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# INTERNATIONAL STANDARD

# ISO 9304

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# Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Eddy current testing for the detection of imperfections

*Tubes en acier sans soudure et soudés (sauf à l'arc immergé) pour service sous pression — Contrôle par courants de Foucault pour la détection des imperfections*

Reference number
ISO 9304 : 1989 (E)

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# Foreword

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International Standard ISO 9304 was prepared by Technical Committee ISO/TC 17, *Steel*.

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## Introduction

This International Standard concerns eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for pressure purposes for the detection of imperfections.

Two different acceptance levels are considered (see tables 1 and 2). The choice between these acceptance levels is within the province of the ISO Technical Committee responsible for the development of the relevant quality standards.



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# Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Eddy current testing for the detection of imperfections

## 1 Scope

This International Standard specifies requirements for eddy current testing of seamless and welded tubes for pressure purposes, with the exception of submerged arc-welded (SAW) tubes, for the detection of imperfections, according to two different acceptance levels (see tables 1 and 2). It is applicable to the inspection of tubes with an outside diameter greater than or equal to 4 mm.

## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 235 : 1980, *Parallel shank jobber and stub series drills and Morse taper shank drills.*

ISO 286-2 : 1988, *ISO system of limits and fits — Part 2 : Tables of standard tolerance grades and limit deviations for holes and shafts.*

ISO 4200 : 1985, *Plain end steel tubes, welded and seamless — General tables of dimensions and masses per unit length.*

## 3 General requirements

**3.1** The eddy current inspection covered by this International Standard is usually carried out on tubes after completion of all the production process operations.

This inspection shall be carried out by suitable trained operators and supervised by competent personnel nominated by the manufacturer. In the case of third-party inspection, this shall be agreed between the purchaser and manufacturer.

**3.2** The tubes to be tested shall be sufficiently straight to ensure the validity of the test. The surfaces shall be sufficiently free from foreign matter which would interfere with the validity of the test.

## 4 Method of test

**4.1** For full peripheral testing of seamless and welded tubes, the tube shall be tested for imperfections using a concentric coil or a rotating tube/pancake coil eddy current technique. See figures 1 and 2.

NOTE — It is recognized that there is a short length at both tube ends which may not be able to be tested.



