INTERNATIONAL STANDARD

ISO 18175

First edition
2004-03-15

Non-destructive testing — Evaluating performance characteristics of ultrasonic pulse-echo testing systems without the use of electronic measurement instruments

Essais non destructifs — Évaluation des caractéristiques fonctionnelles des systèmes de contrôle ultrasonore par réflexion sans utilisation d'instruments de mesure électroniques

Reference number
ISO 18175:2004(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18175 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Accoustical methods*.

Non-destructive testing — Evaluating performance characteristics of ultrasonic pulse-echo testing systems without the use of electronic measurement instruments

WARNING — This International Standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this International Standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This International Standard describes procedures for evaluating the following performance characteristics of ultrasonic pulse-echo examination instruments:

- horizontal limit and linearity;
- vertical limit and linearity;
- resolution-entry surface and far surface;
- sensitivity and noise;
- accuracy of calibrated gain controls.

Relevant terminology can be found in ASTM Terminology E 1316 and IEEE Standard 100. Evaluation of these characteristics is intended to be used for comparing instruments or, by periodic repetition, for detecting long-term changes in the characteristics of a given instrument that may be indicative of impending failure, and which, if beyond certain limits, will require corrective maintenance.

Ultrasonic examination instruments using pulsed-wave trains and A-scan presentation (rf or video) may also be evaluated. The procedures are applicable to shop- or field-conditions and additional electronic measurement instrumentation is not required.

This International Standard establishes no performance limits for examination systems; if such acceptance criteria are required, these must be specified by the using parties. Where acceptance criteria are implied herein they are only for the sake of example and are subject to more or less restrictive limits imposed by customer's and end user's controlling documents. The specific parameters to be evaluated, conditions and frequency of test, and report data required, must also be determined by the user. This International Standard may be used for the evaluation of a complete examination system, including transducer, instrument, interconnections, fixtures and connected alarm and auxiliary devices, primarily in cases where such a system is used repeatedly without change or substitution. This International Standard is not intended to be used as a substitute for calibration of a system to inspect any given material.

Required test apparatus includes selected reference blocks and a precision external attenuator (where specified) in addition to the instrument to be evaluated.

Precautions relating to the applicability of the procedures and interpretation of the results are included.

Alternate procedures, such as examples described in this International Standard, or others, may only be used with customer approval.

2 Normative references

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

ISO 5577:2000, *Non-destructive testing — Ultrasonic Inspection — Vocabulary*

ASTM E 114-95, *Standard Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method*

ASTM E 127-98, *Standard Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks*

ASTM E 214-01, *Standard Practice for Immersed Ultrasonic Examination by the Reflection Method Using Pulsed Longitudinal Waves*

ASTM E 428-00, *Standard Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection*

ASTM E 1316-02a, *Standard Terminology for Nondestructive Examinations*

JIS Z 2352, *Method for assessing the overall performance characteristics of ultrasonic pulse echo testing instrument*

IEEE Std 100, *IEEE Standard Dictionary of Electrical and Electronic Terms*, Wiley-Interscience, New York

3 Terms and definitions

For the purposes of this document the terms and definitions described in ISO 5577, ASTM E 1316 and IEEE Std 100 apply.

4 Principle

4.1 An examination system to be evaluated comprises an ultrasonic pulse-echo instrument, transducer, interconnecting cables and couplant. For immersion examination systems suitable fixturing is required.

4.2 When checking an entire system to be used for a given inspection, test conditions are selected that are consistent with the intended end-use as determined by the user.

4.3 The ultrasonic response from appropriate reference blocks is obtained, and presented in numerical or graphical form.

5 Significance and use

5.1 This International Standard describes procedures applicable to both shop- and field-conditions. More comprehensive or precise measurements of the characteristics of complete systems and their components will generally require laboratory techniques and electronic equipment such as oscilloscopes and signal generators. Substitution of these methods is not precluded where appropriate; however, their usage is not within the scope of this International Standard.

5.2 This International Standard does not establish system acceptance limits, nor is it intended as a comprehensive equipment specification.

5.3 While several important characteristics are included, others of possible significance in some applications are not covered.

5.4 Since the parameters to be evaluated and the applicable test conditions shall be specified, the practice described in this International Standard shall be prescribed only by those familiar with ultrasonic NDT technology and the required tests shall be performed either by such a qualified person or under his/her supervision.

5.5 Implementation may require more detailed procedural instructions in the format of the using facility.

5.6 In the case of evaluation of a complete system, selection of the specific tests to be made shall be made cautiously. If the related parameters are not critical in the intended application, then their inclusion may be unjustified, e.g., vertical linearity might be irrelevant for a go/no-go test with a flaw gate alarm, while horizontal linearity may be required only for accurate flaw depth or thickness measurement from the instrument display.

5.7 No frequency of system evaluation or calibration is recommended or implied. This is the prerogative of the using parties and is dependent on application, environment and stability of equipment.

5.8 Certain sections are applicable only to instruments having receiver gain controls calibrated in decibels (dB). While these may sometimes be designated “gain,” “attenuator” or “sensitivity” on various instruments, the term “gain controls” will be used in this International Standard when referring to those which specifically control instrument receiver gain but not including reject, electronic distance-amplitude compensation or automatic gain control.

5.9 These procedures can generally be applied to any combination of instrument and transducer of the commonly used types and frequencies, and to most straight-beam examinations, either contact or immersed. Certain sections are also compatible with angle-beam, wheel, delay-line and dual probe techniques. Their use, however, shall be mutually agreed upon and so identified in the test report.

5.10 The validity of the results obtained will depend on the precision of the instrument display readings. This is assumed to be ± 0,04 in (± 1 mm), yielding between 1 % and 2 % of full scale (fs) readability for available instrumentation having suitable screen graticules and display sharpness.

6 Procedures for obtaining ultrasonic response data

6.1 General

6.1.1 A procedure, using this International Standard as a guide, shall be prepared for periodic checking of each specific type of instrument or system to be used. For each procedure determine, from the requesting documents, the instrument examination range to be evaluated, select the appropriate probe, fixtures and reference blocks, and establish the required display conditions. Unless otherwise required, mid-range values are suggested for most panel controls and “reject” shall be off unless specifically desired to be evaluated. It may be desired to vary the instrument controls from these initial values. If so, it is important to observe and report any anomalous effects on the parameters being evaluated when the controls are so varied.

6.1.2 When a procedure requires a change in receiver gain by the use of a calibrated control, it is assumed that those which increase sensitivity with higher panel readings are designated “gain” and those which decrease sensitivity with higher readings are designated “attenuation.” Fine (reference) gain controls, when available, are usually not calibrated in decibels and increase sensitivity with clockwise rotation.

6.1.3 Although the procedures described in this International Standard do not cover the use of electronic distance-amplitude compensation, its use is not precluded. If it is used to affect any one or combination of characteristics, measured under this document, then all characteristics should be evaluated with the same level of compensation as was used on any one, and this level should be referenced in the report. If desired by the using parties, a dual set of test data may be made both with and without distance-amplitude compensation.

6.1.4 If the display screen does not provide a suitable internal graticule, and deflection measurements are being made, fix the eye relative to the external scale in order to minimize parallax. This practice assumes reading precision of within 2 % of full scale. If, for any reason, this is not feasible for the instrument under test, estimate the probable accuracy and include this in the report. Readability can sometimes be improved by the use of an external scale attached to the display screen face having 50 or 100 divisions for full scale.

