DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
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IN REPLY REFER TO
9074
Ser 05Z/223
8 May 24

From: Commander, Naval Sea Systems Command (SEA 05Z)

Subj: GUIDANCE FOR PERFORMING NON-DESTRUCTIVE TESTING AND NON-DESTRUCTIVE TESTING PROCEDURE QUALIFICATION IN SUPPORT OF ADDITIVE MANUFACTURING EFFORTS

Ref: (a) NAVSEA Technical Publication S9074-A4-GIB-010/AM-WIRE DED of 27 May 21
(b) NAVSEA Technical Publication S9074-A2-GIB-010/AM-PBF, Rev 1 of 19 Jan 24
(c) NAVSEA Technical Publication T9074-AS-GIB-010/271 rev 1 of 11 Sep 14

Encl: (1) NDT Acceptance Criteria for Wire DED AM Product
(2) NDT Acceptance Criteria for PBF AM Product
(3) Considerations for Non-Destructive Testing Procedure Qualification
(4) Essential Variables for NDT, Minimally Required
(5) MIL-STD-2132F Section 8.4.2 and Appendix E

1. Purpose. This letter supersedes NAVSEA ltr Ser 05Z/063 of 24 January 2024, due to change to Distribution Statement A with other minor clarifying modifications and the addition of enclosure (5). This letter is issued to provide guidance on Non-Destructive Testing (NDT) and NDT procedure qualification in support of Additive Manufacturing (AM) efforts prescribed in the references (a) and (b) AM Technical Publications.

2. Scope and Applicability

a. This document does not apply to Naval Nuclear Propulsion plant systems, equipment, and facilities under the cognizance of the Deputy Commander, Nuclear Propulsion Directorate (SEA 08). In addition, this document does not supersede or modify existing agreements between SEA 08 and SEA 05 regarding changes to non-reactor plant items in nuclear powered vessels, which require SEA 08 concurrence.

b. This document does not apply to Strategic Weapons Systems and Attack Weapon Systems and associated spares and repair parts under the cognizance of Strategic Systems Programs.

3. Background. AM represents a new product form and manufacturing method, in addition to conventional product forms and methods such as casting, forging, rolling, extruding, and welding. NDT procedures that are to be used to inspect AM products must be qualified such that the inherent variations in as-printed surfaces, build direction, inspected geometry, metallographic crystal structure, micro porosity, and AM processes themselves, as well as secondary processing such as heat treatment, machining, finishing, and chemical surface treatment do not adversely affect the reliability of the NDT method to identify and disposition discontinuities per the acceptance criteria.

4. NAVSEA Discussion

a. NDT Acceptance Criteria for AM. The NDT acceptance criteria referenced in this paragraph shall be utilized for AM process qualification, part verification, and part production efforts executed per the reference (a) and (b) AM Technical Publications. These NDT acceptance criteria are workmanship-based and should be considered the interim requirement until detailed NDT acceptance criteria requirements are established and documented. If alternate NDT acceptance criteria (discontinuity types, sizes, location, and orientations), vice the criteria of enclosure (1) or (2) of this letter, is invoked for AM efforts that are per reference (a) or reference (b), it shall be approved by the appropriate approval authority per the appropriate procurement specification, drawing, or other acquisition document.

(1) Directed Energy Deposition. The interim NDT acceptance criteria for wire Directed Energy Deposition AM product produced per reference (a) is provided in enclosure (1).

(2) Powder Bed Fusion. The interim NDT acceptance criteria for Powder Bed Fusion AM product produced per reference (b) is provided in enclosure (2).

b. NDT for AM Procedure Qualification. NDT procedures are required to be qualified per reference (c), paragraph 1.7.2. Enclosure (3) is to aid in the execution and development of NDT method(s) and technique(s) suitable to inspect AM manufactured components. As such, it contains information relevant to Examiners performing NDT procedure qualification to support AM process qualification, AM part verification, and AM part production inspections. A conventional, qualified NDT procedure must be requalified if the Examiner identifies an essential variable with the AM product offered for inspection that does not fall within the scope of the existing procedure qualification. Enclosure (4) contains the minimum essential variables for NDT procedures.

