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INTERNATIONAL STANDARD



2604 / II

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## Steel products for pressure purposes — Quality requirements — Part II : Wrought seamless tubes

*Produits en acier pour appareils à pression — Spécifications de qualité — Partie II : Tubes laminés sans soudure*

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**Descriptors:** pressure equipment, metal tubes, seamless pipes, pressure pipes, steels, specifications, chemical composition, mechanical properties, heat treatment, testing conditions.

## FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2604/11 (originally ISO/DIS 2605) was drawn up by Technical Committee ISO/TC 17, *Steel*, and circulated to the Member Bodies in October 1971.

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It has been approved by the Member Bodies of the following countries :

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The Member Bodies of the following countries expressed disapproval of the document on technical grounds :

- France
- Norway
- Sweden
- U.S.A.

# Steel products for pressure purposes – Quality requirements – Part II : Wrought seamless tubes

## 1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the quality requirements for plain end wrought seamless tubes for pressure purposes manufactured from the steel types listed in table 3.

NOTE – The word “tube” is synonymous with “pipe”.

This International Standard does not cover :

- a) casing, tubing, drill pipe and linepipe for use by the oil and natural gas industries, and
- b) tubes for the transport of gas, water and sewage.

## 2 REFERENCES

ISO/R 85, *Bend test for steel.*

ISO 148, *Steel – Charpy impact test (V-notch)*.<sup>1)</sup> <https://standards.iteh.ai/catalog/standards/sist/6ace10-259d-4e07-91ed-3e56183a7549/iso-2604-2-1975>

ISO/R 165, *Flanging test on steel tubes.*

ISO/R 166, *Drift expanding test on steel tubes.*

ISO/R 202, *Flattening test on steel tubes.*

ISO/R 205, *Determination of proof stress and proving test for steel at elevated temperatures.*

ISO 375, *Steel – Tensile testing of tubes.*

ISO/R 377, *Selection and preparation of samples and test pieces for wrought steel.*

ISO/R 404, *General technical delivery requirements for steel.*

ISO/R 643, *Micrographic determination of the austenitic grain size of steels.*

ISO/R 783, *Mechanical testing of steel at elevated temperatures – Determination of lower yield stress and proof stress and proving test.*

ISO 2566/1, *Steel – Conversion of elongation values – Part I : Carbon and low alloy steels.*

ISO 2605/1, *Steel products for pressure purposes – Derivation and verification of elevated temperature properties –*

*Part I : Yield or proof stress of carbon and low alloy steel products.*<sup>2)</sup>

ISO 2605/II, *Steel products for pressure purposes – Derivation and verification of elevated temperature properties – Part II : Proof stress of austenitic steel products.*<sup>2)</sup>

ISO 2694, *Pressure vessels.*<sup>2)</sup>

ISO/DATA No. 1, *Summary of average stress rupture properties for wrought boiler and pressure vessel steels for times of 10 000 hours to 250 000 hours and master curves.*

## 3 GENERAL REQUIREMENTS

### 3.1 Information to be supplied by the purchaser

**3.1.1** The purchaser shall state on his enquiry and order the requirements given below :

- a) the tube dimensions and tolerances (see 3.8);
- b) the steel type (see table 3);
- c) the test category (see 3.11);
- d) the inspection procedures and type of documents (see 3.9, 3.15, 4.2 and 5.2).

**3.1.2** Certain alternatives are permitted by this International Standard and the purchaser may also state on his enquiry and order his requirements as follows, but if no such statement is made, supply will be at the option of the manufacturer :

- e) the deoxidation practice (see 3.2.3);
- f) heat-treatment condition of supply (see 3.4);
- g) if a product (check) analysis is required (see 3.5.2);
- h) if additional mechanical tests are required (see 3.6.1.2);
- i) any special requirements for freedom from defects (see 3.7.2);
- j) any special straightness requirements (see 3.7.4);

1) At present at the stage of draft (revision of ISO/R 148).

2) At present at the stage of draft.

- k) if special protection is required (see 3.7.6);
- l) if cast separation is required (see 3.12.1.3);
- m) if room temperature impact tests are required and, if so, the number of test pieces (see 3.12.1.6);
- n) if the hydraulic test is to be omitted (see 3.12.3);
- o) if a drift expanding or flanging test, when appropriate, is required (see 3.13.3);
- p) the details of non-destructive tests, if required (see 3.13.6);
- q) if elevated temperature proof stress tests are required and, if so, the testing temperature selected from table 5 (see 4.2.2.2);
- r) if low temperature V-notch impact tests are required and, if so, the testing temperature selected from table 7 (see 5.2.2);
- s) if a maximum copper content is required (see table 3, note 1).

### 3.2 Manufacture of the steel

**3.2.1** Unless otherwise stated on the enquiry and order, the steelmaking process and the deoxidation practice within the provisions of 3.2.2, 3.2.3 and table 3 will be at the option of the steel manufacturer.