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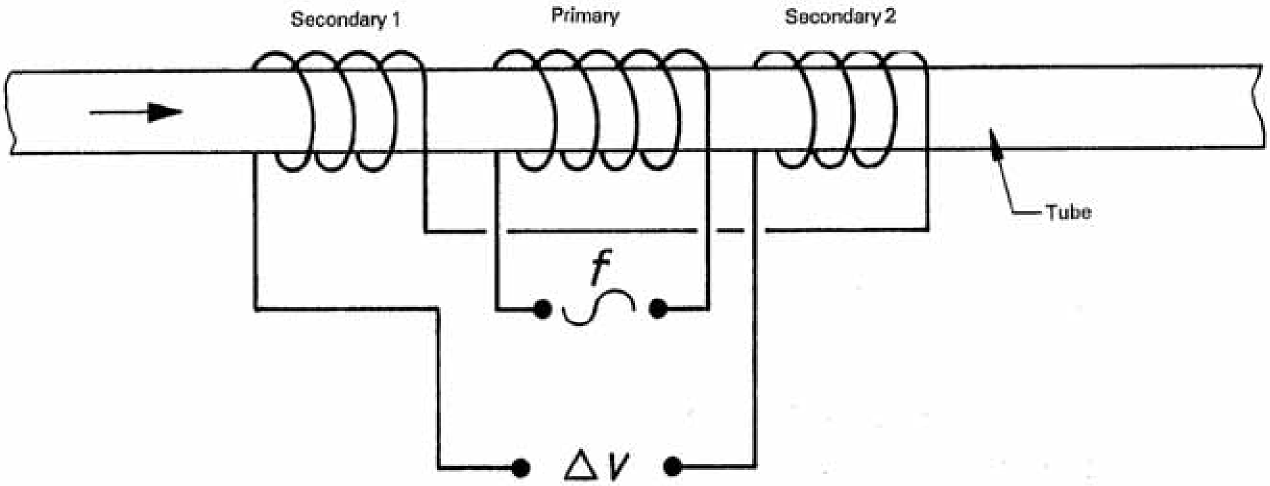
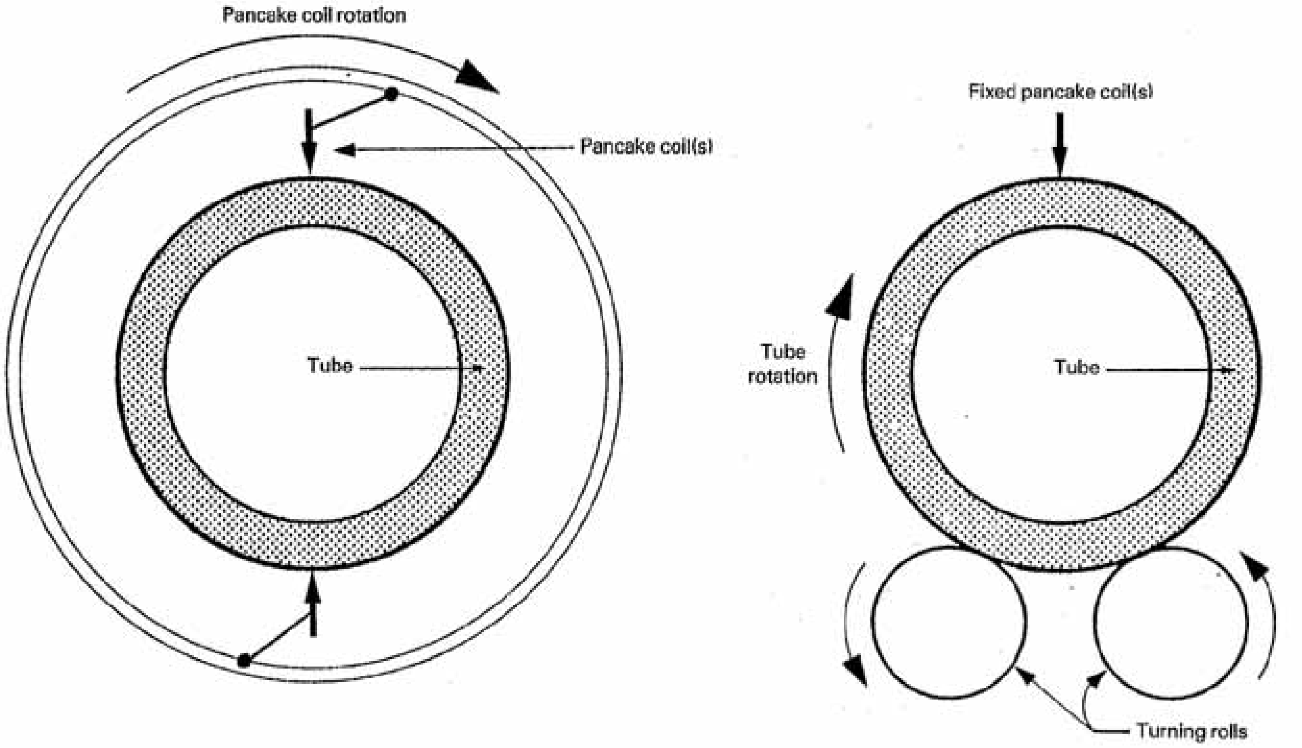



NOTE — The above diagram is a simplified form of a multi-coil arrangement which may contain, for example, split primary coils, twin differential coils, calibrator coil, etc.