5. NAVSEA points of contact for this letter are Dr. Pranaam Haldipur, 202-781-3856, pranaam.haldipur.civ@us.navy.mil, Mark Massie, mark.h.massie.civ@us.navy.mil, 202-781-2425, Mike Bjornson, michael.j.bjornson.civ@us.navy.mil, 202-781-3432, Greg Archer, gregory.c.archer.civ@us.navy.mil, 202-781-0128, and Dr. Justin Rettaliata, 202-781-5312, justin.m.rettaliata.civ@us.navy.mil.

6. This letter does not authorize any change in the terms, conditions, delivery schedule, price, or amount of any other Government contract. If you consider these requirements represent a change for which you are entitled to an equitable adjustment, you are to comply with the requirements of the "Notification of Changes" clause of the contract.

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Table 1. Wire DED Acceptance Criteria for AM Procedure Qualification

NDT	*MIL-STD-2035A*	*MIL-STD-2035A*
	Linear [1/]	Non-Linear [1/]
VT	*§ 4.2 (as applicable per defect type)*	*§ 4.2 (as applicable per defect type)*
MT	§ 6.2.1	§ 6.2.2
PT	§ 7.2.1	§ 7.2.2
UT	§ 8.2.1	§ 8.2.1
RT	§ 5.2.1, 5.2.2	§ 5.2.1, 5.2.2
NOTES: 1/ Utilize Class 1 criteria for welds. Reference NAVSEA S9074-A4-GIB-010/AM-WIRE DED to determine what NDT methods are invoked.		

Table 2. Wire DED Acceptance Criteria for NAVSEA S9074-AR-GIB-010A/278 Parts, for Part Verification and Part Production

NDT	*MIL-STD-2035A*	*MIL-STD-2035A*
	Linear [1/]	Non-Linear [1/]
VT	*§ 4.2 (as applicable per defect type)*	*§ 4.2 (as applicable per defect type)*
MT	§ 6.2.1	§ 6.2.2
PT	§ 7.2.1	§ 7.2.2
UT	§ 8.2.1	§ 8.2.1
RT	§ 5.2	§ 5.2
NOTES: 1/ Determine acceptance criteria class based on Table 3. Reference NAVSEA S9074-A4-GIB-010/AM-WIRE DED to determine what NDT methods are invoked.		

Table 3. Wire DED Acceptance Criteria Classes for NAVSEA S9074-AR-GIB-010A/278 Parts, Part Verification and Part Production

Wire DED Part Application [1/]	VT/MT/PT [2/]	RT [3/ 4/]	UT [3/ 4/ 5/]
	MIL-STD-2035 Welds Class	MIL-STD-2035 Welds Class	MIL-STD-2035 Welds Class
M-1	2	2	1
M-2	3	3	3
P-1, P-LT	1	1	1
P-2	2	2	2
A-1, A-2	1	1	1
A-3, A-4	2	2	2
A-F, A-LT	1	1	1
Turbine Parts	6/	6/	6/
Propulsion Reduction Gears & Steam Turbine Driven Auxiliary Gears	6/	6/	6/
Forced Draft Blowers	6/	6/	6/

1/ Application should be determined based on the definitions provided in NAVSEA S9074-AR-GIB-010A/278.
2/ VT shall be performed on 100% of all accessible surfaces; MT or PT shall be performed on 100% of all accessible surfaces. Final inspection shall be performed in the final surface condition.
3/ Reference NAVSEA S9074-A4-GIB-010/AM-WIRE DED for volumetric coverage requirements.
4/ UT shall be the preferred method of volumetric inspection. RT may be used where part configuration is favorable. RT may be used to supplement UT for zones where obtaining UT coverage is not possible.
5/ When fatigue performance is a design consideration, Class 1 shall be used or alternative acceptance criteria as approved by the appropriate approval authority.
6/ NDT criteria shall be approved by NAVSEA on a case basis

