Designation: ~~E317 – 16~~ E317 – 21

Standard Practice for
Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments[1]

This standard is issued under the fixed designation E317; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This practice describes procedures for evaluating the following performance characteristics of ultrasonic pulse-echo examination instruments and systems: Horizontal Limit and Linearity; Vertical Limit and Linearity; Resolution - Entry Surface and Far Surface; Sensitivity and Noise; Accuracy of Calibrated Gain Controls. Evaluation of these characteristics is intended to be used for comparing instruments and systems or, by periodic repetition, for detecting long-term changes in the characteristics of a given instrument or system that may be indicative of impending failure, and which, if beyond certain limits, will require corrective maintenance. Instrument characteristics measured in accordance with this practice are expressed in terms that relate to their potential usefulness for ultrasonic testing. Instrument characteristics expressed in purely electronic terms may be measured as described in Guide E1324.

1.2 Ultrasonic examination systems using pulsed-wave trains and A-scan presentation (rf or video) may be evaluated.

1.3 The procedures are applicable to shop or field conditions; additional electronic measurement instrumentation is not required.

1.4 This practice 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 for example only and are subject to more or less restrictive limits imposed by customer's and end user's controlling documents.

1.5 The specific parameters to be evaluated, conditions and frequency of test, and report data ~~required,~~required must also be determined by the user.

1.6 This practice may be used for the evaluation of a complete examination system, including search unit, instrument, interconnections, fixtures and connected alarm and auxiliary devices, primarily in cases where such a system is used repetitively without change or substitution. This practice is not intended to be used as a substitute for calibration or standardization of an instrument or system to inspect any given material. There are limitations to the use of standard reference blocks for that purpose.[2]

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

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.
Current edition approved ~~June 1, 2016~~June 1, 2021. Published ~~June 2016~~June 2021. Originally approved in 1967. Last previous edition approved in ~~2011~~2016 as ~~E317 - 11.~~E317 – 16. DOI: ~~10.1520/E0317-16.~~10.1520/E0317-21.

[2] Beck, K. H., "Limitations to the Use of Reference Blocks for Periodic and Preinspection Calibration of Ultrasonic Inspection Instruments and Systems," *Materials Evaluation*, Vol 57, No. 3, March 1999.

***A Summary of Changes section appears at the end of this standard**

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

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

1.10 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.11 *This 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 standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.12 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E114 Practice for Ultrasonic Pulse-Echo Straight-Beam Contact Testing

E127 Practice for Fabrication and Control of Flat Bottomed Hole Ultrasonic Standard Reference Blocks

~~E428 Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing (Withdrawn 2019)~~[4]

E1316 Terminology for Nondestructive Examinations

E1324 Guide for Measuring Some Electronic Characteristics of Ultrasonic Testing Instruments

2.2 *Other Standard:*[4]

IEEE Std 100 *IEEE Standard Dictionary of Electrical and Electronic Terms*

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, see Terminology E1316. Other relevant definitions may be found in IEEE Standard 100.

4. Summary of Practice

4.1 An examination system to be evaluated comprises an ultrasonic pulse-echo instrument, search unit, 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 examination, test conditions are selected that are consistent with the intended end-use as determined by the user.

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

5. Significance and Use

5.1 This practice 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 practice.

5.2 This document 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.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Published by Wiley-Interscience, New York, NY.

5.4 Since the parameters to be evaluated and the applicable test conditions must be specified, this practice 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 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 should be done cautiously; if the related parameters are not critical in the intended application, then their inclusion may be unjustified. For example, vertical linearity may be irrelevant for a go/no-go test with a flaw gate alarm, while horizontal linearity might be required only for accurate flaw-depth or thickness measurement from the display screen.

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 practice in 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 search unit of the commonly used types and frequencies, and to most straight-beam examination, either contact or immersed. Certain sections are also compatible with angle-beam, wheel, delay-line, and dual-search unit techniques. Their use, however, should 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 document as a guide, should be prepared for each specific type of instrument or system to be evaluated. For each procedure determine from the requesting documents the instrument examination range to be evaluated, select the appropriate search unit, fixtures, and test blocks, and establish the required display conditions. Unless otherwise required, mid-range values are suggested for most panel controls and "reject" must be off unless specifically desired to be evaluated. It may be desirable 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 sometimes not calibrated in decibels and increase sensitivity with clockwise rotation.

6.1.3 Although the procedures in this practice do not describe 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 shall 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 to minimize parallax. This practice assumes reading precision of within 2 % of full scale. If, for any reason, this is not feasible for the system 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 having 50 or 100 divisions for full scale.