**3.2.2** The steel shall be produced by the open hearth, electric or one of the basic oxygen processes. Other processes may be used by agreement between the interested parties<sup>1)</sup>. If he so requests, the purchaser shall be informed of the steelmaking process used.

**3.2.3** Deoxidation practice shall be as defined in table 3 for the steel type specified.

NOTE – ISO documents covering the use of tubes for pressure purposes place additional limitations on deoxidation practice for certain applications. For such applications the purchaser shall ensure that these limitations are stated on the enquiry and order.

### 3.3 Manufacture of the product

The tubes shall be manufactured by a seamless process and may be hot-finished or cold-finished. The terms "hot-finished" and "cold-finished" apply to the condition of the tube before it is heat-treated in accordance with 3.4.

### 3.4 Heat treatment

**3.4.1** The tubes shall be supplied in the hot-finished condition or the heat-treated condition given in table 3 for the particular steel type ordered. Where more than one level of properties is specified in table 3 for a given steel type, the level required shall be stated on the enquiry and order.

**3.4.2** By agreement between the interested parties, the tubes may be delivered in a condition other than the final heat-treated condition according to table 3, in which case they shall be suitable for subsequent manipulation and the purchaser shall be informed of the heat treatment necessary to give the required properties (see also 3.6.1 and 3.12.1.4).

### 3.5 Chemical composition

#### 3.5.1 Ladle analysis

The steel shall show on ladle analysis the composition given in table 3 appropriate to the steel type specified.

#### 3.5.2 Product analysis

**3.5.2.1** If a check analysis on the product is required, the permissible deviations given in table 4 shall apply to the ladle analysis specified in table 3 for samples taken from the standard position (see 3.5.2.2).

If a check analysis for acceptance purposes is required, this shall be stated on the enquiry and order.

**3.5.2.2** If a check analysis on the product is required, the number of samples to be taken shall be agreed between the interested parties.

The samples shall be taken either from the test pieces used for the verification of the mechanical properties, or from drillings through the whole thickness of the tube at the same location as for the mechanical test samples.

The requirements of 3.2 and 3.3 of ISO/R 377, covering the method of selection and preparation of samples for chemical analysis, shall apply.

#### 3.5.3 Cases of dispute

In cases of dispute, the methods for chemical analysis shall be in accordance with the relevant ISO documents. If no ISO document is available, the method to be used shall be agreed between the interested parties.

### 3.6 Mechanical and technological properties

#### 3.6.1 Mechanical properties

**3.6.1.1** The mechanical properties at room temperature to be obtained on test pieces selected, prepared and tested in accordance with 3.12.1 and 3.13 are given in table 3.

**3.6.1.2** If heat treatments which are different from, or additional to, the normal reference heat treatment are to be carried out after the delivery of the tubes (which may have an adverse effect on the mechanical properties), the purchaser may require, at the time of enquiry and order, additional mechanical tests on additional samples which

1) Such as the user, purchaser and manufacturer of the equipment, the producer of the supplied construction material and the inspection and/or certifying authority.

have been given heat treatments different from, or additional to, those in table 3. In this case the heat treatment of the samples and the mechanical properties to be obtained on them shall be agreed between the interested parties at the time of enquiry and order.

NOTE – The mechanical properties can be affected by heating or reheating during fabrication. Purchasers who intend to heat or reheat any of the steels are advised to discuss the application and proposed heating or reheating treatment with the supplier.

**3.6.2 Weldability**

The steels covered by this International Standard are generally regarded as being weldable. However, the general weldability of any of the steels, but especially of the steels with relatively high alloy content, cannot be guaranteed as the behaviour of the steel during and after welding is dependent not only on the steel but also on the welding conditions and the final use for which the steel is employed. Therefore, where appropriate, the welding procedure shall be agreed between the interested parties at the time of enquiry and order.

**3.7 Appearance and soundness**

**3.7.1** The tubes shall have a workmanlike finish and shall be clean and free from such surface and internal defects as can be established by the test category (see 3.11).

**3.7.2** Any special requirements for freedom from defects shall be agreed between the interested parties at the time of enquiry and order.

**3.7.3** The requirements for surface defects, rectification and internal defects given in 8.1, 8.2 and 8.3 of ISO/R 404 shall apply.

**3.7.4** The tubes shall be reasonably straight. Complete straightness cannot be guaranteed. Special requirements regarding straightness shall be the subject of agreement.

**3.7.5** The ends shall be cut square with the axis of the tube.

**3.7.6** The tubes may be supplied uncoated or with the manufacturer's standard mill protective coating, unless otherwise specified.