Table 4. Wire DED Acceptance Criteria for NAVSEA T9074-AD-GIB-010/1688 Parts, Part Verification and Production Criteria

Submarine Structural Component AM Wire DED NDT Requirements			
Method	**Extent of Inspection**	**Timing of Inspection**	**Acceptance Criteria**
VT	1/	After cooled to ambient	NAVSEA T9074-AD-GIB-010/1688 Rev 1, § 7.4 to 7.4.5
MT	100% of all accessible surfaces	3/ 6/	NAVSEA T9074-AD-GIB-010/1688 Rev 1, § 7.5
PT	100% of all accessible surfaces	6/	NAVSEA T9074-AD-GIB-010/1688 Rev 1, § 7.7.1 5/
UT	Per NAVSEA T9074-AD-GIB-010/1688 Rev 1, Table 15-1 RT Coverage Minimum	4/	MIL-STD-2035A Class 1, § 8.1 and 8.2.1 for welds
RT	2/	2/	MIL-STD-2035A Class 2, § 5.2.1 and 5.2.3 for welds

NOTES:
1/ All accessible surfaces of AM builds where the as-printed surface condition is the final surface condition shall receive 100% VT. This is in addition to MT/PT for as-printed surfaces.
2/ UT is the primary volumetric inspection method. RT may be used to supplement UT to achieve required coverage when approved by NAVSEA. The submittal to NAVSEA for approval shall include the proposed procedure, shooting sketch, and acceptance criteria. If RT is supplementing UT, the UT scan plan and coverage shall also be provided.
3/ Regarding MT of builds of MIL-100S: For builds that will be put into service without heat treatment, MT shall be completed no sooner than 160 hours after the build has been completed and cooled to ambient. MT is required of components that have lost preheat prior to returning to fabrication. MT of heat treated builds may be performed once the component has cooled to ambient following all heat treatments.
4/ For MIL-100S builds, UT shall be performed no sooner than 8 hours after the build has cooled to ambient. For other materials, UT shall be performed once the build has cooled to ambient.
5/ When PT is substituted for MT, the acceptance criteria shall be the same as for MT.
6/ Final inspection shall be performed after all required machining or grinding has been completed.

Table 5. Wire DED Acceptance Criteria for MIL-STD-1689A (SH) Parts, Part Verification and Production Criteria

Ships Structural Component AM Wire DED NDT Requirements			
Method	**Extent of Inspection**	**Timing of Inspection**	**Acceptance Criteria**
VT	1/	After cooled to ambient	MIL-STD-1689A (SH), § 8.2
MT	100% of all accessible fillet surface areas and all surface areas exposed to seawater below the limiting draft line	3/ 6/	MIL-STD-1689A (SH), § 8.3.1
PT	100% of all accessible AM product form surface areas within 3 inches of the contiguous surface to which welds will be applied	6/	MIL-STD-1689A (SH), § 8.6.1 5/
UT	Per MIL-STD-1689A (SH), § 16.2.2 RT Coverage Minimum	4/	MIL-STD-2035A Class 2, § 8.1 and 8.2.2 for welds
RT	2/	2/	MIL-STD-2035A Class 3, § 5.2.1 and 5.2.4 for welds

NOTES:

1/ All accessible surfaces of AM builds where the as-printed surface condition is the final surface condition shall receive 100% VT. This is in addition to MT/PT for as-printed surfaces.

2/ UT is the primary volumetric inspection method. RT may be used to supplement UT to achieve required coverage when approved by NAVSEA. The submittal to NAVSEA for approval shall include the proposed procedure, shooting sketch, and acceptance criteria. If RT is supplementing UT, the UT scan plan and coverage shall also be provided.

3/ Regarding MT of builds of MIL-100S: For builds that will be put into service without heat treatment, MT shall be completed no sooner than 160 hours after the build has been completed and cooled to ambient. MT is required of components that have lost preheat prior to returning to fabrication. MT of heat treated builds may be performed once the component has cooled to ambient following all heat treatments.

