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Steel — Ultrasonic testing of steel flat products of thickness equal to or greater than 6 mm

Aciers — Contrôle ultrasonore des produits plats en acier d'épaisseur égale ou supérieure à 6 mm

Reference number
ISO 17577:2016(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 17, *Steel*, Subcommittee SC 7, *Methods of testing (other than mechanical tests and chemical analysis)*.

This second edition cancels and replaces the first edition (ISO 17577:2006), which has been technically revised.

This corrected version of ISO 17577:2016 incorporates the following corrections.

Table 4 (third column, third row) "$100^{b} < S \leq 5000$" was changed to "$100^{b} < S \leq 500$".

Steel — Ultrasonic testing of steel flat products of thickness equal to or greater than 6 mm

1 Scope

This International Standard specifies a method for the automated and/or manual ultrasonic testing of uncoated steel flat products for internal discontinuities by the pulse echo technique.

It is applicable to non-alloyed or alloyed steel flat products, in a nominal thickness range of 6 mm to 200 mm. However, this International Standard may be applied to austenitic and austenitic-ferritic steels, provided that the difference between the amplitude of the noise signal and that of the echo detection threshold is sufficient for the limit fixed. Unless otherwise agreed, for testing of steel flat products for welded steel tubes, ISO 10893-9 applies.

Other techniques of testing (e.g. by transmission) or other test equipment may be used at the manufacturer's discretion, provided that they give identical results to those obtained under the conditions of this International Standard. In the event of a dispute, only the method defined in this International Standard will prevail.

Testing of flat products, of thickness less than 6 mm and over 200 mm, may be the subject of special agreements between the parties concerned.

Testing is normally carried out in the place of production or on the premises of the supplier.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 10893-9, *Non-destructive testing of steel tubes — Part 9: Automated ultrasonic testing for the detection of laminar imperfections in strip/plate used for the manufacture of welded steel tubes*

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 following terms and definitions apply.

3.1
internal discontinuity
any imperfection lying within the thickness of the flat products, e.g. planar or laminar imperfection, single-plane or multi-plane inclusion bands or clusters

3.2
defect
unacceptable internal discontinuities, i.e. exceeding the specified maximum size or population density limits

3.3
population density
number of individual internal discontinuities of a size greater than a specified minimum size and less than a specified maximum size per specified area of body or length of edge zone

3.4
manual and assisted manual testing
testing by an operator applying an ultrasonic probe to the flat-product surface, manually executing the appropriate scanning pattern on the flat-product surface and visually assessing ultrasonic signal indications on the electronic equipment screen either by direct viewing or by built-in signal amplitude alarm devices

3.5
automated and semi-automated testing
testing using a mechanized means of applying the ultrasonic probe or probes to the flat-product surface and executing the appropriate scanning pattern, together with ultrasonic signal evaluation by electronic means

Note 1 to entry: Such testing can be either fully automated with no operator involvement or semi-automated when the operator performs basic equipment operation functions.

3.6
dead zone
zone adjacent to the scanning surface within which reflectors of interest are not revealed

4 Principle

The method used is based on the reflection of ultrasonic waves (generally longitudinal waves), the mean direction of which is perpendicular to the main surface of the flat products.

The examination consists of the following:

a) locating any discontinuity by comparing the amplitude of the discontinuity echo with the amplitude of the echo of a flat-bottomed hole of a given diameter and located at the same depth as the discontinuity (DGS-method);

   NOTE Only those discontinuities giving an echo height exceeding in amplitude that of the echo obtained with the reference flat-bottomed hole are taken into consideration.

b) Then determining its area, the contour of the discontinuity being defined by the positions of the centre of the probe corresponding to an echo amplitude of half the maximum amplitude of the discontinuity under consideration (6 dB drop technique).

The examination shall be carried out from one side only.

In the case of automated testing, the location of a discontinuity and the determination of its area can be realized using different algorithms together with high scanning density. In case of dispute, the 6 dB drop technique in 8.1.1 should be used.

5 Personnel

Automated testing shall be carried out only by qualified personnel under the responsibility of Level 2 or Level 3 qualified person. Qualification shall include regular training, success in examination, experience and satisfactory vision test according to the standards mentioned below. Manual testing shall be carried out only by personnel qualified at minimum Level 1 and under the responsibility of Level 2 or Level 3 qualified person.

Qualification of the responsible person shall be in accordance with ISO 9712, ISO 11484 or an appropriate national/ regional standard.