**3.8 Dimensions and tolerances**

**3.8.1** The dimensions shall be in accordance with the appropriate ISO document.

**3.8.2** The tolerances on the outside diameter and thickness of the tubes depend upon the method of manufacture, the steel type and the heat treatment and shall be selected from the appropriate ISO document.

**3.8.3** The requirements of 8.4 of ISO/R 404 shall apply.

**3.9 Inspection procedures**

The purchaser shall indicate on his enquiry and order which of the five inspection procedures listed in clause 4 of ISO/R 404 is to be followed.

NOTE – The inspection procedure selected shall, if appropriate, be compatible with the requirements of the ISO document covering the use of the product.

**3.10 General rules for carrying out acceptance tests**

The requirements of clause 5 of ISO/R 404 covering the following shall apply :

- a) place of acceptance;
- b) submission for inspection;
- c) rights of the inspector;
- d) acceptance.

**3.11 Test categories**

The tubes shall be subjected to the tests given in table 1 below for the appropriate test category.

TABLE 1 – Test categories

Tests <sup>1)</sup>	Test categories			
	II	III	IV	V
Visual inspection	X	X	X	X
Hydraulic	X	X	X <sup>2)</sup>	X <sup>2)</sup>
Tensile	X	X	X	X
Flattening or bend	X	X	X	X
Drift expanding or flanging		X		X
Non-destructive testing			X <sup>2)</sup>	X <sup>2)</sup>

1) If required, an impact test at room temperature may be carried out for any of the test categories (see 3.12.1.6).

2) See 3.12.3.

**3.12 Number, selection and preparation of samples and test pieces**

**3.12.1 Mechanical tests at room temperature**

**3.12.1.1** The requirements of 2.3 and 2.4 of ISO/R 377, covering the identification and preparation of samples and test pieces, shall apply.

**3.12.1.2** For test categories II and III, the number of tubes on which mechanical tests at room temperature are to be performed shall be as follows :

- a) up to and including 323,9 mm outside diameter : one tube in each 200 tubes as made;

- b) over 323,9 mm outside diameter : one tube in each 100 tubes as made.

The samples shall be taken at random from batches containing not more than 200 tubes as presented for inspection. If the number of samples specified in this clause, when applied to a particular order, necessitates a number of tubes which includes a fraction, the fraction shall be treated as unity.

A batch is a convenient quantity of tubes of the same type of steel, diameter and thickness, such that a suitable number of sample tubes taken at random from a batch for purposes of test will adequately represent the whole batch.

**3.12.1.3** For test categories IV and V, the number of tubes on which mechanical tests at room temperature are to be performed shall be as follows :

- a) not heat-treated : 2 % of the tubes from each batch;  
 b) heat-treated : 2 % of the tubes from each heat-treatment batch.

For tubes not heat-treated, a batch shall consist only of tubes of the same diameter and thickness and of the same steel type. For tubes which are heat-treated, a batch shall consist only of tubes of the same diameter and thickness, and of the same steel type, subjected to the same finishing treatment in a continuous furnace, or heat-treated in the same furnace charge in a batch-type furnace.

Cast separation may be carried out when specified on the enquiry and order and agreed between the interested parties.

NOTE – Cast separation is required for all tubes having specified elevated or low temperature properties and which are subjected to acceptance tests for these properties.

**3.12.1.4** The test sample shall be cut from the tube after final heat-treatment. If the tubes are to be delivered in a condition different from the specified final heat-treatment condition, the test samples shall be in the reference heat-treatment condition required by table 3.

**3.12.1.5** From each tube selected for testing, one test piece shall be prepared for each of the mechanical tests required by 3.11.

For the tensile test, the test piece may be taken longitudinally or transversely at the option of the manufacturer. The dimensions of the test piece shall comply with the appropriate ISO document.

For the bend test, the test piece shall consist of a circumferential strip cut from the tube and of full thickness of the tube or, for large tubes, a test piece machined from a circumferential strip to a rectangular cross-section 38 mm X 19 mm. The edges may be rounded to a radius of 1,6 mm.

**3.12.1.6** Where the dimensions of the tube permit the taking of a full size (10 mm X 10 mm) test piece, and if agreed between the interested parties, or if required by the

application code (see for example ISO 2694) one or, if agreed at the time of enquiry and order, three V-notch impact test pieces shall be taken from one of the tubes selected.

The form and dimensions of the test pieces shall be in accordance with ISO 148.

The test pieces shall be cut so that the longitudinal axes are transverse to the longitudinal axis of the tube. The notch shall be perpendicular to the original surface of the tube.

### 3.12.2 Visual inspection

Every tube shall be inspected.

### 3.12.3 Hydraulic test

A hydraulic test shall be carried out on each tube except that, by agreement between the interested parties, the hydraulic test may be omitted for tubes of test categories IV and V which have been ultrasonically tested for acceptance purposes in accordance with the annex.

