INTERNATIONAL STANDARD

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Welded steel tubes for pressure purposes — Ultrasonic testing for the detection of laminar imperfections in strips/plates used in the manufacture of welded tubes

Tubes en acier soudés pour service sous pression — Contrôle par ultrasons pour la détection des imperfections de laminage des feuillards/plaques utilisés pour la fabrication de tubes soudés

Reference number
ISO 12094:1994(E)

Foreword

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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.

International Standard ISO 12094 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 19, *Technical delivery conditions for steel tubes for pressure purposes*.

Annex A forms an integral part of this International Standard.

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Introduction

This International Standard covers ultrasonic testing for the detection of laminar imperfections in strips/plates used in the manufacture of welded steel tubes for pressure purposes.

Three different acceptance levels of laminar imperfection are considered. The choice between these acceptance levels is within the province of the ISO Technical Committee responsible for the development of the relevant product standards.

Other less severe acceptance criteria may be specified in the relevant technical delivery document.

Welded steel tubes for pressure purposes — Ultrasonic testing for the detection of laminar imperfections in strips/plates used in the manufacture of welded tubes

1 Scope

1.1 This International Standard specifies requirements for the ultrasonic testing of strips/plates used in the manufacture of welded tubes for the detection of laminar imperfections according to three different acceptance levels.

This ultrasonic inspection of the strips/plates shall be carried out in the pipe mill before or during pipe production, in the flat form.

NOTES

1 In the case of electric resistance or induction welded tubes, an alternative ultrasonic testing specification for the detection of laminar imperfections is available, which may be applied, at the manufacturer's option, by ultrasonic testing of the tubes subsequent to seam welding in accordance with ISO 10124.

2 By agreement betwen the purchaser and manufacturer, the requirements of this International Standard may be applied on strips/plates of SAW tubes in the pipe form after seam welding.

1.2 This International Standard covers the inspection of strips/plates with a thickness greater than or equal to 4,0 mm.

1.3 It is stressed that the test techniques specified within this International Standard are based on statistical scanning of the product surface due to limitations imposed by the manufacturing process.

1) To be published.

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 indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 10124:—[1], *Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Ultrasonic testing for the detection of laminar imperfections.*

ISO 11484:1994, *Steel tubes for pressure purposes — Qualification and certification of non-destructive testing (NDT) personnel.*

3 General requirements

3.1 This ultrasonic inspection of the strips/plates shall be carried out before or during pipe production in the flat form (see also notes 1 and 2).

This inspection may be performed using ultrasonic equipment of any design and configuration, provided that it fulfils the requirements of this International Standard.

This inspection shall be carried out by personnel qualified in accordance with ISO 11484, as nominated by the manufacturer. In the case of third-party in-

spection, this shall be agreed between the purchaser and manufacturer.

3.2 The strip/plate to be tested shall be sufficiently free from surface undulations. The surface shall be sufficiently free from foreign matter which would interfere with the validity of the test.

4 Method of test

4.1 The strip/plate shall be tested using an ultrasonic pulse echo technique for the detection of laminar imperfections, with ultrasound transmitted in the direction normal to the surface, or using the ultrasonic through-transmission technique at the discretion of the manufacturer.

4.2 During testing, the strip/plate and/or the transducer assembly shall be moved relative to each other so that the strip/plate surface is scanned along equispaced scan lines parallel or transverse to the principal rolling direction of the strip/plate, with a minimum coverage and a maximum allowable gap between adjacent scanning tracks as given in table 1. For the oscillating technique, the minimum coverage shall be half of the values given in table 1.

Table 1 — Minimum coverage of the strip/plate and maximum gap between adjacent scanning tracks

Acceptance level	Minimum coverage, C_{min} %	Maximum gap between adjacent scanning tracks mm
B1	20	100
B2	10	150
B3	5	200

4.3 The longitudinal strip/plate edges shall be 100 % ultrasonically inspected for the detection of laminar imperfections over a width of at least 15 mm plus, if appropriate, the total width of edge material which will be removed from each original strip/plate edge due to subsequent operations prior to seam welding, in order to detect the relevant minimum imperfection length l_{min} as given in table 2.

NOTE 3 The longitudinal edges are defined as those parallel to the principal rolling direction.