6.1.5 When tests are being done by the contact method, position the probe securely and make certain that couplant changes are not measurably affecting the results. See ASTM Practice E 114.

6.1.6 When using the immersion method, allow adequate time for thermal stabilization, remove bubbles and particles from the probe and test surfaces and maintain the probe manipulator and reference blocks in stable positions. See ASTM Practice E 214.

6.2 Horizontal limit and linearity

6.2.1 Significance

Horizontal limit and linearity have significance when determination of depth of a discontinuity is required. A specified minimum trace length is usually necessary to obtain the horizontal readability desired. Nonlinearity of sweep trace may affect accuracy of flaw depth or thickness determination made directly from the display screen.

6.2.2 Apparatus

A reference block is required that will give several (preferably 11) noninterfering multiple back reflections for the sweep range and other test conditions of interest. Any block having good ultrasonic transmittivity, flat parallel faces, and a thickness of about one-tenth of the specified sweep range will usually be adequate. The aluminum blocks shown in Figure 1 will be satisfactory for mid-range frequencies and sweep settings on most instruments when the beam is directed through the thickness T. For other test frequencies or very large probes, different block dimensions or other block designs may be required to eliminate interference. The couplant system used, either contact or immersed, shall provide stable indications during the measuring procedure. A horizontal scale permitting reading accuracy as specified in 6.1.4 is required.

NOTE An encapsulated transducer-targets assembly may be used for this purpose.

6.2.3 Procedure

Couple the appropriate block to the probe so that the sound beam does not intercept any test holes. Adjust the instrument gain, sweep-delay and sweep-length controls to display 11 noninterfering back reflections. Set the amplitude of each back reflection at 50 % fs before measuring its position. Further adjust the sweep controls (range, centering or delay) to position the leading edge of the third and ninth back reflections at the 20 % and 80 % scale divisions respectively (with each set in turn at 50 % fs). After the third and ninth back reflections are positioned accurately on the 20 % and 80 % divisions as described, read and record the scale positions of each other multiple. Alternatively, if sweep-delay is not available, position the second and eighth back reflections at the 20 % and 80 % scale divisions respectively; read and record the scale positions of the initial pulse start and of the remaining multiples. An example of an acceptable alternate procedure is given in JIS Z 2352 wherein the leading edge of the first reference block back-wall signal is set to correspond to zero on the horizontal scale and the sixth one set to full scale. Departures of the second to fifth back wall signals from scale graduations at 20 %, 40 %, 60 % and 80 % of full scale are noted and used to express the degree of nonlinearity of the time base.

NOTE Either more or fewer reflections can be used by suitably modifying the procedure; e.g., six back reflections may be used if interference echoes are obtained with 11, in which case the second back reflection is positioned at the 20 % scale division and the fifth back reflection at the 80 % scale division. Measurement of the horizontal position of each multiple echo should be made at the same amplitude on the leading edge of the indication. Any specific value may be selected if it is used consistently. Typically used values are baseline break, half amplitude or signal peak.

6.2.4 Interpretation of data

6.2.4.1 Horizontal limit is given by the maximum available trace length falling within the display screen graticule lines expressed in linear units (inches or millimetres). Unless otherwise noted, this is also assumed to represent 100 % fs. Failure to obtain full-scale deflection may indicate an equipment malfunction.

6.2.4.2 Linearity test results shall be presented in tabular form and may also be plotted in the manner shown in Figure 2. The deviation is given by the displacement (in % full scale) from the straight line through the set-up points representing ideal linearity. For the test point shown (sixth multiple at 55 % fs) the error is 5 % fs. Maximum nonlinearity is given by the "worst case" test point. Linear range is given by the set of contiguous points falling entirely within a specified tolerance.

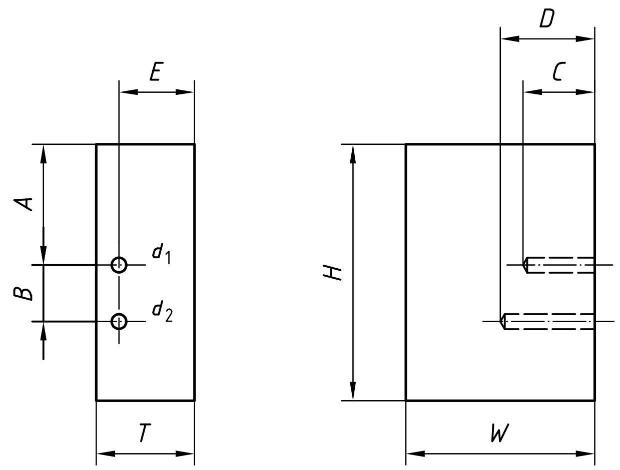
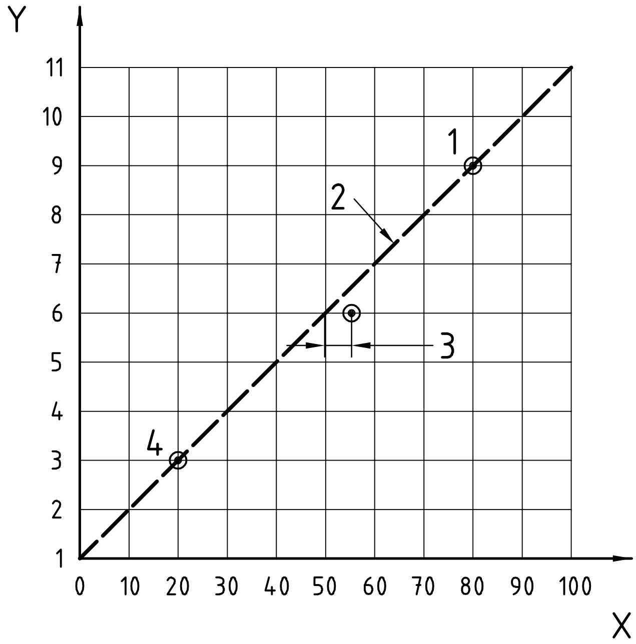


Table of Dimensions

Dimension on Figure 1	Imperial block in		Metric block mm	
	Dimension	Tolerance	Dimension	Tolerance
A	1,25	0,05	32	1
B	1,00	0,05	25	1
C	0,75	0,05	19	1
D	1,00	0,05	25	1
E	0,75	0,05	19	1
H	3,00	0,05	75	1
T	1,00	0,01	25,0	0,2
W	2,00	0,05	50	1
d_1 and d_2	0,047 dia.	0,005	1,2 dia.	0,1
All surfaces:				
Flatness		0,001		0,02
Parallelism		0,001		0,02
Finish	63 µin or smoother		1,5 µm or smoother	

NOTE Material: 7075T6 aluminium; plug-drilled holes with water-soluble plastic.

Figure 1 — Suggested test blocks for evaluation of horizontal and vertical linearity



NOTE An example of a read point for this diagram is 55,6.

Key

X position of signal on sweep trace, % fs

Y back reflection number

1 set point (80,9)

2 ideal linearity line

3 deviation (5 % fs)

4 set point (20,3)

Figure 2 — Example of data plot for determination of horizontal linearity

6.3 Vertical limit and linearity

6.3.1 Significance

Vertical limit and linearity have significance when echo signal amplitudes are to be determined from the display screen or corresponding output signals, and are to be used for evaluation of discontinuities or acceptance criteria. A specified minimum trace deflection and linearity limit may be required to achieve the desired amplitude accuracy. For other situations they may not be important, e.g., go/no-go examinations with flaw alarms or evaluation by comparison with a reference level using calibrated gain controls. This practice describes both the two-signal ratio technique (Method A) and the input/output attenuator technique (Method B). Both methods assume that the test indications used for measurement are free of interferences resulting from nearby signals such as the initial pulse, interface echo, or adjacent multiples. If linearity is of concern under such conditions, e.g. for near-surface signals, it may be evaluated by the procedure described in 6.4.3.