NOTE Examples of appropriate standards are listed in the Bibliography.

6 Testing system

6.1 General requirements

The pulse echo technique with normal incidence to the scanning surface shall be used for the ultrasonic testing.

The instrument shall be equipped with time-base regulation and the gain control shall be calibrated in decibels. The electronic equipment shall be appropriate for the ultrasonic probes and frequencies used.

The transmitted pulse repetition frequency shall be appropriate for the applied scanning speed.

The instrument shall detect the ultrasonic signals of internal discontinuities by using a gate function. The output signal shall be provided for devices like display monitor or recording equipment.

The coupling medium shall ensure an adequate contact between the probe and the surface of the flat products and maintain sufficient coupling during scanning.

6.2 Manual testing instrument

The instrument shall be equipped with an A-scan display monitor that allows the assessment of the path of ultrasonic waves in the flat products. The A-scan shall be clearly visible, the peaks corresponding to the successive echoes being sharp and very clear.

6.3 Automated testing system

The automated testing system shall be equipped with the following:

a) a suitable mechanical means for scanning the surface of flat products with a defined density;

b) probe holders that are capable of following the surface contour of a flat product to be tested, in order to maintain normal incidence;

c) appropriate electronics including, for example, transmitters, receivers, multiplexer, gates, display monitor, as well as a means for data collection;

d) appropriate means for signal evaluation, recording (e.g. mapping) and storing;

e) means for setting of equipment (i.e. test sensitivity, range and gate position), for example, by the use of reference blocks, input of artificial signals, downloading distance-amplitude curves (DAC) or downloading stored calibration files;

f) means for control of pulse repetition frequency related to the scanning speed;

g) means for coupling and function check (e.g. by surveillance of back-wall echo);

h) function to indicate the location of discontinuities with reference to an edge of the flat product (printer, recorder or display).

6.4 Performance of electronic equipment

6.4.1 Linearity

a) Linear amplifiers: the deviation of the vertical linearity shall not exceed ± 1 dB in any part of a 20 dB span.

b) Logarithmic amplifiers: the deviation of the vertical linearity shall not exceed ± 1 dB in any part of a 20 dB span and ± 2 dB in any part of a 60 dB span.

c) Horizontal linearity: the deviation of the horizontal linearity shall not exceed ± 2 % of the testing range.

The vertical linearity shall be checked at least once a year, unless the conditions dictate a higher frequency of checking. The results of all checks shall be recorded.

6.4.2 Dead zone

The dead zone results from combination of probe characteristics with the actual setting of the instrument used.

The dead zone of single-element probes connected to the instrument used shall be as small as possible, i.e. max. 15 % of the thickness of the flat products or 15 mm, whichever is the smaller. For product thicknesses less than 10 mm, the dead zone shall be less than or equal to 1,5 mm.

6.5 Probes

The probes shall be single-element probes, dual-element probes or multiple dual-element probes, depending on the thickness of the flat products as given in Table 1.

Table 1 — Probe types

Specified thickness of the flat products or path length mm	Probe type[a, b]
$6 \leq e \leq 60$	Dual-element probe
$60 < e \leq 200$	Single or dual-element probe

[a] In the event of dispute, the type of probe to be used shall be the subject of an agreement between the parties involved.

[b] As long as the stipulation of the dead zone is satisfied, it is permissible to use single-element probes or flat products of less than or equal to 60 mm thickness.

The probes shall have a nominal frequency in the range of 2 MHz to 5 MHz. Probes with a frequency outside the range of 2 MHz to 5 MHz can be used for material with special acoustic characteristics, if agreed at time of enquiry and order.

The focal zone of dual-element probes shall be adapted to the thickness of the flat products.

The relevant dimension of transducers shall be less than or equal to 30 mm in diameter or in rectangularity.

6.6 Coupling medium

The coupling medium shall ensure an adequate coupling between the probe and the surface of the flat products. Water is normally used, but other coupling media (e.g. oil, paste) may be used at the discretion of the supplier. The coupling medium should be chosen to avoid inter-crystalline corrosion, e.g. when applied to austenitic steel, and in such cases should be adequately removed after testing by an appropriate method.

7 Test procedure

7.1 Time of testing

Unless otherwise agreed at the time of enquiry and order, the time for ultrasonic testing shall be left at the discretion of manufacturer.

7.2 Scanning plan

7.2.1 General

For the flat-product body, the testing is based on statistical methods unless otherwise specified in the order.