4/ For MIL-100S builds, UT shall be performed no sooner than 8 hours after the build has cooled to ambient. For other materials, UT shall be performed once the build has cooled to ambient.

5/ When PT is substituted for MT, the acceptance criteria shall be the same as for MT.

6/ Final inspection shall be performed after all required machining or grinding has been completed, or in the case of MT, inspection may be performed within 1/32 inch of the final surface provided a dc continuous magnetization method is used for the inspection.

Table 6. PBF Procedure Qualification, Part Verification, and Part Production Criteria

NDT METHOD 1/	DISCONTINUITY/CONDITION	CLASS A 2/ 3/	CLASS B 2/	CLASS C 2/
VT	Color for titanium	Not colored other than bright silver		
VT	Color for steel, stainless steel, Ni-base	Not black		
VT	Overheating (other than above)	Reject any		
VT, RT	Crack	Reject any		
VT, RT	Lack of Fusion or Other Linear (Length/Width>3)	Reject any		
PT, MT	Crack	Reject any >1/16" indication, including bleedout		
PT, MT	Lack of Fusion or Other Linear (Length/Width>3)	Reject any >1/16" indication, including bleedout		
PT, MT	Surface Porosity	MIL-STD-2035A Class 1, § 6.2.2	MIL-STD-2035A Class 2, § 6.2.2	MIL-STD-2035A Class 3, § 6.2.2
VT, RT Surface Porosity	Porosity - Maximum dimension for an individual pore	0.25T or 1/32", whichever is less	0.33T or 1/16", whichever is less	0.5T or 3/32", whichever is less
	Porosity - Maximum spacing between 2 pores to count as a single pore of size equivalent to the encompassing boundary	8 times largest pore	4 times largest pore	2 times largest pore
	Maximum accumulated pore length in any 3" line (include all pores within 1/16" of centerline)	1T or 1/8", whichever is less	1.33T or 1/4", whichever is less	2T or 3/8", whichever is less
RT (includes powder-filled)	Subsurface Porosity - Maximum dimension for an individual pore	0.33T or 1/16", whichever is less	0.5T or 3/32", whichever is less	Not Applicable
	Subsurface Porosity - Maximum spacing between 2 pores to count as a single pore of size equivalent to the encompassing boundary	4 times largest pore	2 times largest pore	Not Applicable
	Maximum accumulated pore length in any 3" line (include all pores within 1/16" of centerline)	1.33T or 1/4", whichever is less	2T or 3/8", whichever is less	Not Applicable
UT	Discontinuity	MIL-STD-2035A Class 1, § 8.1 and 8.2.1		Not Applicable
Macrosection	Crack, Lack of Fusion, or other Linear (Length/Width>3) discontinuity	Reject any >1/32" or 10% of local thickness, whichever is less Reject multiple <1/32" if they are within 1/8" of each other, or any other linear or rounded discontinuity		

1/ Reference NAVSEA S9074-A2-GIB-010/AM-PBF to determine what NDT methods are invoked. Determine acceptance criteria class based on Tables 7 and 8 for VT, MT, PT, and RT.
2/ 'T' is defined as the shortest dimension between opposing surfaces through the discontinuity
3/ Use Class A criteria where NDT is invoked for AM procedure qualification per NAVSEA S9074-A2-GIB-010/AM-PBF

Table 7. PBF Acceptance Criteria Classes for Part Verification and Part Production (VT, MT, and PT)

PBF Part Application [1/]	VT/MT/PT [2/ 3/]
M-1	Class B
M-2	Class C
P-1, P-LT	Class A
P-2	Class B
A-1, A-2	Class A
A-3, A-4	Class B
A-F, A-LT	Class A
Turbine Parts	[4/]
Propulsion Reduction Gears & Steam Turbine Driven Auxiliary Gears	[4/]
Forced Draft Blowers	[4/]

1/ Application should be determined based on the definitions provided in NAVSEA S9074-AR-GIB-010A/278
2/ VT shall be performed on 100% of all accessible surfaces; MT or PT shall be performed on 100% of all accessible surfaces. Final inspection for VT, MT, and PT shall be performed in the final surface condition.
3/ Criteria classes are defined in Table 6.
4/ NDT criteria shall be approved by NAVSEA on a case basis.