Method A (ratio technique) discloses only nonlinearity that occurs in the instrument circuitry between the gain controls being used to set the amplitudes and the display.

Method B (input/output technique) evaluates the entire receiver/display system at constant gain as established initially by the panel controls. Because of this and other differences, the two methods may not give identical results for linearity range. Further, Method A may not disclose certain types of nonlinear response shown by Method B.

6.3.2 Method A

6.3.2.1 Apparatus

A reference block is required that produces two noninterfering signals having an amplitude ratio of 2 to 1. These are compared over the usable screen height as the instrument gain is changed. The two amplitudes are referred to as H_A and H_B ($H_A > H_B$). The two signals may occur in either screen order and do not have to be successive if part of a multiple-echo pattern. Unless otherwise specified in the requesting document, any reference block that will produce such signals at the nominal test settings specified can be used. For many commonly used probes and test conditions, the reference block shown in Figure 1 is usually satisfactory when the beam is directed along the H dimension toward the two holes. The method is applicable to either contact or immersion tests; however, if a choice exists, the latter may be preferable for ease of set-up and coupling stability.

NOTE An encapsulated transducer-targets assembly may be used for this purpose.

6.3.2.2 Procedure

To obtain test data, position the probe so that two echo signals are obtained having amplitudes in the ratio of about 2 to 1. Determine that there is sufficient range in the gain controls to vary H_A (the larger) from 10 % fs to 100 % fs. Manipulate the probe and adjust the instrument controls until H_A and H_B meet the conditions listed in Table 1. The preferred values are desired because the data can be more easily presented and evaluated. However, positioning difficulties or lack of a fine gain or pulse-length control may not permit obtaining the exact values. When optimum set-up conditions are established, secure the probe in place, observing the precautions noted in 6.1. Adjust the gain controls in steps so that H_A is set in increments of 10 % or less from 10 % fs to 100 % fs. Read and record the values of H_A and H_B within the accuracies prescribed in 6.1.4.

NOTE To better define the response characteristic, particularly near the upper and lower limits, additional readings may be taken at smaller gain increments.

Table 1 — Vertical linearity range by Method A using two-signal (ratio) technique/initial values for H_A and H_B giving ratios of 1,8 to 2,2

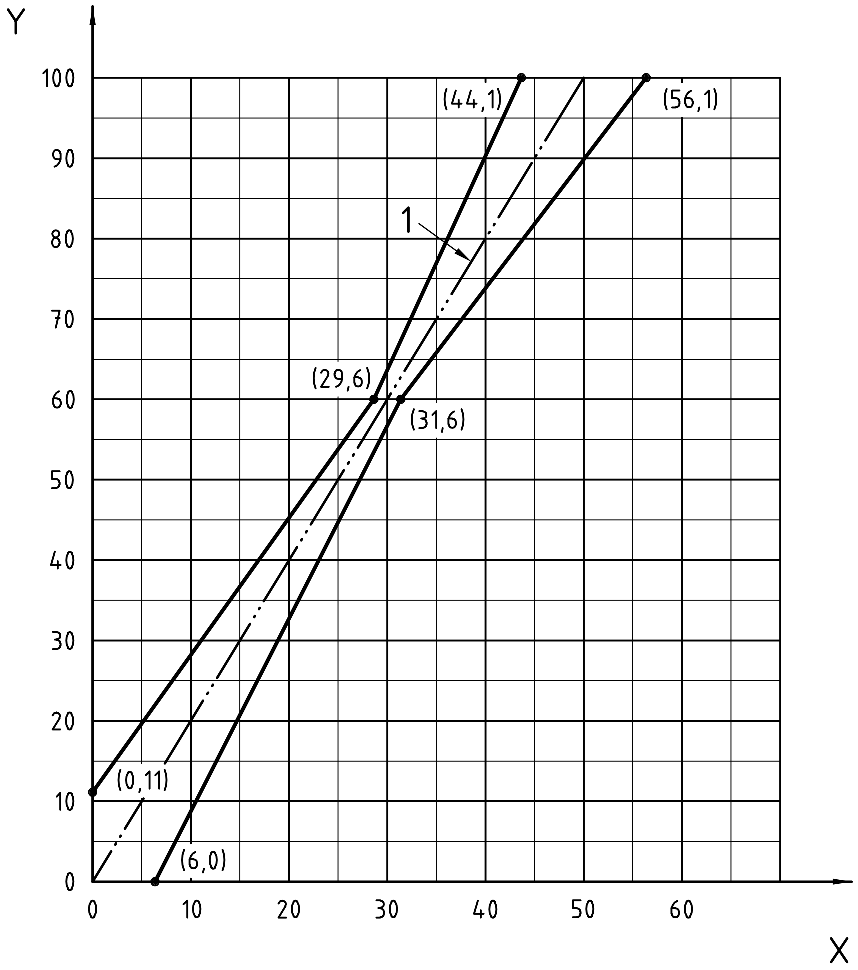
H_A % fs	H_B % fs
Preferred values	
60	30
Acceptable values	
65	30 to 36
64	29 to 36
63	29 to 35
62	28 to 34
61	27 to 34
60	27 to 33
59	27 to 33
58	26 to 32
57	26 to 32
56	25 to 31
55	25 to 31
NOTE Preferred setup values permit determination of vertical linearity range directly from the data plot of Figure 3	

6.3.2.3 Interpretation of data

Vertical limit is given by the maximum vertical deflection (baseline to peak for video and peak to peak for rf) within the usable graticule range that can be obtained from a large reflector (e.g., the reference block surfaces) as the gain is increased. This is reported in linear units (inches or millimetres) and equivalent graticule divisions are noted. Unless otherwise stated, this is assumed to represent 100 % fs. Failure to obtain full-scale deflection may indicate an equipment malfunction. Linearity test data may be reported in tabular form or preferably presented graphically. Unless otherwise specified in the requesting document, vertical linearity range should be determined graphically using the method shown in Figure 3. If the preferred set-up condition (H_A = 60 % fs, H_B = 30 % fs) is established initially, the test results may be plotted directly on the scales shown. The limit lines provide a graduated tolerance for H_B of ± 1 graph division starting at the set-up point (to provide for reading error) to ± 6 divisions at the extremes. Ideal linearity is defined by a straight line extending from the origin through any set-up point to full scale. The linear range is determined by interconnecting adjacent data points and noting the first locations above and below the set-up point that intersects the limit lines. The upper linearity limit is given by the corresponding value for H_A and the lower by that for H_B. If the preferred set-up values were not obtained, a new linearity line and corresponding limits shall be constructed following the same approach.

NOTE 1 If the requesting document specifies that the test results be presented in ratio form (i.e., H_A/H_B versus H_A) the necessary values can be calculated from the tabular data and presented in any format specified. To establish linearity limits the desired tolerances must also be stated.

NOTE 2 If the instrument graticule cannot be read directly in % of full scale, the recorded values of H_A and H_B should be converted to percentages of full scale before plotting. If that is not done, new coordinates with appropriate scale and limit lines must be constructed.



