and if the bleed out does not alter the inspection results; development periods of more than 30 min are permitted;

j) the inspection of the areas being tested shall be performed after the applicable development time as specified in 5.3 i), to assure proper bleed out of penetrant from the imperfections on to the developer coating. It is good practice to observe the surface while applying the developer as an aid to evaluating indications. For fluorescent penetrant indications, the inspection shall be carried out in a darkened area using a UV-A radiation source with a background of light level not exceeding 20 lux and a black light intensity of at least 10 W/m^2 on the surface of the area being inspected. For visible penetrant indications, the illumination of the surface of the area being inspected shall be not less than 500 lux.

6 Evaluation of indications

6.1 Four acceptance levels, corresponding to four severity levels with maximum permissible number or maximum permissible dimensions (diameter or length) have been established in accordance with Tables 2 and 3.

6.2 The inspection shall be carried out visually without image magnification.

A remote inspection technique, such as using television camera, is permitted provided the manufacturer can demonstrate that the acceptance criteria are not affected.

Table 2 — Tube surface — Maximum permissible number and dimension (diameter, length) of imperfections within a frame aperture of 100 mm × 150 mm

Acceptance level	Nominal wall-thickness T mm	Type of indication					
		Rounded		Linear		Accumulated	
		Number	Diameter mm	Number	Length mm	Number	Sum of dimensions mm
P1	$T \leqslant 16$	5	3,0	3	1,5	1	4,0
	$16 < T \leqslant 50$	5	3,0	3	3,0	1	6,0
	$T > 50$	5	3,0	3	5,0	1	10,0
P2	$T \leqslant 16$	8	4,0	4	3,0	1	6,0
	$16 < T \leqslant 50$	8	4,0	4	6,0	1	12,0
	$T > 50$	8	4,0	4	10,0	1	20,0
P3	$T \leqslant 16$	10	6,0	5	6,0	1	10,0
	$16 < T \leqslant 50$	10	6,0	5	9,0	1	18,0
	$T > 50$	10	6,0	5	15,0	1	30,0
P4	$T \leqslant 16$	12	10,0	6	10,0	1	18,0
	$16 < T \leqslant 50$	12	10,0	6	15,0	1	25,0
	$T > 50$	12	10,0	6	25,0	1	35,0

Table 3 — Weld seam — Maximum permissible number and dimension (diameter, length) of imperfections within a frame aperture of 150 mm × 50 mm

Acceptance level	Nominal wall-thickness T mm	Type of indication					
		Rounded		Linear		Accumulated	
		Number	Diameter mm	Number	Length mm	Number	Sum of dimensions mm
P1	$\leqslant 16$	1	3,0	1	1,5	1	4,0
	> 16	1	3,0	1	3,0	1	6,0
P2	$\leqslant 16$	2	4,0	2	3,0	1	6,0
	> 16	2	4,0	2	6,0	1	12,0
P3	$\leqslant 16$	3	6,0	3	6,0	1	10,0
	> 16	3	6,0	3	9,0	1	18,0
P4	$\leqslant 16$	4	10,0	4	10,0	1	18,0
	> 16	4	10,0	4	18,0	1	27,0

NOTE The 50 mm width of the frame aperture is centred on the axis of the weld seam.

6.3 Only relevant indications with major dimensions equal to or greater than those given in Table 1 shall be taken into consideration for the acceptance levels. Relevant indications are those which result from unacceptable imperfections. Similar indications produced by machining marks or other non-relevant surface conditions shall not be considered. Any indication in excess of the dimensions of the acceptance level according to 6.1, which is believed to be non-relevant, shall be re-examined to verify whether or not actual defects are present. Surface conditioning may precede the re-examination.

6.4 Relevant indications obtained by the liquid penetrant testing in accordance with this part of ISO 10893 shall undergo the following evaluation and classification.

a) For testing the total surface of the tube or part of tube, an imaginary frame aperture of 100 mm × 150 mm shall be placed over the area showing the greatest number of indications. The classification based on the kind, number and dimension of the indications shall be taken according to Table 2.

b) For testing the weld seam, an imaginary frame aperture of 50 mm × 150 mm shall be placed over the area showing the greatest number of indications, with the 50 mm dimension centred over the weld seam. The classification based on the kind, number and dimension of the indications shall be taken according to Table 3.

c) For testing the bevel face at the tube ends, linear indications with a length less than 6 mm shall be acceptable.

d) For calculating the cumulative length of accumulated indications, the length of the major axis of each linear or rounded indication shall be taken into account. Where the separation between to adjacent indications is less than the length or the diameter of the larger of the two indications, they shall be considered as one indication and the sum of the individual lengths or diameters plus the separation shall be used to calculate the overall length.

7 Acceptance

7.1 Any tubes showing no indications in excess of that permitted by the corresponding acceptance level shall be deemed to have passed the test.

7.2 Any tubes showing indications in excess of that permitted by the corresponding acceptance level shall be deemed suspect.

7.3 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 using a suitable method. After checking that the remaining thickness is within tolerance, the tube shall be retested as previously specified. If no indications are obtained equal to or greater than the acceptance 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.

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

8 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 10893-4;

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;

f) description of the acceptance level and the reference standard, when used;

g) date of test;

h) operator identification.

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ICS 23.040.10; 77.040.20; 77.140.75

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