### 3.12.4 Non-destructive testing

All tubes to test categories IV and V shall be non-destructive tested for acceptance purposes.

## 3.13 Test methods and test results

### 3.13.1 Tensile test at room temperature

**3.13.1.1** The tensile test shall be carried out in accordance with ISO 375.

**3.13.1.2** The tensile strength  $R_m$ , the lower yield stress  $R_{eL}$  or proof stress  $R_p$ , and the elongation  $A$  shall be determined. The results obtained shall meet the requirements given in table 3.

For acceptance purposes, the proof stress (total elongation)  $R_t$  may be determined. The 0,5 % proof stress (total elongation)  $R_{t0,5}$  shall be used for ferritic steels having a specified lower yield stress  $R_{eL}$  or 0,2 % proof stress (non-proportional elongation)  $R_{p0,2}$ . The 1,0 % proof stress (total elongation)  $R_{t1,0}$  shall be used for austenitic steels having a specified 1,0 % proof stress (non-proportional elongation). However, in cases of dispute, the lower yield stress  $R_{eL}$ , or proof stress (non-proportional elongation)  $R_{p0,2}$  ( $R_{p1,0}$  for austenitic steels), shall be determined.

The percentage elongation shall be reported with reference to a  $5,65\sqrt{S_0}$  gauge length. If other gauge lengths are used, the corresponding elongation on  $5,65\sqrt{S_0}$  should be obtained by reference to ISO 2566/1. In cases of dispute, a gauge length of  $5,65\sqrt{S_0}$  shall be used.

### 3.13.2 Flattening or bend test

**3.13.2.1** At the option of the manufacturer, and as determined by the dimensions of the tube, either a flattening test (see 3.13.2.2) or a bend test (see 3.13.2.3) shall be carried out.



**3.13.2.2** The flattening test shall be carried out in accordance with ISO/R 202. The test piece shall show no crack or flaw when the distance between the platens is not greater than the value given by the formula :

$$H = \frac{(1 + C) a}{C + a/D}$$

where

*H* is the distance, in millimetres, between platens;

*a* is the specified thickness, in millimetres;

*D* is the specified outside diameter, in millimetres;

*C* is a constant depending on the steel type (see table 3).

**3.13.2.3** The bend test shall be carried out in accordance with ISO/R 85. The test piece shall be doubled over, cold, in the direction of original curvature, round a bar of the diameter specified in table 3 as being appropriate to the steel type specified. It shall show no crack or flaw, but slight premature failure at the edges shall not be considered a cause for rejection.

### 3.13.3 *Drift expanding or flanging test*

Unless otherwise agreed at the time of enquiry and order, it is at the option of the tube manufacturer whether or not a drift expanding or flanging test is carried out.

**3.13.3.1** The drift expanding test shall be carried out in accordance with ISO/R 166. The test piece shall, without cracking, be expanded by a mandrel having an included angle of 30°, 45° or 60° at the option of the manufacturer, to increase the outside diameter by the amount specified in table 3 as being appropriate to the steel type specified.

**3.13.3.2** The flanging test shall be carried out in accordance with ISO/R 165. The outside diameter of the flange shall exceed the outside diameter of the tube by the amount shown in table 3 as being appropriate to the steel type specified. After flanging, the tube shall show no crack or flaw.

### 3.13.4 *Impact test at room temperature*

**3.13.4.1** The impact test shall be carried out in accordance with ISO 148.

**3.13.4.2** If one test piece is used, the value obtained shall meet the requirements given in table 3.

**3.13.4.3** If three test pieces are used, the average value obtained shall meet the requirements given in table 3. One individual value may be below the specified value provided that it is not less than 70 % of that value.

### 3.13.5 *Hydraulic test*

Every tube, except as provided in 3.12.3, shall be hydraulically tested at the manufacturer's works.

The hydraulic pressure for all test categories shall be 1,5 times the design pressure, but not greater than the pressure calculated from the formula :

$$P = \frac{20 S a}{D}$$

where

*P* is the test pressure, in bars;

*D* is the specified outside diameter, in millimetres;

*a* is the specified thickness, in millimetres;

*S* is the stress, in newtons per square millimetre, which shall be taken as 80 % of the minimum yield stress at room temperature for ferritic steels and 70 % of the minimum 1,0 % proof stress (non-proportional elongation),  $R_{p1,0}$ , at room temperature for austenitic steels as specified in the order.

The test pressure shall be maintained sufficiently long for proof and inspection. Any tube failing to withstand the hydraulic pressure test shall be deemed not to comply with this International Standard.

### 3.13.6 *Non-destructive testing*

Non-destructive testing shall be carried out on tubes tested to quality categories IV and V by a method to be agreed between the interested parties. If the tubes are to be ultrasonically tested, the annex shall be used as the basis for agreement.

