
**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*

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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, *Acoustical methods*.

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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

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3 Terms and definitions

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

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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.

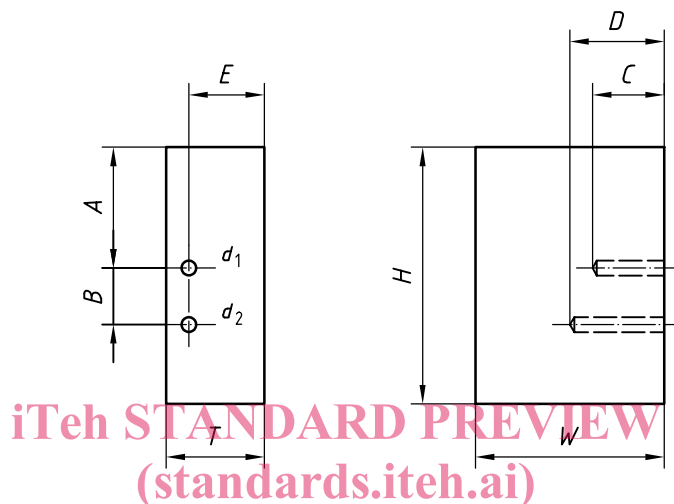
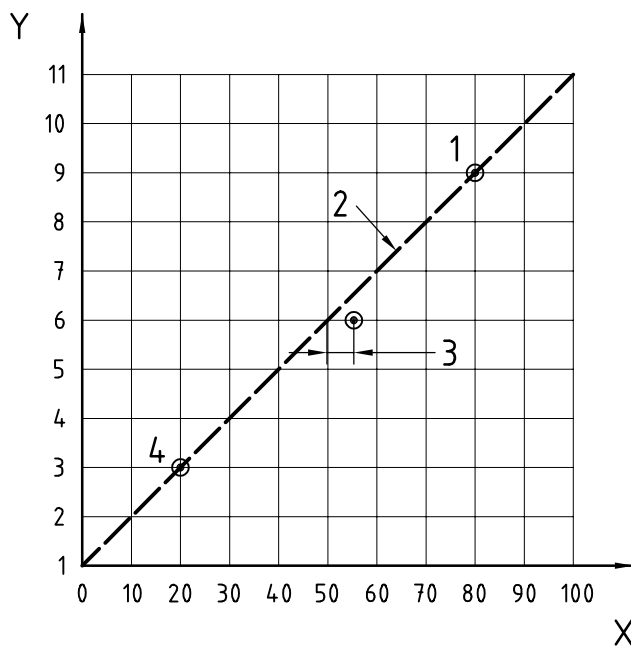


Table of Dimensions

Dimension on Figure 1	Imperial block in		Metric block mm	
	Dimension	Tolerance	Dimension	Tolerance
<i>A</i>	1,25	0,05	32	1
<i>B</i>	1,00	0,05	25	1
<i>C</i>	0,75	0,05	19	1
<i>D</i>	1,00	0,05	25	1
<i>E</i>	0,75	0,05	19	1
<i>H</i>	3,00	0,05	75	1
<i>T</i>	1,00	0,01	25,0	0,2
<i>W</i>	2,00	0,05	50	1
<i>d</i> ₁ and <i>d</i> 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)

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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.

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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	