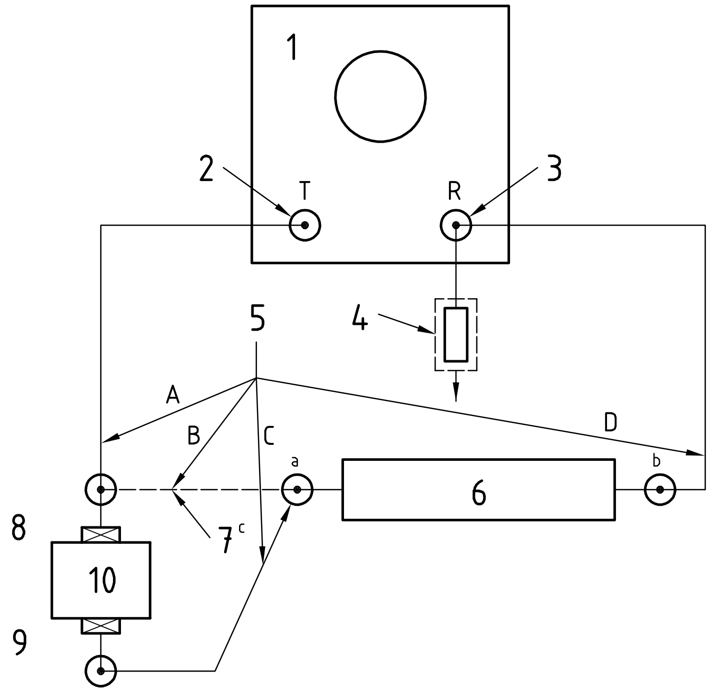
Key

X H_B % fs

Y H_A % fs

1 ideal linearity line

Figure 3 — Data plot for determination of vertical linearity range by Method A (ratio technique)



Key

1 pulse echo instrument, through-transmission mode
2 transmit jack
3 receive jack
4 shielded terminator
5 coaxial cables
6 step attenuator
7 alternate line for one-probe operation
8 search unit 1
9 search unit 2
10 delay path

[a] In.

[b] Out.

[c] When in use, disconnect line C. See also 6.3.3.1.

Figure 4 — Recommended system configuration for determination of vertical linearity (Method B) and gain control calibration

6.3.3 Method B

6.3.3.1 Apparatus

This method requires the use of an auxiliary external-step attenuator meeting the following minimum specifications which are usually certified by the supplier:

— frequency range: dc to 100 MHz

— impedance: 50 Ω or 75 Ω

— attenuation: 0 dB to 80 dB in 1 dB steps

— accuracy: ± 0,2 dB for any indicated dB step size

The instrument shall be operable in a through-transmission mode with the attenuator inserted between the source of the received signal and the receiver input jack as shown in Figure 4. Either the single-search-unit or the alternative two-search-unit configuration may be used. The attenuator shall be connected to the receiver input with a short length [6 ft (1,8 m) or less] of coaxial cable of no more than 30 pf/ft (9,14 pf/m) capacitance. The terminator should be a shielded, noninductive resistor preferably mounted in a coaxial connector. See the Note below regarding termination errors.

In the single-search-unit configuration the pulser is shunted by the attenuator input. Therefore, to isolate the pulser and protect the attenuator if its input rating is exceeded, a dropping resistor may be desirable. If the two-search-unit arrangement is used, no further isolation is required. The path length provided by the test medium should be adequate to separate the initial pulse (or any instrument cross-talk) from the desired signal, usually that from the first back reflection or interface echo (single-search-unit method) or the first transmitted signal (two-search-unit method). For most test situations a total material path of 2 in (50 mm) of water or 6 in (150 mm) of metal such as aluminium will be satisfactory.

NOTE It is assumed that, as is typical of most commercial instruments when operated in the through-transmission mode, the receiver input impedance is large (at least 10 times) compared with that of the attenuator. This can usually be determined from the manual or from the manufacturer, and the terminator suitably adjusted. However, when there is a question about receiver input impedance, an attenuator setting of at least 20 dB should be used in addition to any attenuation increases used in making the measurements. Proper operation of the attenuator can be checked by determining that any combination of steps having an equivalent value produces the same signal change; e.g., an increase of attenuation from 20 dB to 26 dB should produce the same display change as the increase from 30 dB to 36 dB.

6.3.3.2 Procedure

With approximately 30 dB of attenuation in the external attenuator, adjust the instrument sweep and gain controls to produce a centre screen deflection of 50 % fs within readability tolerance (i.e., 2 % fs or better). Decrease the external attenuation in 1 dB steps until full-scale deflection is reached and record the signal amplitude for each step in percent of full scale. Reset the external attenuator to again give 50 % fs and increase the external attenuation in 2 dB steps for five steps, and then in 4 dB steps thereafter until the signal essentially disappears; record signal amplitudes for each step.

NOTE Smaller attenuation increments may be used to better define the linearity response. Optional values are given in Table 2.

6.3.3.3 Interpretation of data

Deviations from ideal linearity may be determined either by comparison with tabular values or by graphical means. Vertical linear range can then be established for any specified deviation, usually stated in percent of full scale. This practice, unless modified by the requesting document, prescribes a tolerance of ± 5 % fs in determining upper and lower linearity limits. In addition ± 1 % fs is allowed for reading errors. To use the tabular method, subtract the amplitude readings obtained for each step from that for the appropriate attenuator step as given in Table 2. The difference (which may be either positive or negative) is the deviation from ideal linearity in percent of full scale. The linear range extends from the lowest to the highest values of sequential amplitudes all falling within prescribed limits. Graphic methods require either logarithmic scales or inverse log calculations to give a straight linearity plot. The preferred format that is convenient to use is shown in Figure 5. Deviation from ideal linearity can be read directly in percent of full scale, and vertical linearity range established by the limit lines shown. Other limit lines for any specified tolerances may be constructed in a similar manner.

6.3.3.4 Acceptable alternate method

If the instrument's gain/attenuator controls are marked in decibels, and if they have been previously calibrated using an external means of known and traceable accuracy (such as is given in 6.6), an alternate procedure for display linearity checking may, with customer approval, be used. With this method gain control settings are changed in 2 dB increments over a range of 26 dB and the amplitude of the initial 100 % fs signal from a suitably chosen reference block target is noted for each step and used to determine vertical display linearity. For this method 100 % fs shall be taken as the maximum extent of the linear vertical range of the instrument, within the linearity limits established by the controlling document.