**Figure 1 — Simplified diagram of concentric coil technique**




a) Rotating pancake coil technique (linear tube movement through the rotating pancake coil assembly)

b) Rotating tube technique (linear pancake coil traverse along the tube length)

NOTE — The pancake coils used in a) and b) above take many forms, for example, single coil, multi-coil of various configurations depending on the equipment used and other factors.

**Figure 2 — Simplified diagram of rotating tube/pancake coil technique (helical scan)**



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**4.1.1** When testing seamless or welded tubes using the eddy current concentric coil technique, the maximum outside diameter of tube to be tested is restricted to 177,8 mm.

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

**4.1.2** When testing seamless or welded tubes using the rotating tube/pancake coil eddy current technique, the tube and/or the test coils shall be moved relative to each other so that the whole of the tube surface is scanned. There is no restriction on the maximum outside diameter using this technique.

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

**4.2** When testing the weld of welded tubes using the segment coil technique (see figure 3), the test coil shall be maintained in proper alignment with the weld, such that the whole of the weld is scanned.

NOTES

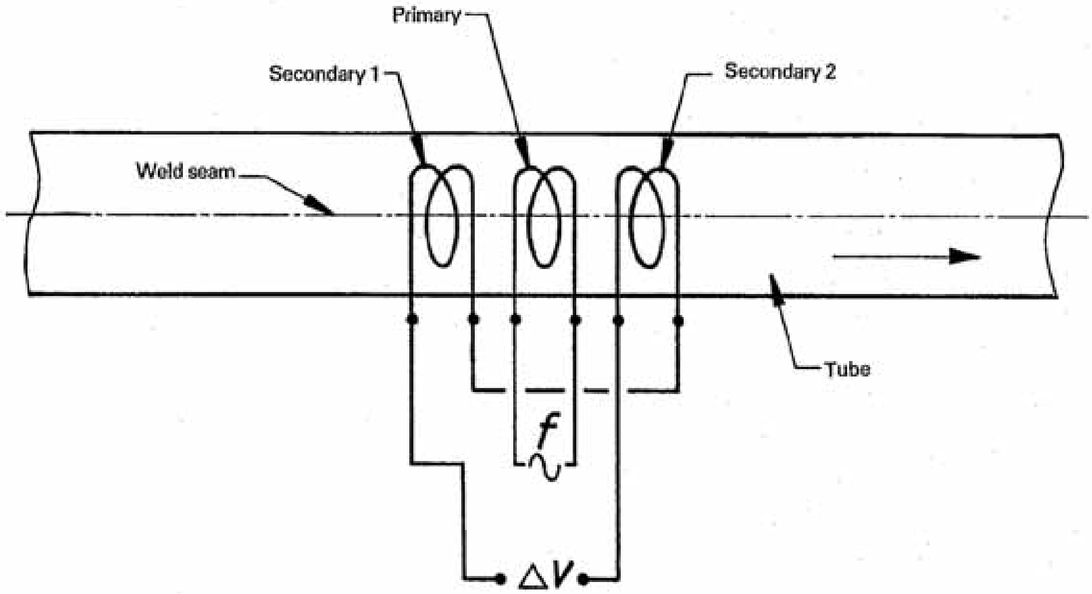
1 It is emphasized that the sensitivity of the test is at a maximum at the tube surface adjacent to the test coil and decreases with increasing thickness (see annex A).

2 It is recognized that there is a short length at both tube ends which may not be able to be tested.

**4.3** The equipment for automatic testing shall be capable of differentiating between acceptable and suspect tubes by means of an automatic trigger/alarm level combined with a marking and/or sorting system.

## 5 Reference standards

**5.1** The reference standards defined in this International Standard 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.




NOTE — The segment coil above may take many forms depending, for example, on the equipment used and the product to be inspected.

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



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**5.2** The testing equipment shall be calibrated using a reference standard introduced into a tubular test piece. The test piece shall be of the same nominal diameter, thickness and surface finish as the tube to be tested and shall have similar electromagnetic properties.

