Designation: E1001 – 06

Standard Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves[1]

This standard is issued under the fixed designation E1001; 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 Department of Defense.

1. Scope

1.1 This practice describes procedures for the ultrasonic examination of bulk materials or parts by transmitting pulsed, longitudinal waves through a liquid couplant into the material and observing the indications of reflected waves (see Fig. 1). It covers only examinations in which one search unit is used as both transmitter and receiver (pulse-echo) and in which the part or material being examined is coupled to the test part by a liquid column or is totally submerged in the couplant (either method is considered to be immersion testing). This practice includes general requirements and procedures which may be used for detecting discontinuities and for making a relative or approximate evaluation of the size of discontinuities.

1.2 This practice replaces Practice E214 and provides more detailed procedures for the selection, calibration, and operation of an inspection system and for evaluation of the indications obtained.

1.3 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C1212 Practice for Fabricating Ceramic Reference Specimens Containing Seeded Voids

C1336 Practice for Fabricating Non-Oxide Ceramic Reference Specimens Containing Seeded Inclusions

E127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks

E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments

E428 Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

2.2 *ASNT Documents:*[3]

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

2.3 *Aerospace Industries Association Document:*

NAS-410 Certification and Qualification of Nondestructive Testing Personnel [4]

NOTE 1—For DoD contracts, unless otherwise specified the issues of the documents, which are DoD adopted, are those listed in the issue of the DoDISS (Department of Defense Index of Specifications Standards) cited in the solicitation.

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, see Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *effective beam diameter*—that distance through which a search unit can be traversed across a calibration reflector so that the corresponding echo amplitude is at least one half (-6 dB) of the maximum amplitude. The effective beam diameter is not a characteristic of the search unit alone, but is dependent on propagating medium, distance to the discontinuity, reflector geometry, etc.

3.2.2 *scan index*—the length of the step created by indexing the scan of the search unit over the part, that is continuously

[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.

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[2] 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.

[3] Available from The American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.

[4] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

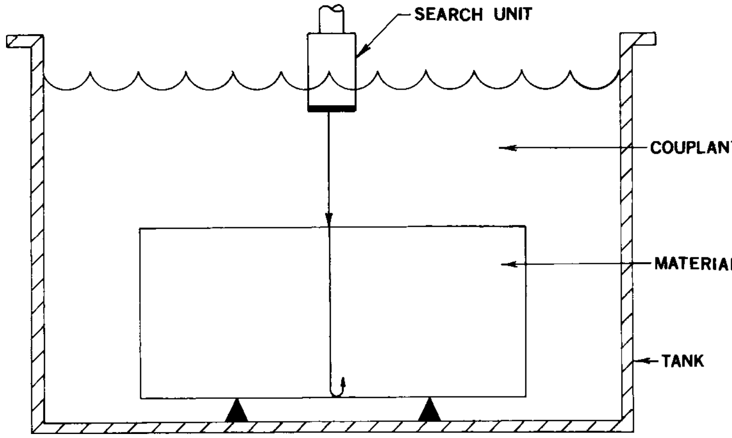

FIG. 1 Basic Immersion Setup

scanning in one direction, then stepping in the direction perpendicular to the scan or making a linear advance per rotation (pitch) for rotary scan of cylindrical parts. The allowable scan index should be correlated with the search unit effective beam diameter to ensure full coverage of the part as described in 8.2 below.

3.2.3 *transfer*—a change in scanning gain to compensate for differences in attenuation of the reference standard and the part or material being inspected.

4. Summary of Practice

4.1 This practice describes a means for obtaining an evaluation of discontinuities in materials by immersed examination with longitudinal ultrasonic waves. Equipment, reference standards, examination and evaluation procedures, and documentation are described in detail.

5. Basis of Application

5.1 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, or a similar document certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

5.2 *Written Procedure*—A detailed written procedure shall be used for the performance of ultrasonic examinations in accordance with this practice. The written procedure should address all applicable portions of this practice, for the purposes of consistency in application and the repeatability of the examination results. Specific requirements regarding preparation and approval of the written procedure should be determined by purchaser and supplier agreement.

6. Significance and Use

6.1 This practice provides guidelines for the application of immersed longitudinal wave examination to the detection and quantitative evaluation of discontinuities in materials.

6.2 Although not all requirements of this practice can be applied universally to all inspection situations and materials, it does provide a basis for establishing contractual criteria between suppliers and purchasers of materials for performing immersed pulse-echo examination, and may be used as a general guide for writing detailed specifications for particular applications.