Scanning of the flat products shall be carried out in accordance with 7.2.2 and/or 7.2.3 and corresponding to the required quality class.

By agreement at the time of ordering, a scanning with defined scan coverage or a scanning of all body parts of the flat products may be provided, the operating conditions being included in the agreement.

7.2.2 Testing of the flat-product body

For the flat-product body, the scanning comprises continuous testing along the lines of a grid parallel to the edges of the flat products, or along the parallel or oscillating lines distributed uniformly over the area, given the same degree of coverage:

a) for Classes B_1 and B_2 the scanning pattern shall be the grid lines of a 200 mm square, or vertical or horizontal lines at 100 mm pitch;

b) for Classes B_3 and B_4 the scanning pattern shall be the grid lines of a 100 mm square, or vertical or horizontal lines at 50 mm pitch.

7.2.3 Testing of the edges of the flat products

Scanning of the edges comprises a full testing of a zone in accordance with Table 2 over the four edges of the flat products.

Table 2 — Zone width for flat-product edges

Thickness of the flat products mm	Zone width mm
$6 \leq e \leq 60$	50
$60 < e \leq 100$	75
$100 < e \leq 200$	100

7.3 Scanning condition

7.3.1 In the case of scanning with a dual-element probe, the direction of the acoustical barrier shall be oriented perpendicular or 45° to the scanning direction.

7.3.2 The scanning speed shall not impede the testing.

a) In the case of automated testing, the scanning speed and the pulse repetition frequency shall be set to ensure full coverage of the scan lines by ultrasonic pulses.

b) The scanning speed of manual testing without an automated alarm system shall be less than or equal to 500 mm/s.

NOTE The maximum scanning speed depends on different factors such as product thickness, sensitivity or coupling conditions.

7.4 Sensitivity and range setting

7.4.1 The test sensitivity shall be determined using the flat-bottomed holes of the flat products or the reference block.

7.4.2 At least three flat-bottomed holes for each class shall be used for determination of the test sensitivity as given in Table 3.

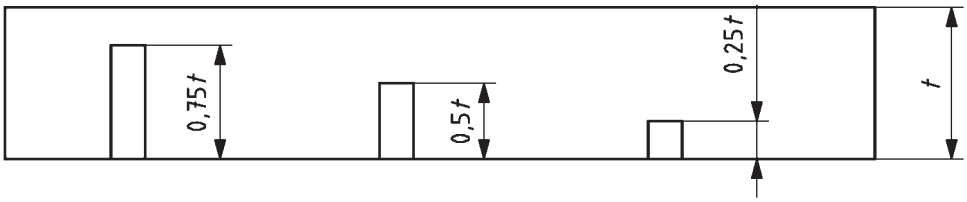
Table 3 — Diameters of flat-bottomed holes for setting test sensitivity

Classes		Diameters of the flat-bottomed holes mm	
Flat-product body	**Flat-product edges**	**Single-element probe**	**Dual-element probe**
B_1, B_2	E_1	11[a]	5
B_3	E_2, E_3	8[a]	
B_4	E_4	5	

[a] By agreement at the time of enquiry and order, the 5 mm flat-bottomed hole may be specified.

NOTE Flat-bottomed holes of diameter 5,6 mm may be used, provided that the sensitivity is adjusted with the same level as 5,0 mm flat-bottomed holes.

7.4.3 The depth of the flat-bottomed holes is given in Figure 1.



Key

t thickness

Figure 1 — Depths of flat-bottomed holes for setting the test sensitivity

7.4.4 The tolerance of the diameter of the flat-bottomed holes shall be ± 5 %. The tolerance of the depth of the flat-bottomed holes shall be ± 10 % or ± 2 mm of the product thickness, whichever is the smaller.

7.4.5 The reference block shall be made of steel with appropriate acoustical properties that are representative for the tested flat products. The reference block may not necessarily be from the same production lot.

7.4.6 The test sensitivity shall be determined from at least three points distributed over the entire field of use of the probe. After setting the lowest echo level or setting the same echo-height level using the distance-amplitude correction, the test sensitivity of the instrument shall be set, regarding the required class.

7.4.7 In the case of manual testing, the distance-amplitude characteristics from the relevant flat-bottomed holes may be used and the curves drawn on the display.

7.4.8 When testing with a dual-element probe, a 5,0 mm diameter hole is used for setting the test sensitivity.

7.4.9 Where the relation between the back-wall echo amplitude and the echo amplitude of the flat-bottomed hole is known the back-wall echo may be used for setting the test sensitivity.