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

a) reference holes as defined in 5.4 when using the eddy current concentric coil technique;

b) a reference hole or a reference notch as defined in 5.6 when using the rotating tube/pancake coil technique;

c) a reference hole as defined in 5.5 when using the segment coil technique.

**5.4** When using the eddy current concentric coil technique, the test piece shall contain three circular holes, drilled radially through the full thickness of the test piece. The three holes shall be circumferentially displaced 120° from each other, and shall be sufficiently separated longitudinally and from the extremities of the test piece so that clearly distinguishable signal indications are obtained.

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

The diameter of the drill required to produce these holes depends on the tube outside diameter as shown in table 1.

The diameter of the reference hole or reference holes shall be verified and shall not exceed the specified drill diameter by more than 0,1 mm for drill diameters less than 1,1 mm and by more than 0,2 mm for drill diameters greater than or equal to 1,1 mm.

**5.5** When using the segment coil technique, the test piece shall have a single circular hole drilled radially through the full thickness of the test piece.

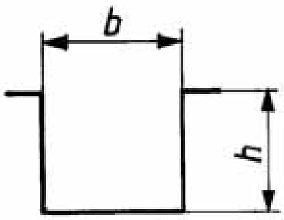
**5.5.1** The reference hole shall be sufficiently separated from the extremities of the test piece, so that a clearly distinguishable signal indication is obtained.

**5.5.2** The diameter of the drill required to produce this hole depends on the tube outside diameter as shown in table 1.

**5.6** When using the rotating tube/pancake coil technique, the test piece shall contain either a reference hole (in accordance with table 1) drilled radially through the full thickness of the test piece or a longitudinal reference notch on the external surface of the test piece.

**5.6.1** The reference hole or notch shall be sufficiently separated from the extremities of the test piece, so that a clearly distinguishable signal indication is obtained.

**5.6.2** The reference notch, when used, shall be of the "N" type (see figure 4) and shall lie parallel to the major axis of the tube. The sides shall be nominally parallel and the bottom shall be nominally square to the sides.




$b$ = width $h$ = depth

**Figure 4 — "N"-type notch**

**Table 1**

| Acceptance Level L 2 | | Acceptance Level L 4 | |
|---|---|---|---|
| Tube outside diameter $D$[1] mm | Drill diameter[2] mm | Tube outside diameter $D$[1] mm | Drill diameter[2] mm |
| $D \leqslant 6$ | 0,50 | $D \leqslant 26{,}9$ | 1,20 |
| $6 < D \leqslant 19$ | 0,65 | $26{,}9 < D \leqslant 48{,}3$ | 1,70 |
| $19 < D \leqslant 25{,}4$ | 0,80 | $48{,}3 < D \leqslant 63{,}5$ | 2,20 |
| $25{,}4 < D \leqslant 31{,}8$ | 0,90 | $63{,}5 < D \leqslant 114{,}3$ | 2,70 |
| $31{,}8 < D \leqslant 42{,}4$ | 1,10 | $114{,}3 < D \leqslant 139{,}7$ | 3,20 |
| $42{,}4 < D \leqslant 60{,}3$ | 1,40 | $139{,}7 < D \leqslant 177{,}8$ | 3,70 |
| $60{,}3 < D \leqslant 76{,}1$ | 1,80 | $177{,}8 < D$ | By agreement |
| $76{,}1 < D \leqslant 114{,}3$ | 2,20 | | |
| $114{,}3 < D \leqslant 152{,}4$ | 2,70 | | |
| $152{,}4 < D \leqslant 177{,}8$ | 3,20 | | |
| $177{,}8 < D$ | By agreement | | |

1) See ISO 4200.

2) Tolerances according to ISO 235 (jobber series) and ISO 286-2 (h8).



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**5.6.3** The reference notch shall be formed by machining, spark erosion or other methods.