Table 2 — Determination of vertical linearity range by Method B using input/output technique with external attenuator

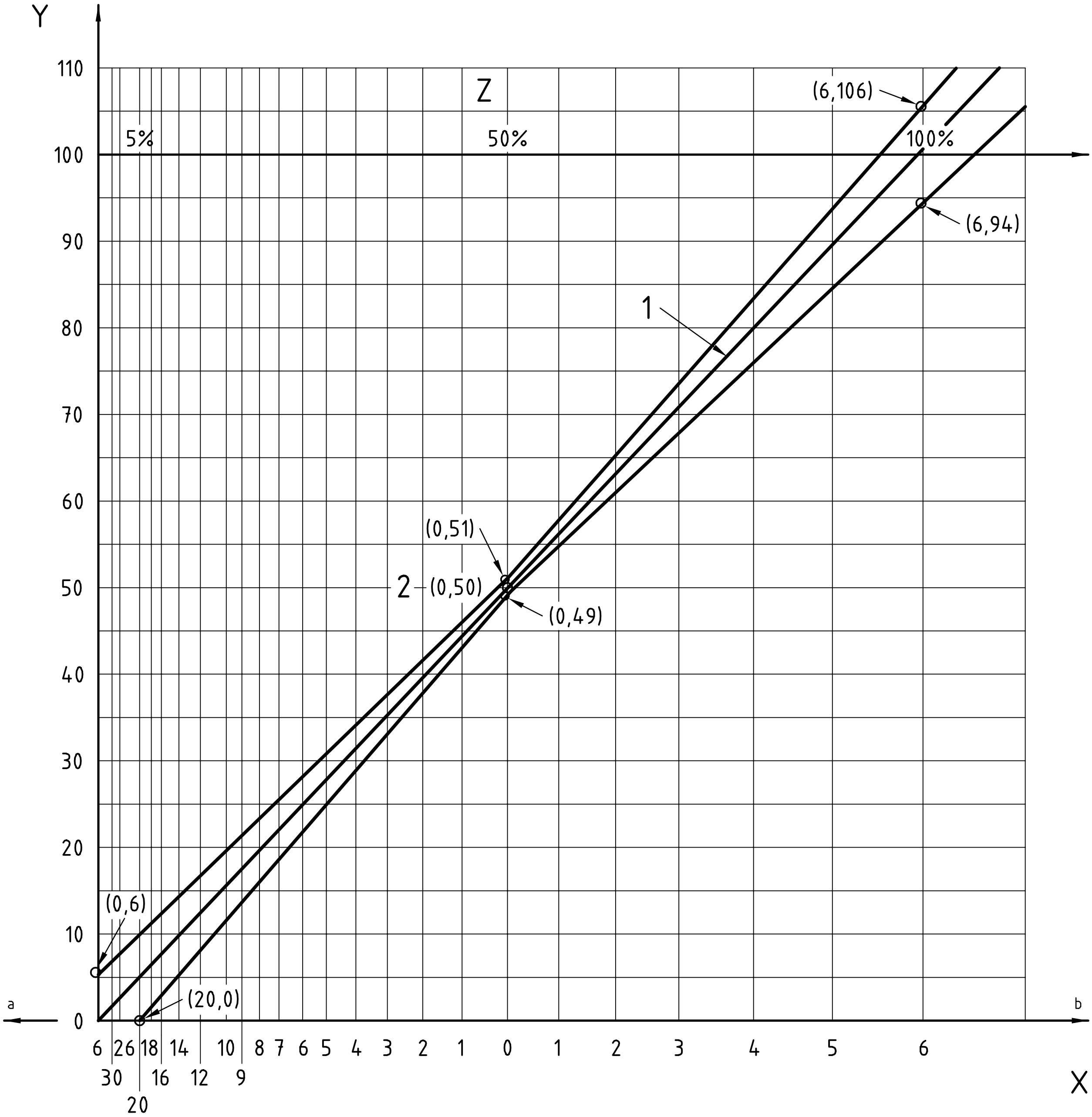
Vertical signal amplitude versus relative attenuation							
Decreasing external attenuation				Increasing external attenuation			
– dB	H_R[a] % fs	H_T[b] % fs	$H_R - H_T$ % fs	+ dB	H_R % fs	H_T % fs	$H_R - H_T$ % fs
0	50	50	0	0	50	50	0
0,5[c]		53		1[c]		45	
1,0		56		2		40	
1,5[c]		59		3[c]		35	
2,0		63		4		32	
2,5[c]		67		5[c]		28	
3,0		71		6		25	
3,5[c]		75		7[c]		22	
4,0		79		8		20	
4,5[c]		84		9[c]		18	
5,0		89		10		16	
5,5[c]		94		12[c]		13	
6,0		100		14		10	
6,5[d]		106		16[c]		8	
7,0[d]		112		18		6	
7,5[d]		119		20[c]		5	
8,0[d]		126		22		4	
				24[c]		3	
				26		2,5	
				28[c]		2	
				30		1,5	
				32[c]		1,2	
				34		1,0	

a H_R is the read value of vertical indication from test fixture.

b H_T is the theoretical value for ideal linear response.

c Suggested optional attenuator increments.

d Increments possibly required for full-scale deflection.



Key

X relative attenuation, dB

Y amplitude signal, % fs

Z relative input, %

1 ideal linearity line

2 reference point

a Increase.

b Decrease.

Figure 5 — Data plot for determination of vertical linearity by Method B (input/output technique)

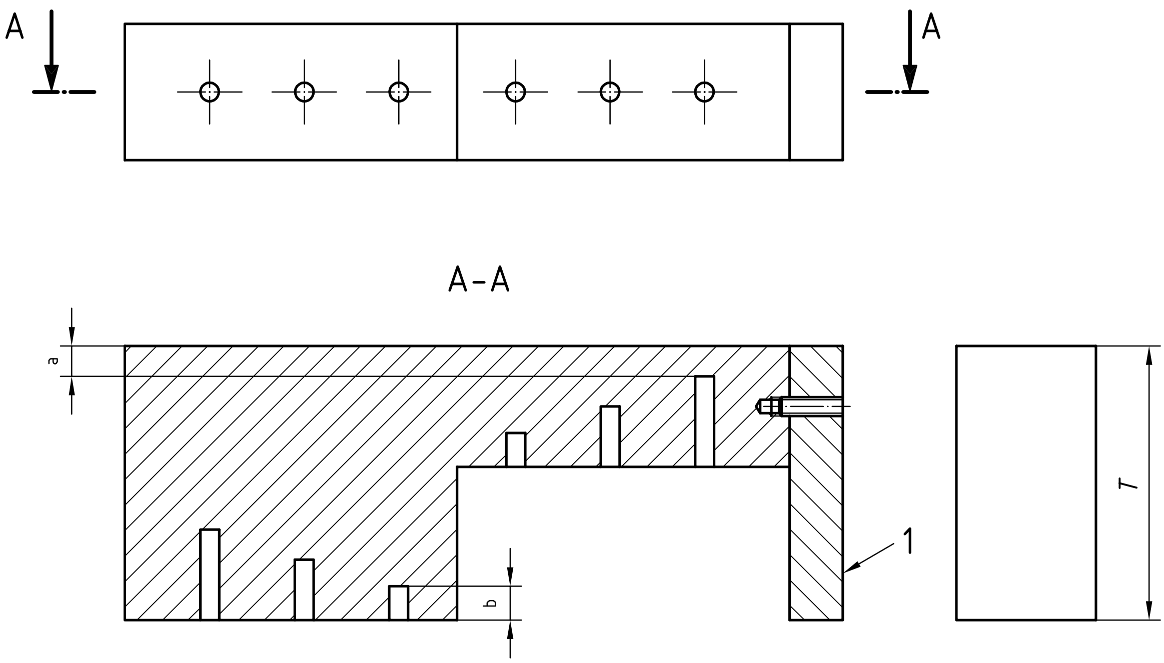
6.4 Resolution

6.4.1 Significance

Depth resolution has significance when it is important to identify and quantify reflectors positioned closely together along the depth axis whether they are internal discontinuities or a discontinuity and a boundary. This procedure is concerned with entry and back surface resolution only. Since vertical linearity of signals within interference regions (e.g., near surface indications) may sometimes be required, provision is also made for checking this. Resolution, as determined by this practice, includes the combined effects of instrument, probe and interconnects, and is therefore a system check for the specific components and test conditions used.