Table 8. PBF Acceptance Criteria Classes for Part Verification and Part Production (RT)

Specimen Thickness (inches) [1/]	Criticality Level [2/]	Criteria Class [3/]
Less than 1	1	Class A
	2	Class B
	3	Class B
1 and Greater	1	Class B
	2	Class B
	3	Class B

NOTES:
1/ Specimen thickness per paragraph 3.2.4 of NAVSEA T9074-AS-GIB-010-271.
2/ Criticality level 1: Areas requiring 75 percent minimum RT coverage per NAVSEA S9074-AR-GIB-010/278 paragraph 12.5.3.
Criticality level 2: Areas requiring 50 percent minimum RT coverage per NAVSEA S9074-AR-GIB-010/278 paragraph 12.5.3.
Criticality level 3: Areas not requiring RT but are inadvertently radiographed or radiographed for information purposes.
3/ Criteria classes are defined in Table 6

Ref: (a) NAVSEA Technical Publication T9074-AS-GIB-010/271 Rev 1 of 11 Sep 14
(b) MIL-STD-2035A of 15 May 95
(c) MIL-STD-2132F of 27 Jun 22

1. NAVSEA provides the following guidance in qualifying Non-Destructive Testing (NDT) procedures to the acceptance criteria provided in enclosures (1) and (2) of the cover letter for AM product. Reference (a), paragraph 1.7.2, requires that NDT procedures are qualified by proving that known discontinuities, either natural or artificial, can be reliably detected and evaluated. The following should be considered when qualifying an NDT procedure in accordance with reference (a) paragraph 1.7.2:

    a. Discontinuities shall be representative of typical expected flaw types and shall be of a size near the threshold of acceptance or rejection.

    b. Conditions affecting discontinuity detectability must be consistent between production NDT inspections and NDT procedure qualification (e.g., geometry, grain size and orientation, surface finish, density).

    c. Qualification of an NDT procedure to workmanship based acceptance criteria, such as reference (b) Class 1, does not automatically translate to NDT procedure qualification for alternate acceptance criteria, and vice versa. This guidance should be used to determine if a qualified NDT procedure can be applied to another product with different criteria or discontinuities of interest.

    d. Alternative methods and techniques (e.g., computed tomography (CT), computed radiography (CR), digital radiography (DR), phased array ultrasonic testing (PAUT), or infrared thermography (IR)) may be used if conventional methods and techniques are determined ineffective. All alternative methods shall be qualified for the AM application as described in reference (a) paragraph 1.7.2.

    e. Alternative techniques for determining discontinuity acceptance (i.e. discontinuity characterization in lieu of amplitude and length or contrast disposition only) may be used if specifically approved by NAVSEA.

    f. The record of procedure qualification data and documentation must be submitted with any request to validate the technical adequacy of a procedure.

    g. Procedure qualification documentation should be collocated with the master copy of the procedure and all revisions.

2. Essential variables within an NDT procedure are those process attributes that have an effect on the performance, quality, and reliability of detecting discontinuities and evaluating indications. The minimally required essential variables are provided in enclosure (4), and are listed by inspection method. The following should be considered with regards to these essential variables when qualifying an NDT procedure in accordance with reference (a) paragraph 1.7.2:

a. Technical publications such as ASTM specifications, ASME codes, and government standards provide a range of acceptable allowances for essential variables; sometimes the variable is a minimum or maximum requirement. Such ranges are not intended to be directly copied by an activity into their procedure, but are offered as boundaries to construct the appropriate level of control and repeatability for the inspection and should be determined and specified in the procedure. Where ranges of an essential variable exists in a procedure, the extremes of the specified range shall have been demonstrated.

b. It is the Examiner's responsibility to identify and understand how the essential variables contained within their procedure affect the test. The Examiner is responsible for the procedure qualification and must demonstrate that the inspection, when performed within the specified bounds of the essential variables, is satisfactory.

c. Procedure qualification records must include the range demonstrated of each essential variable, a record of what was inspected, the inspection results, and any other pertinent information justifying why other variables may have not been demonstrated.