6.1.5 For instruments that provide digital readout of signal amplitude, the manufacturer's specified accuracy, if available, shall be noted in the report.

6.1.6 When tests are being done by the contact method, position the search unit securely and make certain that couplant changes are not measurably affecting the results. Refer also to Practice E114.

6.1.7 When using the immersion method, allow adequate time for thermal stabilization; remove bubbles and particles from search unit and test surfaces; maintain the search-unit manipulator and test blocks in stable positions.

6.2 *Horizontal Limit and Linearity:*

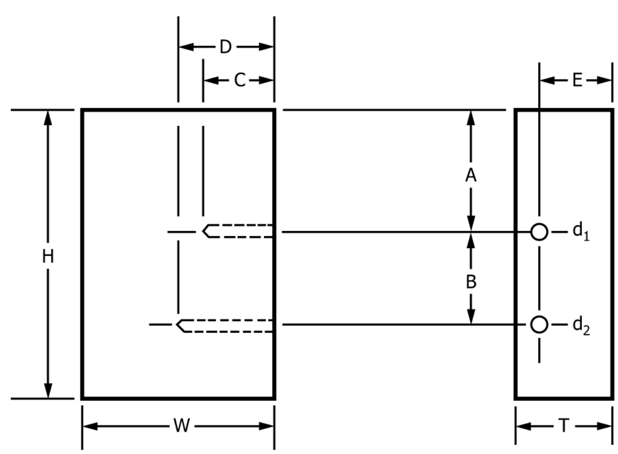
6.2.1 *Significance*—Horizontal limit and linearity have significance when determination of depth of a discontinuity is required. A specified minimum trace length is usually necessary to obtain the horizontal readability desired. Nonlinearity of sweep trace may affect accuracy of flaw depth or thickness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

6.2.2 *Apparatus*—A test block is required that will give several (preferably eleven) noninterfering multiple back reflections for the sweep range and other test conditions of interest (see Fig. 1). 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 Table 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 search units, different block dimensions or other block designs may be required to eliminate interferences. The couplant system used, either contact or immersed, must provide stable indications during the measurements. A horizontal scale permitting reading accuracy as specified in 6.1.4 is required or, if provided, digital readout of depth indication may be used.

NOTE 1—~~An~~ An encapsulated transducer-targets assembly may be used for this purpose.

6.2.3 *Procedure*—Couple the appropriate block to the search unit so that the sound beam does not intercept any test holes. Adjust the instrument gain, sweep-delay, and sweep-length controls to display eleven noninterfering back reflections. Set the amplitude of each back reflection at 50 % fs before measurement of 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. To calibrate the digital readout of horizontal position on instruments so equipped this procedure will require positioning a "gate" to provide an indication from each desired reflection.

NOTE 2—Either more or fewer reflections can be used by suitably modifying the procedure. For example, six back reflections may be used if interference



Material: 7075T6 aluminum
Plug drilled holes with water-insoluble plastic.

FIG. 1 Suggested Test Blocks for Evaluation of Horizontal and Vertical Linearity

TABLE 1 Linearity Test Block Dimensions

	Table of Dimensions			
	US Customary 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	0.2
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 µ in. or smoother		1.5 µm or smoother	

echoes are obtained with eleven, 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 graticule lines or the corresponding digital output limits 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. If an equipment malfunction is found to be the case, the instrument shall be repaired before continuing the evaluation.

6.2.4.2 Linearity test results may be presented in tabular form or, preferably, plotted in the manner shown in Fig. 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)~~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.

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 analog or digital output signals, and are to be used for evaluation of discontinuities or acceptance