7.4.10 The use of rectangular notches is permitted, provided that the length and width of the notch are chosen to provide an ultrasonic signal response essentially equivalent to that obtained from the stipulated flat-bottomed hole using the same combination of ultrasonic instrument and probe(s).

7.4.11 A reference block that has a thickness differing from that of the flat products to be tested may be used for setting the test sensitivity, if the difference of the sensitivity between the two thicknesses has been measured and compensated.

7.4.12 Distance-amplitude curves can be supplied by the manufacturer of the probe.

7.4.13 The frequency of checking the test sensitivity shall be at least once per 8 h shift.

NOTE When setting the test sensitivity with a dual-element probe, it has to be considered whether to have a variation of sensitivity depending on the direction of the acoustic barrier in relation to the rolling direction.

8 Determination of the discontinuity size

8.1 Testing the flat-product body

8.1.1 Testing with dual-element probes

The area of discontinuities giving responses that exceed the distance-amplitude curve shall be determined using the 6 dB drop technique, i.e. the contour of the discontinuity being defined as positions of centre of the probe, when the response from the discontinuity is equal to half the maximum amplitude. A rectangle that encompasses the whole of the discontinuity is then determined; the major dimension of which is called the length of the discontinuity, and the minor dimension is called the width of the discontinuity. The area of the rectangle is also calculated. The area of the rectangle defines the area, S, of the discontinuity.

Two adjacent discontinuities shall be considered to represent a single discontinuity, the area being equal to the sum of the two, if the distance between them is less than or equal to the length of the smaller of the two.

In the case of automated testing, the location of a discontinuity and the determination of its area can be realized using different algorithms, together with high scanning density. In case of dispute, the 6 dB drop technique should be used.

8.1.2 Testing with single-element probes

The test consists of the following:

a) for flat products of Class B_1 and B_2: determination of the area in accordance with the method defined in 8.1.1;

b) for flat products of Class B_3 and B_4: simple counting of the discontinuities, which can be done when they are detected using the distance-amplitude curves for 5 mm, 8 mm and 11 mm diameter holes;

c) the following is thus determined:

   1) for Class B_3: the number N1 of discontinuities giving echoes with an amplitude greater than the 11 mm diameter curve, and the number N2 of discontinuities (Table 5) giving echoes with an amplitude between characteristic curves for the 8 mm and 11 mm holes;

2) for Class B_4: the number N1 of discontinuities giving echoes with an amplitude greater than the 8 mm diameter curve, and the number N3 of discontinuities (Table 5) giving echoes with an amplitude between characteristic curves for the 5 mm and 8 mm holes.

In the case of automated testing, the location of a discontinuity and the determination of its area can be realized using different algorithms, together with high scanning density. In case of dispute, the adequate technique described in this subclause should be used.

8.2 Testing the edges

The test consists of scanning the total area of the edges (or areas to be welded according to sketches) where discontinuities were located as defined in 7.2.3, under the same conditions as for the flat-product body in 8.1.

The following shall be determined:

a) the maximum dimension (L_{max}) and the minimum dimension (L_{min}) of the discontinuity in the rolling direction;

b) the area (S) of the discontinuity;

c) the number of discontinuities smaller than the maximum area (S_{max}) and longer than the minimum dimension (L_{min}) per 1 m length.

The determination of these properties of the discontinuity is obtained using the 6 dB drop technique.

The area of the rectangle defines the area, S, of the discontinuity. Two adjacent discontinuities shall be considered to represent a single discontinuity, the area being equal to the sum of the two, if the distance between them is less than or equal to the length of the smaller of the two.

In the case of automated testing, the location of a discontinuity and the determination of its area can be realized using different algorithms together with high scanning density. In case of dispute, the 6 dB drop technique in 8.1.1 should be used.

9 Acceptance criteria

Tables 4 and 5 give the acceptance criteria for the quality classes (B_1, B_2, B_3 and B_4) for the flat-product body, depending on the type of probe used, and Tables 6 and 7 for the edge classes (E_1, E_2, E_3 and E_4) (see also Figure 2).

If no quality class is specified by the purchaser at the time of enquiry and order, Class B_1 for flat-product body and Class E_1 for flat-product edges apply.

10 Test report

If agreed at the time of order, the manufacturer shall submit a test report which includes at least the following points:

a) reference to this International Standard, i.e. ISO 17577;

b) reference data of the examined flat products (identification of the flat product, dimensions);

c) characteristics of the ultrasonic probe (type, dimensions, frequency) and of the test instrument;

d) operation conditions (coupling medium, scanning pattern, method of area determination, setting of the test equipment);

e) test results;

f) date of the test report;

g) operator identification.