3. Special consideration for Ultrasonic Testing (UT) in accordance with reference (a).

(a) Where the AM product form offered for inspection prohibits satisfactory or complete shear wave angle beam coverage longitudinal straight beam may be used; provided the same or acoustically similar calibration reflectors and Test Metal Distances are used.

(b) When shear wave mode for angle beam may not be performed due to attenuation or noise limits, use of the longitudinal wave mode for angle beam testing may be qualified.

Full coverage for weldment inspection in accordance with reference (a) is defined by performing shear wave angle beam inspection where the sound beam is directed along the weld bead direction in two opposing directions and transverse to the weld bead direction in two opposing directions (i.e.- four legs of coverage). Unless otherwise permitted by the AM component's acceptance criteria, fabrication specification, and/or drawing; changes in the minimum coverage, wave mode, and/or longitudinal straight beam in lieu of shear wave angle beam shall be approved by the respective approval authority.

Calibration standards manufactured in accordance with reference (a) paragraph 6.2.1 requires that the acoustic velocity of the calibration standard be within ± 3% and that the acoustic penetrability be within ±1 dB of the material to be tested. It is foreseeable that achieving compliance to both singular data points for AM material is unlikely; as it is understood that subtle characteristics to AM process parameters (i.e. print direction, heat treatment, print orientation, alloying content, etc.) may result in the minute or gross variances in acoustic velocity and penetrability that can be localized or randomly distributed. When qualifying and inspecting to UT procedures for AM material, the following shall apply.

a. If acoustic velocity results do not conform to the ± 3% requirement, additional consideration shall be provided in the UT procedure as to the accuracy of indication charting and/or contain additional techniques for an inspector to apply in compensating for such variance. Acoustic velocity results shall be determined for each wave mode (longitudinal or shear) employed; and, where applicable and accessible, when changes to the AM process, build strategy, or form offered for inspection is suspected to have a negative impact on baseline acoustic velocity testing or assumptions.

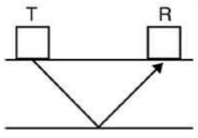
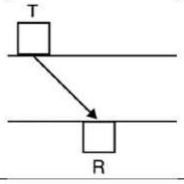
b. Acoustic penetrability testing and compensation is critical in ensuring that the minimum amount of gain needed to penetrate more attenuative cross sections of material is maintained during production scanning to meet the required sensitivity level. Acoustic penetrability (compatibility) testing shall be determined in accordance with reference (c) paragraph 8.4.2 with the following modifications; reference (c) paragraph 8.4.2 is attached to this letter as enclosure (5):

Reference (c) paragraph 8.4.2.(e) does not apply.

Tolerances for the thickness of the calibration standard shall be within the tolerances defined for the drawing of the material tested.

Acoustic compatibility testing shall be performed using search units of the same frequency, wave mode, and refracted angle used during production scanning. It is understood that it may not be practical to employ the same (e.g.-make/model) search units used for acoustic compatibility testing as used for inspection (i.e. use of dual element search units); but the frequency, wave mode, and refracted angle shall be the same.

Shear wave acoustic compatibility testing, as defined by reference (c) paragraph 8.4.2.2, may be used for both longitudinal wave angle beam and shear wave angle beam testing. For determining the compensation factor to account for the acoustic compatibility technique and technique used for production scanning the following table may be referenced:

Acoustic compatibility technique 1/	Examination	Compensation factor
	1-1/2 Node	3X
	Full-node	2X
	half-node	1X
	1-1/2 Node	6X
	Full node	4X
	Half-node	2X

1/ T = transmitting search unit; R = receiving search unit.