6.3 This practice is directed towards the evaluation of discontinuities detectable at normal beam incidence. If discontinuities at other orientations are of concern, alternate scanning techniques are required.

7. Apparatus

7.1 *Electronic Equipment*—The electronic equipment should be capable of producing and processing electronic signals at frequencies in the range of search unit frequencies being used. The equipment and its display should be capable of meeting the requirements to be completed in Table 1, as agreed upon between the supplier and the purchaser, and as measured in accordance with procedures described in Practice E317 or equivalent procedures (see Note 2). These requirements are applicable only for the frequencies required for the inspection. Also, the equipment, including the search unit, should be capable of producing echo amplitudes of at least 60 %, of full scale, with the noise level no greater than 20 %, from the appropriate reference reflector at a material distance equal to the thickness of the part to be inspected. Alternatively, if these

TABLE 1 Minimum Equipment Requirements (Longitudinal Wave)

Instrument Characteristics	Ultrasonic Test Frequency, MHz			
	2.25	5.0	10.0	15.0
Vertical limit, in. [mm], trace to peak or percent of full screen height				
Upper linearity limit, in. [mm], trace to peak or percent of full screen height				
Lower linearity limit, in. [mm], trace to peak or percent of full screen height				
Ultrasonic sensitivity, reflector size, material distance, in. [mm]				
Signal-to-noise ratio				
Entry surface resolution, in. [mm]				
Back surface resolution, in. [mm]				
Horizontal limit, in. [mm] or percent of full screen width				
Horizontal linearity range, in. [mm] or percent of full screen width				

conditions can be met at one half the part thickness, the part may be inspected from both sides. The instrument must have a pulser of the sufficient voltage, repetition rate and waveshape to provide total volume coverage at the desired scanning speed.

NOTE 2—Significantly higher frequencies than those shown in Table 1 (for example, 50 MHz) may be necessary for the smaller critical flaw size of advanced ceramics.

7.2 *Voltage Regulator*—If fluctuations in line voltage cause variations exceeding ±5 % of the vertical limit in an indication with an amplitude of one half the vertical limit, a voltage regulator should be required on the power source. This requirement is not applicable to battery-operated units.

7.3 *Search Units*—The search unit selected should be compatible with the electronic equipment being used and with the material to be inspected. The search units should be of the immersion type. Only straight-beam (longitudinal) search units, with flat or focused acoustic lenses, should be used. Focused or dual element search units may provide better near-surface resolution and detection of small discontinuities. Generally, round or rectangular search units are used for examination whereas round search units with symmetrical sound beam patterns are used for evaluation.

7.4 *Alarm*—For the examination of parts or material with regular shape and parallel surfaces, such as plate, machined bar stock, and forgings, an audible alarm should be used in preference to a visual alarm, since the examination process can be accomplished at a speed which prevents reliable visual monitoring of the instrument screen. As a matter of practicality, an audible alarm should be used in conjunction with visual monitoring wherever possible. The alarm should be adjustable to allow triggering at any commonly required level of indication amplitude and depth of material. During operation the audible or visible signal produced by the alarm should be easily detectable by the operator.

NOTE 3—Alarm requirements are not applicable if recording equipment is used unless otherwise specified in the contractual agreement.

7.4.1 *Alarm Gate Synchronization*—To ensure that the alarm gate tracks the inspection area, the gate should lock on the first interface pulse from the test piece rather than on the initial pulse from the system. Gating from the initial pulse can result in either partial loss of the inspection area from the gate, or the inclusion of the back reflection and interface signal in the gated area. This will trigger the gate as would an imperfection.

7.5 *Manipulating Equipment* should be provided to adequately support a search tube, containing the search unit, and to allow angular adjustment in two mutually perpendicular, vertical planes. A manipulator may be attached between the search tube and search unit to provide the necessary angular adjustments. The scanning and indexing apparatus should have sufficient structural rigidity to provide support for the manipulator and should allow smooth, accurate positioning of the search unit. This apparatus should permit control of the scan in accordance with 9.3.1 and control of the index in accordance with 9.2.1. Also, the scanning apparatus should be sufficiently rigid to keep search unit backlash to within tolerances as specified in the contractual agreement. Water-path distances should be continuously adjustable.

7.6 *Tank*—The container or tank should permit accurate positioning of the search unit, reference blocks, and part or material to be examined in accordance with the requirements of Section 8.