NOTE — It is recognized that the bottom or the bottom corners of the notch may be rounded.

## 6 Dimensions of reference notch

The dimensions of the reference notch shall be as follows.

### 6.1 Length

50 mm minimum (at full depth) or a minimum of twice the width of each individual test coil.

### 6.2 Width, *b* (see figure 4)

Not greater than the reference notch depth.

### 6.3 Depth, *h* (see figure 4)

As given in table 2.

**Table 2**

| Acceptance level | Notch depth in % of the specified thickness |
|---|---|
| L 2 | 5 |
| L 4 | 12,5 |

NOTE — The values of notch depth specified in this table are the same, for the corresponding categories, in all International Standards concerning non-destructive testing of steel tubes where reference is made to different acceptance levels. It should, however, be kept in mind that although the reference standards are identical, the various test methods involved can give different test results.

#### 6.3.1 Minimum notch depth

0,5 mm

#### 6.3.2 Maximum notch depth

1,5 mm

### 6.4 Tolerance on depth, *h*

± 15 % of reference notch depth or ± 0,05 mm, whichever is the larger.

### 6.5 Verification

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

## 7 Equipment calibration and checking

**7.1** The equipment shall be adjusted to consistently produce, to the satisfaction of the purchaser, clearly identifiable signals from the reference standard(s). These signals shall be used to set the trigger/alarm level of the equipment.

When using multiple reference holes in the test piece (concentric coil eddy current technique), the full amplitude obtained from the reference hole giving the smallest signal shall be used to set the trigger/alarm level of the equipment. When using a single reference hole in the test piece, the test piece shall be passed through the inspection equipment with the reference hole, on successive runs, positioned at 0°, 90°, 180° and 270° and the full amplitude of the smallest signal obtained from the reference hole shall be used to set the trigger/alarm level of the equipment.

When using the reference hole or notch (rotating tube/pancake coil eddy current technique), the full signal amplitude shall be used to set the trigger/alarm level of the equipment.

When using the single reference hole (segment coil eddy current technique for testing the weld of welded tubes), the full signal amplitude shall be used to set the trigger/alarm level of the equipment.

**7.2** During calibration, the relative speed of movement between the test piece and the test coils shall be the same as that to be used during the production test. The same equipment settings, for example frequency, sensitivity, phase discrimination, rate filtering, magnetic saturation, etc., shall be employed.

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

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.

NOTE — In cases where a production testing run is continuous from one shift period to the next, the 4 h maximum period may be extended by agreement between purchaser and manufacturer.

**7.4** The equipment shall be recalibrated following any system adjustments or whenever the specified nominal tube diameter, thickness or grade of steel is changed.

**7.5** If on checking during production testing the calibration requirements are not satisfied, even after increasing the test sensitivity by 3 dB to allow for system drift, then all tubes tested since the previous check shall be retested after the equipment has been recalibrated.

Retesting shall not be necessary even after a drop in test sensitivity of more than 3 dB since the previous calibration, provided that suitable recordings from individually identifiable tubes are available which permit accurate classification into suspect and acceptable categories.

## 8 Acceptance

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



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**8.2** Any tube producing signals equal to or greater than the trigger/alarm level shall be designated suspect or, at the manufacturer's option, may be retested as specified above.

**8.3** If on retesting no signal is obtained equal to or greater than the trigger/alarm level, the tube shall be deemed to have passed this test.

Tubes giving signals equal to or greater than the trigger/alarm level shall be designated suspect.

**8.4** 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 explored by dressing using an acceptable 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.

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

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

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

## 9 Test report

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

a) reference to this International Standard;

b) date of test report;

c) acceptance level;

d) statement of conformity;

e) material designation by grade and size;

f) type and details of inspection technique;

g) description of the reference standard.



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# Annex A
(informative)

## Guidance notes on limitations associated with the eddy current test method

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

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



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