### 3.14 *Retests*

The requirements of 6.5 and 7.6 of ISO/R 404 shall apply, except in the case of impact tests, where the average of the results on three test pieces shall be taken. In this latter case the following procedure shall be used :

If the average of three impact values is lower than the specified value, or if any one value is lower than 70 % of this specified value, three additional test pieces shall be taken from the same sample and tested. The average value of the six tests shall be not less than the specified value. Not more than two of the individual values may be lower than the specified value and not more than one may be lower than 70 % of this value.

### 3.15 *Documents*

The purchaser shall state at the time of enquiry and order which of the documents permitted by clause 4 of ISO/R 404 are to be provided (see also 3.9).

### 3.16 *Marking*

**3.16.1** The tubes shall be legibly marked to show :

a) the identification symbols for the type of steel as given in table 3;

- b) the brand of the manufacturer of the tubes;
- c) a designation of the method of manufacture;
- d) symbols, letters or numbers which relate the test certificates, test pieces and products to each other.

**3.16.2** If paint is used for marking, it shall be free of lead, copper, zinc and tin.

**3.16.3** On small diameter tubes which are bundled or boxed, the information in 3.16.1 may be marked on a tag securely attached to the bundle or box in which they are shipped.

## 4 SPECIAL REQUIREMENTS FOR TUBES IN STEEL TYPES HAVING SPECIFIED ELEVATED TEMPERATURE PROPERTIES

### 4.1 Mechanical properties

**4.1.1** For the steel types which have specified elevated temperature properties, the minimum elevated temperature proof stress values, derived in accordance with clause 2 of ISO 2605/I (in the case of austenitic steels, ISO 2605/II), are given in table 5.

**4.1.2** For the same steel types, average stress rupture properties are given in table 6.

### 4.2 Verification and testing

**4.2.1** All the test categories shown in 3.11 apply.

#### 4.2.2 Elevated temperature proof stress

**4.2.2.1** The elevated temperature proof stress values shall be verified either by elevated temperature acceptance testing or by the procedure given in clause 3 of ISO 2605/I or, in the case of austenitic steels, in ISO 2605/II.

#### 4.2.2.2 VERIFICATION BY ACCEPTANCE TESTS

One test shall be made on each cast using a test sample prepared in accordance with 3.12.1, and with the test piece taken at a position adjacent to one of the test pieces used for the tensile test at room temperature. If tubes or more than one thickness are to be supplied from one cast, then the test shall be made on the thickest tube.

The proof stress tests at elevated temperature shall be carried out in accordance with ISO/R 205 or ISO/R 783 at a temperature selected from table 5 and agreed between the interested parties at the time of enquiry and order.

For retests the requirements of 6.5 of ISO/R 404 shall apply.

#### 4.2.2.3 VERIFICATION WITHOUT ACCEPTANCE TESTS

The elevated temperature proof stress values shall be verified by the procedure given in clause 3 of ISO 2605/I or, in the case of austenitic steels, ISO 2605/II. The 95 % lower confidence limits of the elevated temperature proof stress values which are necessary for the application of that procedure are given in figures 1 to 13 for the various steel types.

#### 4.2.3 Stress rupture properties.

For steel tubes supplied to this International Standard, the average stress rupture properties given in table 6 are valid provided that :

- a) the product has been manufactured strictly in accordance with the technical requirements of this International Standard, to ensure that the stress rupture requirements are complied with :
- b) the producer of the steel supplies a statement to this effect, which shall be agreed by the interested parties.

## 5 SPECIAL REQUIREMENTS FOR TUBES IN STEEL TYPES HAVING SPECIFIED LOW TEMPERATURE PROPERTIES

### 5.1 Mechanical properties

For the steel types which have specified low temperature properties, the minimum longitudinal Charpy V-notch impact values are given in table 7 (see also 5.2.6)

### 5.2 Verification and testing

**5.2.1** All the test categories shown in 3.11 shall apply to the tubes covered by this sub-clause.

**5.2.2** Tests shall only be carried out if so stated on the enquiry and order and if the thickness of the tube is  $\geq 6$  mm.

NOTE – International Standards covering the use of tubes in the construction of pressure vessels include mandatory low temperature test requirements.

**5.2.3** If low temperature impact tests are required, the number of tubes on which impact tests are to be carried out shall be :

- a) not heat-treated : one tube per batch;
- b) heat-treated : one tube per heat-treatment batch where a heat-treatment batch is as defined in 3.12.1.3.

**5.2.4** From the sample tube, three longitudinal ISO V-notch test pieces shall be prepared, the form and dimensions of which shall be in accordance with ISO 148.

The test pieces shall be cut so that the longitudinal axes are transverse to the longitudinal axis of the tube. The notch shall be perpendicular to the original surface of the tube.



**5.2.5** The tests shall be carried out in accordance with ISO 148 at a temperature selected from table 7 and agreed between the interested parties at the time of enquiry and order.