Table 4 — Acceptance criteria for testing the body of flat products using dual-element probes

Class	Unacceptable individual discontinuity mm²	Acceptable frequency of discontinuities	
		Area[a] considered mm²	Maximum population density
B_1	$S > 1\,000$	$500 < S \leq 1\,000$	15 in the most populated/ 1 m × 1 m square
B_2	$S > 500$	$100^b < S \leq 500$	
B_3	$S > 100$	$50^b < S \leq 100$	10 in the most populated/ 1 m × 1 m square
B_4	$S > 50$	$20 < S \leq 50$	10 in the most populated/ 1 m × 1 m square

[a] Area of each discontinuity in the cluster in question.

For 1 000 mm², 500 mm²,100 mm² and 50 mm² are determined in 8.1.1.

For 20 mm², the discontinuity giving echoes with an amplitude above the distance-amplitude curve of a flat- bottomed hole of diameter 5,0 mm.

[b] By agreement at the time of enquiry and order, a minimum area of 20 mm² may be specified.

Table 5 — Acceptance criteria for testing the body of flats product using single-element probes

Class	Unacceptable individual discontinuity	Acceptable frequency of discontinuities	
		Area[a] considered	Maximum population density
B_1	$S > 1\,000$ mm²	500 mm² < $S \leq 1\,000$ mm²	15 in the most populated/ 1 m × 1 m square
B_2	$S > 500$ mm²	100 mm²[b] < $S \leq 500$ mm²	
B_3	Discontinuities where the echo has an amplitude above the distance-amplitude curve for a flat-bottomed hole of diameter 11 mm	N2 between diameters of 8 mm[b] and 11 mm	10 in the most populated/ 1 m × 1 m square
B_4	Discontinuities where the echo has an amplitude above the distance-amplitude curve for a flat-bottomed hole of diameter 8 mm	N3 between diameters of 5 mm and 8 mm	10 in the most populated/ 1 m × 1 m square

[a] Area of each discontinuity in the cluster in question (see 8.1.2).

[b] By agreement at the time of enquiry and order, the 5 mm flat-bottomed hole may be specified.

Table 6 — Acceptance criteria for testing the edge zone of flat products with dual-element probes

Class[a]	Permissible individual discontinuity size		Minimum discontinuity dimension considered	Permissible number of discontinuities smaller than the maximum area S_{max} and longer than L_{min} per 1 m length
	Maximum dimension L_{max} mm	Maximum area S_{max} mm^2	L_{min} mm	
E_1	50	1 000	25	5
E_2	40	500	20 [b]	4
E_3	30	100	15[b]	3
E_4	20	50	10	2

NOTE 1 Counting of the discontinuities is carried out using the distance-amplitude curve for the 5,0 mm diameter holes.

NOTE 2 The length and area of the discontinuity of E_1, E_2, E_3 and E_4 are determined in 8.1.1.

NOTE 3 The number of discontinuities is determined as the number of discontinuities giving echoes with an amplitude above the distance-amplitude curve of flat-bottomed holes of diameter 5,0 mm.

[a] Discontinuities giving echoes with an amplitude above the distance-amplitude curve of a flat-bottomed hole of diameter 5,0 mm shall be considered.