7.7 *Reference Standards*—Ultrasonic reference blocks, or reference specimens, are used to standardize the ultrasonic equipment and to evaluate the indications received from discontinuities within the test part. The ultrasonic characteristics of the reference standards such as attenuation, noise level, surface condition, and sound velocity, should be similar to the material being inspected. Metal reference standards should not be used for examining advanced ceramics because of the large differences in attenuation velocity and acoustic impedance. Standardization (*1*) verifies that the instrument/search unit combination is performing as required, and (*2*) establishes a detection level for discontinuities. Reference blocks as described in Practices E127 and E428 have been used as standards for calibrating system performance, and may continue to be so used in cases where much empirical evidence has shown that satisfactory inspection results are obtained. However, it is more desirable in the general case to use a part identical in shape, dimensions and material properties to the parts to be inspected. (See Ref. (**1**)[5].)

7.7.1 *Flat Blocks*—The three most commonly used sets of reference blocks are (*1*) area-amplitude blocks, containing blocks with the same material path and various sizes of reference reflectors; (*2*) distance-amplitude blocks containing blocks with one-size reference reflector at various material paths; and (*3*) a combination including both area-amplitude and distance-amplitude blocks in one set. These sets are described in Practice E127. However, in general their use is not recommended for system calibration (see 7.7 above). Other types of reference blocks may be used when mutually agreed upon between the supplier and the purchaser. Practices C1212 and C1336 containing seeded voids and seeded inclusions may be used for advanced ceramics.

7.7.2 *Curved Surfaces*—Reference blocks with flat surfaces should not be used for establishing gain settings for examinations on test surfaces with radii of curvature less than about 8 in. [200 mm]. For test surfaces with radii of curvature less than 5 in., reference blocks with the same nominal curvature should be used, unless otherwise agreed upon between the supplier and the purchaser. (See (**2**).)

7.8 *Reference Reflectors (Targets)*—Flat-bottom holes, (FBH), or other artificial discontinuities, located either directly in the test part or material, in a representative sample of the part or material, or, if previously found to yield satisfactory inspection, in reference blocks, should be used to establish the reference echo amplitude or to perform distance-amplitude correction, or both. For most examinations, the bottom surface of a suitable diameter flat-bottom hole is the common reference reflector. However, other types of artificial discontinuities (notches, side-drilled holes, etc.) may be used when mutually agreed upon between the supplier and the purchaser. Seeded

[5] The boldface numbers in parentheses refer to a list of references at the end of this standard.

voids (Practice C1212), seeded inclusions (Practice C1336), and laser-drilled holes are common reflectors for advanced ceramics.

8. General Examination Requirements

8.1 *Material Condition*—Perform ultrasonic examination of parts or material before machining if surface roughness and part geometry are within the tolerance specified in the contractual agreement. Surfaces may already be sufficiently free of roughness and waviness to permit a uniform examination over the required areas. When it is determined that surface roughness precludes adequate detection and evaluation of subsurface discontinuities, smooth the areas in question by machining, grinding, or other means before the examination is performed. For advanced ceramics, care should be taken to avoid generating surface or near-surface cracks by the smoothing operation. During examination and evaluation, ensure that the entry surface and back surface are free of loose scale, machining, or grinding particles or other loose foreign matter.

8.2 *Coverage*—In all examinations, perform scanning to locate discontinuities that are oriented parallel with the entry surface, or that are in a plane approximately normal to the major working direction parallel to the grain flow of the part or both. Inspect areas of the part, which have not undergone significant material flow, by methods that will detect randomly oriented discontinuities. To insure complete coverage of the entire volume of the material it is necessary that the scanning spacing (index) is less than the effective beam length in the index direction at any depth in the material. Furthermore, to insure repeatable response at the same amplitude from a given length discontinuity it is necessary that the scan index not exceed the absolute difference between minimum discontinuity length and beam length. This is known as "invariant worst case interception". (See (**3**).)

8.2.1 *Resolution*—If entry surface resolution (based on 2:1 signal-to-noise ratio) is not sufficient to allow detection of the required reference reflectors near the examination surfaces, perform additional examinations from the opposite side. If surface roughness prevents the required resolution from being obtained, correct the problem before performing the examination. Also, for each examination direction, perform examinations from opposite sides when the maximum material travel distance is such that the minimum size reference reflector cannot be detected by examinations applied from only one side (see 7.1).

8.3 *Ultrasonic Frequency*—In general, the higher frequencies provide a more directive sound beam and provide better depth and lateral resolution. The lower frequencies provide better penetration and better detection of misaligned planar discontinuities. For a particular test, select the frequency based on the material being inspected, the anticipated type of discontinuities, and other inspection requirements.