Table 2 — Minimum lamination length on the strip/plate edges to be detected (trigger/alarm condition)

Acceptance level	Minimum longitudinal dimension, l_{min} mm
E1	10
E2	20
E3	30

4.4 The maximum dimension of each individual transducer measured at right angles to the scanning direction shall be 30 mm.

NOTE 4 In the case of TR-probes with different sizes of transducer within the transducer assembly, the dimension of the smallest transducer shall be used to calculate the coverage.

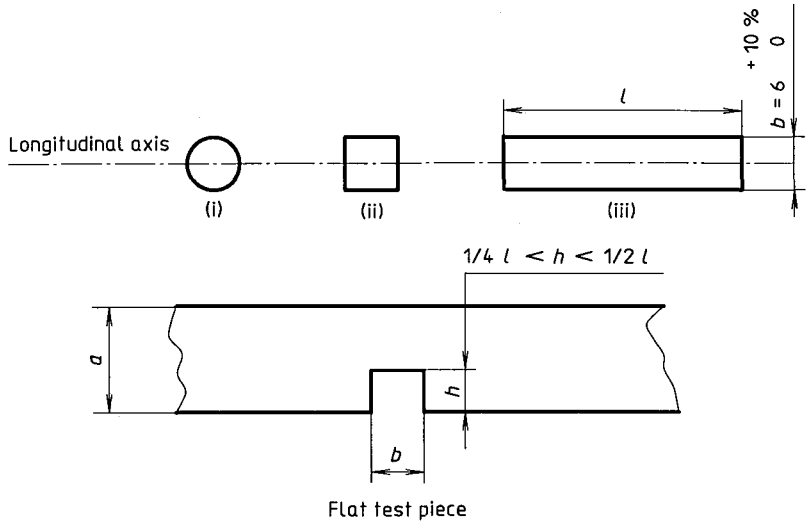
4.5 The equipment for automatic testing shall be capable of differentiating between acceptable and suspect strips/plates by means of an automatic trigger/alarm level combined with marking and/or sorting systems.

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.

5.2 The ultrasonic equipment shall be calibrated either electronically with a test piece (see 7.1.1) or using reference standards comprising flat-bottomed round square or rectangular recesses (see figure 1) machined into the surface of a flat test piece (see 7.1.2). The flat-bottomed reference standard shall be used as the primary means of establishing the test sensitivity. When using other types of reference reflectors, the test sensitivity shall be adjusted such that it is equivalent to that obtained when using the flat-bottomed hole. The choice of the calibration technique and the type of reference standard shall be at the option of the manufacturer.

Dimensions in millimetres



l = length of rectangular recess (only restriction: $l > 6$)

b = width of rectangular recess

h = depth of rectangular recess

a = thickness of test piece

Figure 1 — Reference standard recess forms

For the through-transmission technique, either the recess shall be filled with a suitable attenuating material, or a suitable thickness of attenuating material of the same area dimensions as the reference standard shall be attached to the surface of the test piece.

5.3 The test piece shall have a similar surface finish and similar acoustic properties (e.g. velocity, attenuation coefficient, etc.) as the strip/plate to be tested. The test piece shall be of convenient length and width dimensions, as selected by the manufacturer, for calibration purposes.

6 Dimensions of reference standard

6.1 The dimensions of the reference standard, when used, shall be as follows.

6.1.1 Width

6 mm $^{+10}_{0}$ %

6.1.2 Recess depth

Between 1/4 and 1/2 of the nominal strip/plate thickness with a maximum of 10 mm.

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

7 Equipment calibration and checking

7.1 The equipment shall be calibrated statically using either electronic means in accordance with 7.1.1 or a reference standard in accordance with 7.1.2.

7.1.1 Calibration using an electronic technique

With the transducer assembly positioned on the test piece, the full amplitude of the first back-wall echo minus 6 dB shall be used to set the trigger/alarm level of the equipment, or the test sensitivity shall be established with DGS curves as supplied by the transducer manufacturer or DAC curves as prepared by the tube/plate manufacturer using, in both cases, the 6 mm flat-bottomed hole curve.

At the start of the production testing run, the manufacturer shall demonstrate that, at the set sensitivity, the equipment will detect, under static conditions, the reference recess as given in 5.2 and figure 1. If not, the necessary adjustment in sensitivity shall be made prior to the production testing run.

