Designation: E 1001 – 99a

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 E 1001; 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 (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 totally submerged in the couplant (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 complements Practice E 214 by providing more detailed procedures for the selection and calibration of the 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:*

C 1212 Practice for Fabricating Ceramic Reference Specimens Containing Seeded Voids[2]

C 1336 Practice for Fabricating Non-Oxide Ceramic Reference Specimens Containing Seeded Inclusions[2]

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks[3]

E 214 Practice for Immersed Ultrasonic Examination by the Reflection Method Using Pulsed Longitudinal Waves[3]

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments[3]

E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection[3]

E 1316 Terminology for Nondestructive Examinations[3]

2.2 *ASNT Documents:*

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing[4]

ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel[4]

2.3 *Military Standards:*

MIL-STD-410E Nondestructive Testing Personnel Qualification and Certification (Eddy-Current, Liquid Penetrant, Magnetic Particle, Radiographic, and Ultrasonic)[5]

NAS-410 Nondestructive Testing Personnel Qualification and Certification[5]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, see Terminology E 1316.

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 *evaluation*—the determination of the relative or approximate size of a discontinuity, or its indication amplitude relative to the amplitude of a reference discontinuity.

3.2.3 *examination*—the automatic or manual scanning of a part to locate discontinuities.

[1] This practice is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Testing Procedure.

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[2] *Annual Book of ASTM Standards,* Vol 15.01.

[3] *Annual Book of ASTM Standards,* Vol 03.03.

[4] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

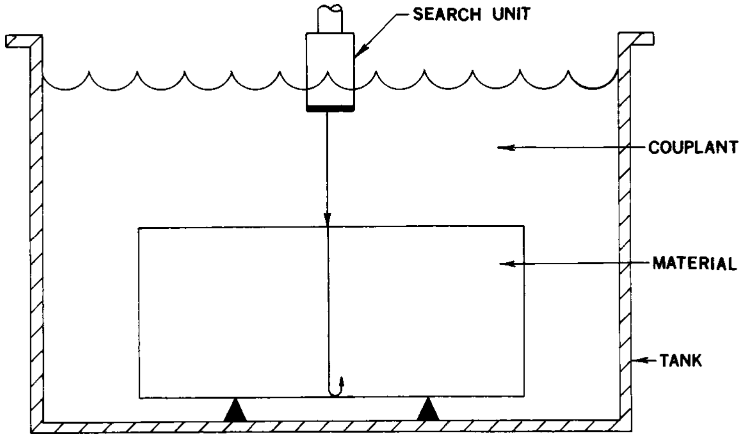

FIG. 1 Basic Immersion Setup

3.2.4 *gain*—the amount of amplification or attenuation, or both, applied to an electrical signal that dictates its amplitude as displayed on the cathode-ray tube (CRT).

3.2.5 *scan index*—the length of the step created by rastering the search unit over the part, that is continuously scanning in one direction, then stepping in the direction perpendicular to the scan. The allowable scan index should be correlated with the search unit effective beam diameter to ensure full coverage of the part.

3.2.6 *standardize*—to adjust the gain of an ultrasonic instrument so that the amplitude of the echo from a specified reference reflector is a specified value.

3.2.7 *transfer*—a change in scanning gain to compensate for differences in attenuation of the reference blocks 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. Significance and Use

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

5.2 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.

5.3 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.

6. Apparatus

6.1 *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 E 317 or equivalent procedures (see Note 1). 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 conditions can be met at one half the part thickness, the part may be inspected from both sides.

NOTE 1—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.

6.2 *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.

6.3 *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

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				

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.

6.4 *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 2—This requirement may not be applicable if recording equipment is used.

6.4.1 *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.

6.5 *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 8.3.1 and control of the index in accordance with 8.2.1. 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.

6.6 *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 7.

6.7 *Reference Artifacts*—Ultrasonic reference blocks, often called test 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 blocks such as attenuation, noise level, surface condition, and sound velocity, should be similar to the material being inspected. Metal reference blocks 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.

6.7.1 *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 E 127. However, other types of reference blocks may be used when mutually agreed upon between the supplier and the purchaser, for example, those given in Practice E 428. Practices C 1212 and C 1336 containing seeded voids and seeded inclusions may be used for advanced ceramics.

6.7.2 *Curved Surfaces*—Reference blocks with flat surfaces may be used for establishing gain settings for examinations on test surfaces with radii of curvature 5 in. (130 mm) or greater. 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.

6.8 *Reference Reflectors*—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 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 voids (Practice C 1212), seeded inclusions (Practice C 1336), and laser-drilled holes are common reflectors for advanced ceramics.