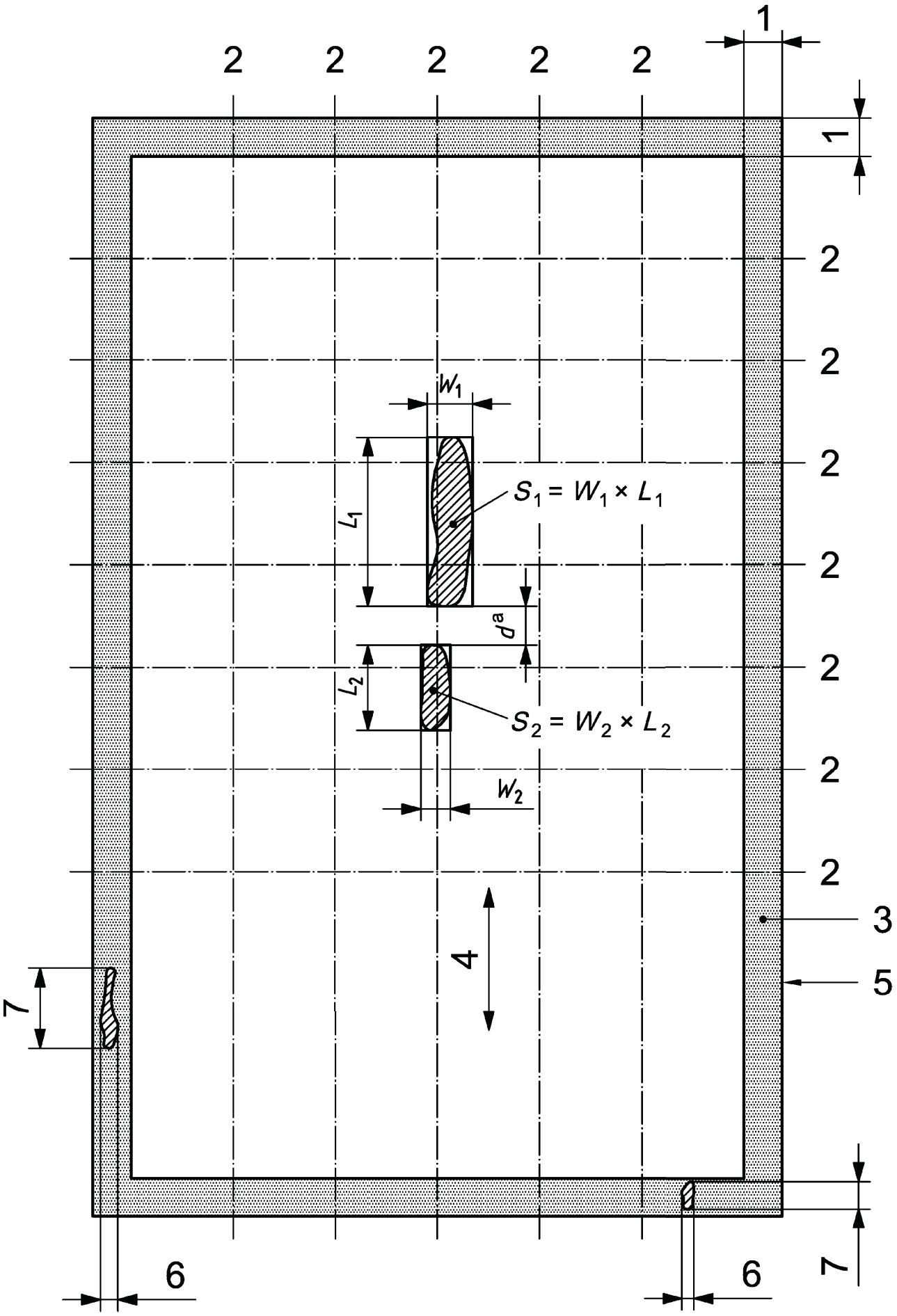
[b] By agreement at the time of enquiry and order, a minimum dimension (L_{min}) of 10 mm may be specified.

Table 7 — Acceptance criteria for testing the edge zone of flat products with single-element probes

Class	Permissible individual discontinuity size diameter D	Maximum dimension L_{max}[a] mm	Permissible number of discontinuities per 1 m length
E_1	11 mm < D	50	5
E_2	8 mm[b] < D ≤ 11 mm	40	4
E_3	8 mm[b] < D ≤ 11 mm	30	3
E_4	5 mm < D ≤ 8 mm	20	2

[a] L_{max} is determinate in 8.1.1.

[b] By agreement at the time of enquiry and order, the 5 mm flat-bottomed hole may be specified.



Key

1 see Table 2 for the value of the edge-zone width
2 scan line
3 edge zone
4 principal rolling direction
5 flat product
6 width
7 length
S area of discontinuity
a If $d \leq L_2$ then $S = S_1 + S_2$

Figure 2 — Schematic representation of terms used

Bibliography

[1] ISO 12710, *Non-destructive testing — Ultrasonic inspection — Evaluating electronic characteristics of ultrasonic test instruments*

[2] ISO 16810, *Non-destructive testing — Ultrasonic testing — General principles*

[3] ISO 16811, *Non-destructive testing — Ultrasonic testing — Sensitivity and range setting*

[4] EN 10160, *Ultrasonic testing of steel flat product of thickness equal to or greater than 6 mm (reflection method)*

[5] ASNT Recommended Practice No. SNT-TC-1A

[6] ACCP ASNT Central Certification Program

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