**5.2.6** The average value of the three tests shall meet the requirements given in table 7. One of the three individual values may be below the specified minimum average value of table 7 provided it is not less than 70 % of that value.

**5.2.7** For retests the following procedure shall be used :

If the average of three impact values is lower than the specified value, or if any one value is lower than 70 % of this specified value, three additional test pieces shall be taken from the same sample and tested. The average value of the six tests shall be not less than the specified value. Not more than two of the individual values may be lower than the specified value, and not more than one may be lower than 70 % of this value.

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ANNEX

ULTRASONIC TESTING OF TUBES FOR LONGITUDINAL DEFECTS

(All dimensions are the nominal specified dimensions.)

**A.1 METHOD OF TEST**

**A.1.1** The tubes shall be tested for defects of a predominantly longitudinal character using an ultrasonic technique.

**A.1.2** The tubes to be tested shall be sufficiently straight and the surfaces shall be free from any foreign matter that interferes with the interpretation of the test.

**A.1.3** During testing, the tubes or search units shall be moved so that the probes traverse the tube surface in a helix. Unless otherwise agreed between purchaser and manufacturer, the pitch of the helix shall be 25 mm (1 in) maximum per probe.

**A.1.4** By agreement between purchaser and manufacturer, the testing shall be in either one or both directions of beam travel.

**A.2.2.1.1** Over 15 mm (0.59 in) bore, both external and internal notches shall be used.

From 15 mm (0.59 in) bore to 10 mm (0.4 in) bore inclusive, the internal notch may be used, at the manufacturer's option.

Below 10 mm (0.4 in) bore, the internal notch shall not be used.

**A.2.2.1.2** The internal standard notch shall not be used when the  $D/a$  ratio is less than 4.

**A.2.2.2 Length**

Standard notch length (at full depth)  
50 mm (2 in) minimum

**A.2.2.3 Width**

Standard notch width

1 mm (0.04 in) maximum for tubes up to and including 25 mm (1 in) thick.

1,5 mm (0.06 in) maximum for tubes over 25 mm (1 in) thick.

**A.2 CALIBRATION STANDARDS**

**A.2.1** The ultrasonic equipment shall be calibrated using a longitudinal standard notch on the outside and inside surfaces, or the outside surface, of a tubular test piece according to the specification requirements, usually in the "as supplied" condition. If the test piece is machined, the minimum notch depth may be reduced. (See A.2.2.4.3.)

If the tube is of ferritic steel, the test piece shall be of ferritic steel; if the tube is of austenitic steel, the test piece shall be of austenitic steel. The test piece shall have the same nominal diameter and thickness as the tube to be tested.

External and internal standard notches, where used, need not be further apart than a distance sufficient to make the signals distinguishable.

**A.2.2** The dimensions of the standard notches shall be as follows :

**A.2.2.1 Shape and location**

The standard notch shall lie in a longitudinal direction. The sides shall be nominally parallel and the bottom shall be nominally square to the sides.

**A.2.2.4 Depth**

Standard notch depth shall be 5% of the specified thickness, with the following limitations :

**A.2.2.4.1** Tolerance on depth :  $\pm 15\%$  of standard notch depth with  $\pm 0,05$  mm ( $\pm 0.002$  in) minimum.

**A.2.2.4.2** For  $D/a$  ratios between 4 and 5 the internal standard notch depth shall be in accordance with table 2.

TABLE 2 – Notch depths

Diameter Thickness	ratio $D/a$	Internal standard notch depth	ratio
		External standard notch depth	
5		1	
4,75		1,6	
4,5		1,9	
4,25		2,2	
4		2,5	

**A.2.2.4.3** For all tubes except those in A.2.2.4.4, A.2.2.4.5, and A.2.2.4.6.

Minimum depth : 0,3 mm (0.012 in), except that where the test piece is machined the minimum depth shall be 0,2 mm (0.008 in).

Maximum depth : 1,5 mm (0.06 in).

**A.2.2.4.4** Maximum depth for austenitic tubing :

for tubes less than or equal to 50 mm (2 in) thickness : 1,5 mm (0.06 in)

for tubes with thickness greater than 50 mm (2 in) : 3 % of specified thickness.

**A.2.2.4.5** For cold-finished austenitic steel tubes, and for ferritic steel tubes containing more than 12 % chromium with thickness less than 3 mm (0.12 in), the minimum depth shall be 0,2 mm (0.008 in).

**A.2.2.4.6** Tubes for nuclear application

Minimum depth : 0,2 mm (0.008 in) for normal applications, 0,1 mm (0.004 in) for the most severe applications.

Maximum depth : As in A.2.2.4.3 and A.2.2.4.4.