6.4.2 Apparatus

Reference blocks that provide metal distances corresponding to the resolution range and hole diameters specified in the periodic checking procedure for the specific type of instrument to be checked shall be selected. For comparative evaluations blocks may be of any agreed-upon material; however, if values for specific test applications are desired, the blocks shall be made from material having ultrasonic properties similar to that to be examined. Specimen characteristics such as metallurgical structure, contour, surface condition and dimensions can significantly affect results. Also, probe, test frequency and operating conditions are major factors. Many types of reference block have been used for resolution measurements including a) aluminium alloy standard reference blocks as specified in ASTM E 127; b) steel or other metal-alloy reference blocks made in accordance with ASTM E 428; c) various commercially available “resolution blocks” having a multiplicity of test holes, notches, etc.; d) special designs meeting user/supplier requirements. Use of ASTM-type aluminium reference blocks is recommended for determination of entry-surface resolution whenever applicable, e.g., comparative tests or aluminium products examination. No equivalent blocks are currently available for far-surface resolution tests. When both entry and far-surface resolution are determined for specific materials, hole sizes and test distances, one or more special reference blocks are usually required. When feasible, it may be desirable to have all the required test holes in a single block for ease of set-up and test. A suggested configuration is shown in Figure 6.



Key

1 support

a Entry surface resolution.

b Far surface resolution.

Figure 6 — Suggested configuration for resolution test block

6.4.3 Procedure

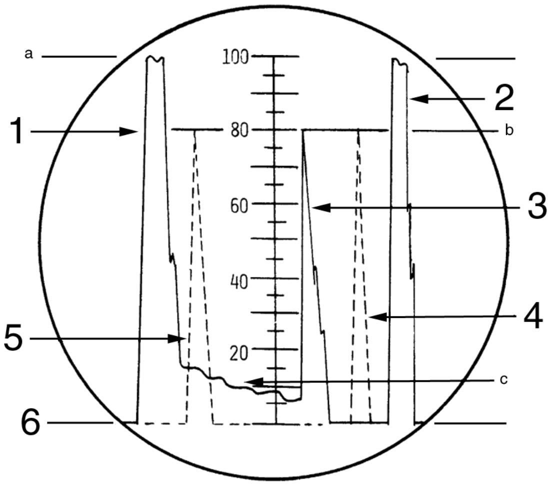
Determine, from the periodic checking procedure for the specific type of instrument to be checked, the blocks, frequency, probe and test conditions required. Select the block with the test hole that establishes the test sensitivity to be used, usually that needed to produce 80 % fs amplitude for the longest metal distance. Using this block, adjust the instrument controls to set the system sensitivity to the specified level without excessive loss of resolution. To obtain optimum sensitivity-resolution performance, adjustment of pulse length as well as one or more gain controls is frequently necessary. In an immersion test, make certain that the probe is positioned laterally for maximum hole-signal amplitude and aligned for interface perpendicularity. Except for interface peaking, no lower gain may be used thereafter, although higher may be required as described. Resolution, either entry or far surface, is determined as follows.

Using the established sensitivity, reposition the probe over each specified hole in turn to optimize the indication, again making certain that the interface signal is maximized by alignment of the probe (at reduced sensitivity if necessary). If the indication from any required test hole does not peak at 80 % fs or more, increase the sensitivity as needed until it does so. Unless otherwise stated, a hole is considered to be resolved under these conditions if its indication is clearly separated from the adjacent interface indication down to at least 20 % fs and there are no residual indications greater than 20 % fs throughout the test region when the probe is repositioned to eliminate the test hole signal. These conditions are illustrated in Figure 7. When this cannot be done because of restricted block dimensions, use a similar type block having a significantly longer metal path. If neither method can be used, estimate the residual noise immediately adjacent to the hole signal and note this limitation in the test report. If linearity within the near surface region must also be determined, e.g., to evaluate in the receiver recovery zone as shown in Figure 8, proceed as follows.

Adjust the instrument controls so that the resolved signal amplitude is 80 % fs; then reduce the sensitivity in small increments using a calibrated gain control until its amplitude is 20 % fs. Record the change of gain (in decibels) required.

NOTE 1 Annex A provides dimensions for a specific design of a Figure 6 type block that is intended to meet the resolution test requirements specified in a number of commonly used material inspection standards.

NOTE 2 Although the above procedure does not describe the use of electronic distance-amplitude compensation, its use is not precluded and substantially improved effective resolution may result. However, if used, the procedures of 6.1.3 should be followed.



Key

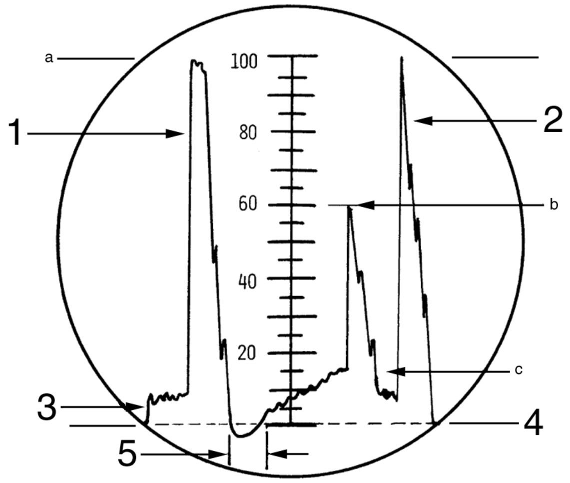
1 entry surface indication
2 far surface indication
3 reference level indication
4 far surface resolution
5 near surface resolution
6 trace base line

[a] Full scale.

[b] All test hole indications 80 % fs minimum.

[c] Residual signals 20 % fs maximum.

Figure 7 — Typical display response for determination of near-surface and far-surface resolution



Key

1 entry surface indication
2 far surface indication
3 electrical noise
4 trace baseline
5 recovery zone

[a] Full scale.

[b] Reference level indication 60 % fs minimum.

[c] Total noise 20 % fs maximum.

Figure 8 — Typical display response for determination of sensitivity and noise

6.4.4 Interpretation of data

Resolution, either entry or far surface, is given by the metal distance from the test-hole bottom to the appropriate surface, the hole diameter and the reference used to establish test sensitivity (if other than the specified resolution block hole). Nonlinearity of the response within the resolved test range is expressed by the difference in decibels between 12 dB and the incremental gain change required to reduce the test hole indication from 80 % fs to 20 % fs. The report should also fully identify the reference blocks, specific holes, probe and test parameters used.

6.4.5 Acceptable alternate procedure and interpretation for far surface resolution

Alternate forms of reference blocks with either 4 mm (5/32 in) diameter flat bottom holes (FBHs) or large flat surfaces spaced at various distances from the nominal back surface of the block may be used with customer approval, as, e.g., type RB-RA and RB-RC blocks illustrated in JIS Z 2352. Acceptable alternate definitions of resolution may be used, such as that distance at which adjacent display screen traces for 100 % fs signals from flat surfaces intersect at a level of 3 % fs (– 30 dB), or that distance from the back surface at which the display trace from a 100 % fs signal intersects the display trace from the back wall signal at a level of 3 % (– 30 dB). Note that the term “100 % fs” refers to the maximum linear range of vertical deflection as defined by the linearity limits established by the controlling document.