7.1.2 Calibration using a reference standard

Under static conditions, with the transducer or each transducer in turn centrally located over the reference

standard, the full signal amplitude of the signal obtained from the reference standard shall be used to set the trigger/alarm level of the equipment.

7.2 During the production testing of the strips/plates the relative translational speeds, together with the equipment pulse repetition frequency, shall be chosen such that the relevant minimum coverage and maximum separation between adjacent scanning tracks given in table 1 will be obtained.

7.3 The calibration of the equipment shall be checked at regular intervals during the production testing of strips/plates of the same thickness and grade.

The frequency of checking the calibration shall be at least every 4 h or once every ten production strip/plate items tested, whichever is the longer time period, but also whenever there is an equipment operation team changeover and at the start and end of the production run.

NOTE 5 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 the purchaser and manufacturer.

7.4 The equipment shall be recalibrated following any system adjustments or whenever the specified nominal strip/plate thickness or grade of steel is changed.

If agreed between the manufacturer and purchaser, this recalibration is not required in the case of automatic equipment with self-calibration.

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 strips/plates 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 strip/plate are available which permit accurate classification into suspect and acceptable categories.

8 Acceptance

8.1 Any strip/plate not producing a trigger/alarm condition shall be deemed to have passed this test.

8.2 Any strip/plate producing a trigger/alarm condition shall be designated suspect, or at the manufacturer's option, may be retested as specified above.

8.3 If on retesting, no trigger/alarm condition is obtained, the strip/plate shall be deemed to have passed this test. Strips/plates producing a trigger/alarm condition shall be designated suspect.

8.4 For suspect strips/plates, 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 a manual ultrasonic compression wave method in accordance with annex A to establish the extent of the laminated suspect area. The strips/plates shall be deemed to have passed this test if the lamination size and frequency of occurrence, given in tables 3 and 4 are not exceeded. In addition, if the width of the laminar imperfection exceeds the minimum width to be considered (see also note 3 to table 3), a 500 mm square with the indication at the centre, shall be 100 % explored to establish the presence or otherwise of other laminar imperfections exceeding the maximum individual lamination size (B_{max}) and to determine if the population density of laminar imperfections greater than B_{min} and less than B_{max} exceeds that permitted in table 3. In the event of further laminar imperfections exceeding the minimum width to be considered being detected, the exploration shall be extended by a further 500 mm square with the new indication at the centre.

b) The surface 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 strip/plate shall be deemed not to have passed the 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;

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, when used;

h) equipment calibration method used.

Table 3 — Acceptance limits (strip/plate body)

Acceptance level	Minimum width dimension to be considered	Minimum individual lamination size, B_{min} [1]	Maximum individual lamination size, B_{max} [1) 2)]	Total summed area of laminations [1) 3)] ($> B_{min}$ and $< B_{max}$)	
				Local per 1 m strip/plate length	Average per metre of total strip/plate length
	mm	mm^2	mm^2	mm^2	mm^2
B1	12	$165 + \frac{w}{4}$	$165 + w$ with a maximum of 2 500 mm^2	$\frac{w}{100} \times 1\,000$	$\frac{w}{200} \times 1\,000$
B2	15	$165 + \frac{w}{2}$	$165 + 2w$ with a maximum of 5 000 mm^2	$\frac{2w}{100} \times 1\,000$	$\frac{w}{100} \times 1\,000$
B3	20	$165 + w$	$165 + 4w$ with a maximum of 10 000 mm^2	$\frac{4w}{100} \times 1\,000$	$\frac{2w}{100} \times 1\,000$

1) w = width, in millimetres, of the strip/plate.

2) B_{max} calculated according to this table shall be rounded up to the next 10 mm^2.

3) For the purpose of determining the extent of the laminated suspect areas, adjacent suspect areas separated by less than the smaller of the two minor axes of the laminations shall be considered as one lamination.