7. General Examination Requirements

7.1 *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.

7.2 *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.

7.2.1 *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 test surfaces, perform additional examinations from the opposite side. If surface roughness prevents the required resolution from being obtained, correct the problem before performing the test. Also, for each inspection 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 6.1).

7.3 *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.

8. Examination (Scanning) Procedure

8.1 *System Setup*:

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

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

8.1.1.2 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.

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

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

8.1.2 *Reference Block Selection*—The reference blocks should have the size and type of reference reflectors specified in the contractual agreement. Unless otherwise specified, for metals, select the increment of metal path distance from the distance-amplitude reference blocks described in Table 2 and in Practice E 127.

NOTE 3—The recommendations of paragraphs 8.1.2.1, 8.1.2.2, and 8.1.2.3 are not applicable to advanced ceramics.

8.1.2.1 For inspection 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 adjacent reference blocks 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 test-piece thickness (or one half the thickness if the part is inspected from both sides).

8.1.2.2 For inspection performed only in the far-field portion of the sound beam, select at least three reference blocks 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 test piece thickness; and (*3*) a metal path approximately equal to or greater than the test-piece thickness (or the required front-surface resolution, one quarter, and one half the thickness if the part is inspected from both sides).

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)

8.1.2.3 For inspections which are performed so that part of the test-piece thickness 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 test-piece thickness (or one half the thickness if the part is inspected from both sides).

8.1.3 *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 4). 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 test surface.

NOTE 4—For focused search units, perform beam normalization so that the material entry surface is at the focus.

8.1.4 *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 5—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). For scanning, specify the maximum variation in the contractual agreement.

8.2 *Initial Scanning Standardization*:

8.2.1 *Scan Index Determination*—Using the reference blocks selected in 8.1.2 and the search unit setup in 8.1.3, 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 block, through which no less than one half of the maximized amplitude is obtained. This distance is dependent on the material travel to the reflector and will vary from one reference block 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.

8.2.2 *Distance-Amplitude Relationship*—Determine the distance-amplitude relationship for the set of reference blocks selected in 8.1.2 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 % of the upper linearity limit. Mark the amplitude of the maximized indication from each reference block on the CRT, and connect the points with a smooth curve. Once this is done, CRT 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 6—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.

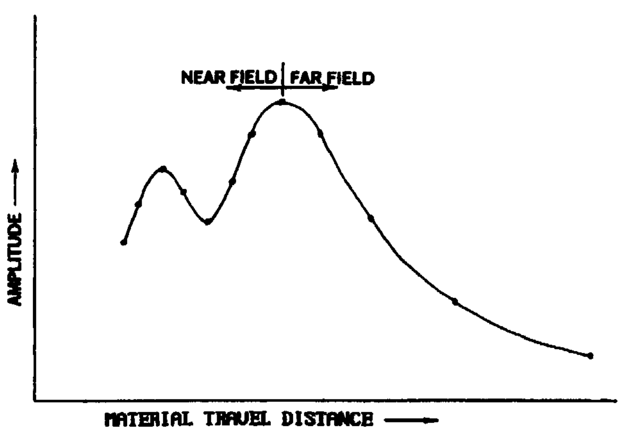

FIG. 2 Typical Distance—Amplitude Curve

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

NOTE 7—For manual scanning it is recommended that the initial scanning gain level be increased by 6 dB with no change in the alarm level.

8.2.3.1 *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 8.2.2. Maximize the amplitude from the reference reflector in this reference block, and adjust the instrument gain to obtain an amplitude equal to 80 % of the upper linear limit. This gain setting is the initial scanning gain level.

8.2.3.2 *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 8.1.2 are approximately equal and so that the lowest amplitude is 80 % of upper linear limit. This gain is the initial scanning gain level. For systems that employ time-varying trigger level controls, select the reference block with a material path which provides the *highest* echo amplitude on the distance amplitude curve as determined in 8.2.2. Maximize the amplitude from the reference reflector in this block, and adjust the instrument gain to obtain an amplitude equal to 80 % of the upper linear limit. This gain is the initial scanning gain level.

8.2.3.3 *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.

8.2.4 *Alarm Setting*:

8.2.4.1 For systems adjusted as in 8.2.3.1 or 8.2.3.2, adjust the alarm trigger level to trigger at 40 % of the upper linear limit. This corresponds to one half the indication amplitude of the lowest point on the distance-amplitude curve.

8.2.4.2 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.

8.2.4.3 *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.

8.3 *Initial Scanning Procedure*:

8.3.1 *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.