9. Examination (Scanning) Procedure

9.1 *System Setup*:

9.1.1 *Tank*—Immerse the part to be inspected, reference standards, and search unit in a suitable tank filled with liquid couplant.

9.1.1.1 The liquid couplant should be clean and deaerated to eliminate attenuation of the sound beam and to improve system signal-to-noise ratio.

9.1.1.2 Care should be taken to ensure that extraneous indications caused by particulates, air bubbles, etc. in the couplant, do not interfere with the examination at the required test sensitivity.

9.1.1.3 Corrosion inhibitors or wetting agents may be added as long as they do not affect the material properties.

9.1.1.4 Residual suspended particulate matter and air bubbles that collect on the material and search unit surfaces should be removed.

9.1.2 *Reference Standard Selection*—The reference standards should have the size and type of reference reflectors specified in the contractual agreement. Unless otherwise specified, for metals, it is recommended that the increment of metal path distance be selected as described in Table 2 and in Practice E127 for distance-amplitude reference blocks.

NOTE 4—The recommendations of paragraphs 9.1.2.1, 9.1.2.2, and 9.1.2.3, which follow are not applicable to advanced ceramics.

9.1.2.1 For examination performed only in the near-field portion of the sound beam, select metal paths from those in Table 2. The metal paths selected should be in increments so that the maximum metal path difference between reference targets does not exceed the requirements described in Table 3. This set should include one reference block with a metal path equal to or less than the required front surface resolution, and one approximately equal to or greater than the thickness of the test piece (or one half the thickness if the part is inspected from both sides).

9.1.2.2 For examination performed only in the far-field portion of the sound beam, select at least three reference blocks

TABLE 2 Distance Amplitude Reference Block-Metal Path Increments, in. [mm]

0.125 [3.2]
0.250 [6.4]
0.375 [9.5]
0.500 [12.7]
0.625 [15.9]
0.750 [19.1]
0.875 [22.2]
1.000 [25.4]
1.250 [31.8]
1.500 [38.1]
1.750 [44.5]
2.000 [50.8]
2.250 [57.2]
2.500 [63.5]
2.750 [69.9]
3.000 [76.2]
3.250 [82.6]
3.500 [88.9]
3.750 [95.3]
4.000 [101.6]
4.250 [108.0]
4.500 [114.3]
4.750 [120.7]
5.000 [127.0]
5.250 [133.4]
5.500 [139.7]
5.750 [146.1]
6.000 [152.4]
6.250 [158.8]
6.500 [165.1]

TABLE 3 Reference Block-Metal Path Selection in Near Field

Metal Path Range, in. [mm]	Maximum Metal Path Difference Between Adjacent Reference Blocks, in. [mm]
0 to 0.25 [0 to 6.4]	0.125 [3.2]
0.25 to 1.0 [6.4 to 25.4]	0.250 [6.4]
1.0 to 3.0 [25.4 to 76.2]	0.500 [12.7]
Over 3.0 [over 76.2]	1.000 [25.4]

with the following metal paths: (*1*) a metal path equal to or less than the required front-surface resolution; (*2*) a metal path approximately equal to one half the thickness of the test piece; and (*3*) a metal path approximately equal to or greater than the thickness of the test piece (or the required front-surface resolution, one quarter, and one half the thickness if the part is inspected from both sides).

9.1.2.3 For examinations which are performed so that part of the thickness of the test piece is in the near field and part is in the far field, the set of reference block metal paths should include blocks which satisfy the above near-field requirements covering the range from the front-surface resolution to the near-field limit and one reference block with a metal path equal to or greater than the thickness of the test piece (or one half the thickness if the part is inspected from both sides).

9.1.3 *Search Unit Adjustment*—Normalize the ultrasonic beam by adjusting the search unit for maximum echo amplitude from the front surface of the part or material. This is accomplished by angling the search unit in two directions, perpendicular to one another and parallel to the sound-entry surface (Note 5). During examination, monitor either the front-surface or back-surface indication. If changes in the shape of the test piece cause the amplitude of the monitored indication to decrease by more than 50 %, re-angle the search unit as necessary over different zones to maintain the beam normal to the examination surface.

NOTE 5—For focused search units, perform beam normalization so that the centerline of the beam is perpendicular to the material entry surface.