Table 4 — Acceptance limits (strip/plate edge)

Acceptance level	Maximum individual lamination size [1)]			Maximum population density of laminations [2)] with $l_{min} < l < l_{max}$ and $E < E_{max}$ per metre length of edge
	Length		Product of longitudinal and transverse dimensions, E_{max}	
	l_{min} mm	l_{max} mm	mm^2	
E1	10	20	250	3
E2	20	40	500	4
E3	30	60	1 000	5

1) For the purpose of determining the extent of the laminated suspect area, adjacent suspect areas separated by less than the smaller of the two minor axes of the laminations shall be considered as one lamination.

2) Only laminar imperfections exceeding 6 mm in width are to be considered.

Annex A
(normative)

Procedure for the determination of the size of laminar imperfections by manual ultrasonic scanning

A.1 Scope

This annex covers the procedure for manual ultrasonic pulse-echo scanning of steel strips/plates for the determination of the extent of laminated suspect areas found by automatic/semi-automatic testing of strips/plates for the detection of laminar imperfections.

In cases of arbitration, i.e. dispute, between the manufacturer and the purchaser or his representative, in the assessment of the extent and frequency of detected laminar imperfections, this procedure shall be used.

This procedure determines the details of the sizing method to establish the extent and frequency of laminar imperfections in steel strips/plates.

A.2 Testing procedure

In order to determine the extent of laminar imperfections, the method of measuring the half-amplitude value shall be used. This method requires that the ultrasonic probe is passed over the laminated suspect area in two directions, transverse (x) and longitudinal (y). The suspect location shall be 100 % scanned as defined in 8.4 a). During the transverse scan, the positions x_1 and x_2 will be determined where, over the greatest transverse extent, the magnitude of the intermediate reflection equals half of the related maximum value (6 dB difference in signal level). If this value is less than the minimum allowable width to be considered, no further explorations shall be done. In a similar manner, during the longitudinal scan, the positions y_1 and y_2 will be determined. The dimensions between points x_1 and x_2 and points y_1 and y_2 are defined as the maximum width and length dimensions respectively. The product of these dimensions is defined as the area of the laminar imperfections.

A.3 Surface condition

The surface of the strip/plate shall be sufficiently free from foreign matter which would interfere with the validity of the test.

A.4 Test equipment requirements

A.4.1 The ultrasonic probe shall be guided over the strip/plate surface either manually or by mechanical means, with ultrasound transmitted in the direction normal to the strip/plate surface.

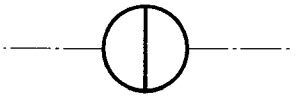
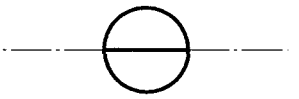
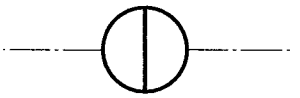
A.4.2 One of the following ultrasonic testing equipments shall be used.

a) Using equipment with a screen display and sensitivity controls in decibels, adjustable in not more than 2 dB steps, the sensitivity control shall be adjusted such that the ultrasonic signals, from the laminated suspect area to be evaluated, lie between 20 % and 80 % of the usable height of the screen display.

b) Using equipment without a screen display where automatic signal amplitude measurement/ assessment facilities are employed, the amplitude measuring unit shall be capable of signal amplitude assessment in decibel steps not exceeding 2 dB.

A.4.3 The selection of the twin TR-probe to be used for manual sizing of the laminated suspect area shall be made in accordance with the details given in table A.1.

Table A.1

Probe-to-lamination distance	Type of twin TR-probe	Plane of acoustic separation
Up to and including 20 mm	Either Nominal frequency: 4 MHz Transducer angle: approx. 5° Transducer size: 8 mm to 12,5 mm Focal depth: approx. 10 mm to 12 mm or Nominal frequency: 4 MHz Tranducer angle: approx. 0° Transducer size: 18 mm to 20 mm Focal depth: approx 10 mm to 12 mm	At right angles to PRD[1)]  Parallel to PRD[1)] 
Above 20 mm	Nominal frequency: 4 MHz Tranducer angle: approx. 0° Transducer size: 18 mm to 20 mm Focal depth: approx 25 mm to 60 mm	At right angles to PRD[1)] 

1) Principal rolling direction.

ICS 23.040.10; 77.040.20; 77.140.30

Descriptors: pipes (tubes), metal tubes, steel tubes, pressure pipes, welded tubes, steel strips, metal plates, tests, non-destructive tests, ultrasonic tests.

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