### A.3 CALIBRATION AND CHECKING OF EQUIPMENT

**A.3.1** The ultrasonic equipment shall be adjusted so that it detects the signals from both the internal and external standard notches (or the signal from the external standard notch, where only an external standard notch is used). During calibration, the rotational speed of automatic

equipment, or the speed of movement of hand-operated equipment, shall be comparable to that used during the test.

**A.3.2** If, on checking during production testing, either or both standard notches are not detected, then all tubes tested since the previous check shall be retested after the instrument has been recalibrated.

### A.4 ACCEPTANCE

**A.4.1** Any tube that does not produce a signal greater than the signal from the standard notch shall be deemed to have passed this test.

**A.4.2** Where a signal greater than that from the standard notch is obtained, the imperfection shall be examined for depth which if found to be less than the depth of the standard notch shall be ignored. Its depth shall not be deducted from the thickness.

**A.4.3** Imperfections having a depth greater than the standard notch may be removed, provided that the thickness remaining after removal is not less than the permissible minimum. The tube shall then be retested ultrasonically, and if the tube no longer produces a signal greater than the signal from the standard notch, it shall be accepted. Alternatively, the length of tube containing the defect may be cut off, and the remainder shall be deemed to have passed the test.

**A.4.4** Acceptance of a tube shall be the subject of a special agreement between the purchaser and the manufacturer if it can be proved that the defect causing the signal greater than the signal from the standard notch does not penetrate the tube surface.

TABLE 3 — Chemical composition, mechanical properties at room temperature and heat treatment