9.1.4 *Water Path*—The distance from the face of the search unit to the front surface of the material should be such that the second front-surface echo does not appear before the first back-surface echo. For focused search units, this distance should be such that the search unit focus is within the material at the depth required to meet front-surface resolution requirements.

NOTE 6—The permissible variation in the water path depends completely on the particular system and application (that is, flat or focused search unit, shape of beam profile, etc.) For establishing the distance-amplitude relationship and evaluating discontinuities, maintain the water path to within ±1⁄16 in. [±1.6 mm]. During scanning, the maximum variation shall not exceed the amount specified in the contractual agreement or approved test procedure.

9.2 *Initial Scanning Standardization*:

9.2.1 *Scan Index Determination*—Using the reference blocks selected in 9.1.2 and the search unit setup in 9.1.3, determine the maximum allowable scan index as follows: (*1*) maximize the echo amplitude from the reflector in each reference block and adjust the amplitude from 50 to 100 % of the upper linearity limit; and (*2*) determine the total traversing distance in the index direction, across each reference target, through which no less than that percentage of the maximized amplitude is obtained, which corresponds to the allowable variation during repeated runs of the reference standard. (See (**3**).) This distance is dependent on the material travel to the reflector and will vary from one reference target to another. This is the effective beam diameter at each material distance. The least of the distances should be used as the maximum allowable scan index.

9.2.2 *Distance-Amplitude Relationship*—Determine the distance-amplitude relationship for the set of reference blocks selected in 9.1.2 by positioning the search unit over each reference block to maximize the echo amplitude from the corresponding reference reflector. With the instrument controls (for example, pulse length and tuning) set to achieve the required resolution, select the reference block which provides the largest amplitude and adjust the gain to obtain an indication which is 80 % to 90 % of the upper linearity limit. Mark the amplitude of the maximized indication from each reference block on the display screen, and connect the points with a smooth curve. Once this is done, display screen time-based controls (for example, sweep delay and length) should not be changed. A typical distance-amplitude curve for tests in both the near and far fields is shown in Fig. 2.

NOTE 7—If a rectangular search unit is used for initial scanning, use the least sensitive portion of the effective beam width to determine the distance-amplitude curve.

9.2.3 *Scanning Gain Determination*—Determine the gain setting for initial scanning without or with electronic distance-amplitude compensation.

NOTE 8—For manual scanning it is recommended that the initial scanning gain level be increased by 6 dB with no change in the alarm level.

9.2.3.1 *Without Electronic Distance-Amplitude Compensation*—Set the initial scanning gain by selecting the reference block with a material path which provides the lowest echo amplitude on the distance-amplitude curve as determined in 9.2.2. Maximize the amplitude from the reference reflector in this reference block, and adjust the instrument gain to obtain an amplitude equal to 80 % to 90 % of the upper linear limit. This gain setting is the initial scanning gain level.

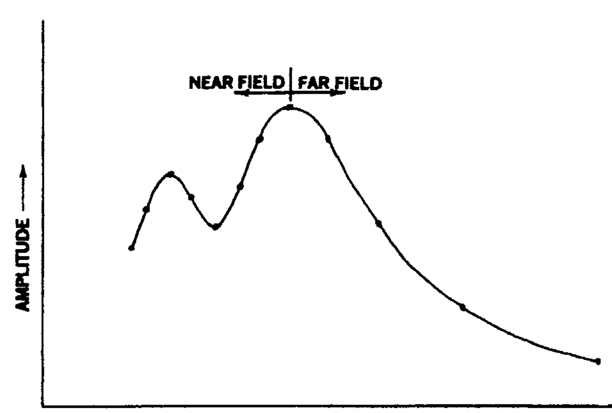

FIG. 2 Typical Distance—Amplitude Curve

9.2.3.2 *With Electronic Distance-Amplitude Compensation*—Electronic distance amplitude compensation generally uses either a time-varying-gain amplifier which adjusts all signals to approximately the same level or time-varying trigger level controls in the gating and alarm circuit. For systems that employ time-varying gain amplifiers, adjust the compensation controls so that the indication amplitudes of all reference blocks selected in 9.1.2 are approximately equal and so that the lowest amplitude is 80 % to 90 % of upper linear limit. This gain is the initial scanning gain level. For systems that employ time-varying trigger level controls, select the reference target with a material path which provides the *highest* echo amplitude on the distance amplitude curve as determined in 9.2.2. Maximize the amplitude from the reference reflector in this block, and adjust the instrument gain to obtain an amplitude equal to 80 % to 90 % of the upper linear limit. This gain is the initial scanning gain level.