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

8.3.3 *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 8.2.3, corrected for transfer (8.2.3.3) 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 8.3.1 (or slower) and the scan index as described in 8.2.1 (or smaller).

8.3.4 *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.

8.3.5 *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 7.1.

9. Evaluation of Discontinuities

9.1 *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 discontinuity depth in the part, or use the applicable distance-amplitude curve established as in 8.2.2. The gain should be as set in 8.2.2, adjusted for transfer if applicable. Manipulate the search unit, laterally and angularly, to obtain the maximum echo amplitude from the discontinuity in the part.

9.1.1 *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.

9.1.2 *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 8—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.

9.2 *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 acceptable. Use a reference block with material travel distance closest to the discontinuity depth in the part or use the applicable distance-amplitude curve established in 8.2.2. If applicable, apply the transfer technique as described in 8.2.3.3.

9.2.1 *Multiple*—Determine the distance between discontinuities by positioning the search unit over each discontinuity where the maximum echo amplitude is obtained. Mark for rejection any part or material where the distance between the locations of maximum amplitudes of any two discontinuities is closer than the minimum allowed in the contractual agreement. It should be noted that maximum amplitude is not necessarily received from the center of a discontinuity.

9.2.2 *Linear*—Determine the approximate length of linear discontinuities having echo amplitudes which are greater than one half the amplitude of the indication from the reference reflector at the equivalent depth. Position the search unit over one extremity of the discontinuity when the amplitude is reduced to half the transfer corrected (if applicable) reference amplitude. Move the search unit toward the opposite extremity of the discontinuity until the amplitude is again reduced to half the reference. The distance between these two positions approximates the discontinuity length. Mark for rejection any part or material with linear discontinuities longer than the maximum allowed in the contractual agreement.

10. Quality Assurance Provisions

10.1 *Personnel Qualifications*—If specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, MIL-STD-410E, NAS-410, or a similar document, and 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.

10.2 *System Performance*—As a minimum requirement, system performance should be verified in accordance with the following schedule (if mutually agreed upon, more stringent or frequent checks may be specified): (*1*) Gain settings, distance-amplitude relationship, and alarm trigger levels should be checked after any interruption of power, change of operating personnel, replacement of a system component, or adjustment of any electrical or mechanical control which cannot be returned exactly to its previous position and (*2*) verification should also be made at such interim periods as are needed to assure that any material previously inspected can be recovered and reinspected if nonconformance to the test criteria, resulting in underinspection, exceeding the extent specified in the contractual agreement is observed.

10.3 *Corrosion Inhibitor and Wetting Agent Control*—When corrosion inhibitor or wetting agent solutions are used in immersion tanks, check the inhibitor and agent concentration in the tank solutions after initial solution makeup and at 90-day intervals. The corrosion inhibitor is used to neutralize the couplant to minimize the possibility of corrosion, rusting, pitting, etc., which can be detrimental to the part or material under examination. Wetting agents are used to deaerate the couplant and enhance adherence of the couplant to the material and search unit.

11. Documentation

11.1 Document all specific test requirements, procedural details, and results for a particular examination in written contractual agreements, procedures, and reports.

11.2 *Contractual Agreement*—Specific examination requirements for a particular test item should include at least the following requirements:

11.2.1 Minimum equipment requirements (6.1 and Table 1),
11.2.2 Positioning backlash (6.5),
11.2.3 Reference blocks (6.7.1 and 6.7.2),
11.2.4 Reference reflectors (6.8),
11.2.5 Material condition (7.1),
11.2.6 Water path variation (8.1.4),
11.2.7 Transfer technique (8.2.3.3),
11.2.8 Back reflection monitoring (8.2.4.1),
11.2.9 Coverage (8.3.2),
11.2.10 Evaluation of multiple discontinuities (9.2.1),
11.2.11 Evaluation of linear discontinuities (9.2.2),
11.2.12 Personnel qualification (10.1),
11.2.13 System performance (10.2), and
11.2.14 Report requirements (11.2).

11.3 *Written Procedure and Report*—Ultrasonic inspections performed in accordance with this practice should be detailed in a written procedure. This should identify the type of ultrasonic equipment, test methods, reference blocks, search unit type, style, and frequency, method of reporting indications, and all other instructions that pertain to the actual test. Procedures should be sufficiently detailed so that another qualified investigator could duplicate the test and obtain equivalent information. All specified data required for the complete record and report of an examination should be agreed upon between the supplier and the purchaser. As a minimum, the following items should be documented either in the written procedure or report:

11.3.1 Specific part number and configuration tested, stage of fabrication of the test item, surface finish, and surface preparation methods.