6.4.6 Acceptable alternate procedure and interpretation for near (entry) surface resolution

Alternate forms of reference blocks, such as type RB-RC illustrated in JIS Z 2352, may be used with customer approval wherein 4 mm (5/32 in) diameter FBHs are located at various distances from the entry surface. An acceptable alternate definition of resolution in this case is that distance from the entry surface at which the intersection of a 100 % fs FBH signal intersects the entry surface at 3 % fs (– 30 dB).

6.5 Sensitivity and noise

6.5.1 Significance

Sensitivity is a measure of a test system's ability to detect discontinuities producing relatively low-amplitude signals because of their size, geometry or distance. Noise can limit detectability of discontinuities by masking their indications. Its source may be electrical or acoustic, and, if due to indications from the material structure, represents a possible limitation of the test method rather than the instrumentation. Generally, sensitivity, resolution and signal-to-noise ratio are interdependent and should be evaluated under similar test conditions.

6.5.2 Apparatus

Unless otherwise specified in the periodic checking procedure for the specific type of instrument to be checked, use reference blocks selected from an area/amplitude set of aluminium alloy standard reference blocks meeting the requirements of ASTM E 127. As discussed in 6.4.2, such blocks can provide a comparative basis for evaluating system performance, but if data are required for other specific materials or test conditions, appropriate special blocks must be used. Where ASTM E 127-type aluminum blocks are applicable, the following selection is suggested for determining the probable minimum size detectable hole.

Test frequency MHz	0,4 to 1,5	1,0 to 2,5	2,0 to 10,0
Block designation	5-0300 to 8-0300	2-0300 to 6-0300	1-0300 to 5-0300

6.5.3 Procedure

With the instrument sensitivity at minimum, determine the smallest hole size that will give an indication having an amplitude of at least 60 % fs and baseline noise of no more than 20 % fs. If the dimensions of the reference block allow, move the probe slightly away from the hole and determine that the noise at the same location as the indication does not exceed 20 % fs. Otherwise follow the procedure of 6.4.3 for residual-noise determination. Record the block number, noise level and signal amplitude if greater than 60 % fs. If the noise at maximum sensitivity exceeds 20 % fs, reduce the gain until 20 % fs is obtained and determine the smallest hole that will then produce a 60 % fs or greater indication. Record the block number, noise level, signal amplitude, and reduced gain (in decibels). If the indication from the smallest available hole exceeds 100 % fs, use the gain control to lower the hole indication to 60 % fs and record the remaining available gain (in decibels) that does not cause the noise to exceed 20 % fs.

NOTE 1 If this requires the use of an uncalibrated gain control, use the instrument's calibrated attenuator if available, or a suitable external attenuator to determine the applicable gain reduction factors (in decibels) using the gain control positions as determined above and a suitable reflector indication on the screen. See 6.6.3 for use of external attenuator to calibrate a gain control.

NOTE 2 Since this is a systems check, the indicated noise will be a summation of both instrument electrical noise and acoustical noise from probe, couplant and test material. If separation of the electrical component is required, note first the noise to the left of the initial pulse. Remove the probe and make certain that the noise remains about the same. If not, lower the pulse repetition rate until the noise to the left of the initial pulse, both with or without the probe connected, is the same. Record this noise as the average electrical noise.

6.5.4 Interpretation of data

6.5.4.1 Sensitivity is expressed by stating the specific hole size/test distance that produces the required 60 % fs signal at a 3-to-1 or greater signal-to-noise ratio, and the gain control settings needed; i.e., either maximum gain or remaining available gain up to that which gives 20 % fs or less noise.

6.5.4.2 System noise is given either by the peak noise amplitude at maximum sensitivity if less than 20 % fs, or by the gain reduction in decibels of the noise below the smallest available hole that gives 60 % fs or greater indication. If so specified, both total noise and electrical noise should be reported.

6.5.5 Acceptable alternate sensitivity measurement and interpretation

An acceptable method that may be used with customer approval for determining “margin of sensitivity” of an instrument is to set and record the gain control value that produces 10 % fs peak noise level when the probe is not coupled to a reference block. The probe is then coupled to an appropriate reference block target as specified in the controlling document and the “margin of sensitivity” recorded as the difference, in decibels, of the gain control value required to set the signal from the reference target to 50 % fs subtracted from that required to produce the “uncoupled” 10 % fs peak noise level.

6.6 Accuracy of calibrated gain controls

6.6.1 Significance

When quantitative measurements of signal amplitudes are to be made by comparison against a reference indication, the use of accurately calibrated gain controls may be desirable or necessary, particularly when the amplitude ratio differs significantly from unity. For this procedure, it is assumed that the controls are calibrated in conventional decibel units. See 6.1.2 regarding gain control nomenclature.

6.6.2 Apparatus

A precision external attenuator, terminating resistor and test set-up similar to that described in 6.3.3.1 are required. The attenuator shall have a range at least equal to that being checked plus the additional attenuation needed to bring the test signal on scale at the highest instrument sensitivity specified.

NOTE 1 The maximum range for any single panel control function is usually 60 dB or less. This method is not recommended for checking larger ranges, obtained, e.g., by sequential use of more than one control, since cross-talk may become a problem.

NOTE 2 A test precision of 1,0 dB is assumed to be adequate and obtainable. Greater precision requires either smaller attenuator steps or use of correction factors for the screen scale readings. See also the NOTE in 6.3.3.1.

6.6.3 Procedure

Select a test system configuration that will produce a stable, on-screen, mid-scale indication when the instrument controls are set for the minimum desired sensitivity and the external attenuator has sufficient available attenuation to equal the desired test range. Use the fine-gain control when available, or pulse-length adjustment to set the reference indication precisely at the 60 % fs graticule line. Record the settings of the external attenuator and the calibrated controls, noting whether they represent decibel gain or decibel attenuation. Increase the instrument gain in the smallest available calibrated increment, and add sufficient external attenuation to return the test indication as closely as possible to the 60 % fs reference line. With 1,0 dB or smaller attenuator increments available, the adjusted amplitude should always lie between 56 % fs and 64 % fs when the correct step is used. Record the new gain control and external attenuator settings. Repeat the procedure until the full range of the relevant instrument control has been checked.

6.6.4 Interpretation of data

Unless otherwise instructed by the periodic checking procedure for the specific type of instrument to be checked, use the results as follows. For each control range tested, tabulate the readings of the control against the incremental attenuation added externally. This value is given by subtracting the initial external attenuation from each subsequent reading of total attenuation. The total error for any range is then the difference (in decibels) between the panel value of control range and that determined by the external attenuator. Report the error, if any, in terms of total deviation per 20 dB of control range and also for the full range of any control of greater range.

NOTE The data obtained can be used to determine the error for any intermediate steps if required.

6.7 Measurement of “dead zone” after transmitter pulse (“main bang”) with the straight-beam technique

6.7.1 Significance

This test is performed, primarily on older analog-type instruments, to provide an indication of any limitation due to instrument characteristics to near-surface resolution when no, or minimal, delay medium is provided between probe element and test material surface. The test is generally not required for modern digital instruments.

6.7.2 Measurement method

When this test is required by the controlling document it is performed by coupling a longitudinal wave, straight-beam, probe to a reference block of appropriate material and with various thickness steps, such as an RB-E block as referred to in JIS Z 2352. With the gain set to produce a 100 % fs signal from the back wall of the thickest section of the block, move the probe over progressively thinner regions of the block. The thickness just before that which produces a reduction in back wall signal amplitude to 80 % fs taken as the dead zone produced by the transmitter pulse.