9.2.3.3 *Transfer* is sometimes required because the reference blocks being used do not have the same attenuation properties as the part or material being inspected. To date, no consensus exists on the correct technique for making transfer corrections. The two most widely used methods are described in Appendix X1. The technique used should be mutually agreed upon between the supplier and the purchaser.

9.2.4 *Alarm Setting: (If used, see Note 3 under 7.4.)*

9.2.4.1 For systems adjusted as in 9.2.3.1 or 9.2.3.2, adjust the alarm trigger level to trigger at 50 % of the rejection limit established by any target in the reference standard. This corresponds to one half the indication amplitude of the lowest point on the distance-amplitude curve.

9.2.4.2 For systems with time-varying trigger level controls, set the compensation controls so that any indications exceeding one half of the reference value at the equivalent metal distance will trigger the alarm. Alternatively, the gain may be increased by 6 dB (doubling the amplitude) and the compensation control set to trigger the alarm at the full reference value at the equivalent metal distance.

9.2.4.3 *Back-Reflection Monitor*—If simultaneous monitoring of back reflection amplitude is desired or required, a dual gating/alarm system is necessary. One gate is set to monitor internal discontinuity indications, and the other is set to monitor back-reflection amplitude as stipulated by the contractual agreement. The operator should determine that the trigger level is actually set at the required percent of back-reflection amplitude, not percent of vertical limit, since the true back-reflection amplitude is often greater than the vertical limit.

9.3 *Initial Scanning Procedure*:

9.3.1 *Scanning Speed*—The maximum scanning speed to be used on the part should provide a clear indication of true-echo amplitude and activate the alarm as appropriate. Check this by scanning all reference blocks utilized in establishing the acceptance/rejection level. However, deviation from the above statement may be made provided that chart or facsimile-type recording equipment is used, and the response time of the recording equipment is compatible with the scanning speed and other system parameters.

9.3.2 *Coverage*—The surfaces of the examination piece that will be scanned should be as specified in the contractual agreement.

9.3.3 *Scanning*—Position the search unit over the part that will be examined using the same search unit-to-part distance (water path) and angular relationship as in setup. The gain should be as described in 9.2.3, corrected for transfer (9.2.3.3) if appropriate. A higher scanning gain may be used by adding a controlled amount of gain. Scan the part at the scanning speed as described in 9.3.1 (or slower) and the scan index as described in 9.2.1 (or smaller).

9.3.4 *Indications*—Note for evaluation all locations that give indication amplitudes which are greater than one half of the reference response at the equivalent depth in the material, that is that trigger the alarm.

9.3.5 *Loss of Back Reflection*—If back-reflection monitoring is required, note any location where the amplitude of the back-surface reflection is below the specified value. Determine that this loss is not caused by non-parallel surfaces or surface roughness. If surface roughness is found to be the cause of back reflection loss, the entire test item should be reviewed for conformance to 8.1.

10. Evaluation of Discontinuities

10.1 *Single Discontinuities*—Select the reference block with the reference reflector equal to the largest acceptable as specified in the contractual agreement and the material path distance closest to the discontnuity depth in the part, or use the applicable distance-amplitude curve established as in 9.2.2. The gain should be as set in 9.2.3, adjusted for transfer if applicable. Manipulate the search unit, laterally and angularly, to obtain the maximum echo amplitude from the discontinuity in the part.

10.1.1 *Accept/Reject*—If all that is required of the evaluation is an accept/reject decision, compare the amplitude of the discontinuity indication to the amplitude of the reference reflector indication. Any discontinuity from which the amplitude is greater than the reference amplitude should be marked for rejection.

10.1.2 *Quantitative Evaluation of Relative Discontinuity Size*—If some quantitative indication of relative discontinuity size is required, additional reference blocks, with different size reflectors, at the proper material distance are required. If the maximized amplitudes are the same, a discontinuity indication can be described as "equivalent to the response from a (specified artificial discontinuity)," for example, "equivalent to the response from a No. 5 flat-bottomed hole." This does not mean that the two discontinuities are the same size, shape, or orientation.

NOTE 9—Size-amplitude relationships of this type are generally valid only if the ultrasonic beam is much larger than the discontinuity size. Caution should be used in evaluating discontinuities based on relative amplitude when focused, dual-element, or other highly directive search units are used.

10.2 *Linear or Multiple Discontinuities*—Evaluate linear and multiple discontinuities by first resetting the gain to achieve an echo amplitude of 80 % upper linear limit from a reference block with the reference reflector equal to the largest