11.3.2 Manufacturer, model number, and serial numbers of all instrumentation used in the test. This includes any recording equipment, alarm equipment, and electronic distance-amplitude equipment.

11.3.3 Type, serial number, and size of search unit. Include frequency, transducer element material (or model number), description of focal length, or search unit stand-off attachments.

11.3.4 Description of manipulating and scanning equipment, and special fixtures.

11.3.5 Couplant, corrosion inhibitor, and wetting agent solution.

11.3.6 Scanning plan. Describe the surface from which the tests were performed and the ultrasonic beam paths used.

11.3.7 Method of applying transfer and amount of transfer applied.

11.3.8 Acceptance classes, reference blocks, water paths, scan-index determination, and distance-amplitude correc tion.

11.3.9 Evaluation procedure.

12. Keywords

12.1 immersion ultrasonics; nondestructive testing; pulse-echo; ultrasonic examination

APPENDIXES

(Nonmandatory Information)

X1. TRANSFER TECHNIQUES

X1.1 The difficulty in transfer measurements, as they are now implemented, is in obtaining meaningful“ back-surface echo” or “relative attenuation” measurements from a reference block containing an artificial discontinuity. Since a common reference block may be a cylinder containing a flat-bottom hole, the problem is described here in those terms. On axis, where the measurement is truly meaningful, the back-surface echo is reduced by scattering from the hole bottom and counterbore, if any. The amount of this reduction depends on search unit size and frequency, hole diameter, metal and water distances, whether a counterbore exists, etc. However, if the measurement is made off axis, the echo amplitude may be affected by different microstructure and sidewall reinforcement (wave guide effect) of the ultrasonic beam. The magnitude of these effects is dependent on the manufacturing process (for example, rolled or extruded) and search unit size and frequency. These two methods are described below.

X1.2 *Method A—Centerline Method:*

X1.2.1 The reference block should be the one with a total length, to the back surface, approximately equal to the thickness of the part to be inspected. Place the search unit over the reference block and manipulate for normal incidence, with the water path equal to that to be used in the inspection. Position the search unit for a maximum flat-bottom hole echo amplitude.