6.8 Sensitivity and resolution for angle beam testing

In cases where the angle beam performances of an instrument or system are required to be checked periodically, special reference blocks and procedures may be followed as required by the controlling document. An example of an acceptable form of these tests is given in JIS Z 2352.

7 Report

7.1 General

The periodic checking procedure for the specific type of instrument to be checked should fully define the extent of the written report required. As a minimum this may involve only confirmation of specified performance or the results of the parameters evaluated. A comprehensive written report should include all relevant information in sufficient detail so that the tests could be duplicated later if desired.

7.2 Format

The following format is recommended for a report requiring complete documentation of the tests.

a) Instrument: name, model, modules and serial numbers.

b) Description of apparatus used for each test including:

   1) probes: type, catalogue number, frequency, size (serial number when available);

   2) interconnecting devices: cables, search tubes;

   3) test fixtures: positioner, bridge, clamps;

   4) couplant;

   5) reference blocks: specify by ASTM nomenclature or, if special, source, drawing number or complete description (material, size and location of test holes, geometry, dimensions, surface);

   6) external attenuator: type, impedance, precision, and terminator.

c) Method of each test including:

   1) contact or immersion technique;

   2) water path where applicable;

   3) control settings relevant to tests, including internal controls when used;

   4) test frequency (tuned or wide band).

d) Test results of each instrument characteristic evaluated.

8 Precision and bias

No ASTM round-robin tests have been made to determine the repeatability of readings or the precision and bias obtainable with the procedures described. The assumed reading precision (2 % of full scale) stated in 5.10 is considered to be obtainable in practice and adequate for the purposes of this International Standard.

9 Keywords

— evaluation of ultrasonic pulse-echo instruments;

— evaluation of pulse-echo examination systems;

— nondestructive testing;

— performance characteristics of ultrasonic examination instruments;

— performance characteristics of ultrasonic examination systems;

— pulse-echo examination instruments;

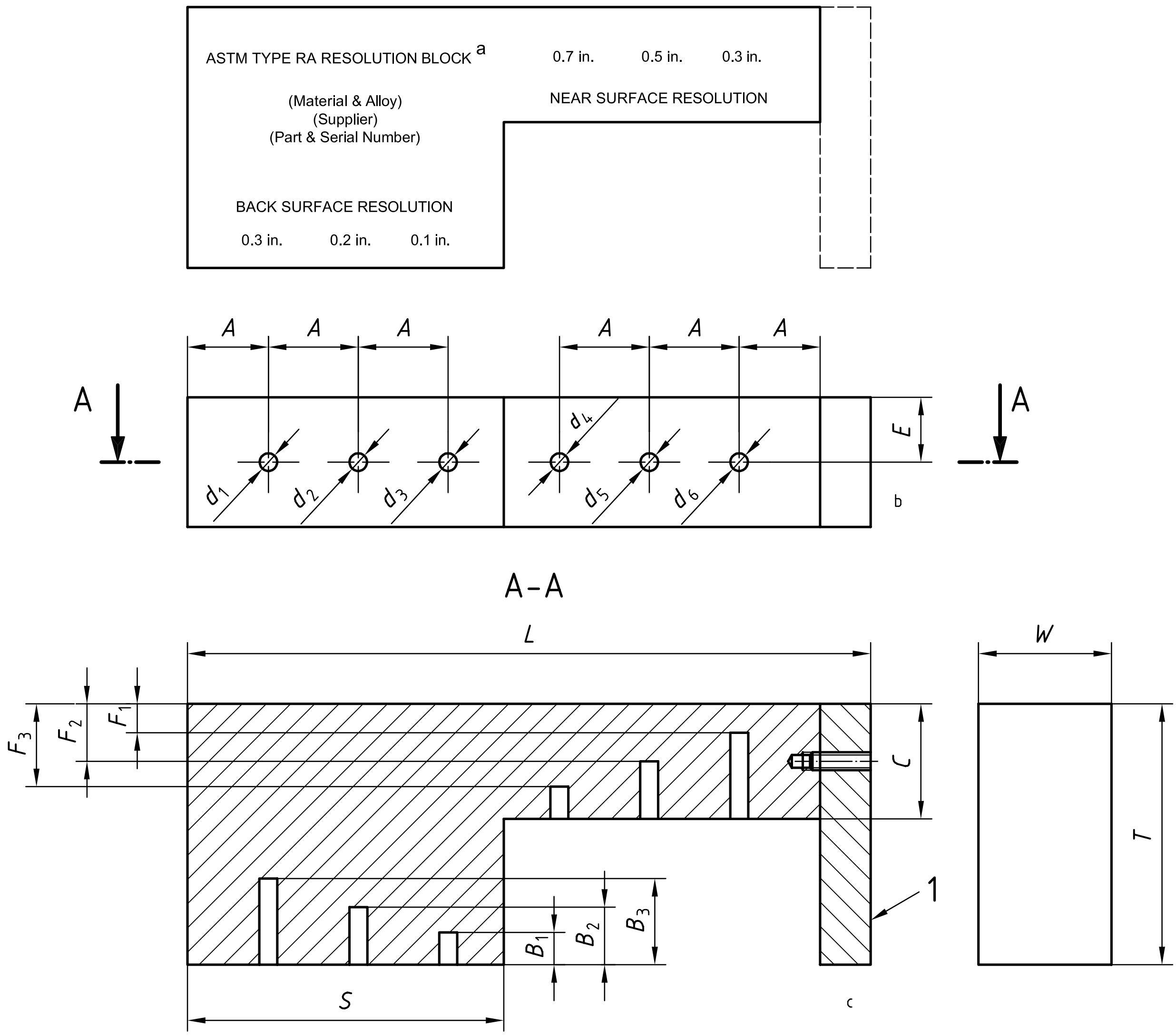
— pulse-echo examination systems;

— ultrasonic examination instruments;

— ultrasonic examination system.

Annex A
(informative)

Specific design for Figure 6 resolution reference block



NOTES

1 Material to be as specified.

2 Surface finish: “a” *Ra* 32 µin (0,8 µm) maximum. Other surfaces *Ra* 63 µin (1,6 µm) maximum.

3 3/64 in diameter flat-bottom holes (d_1...d_6) to be perpendicular to faces within 1°; FB surfaces to be finished smooth to full diameter; holes to be cleaned, dried and plugged leaving air gap of 0,04 in (1 mm) minimum.

4 Legends as shown (or metric equivalents) to be engraved 1/8 in (3 mm) high at approximate locations indicated.

5 Block finish to be anodizing or plating as specified.

6 Location for optional end support; attachment entry into block not to exceed 1/4 in (6 mm).

a See Note 4.

b Not to scale.

c See Note 6.

Figure A.1 — Type RA resolution reference block

Table of Dimensions

Dimension on Figure A.1	Imperial block in		Metric block mm	
	Dimension	Tolerance	Dimension	Tolerance
L	8,00	0,02	200,0	0,5
T	3,30	0,02	82,5	0,5
W	2,00	0,02	50,0	0,5
C	1,00	0,02	25,0	0,5
S	4,00	0,02	100,0	0,5
A	1,00	0,02	25,0	0,5
E	1,00	0,02	25,0	0,5
$d_1...d_6$	0,046 9	0,000 5	1,2	0,01
B_1	0,100	0,005	2,5	0,1
B_2	0,200	0,005	5,0	0,1
B_3	0,300	0,005	7,5	0,1
F_1	0,300	0,005	7,5	0,1
F_2	0,500	0,005	12,5	0,1
F_3	0,700	0,005	17,5	0,1

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