Steel No.	Chemical composition, % 1,2,3)										Mechanical properties at room temperature 7)					Heat treatment									
	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others	low	high	$R_{eL}$ or $R_{p0.2}$ min, 9)	$R_m$	A, K/V min min	Flattening test constant C, D max	Bend test	Drift expanding and flanging test (% increase $D_2$ )	Reference heat treatment <sup>8)</sup>	Temperature °C	Cooling condition 10)	Temperature °C	Cooling condition 10)			
TS 1	≤ 0.16		0.30 - 0.70	0.050	0.050						5, 6	320	440	25	0.10	4 <sub>p</sub>	12	15	19	HF, SCA, A, N					
TS 2	≤ 0.16		0.40 - 0.70	0.050	0.050						5, 6	195	320	440	25	0.10	4 <sub>p</sub>	12	15	19	HF, N				
TS 4	≤ 0.17	≤ 0.35	0.40 - 0.80	0.045	0.045						5, 6	215	360	480	24	0.10	4 <sub>p</sub>	12	15	19	HF, SCA, A, N				
TS 5	≤ 0.17	≤ 0.35	0.40 - 0.80	0.045	0.045						5, 6	215	360	480	24	0.10	4 <sub>p</sub>	12	15	19	HF, N				
TS 6	≤ 0.17	≤ 0.35	0.40 - 1.00	0.045	0.045						7	215	360	480	24	0.10	4 <sub>p</sub>	12	15	19	HF, A, N				
TS 9	≤ 0.21	≤ 0.35	0.40 - 1.20	0.045	0.045						5, 6	235	410	530	22	0.08	4 <sub>p</sub>	10	12	17	HF, N				
TS 10	≤ 0.19	≤ 0.35	0.60 - 1.20	0.045	0.045						5, 6	235	410	530	22	0.08	4 <sub>p</sub>	10	12	17	HF, A, N				
TS 13	≤ 0.22	≤ 0.35	0.60 - 1.40	0.045	0.045						5, 6	265	460	580	21	0.07	4 <sub>p</sub>	8	10	15	HF, SCA, A, N				
TS 14	≤ 0.22	≤ 0.35	0.80 - 1.40	0.045	0.045						5, 6	265	460	580	21	0.07	4 <sub>p</sub>	8	10	15	HF, N				
TS 15	≤ 0.20	≤ 0.35	0.80 - 1.40	0.045	0.045						7	265	460	580	21	0.07	4 <sub>p</sub>	8	10	15	HF, A, N				
TS 18	≤ 0.23	≤ 0.35	0.80 - 1.50	0.045	0.045						5, 6	285	490	610	21	0.07	4 <sub>p</sub>	8	10	15	HF, N				
TS 26	0.12 - 0.20	0.10 - 0.35	0.40 - 0.80	0.040	0.040		0.25 - 0.35				5, 6	260	450	600	22	0.07	4 <sub>p</sub>	8	10	15	N, N+T				
TS 32	0.10 - 0.18	0.10 - 0.35	0.40 - 0.70	0.040	0.040		0.70 - 1.10	0.45 - 0.65			5, 6	275	440	590	22	0.07	4 <sub>p</sub>	8	10	15	N, N+T				
TS 33	0.10 - 0.18	0.10 - 0.35	0.40 - 0.70	0.040	0.040		0.30 - 0.60	0.50 - 0.70			5, 6	275	460	610	15	0.07	4 <sub>p</sub>	8	10	15	N+T				
TS 34	0.08 - 0.15	≤ 0.50	0.40 - 0.70	0.040	0.040		2.00 - 2.50	0.90 - 1.20			5, 6	135	410	560	20	0.07	4 <sub>p</sub>	8	10	15	a) A b) N+T				
TS 37	≤ 0.15	≤ 0.50	0.30 - 0.60	0.030	0.030		4.00 - 6.00	0.45 - 0.65			5, 6	275	490	640	16	0.07	4 <sub>p</sub>	8	10	15	c) N+T				
TS 38	≤ 0.15	0.25 - 1.00	0.30 - 0.60	0.030	0.030		8.00 - 10.00	0.90 - 1.10			5, 6	205	410	560	20	0.07	4 <sub>p</sub>	8	10	15	A				
TS 39	≤ 0.08	≤ 1.00	≤ 1.00	0.040	0.030		11.5 - 14.0				5, 6	135	410	560	20	0.07	4 <sub>p</sub>	8	10	15	a) A b) N+T				
TS 40	0.17 - 0.23	< 0.50	< 1.00	0.030	0.030		10.00 - 12.50	0.80 - 1.20			5, 6	390	590	740	18	0.07	4 <sub>p</sub>	8	10	15	a) A b) N+T				
TS 43	≤ 0.15	0.15 - 0.35	0.30 - 0.80	0.040	0.040						5, 6	435	590	840	15	0.08	4 <sub>p</sub>	6	8	12	N+T				
TS 45	≤ 0.13	0.15 - 0.30	0.30 - 0.80	0.040	0.040						7	245	440	590	16	0.08	4 <sub>p</sub>	6	8	12	a) N b) N+T				
TS 46	≤ 0.03	≤ 1.00	≤ 2.00	0.045	0.030		17.00 - 19.00				7	175	205	490	690	30	0.09	9	15	17	Q				
TS 47	≤ 0.07	≤ 1.00	≤ 2.00	0.045	0.030		17.00 - 19.00				7	195	235	490	690	30	0.09	9	15	17	Q				
TS 48	0.04 - 0.09	≤ 0.75	≤ 2.00	0.045	0.030		17.00 - 20.00				5, 6	195	235	490	690	30	0.09	9	15	17	Q				
TS 50	≤ 0.08	≤ 1.00	≤ 2.00	0.045	0.030		17.00 - 19.00				7	205	245	510	710	30	0.09	9	15	17	Q				
TS 53	≤ 0.08	≤ 1.00	≤ 2.00	0.045	0.030		17.00 - 19.00				7	195	235	510	710	30	0.09	9	15	17	Q				
TS 54	0.04 - 0.10	0.20 - 0.80	≤ 2.00	0.045	0.030		17.00 - 20.00				5, 6	155	195	490	690	30	0.09	9	15	17	Q				
TS 56	0.04 - 0.10	0.20 - 0.80	≤ 2.00	0.045	0.030		16.00 - 20.00				5, 6	195	235	510	710	30	0.09	9	15	17	Q				
TS 57	≤ 0.03	≤ 1.00	≤ 2.00	0.045	0.030		16.00 - 18.50	2.00 - 2.50			7	185	215	490	690	30	0.09	9	15	17	Q				
TS 58	≤ 0.03	≤ 1.00	≤ 2.00	0.045	0.030		16.00 - 18.50	2.50 - 3.00			7	185	215	490	690	30	0.09	9	15	17	Q				
TS 60	≤ 0.07	≤ 1.00	≤ 2.00	0.045	0.030		16.00 - 18.50	2.00 - 2.50			7	205	245	510	710	30	0.09	9	15	17	Q				
TS 61	≤ 0.07	≤ 1.00	≤ 2.00	0.045	0.030		16.00 - 18.50	2.50 - 3.00			7	205	245	510	710	30	0.09	9	15	17	Q				
TS 63	0.04 - 0.09	≤ 0.75	1.00 - 2.00	0.045	0.030		16.00 - 18.00	2.00 - 2.75			5, 6	205	245	510	710	30	0.09	9	15	17	Q				
TS 67	0.04 - 0.10	0.30 - 0.60	1.00 - 1.50	0.045	0.030		15.50 - 17.50	1.60 - 2.00			5, 6	215	265	510	710	30	0.09	9	15	17	Q				
TS 68	≤ 0.15	≤ 0.75	≤ 2.00	0.045	0.030		24.00 - 26.00				5, 6	205	245	510	710	30	0.09	9	15	17	Q				
TS 69	≤ 0.12	≤ 1.00	≤ 1.50	0.045	0.030		19.00 - 23.00				5, 6	165	205	480	680	25	0.09	9	15	17	Q				

VALUES UNDER CONSIDERATION

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