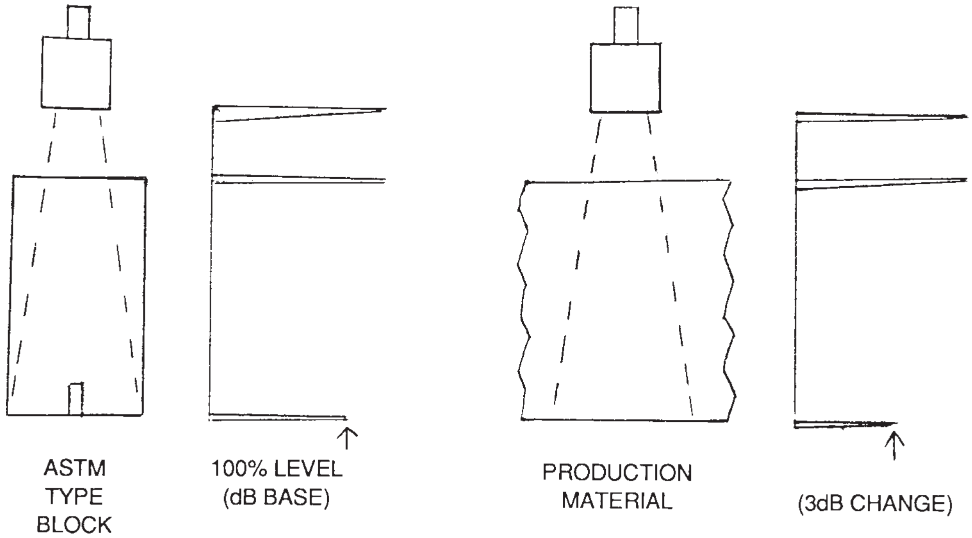

FIG. X1.1 Method A, Centerline

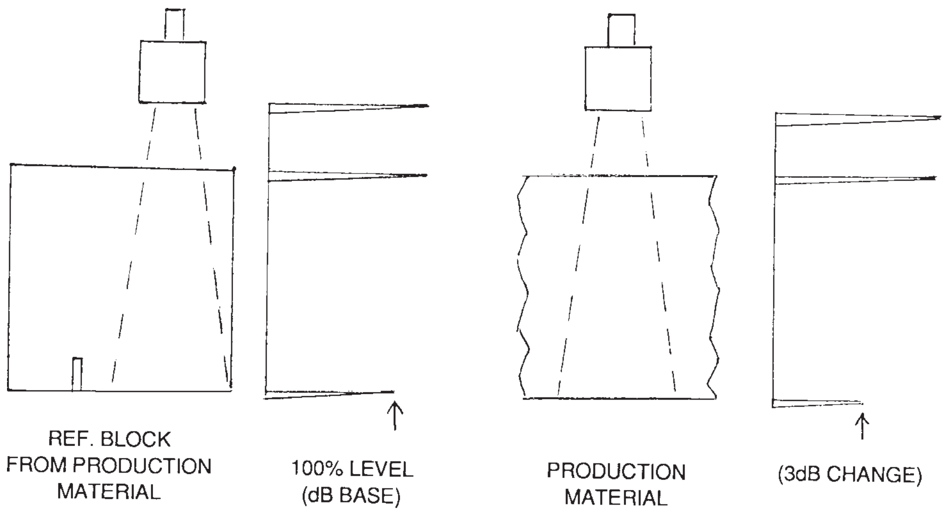

FIG. X1.2 Method B, Off Axis

X1.2.2 Without moving the search unit, adjust the instrument gain so that the first back reflection amplitude is 80 % of the upper linear limit.

NOTE X1.1—A small signal from the FBH may be present on the CRT but will probably not be seen at the gain setting used.

X1.2.3 Place the search unit over the material with the same water path and gain setting as above. Manipulate for maximum back reflection amplitude. Read this amplitude. The ratio of these amplitudes is a relative attenuation comparison expressed either in ±% or ±dB. If the amplitude from the test piece is less than 80 %, the test piece is more attenuating than the reference block, and if required by the contractual agreement, the calculated percentage or dB of gain should be added to ensure detection of discontinuities deep in the piece. The amount of variation allowed in the relative amplitudes before correction is required is usually agreed upon by the supplier and purchaser.

X1.3 *Method B—Off-Axis Method:*

X1.3.1 The reference block should be the one with a total length, to the back surface, approximately equal to the thickness of the part to be inspected. The search unit should be placed over the reference block and manipulated for normal incidence, with the water path equal to that to be used in the inspection. Position the search unit off axis approximately halfway between the flat-bottom hole and the side wall. Without moving the search unit, adjust the instrument gain so that the first back reflection amplitude is 80 % of the upper linear limit.

X1.3.2 Place the search unit over the test piece with the same water path and gain setting as above. Manipulate for maximum back reflection amplitude. Read this amplitude. The ratio of these amplitudes is a relative attenuation comparison, expressed either in ± % or± dB. If the amplitude from the test piece is less than 80 %, the test piece is more attenuating than the reference block, and if required by the contractual agreement, the calculated percentage or dB of gain should be added to ensure detection of discontinuities deep in the piece. The amount of variation allowed in the relative amplitudes before correction is required is usually agreed upon by the supplier and purchaser.

X2. SPECIAL TECHNIQUES

X2.1 The following two techniques, while not strictly immersion in the pure sense, are very similar. Many of the procedures of this proposed recommended practice may be applied to tests using these techniques.

X2.2 *Bubbler Technique*—The bubbler technique is essentially a variation of the immersion method, where the sound beam is projected through a water column into the specimen. The bubbler is usually used with an automated system for high-speed scanning of plate, sheet, strip, cylindrical forms, and other regularly shaped parts. The sound beam is projected through a column of flowing water, and is directed perpendicular to the surface for straight beam longitudinal inspection. Generally, the test specimen is not immersed (Fig. X2.1).

X2.3 *Wheel Search Unit Technique*—The wheel search unit technique is an aspect of the immersion method in that the sound beam is projected through a liquid-filled tire into the specimen. However, additional couplant is normally required between the tire and material as in contact testing. The wheel may be mounted on a stationary fixture while the material is moved past it. The position and angle of the search unit mounting on the wheel axle is variable. This method may be used for high-speed scanning of plate, sheet, strip, and other regularly shaped parts (Fig. X2.2).

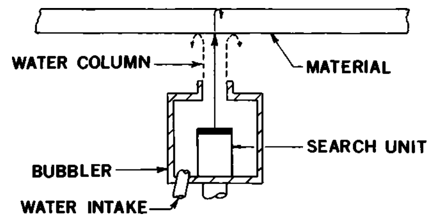

FIG. X2.1 Bubbler Setup

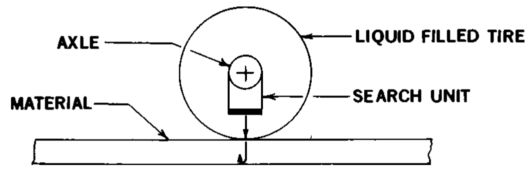

FIG. X2.2 Wheel Scanner