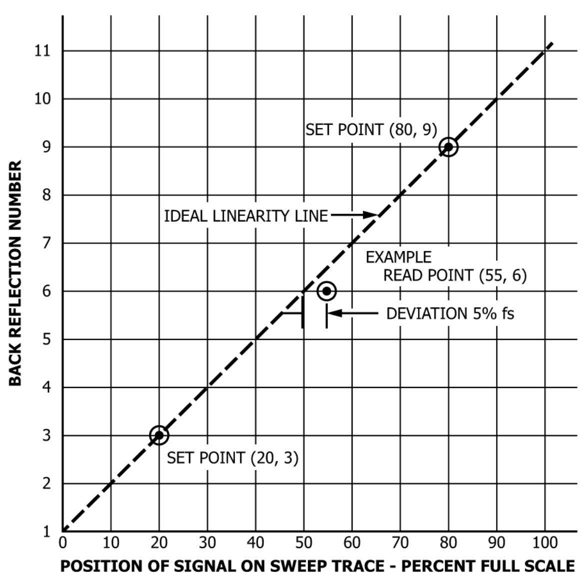


FIG. 2 Example of Data Plot for Determination of Horizontal Linearity

criteria. A specified minimum trace deflection or digital equivalent and linearity limit may be required to achieve the desired amplitude accuracy. For other situations, they may not be important, for example, 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, for example for near-surface signals, it may be evaluated by the procedure in 6.4.3. Method A (ratio technique) will disclose 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*—This method is only applicable when a calibrated external attenuator, as described in 6.3.3.1 for Method B, is not available. A test 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 will be 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 test block that will produce such signals at the nominal test settings specified can be used. For many commonly used search units and test conditions, the test block shown in Fig. 1 will usually be 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 3—An encapsulated transducer-targets assembly may be used for this purpose.

6.3.2.2 *Procedure*—To obtain test data, position the search unit 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 search unit and adjust the instrument controls until H_A and H_B meet the conditions in Table 2. The preferred values are desired because the data may be most 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 search unit 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 4—To better define the response characteristic, particularly near the upper and lower limits, additional readings may be taken at smaller gain increments.

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 or digital output range that can be obtained from a large reflector (for example, the test

TABLE 2 Vertical Linearity Range by Method A Using Two-Signal (Ratio) Technique with Initial Values for H_A and H_B Giving Ratios of 1.8 to 2.2

NOTE 1—Preferred setup values permit determination of vertical linearity range directly from the data plot of Fig. 3.

H_A % Full Scale	H_B % Full Scale
Preferred Values	
60	30
Acceptable	
65	30–36
64	29–36
63	29–35
62	28–34
61	27–34
60	27–33
59	27–33
58	26–32
57	26–32
56	25–31
55	25–31

block surfaces) as the gain is increased. Report this in linear units (inches or millimetres) and note equivalent graticule divisions. Unless otherwise stated, this is assumed to represent 100 % fs. Failure to obtain full-scale deflection may indicate an equipment malfunction. If this is found to be the case, the instrument shall be repaired before continuing the evaluation. 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 Fig. 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 set-up intersecting the limit lines. The upper linearity limit is given by the corresponding value for H_A and the lower limit 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 5—If the requesting document specifies that the test results be presented in ratio form (that is, 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 6—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.

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:

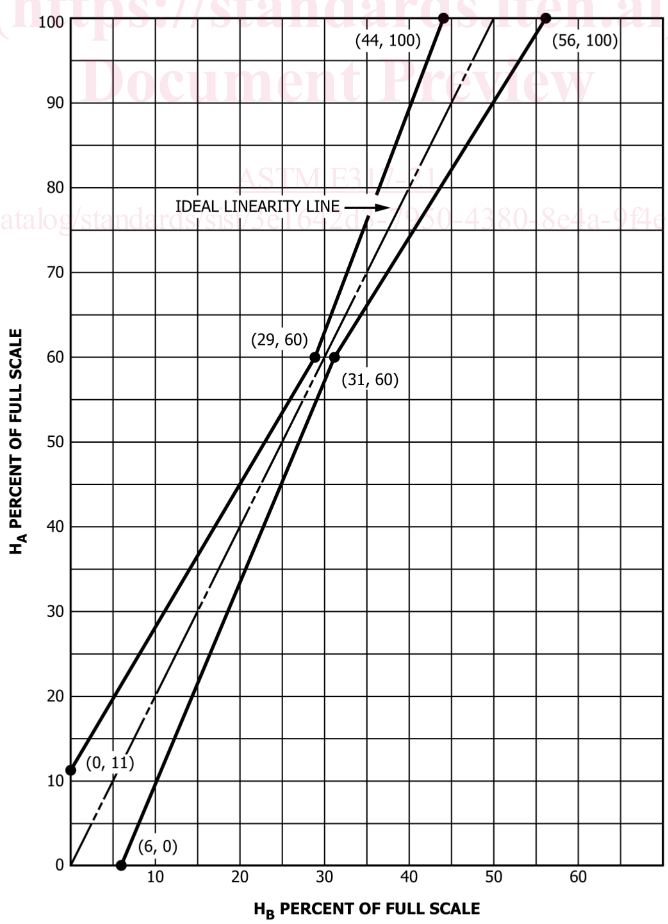


FIG. 3 Data Plot for Determination of Vertical Linearity Range by Method A (Ratio Technique)