Use of prolongations for calibration standards does not exempt acoustic compatibility testing.

Alternative methods of acoustic compatibility may be qualified.

For each production scan, acoustic compatibility testing shall be performed through the cross section and across the inspection surface to be tested in order to identify areas of best and worst penetrability. It is recommended that a minimum of 8 readings be obtained, when practical. All acoustic compatibility readings, either initial or for indication disposition, shall be recorded on the calibration sheet, identifiable to which applicable production scan(s), and be part of the permanent record of inspection. It may not be presumed that acoustic compatibility results from one orientation may be applied to another.

For production scanning, the gain compensation determined from the worst case result of acoustic compatibility testing shall be applied in conjunction with the calibration gain. Additional scan gain (i.e. 6dB) may be used provided the noise levels are not prohibitive.

The noise level shall be below the production scan recording level (i.e., Disregard Level). Where acoustic compatibility testing results in a gain compensation that increases the noise level to a point where it meets or exceeds the production scan recording level, it shall not be considered a qualified inspection technique, and will require an evaluation of the setup to satisfy this noise level requirement. Other means such as reducing testing frequency, change in wave mode, switching from single to dual element search unit, segregating areas of penetrability, a combination thereof, or otherwise determined shall be qualified.

Where relevant indications are identified during production scanning, the acoustic compatibility testing results (gain compensation) obtained adjacent to such indications may be used in conjunction with calibration gain for indication disposition and not necessarily the overall worst case result. Only one acoustic compatibility reading need be obtained for each area of indication disposition. Acoustic compatibility results used in this effort shall be recorded for the applicable indication(s).

Essential Variables for NDT, Minimally Required

Visual (VT)
- Type of welds or surfaces to be inspected
- Measuring devices
- Visual aids
- List of inspection attributes
- Lighting requirements
- Acceptance criteria
- Record requirements

Magnetic Particle (MT)
- Applicable material, shapes, and sizes
- Type and direction of magnetization
- Equipment used for magnetization
- Surface preparation
- Wet or dry method to be used
- Continuous or residual method to be used
- Type of magnetic particles used
- Magnetizing current type and amount
- Demagnetization method and verification
- Particle concentration
- Sketches or charts for typical inspection grids
- Method of particle application and removal
- Acceptance standards
- Method to determine coating thickness

Penetrant Testing (PT)
- Penetrant materials used
- Details of pre-cleaning and drying
- Details of penetrant application
- Details of excess penetrant removal
- Details of developer application
- Method of post-test cleaning
- Acceptance standards

Radiography (RT)
- X-Ray machine model & type
- X-Ray machine manufacturer
- Focal spot size
- Voltage rating
- Isotope type & size
- Film processing methods
- Film type
- Viewing facilities
- Film density and measurement
- Film identification
- Acceptance standards

Ultrasonic Testing (UT)

- Applicable or exempt materials, shapes, and sizes
- Automatic defect alarm and recording equipment
- Special search units, wedges, shoes, or saddles
- Rotating, revolving feeding mechanisms
- Stage of manufacture when test will be made
- Surface from which test will be performed
- Surface finish
- Couplant
- Calibration method
- Scanning details
- Mode of transmission
- Transducer size, frequency, refracted angle
- Acceptance standards
- Method of recording inspection results
- Acoustic velocity
- Acoustic penetrability

Eddy Current (ET)

- Material to be tested
- Process used
- Equipment
- Performance verification description
- Surface preparation
- Calibration/normalization technique
- Scanning technique
- Evaluation criteria
- Recording and reporting requirements

Computed Radiography (CR)

- CR System manufacturer/model
- CR system maximum resolution (pixels/mm)
- CR scanner gain and data mappings settings
- Acquisition/processing/analysis software identification and version
- Inspection monitor manufacturer/model, display format, pixel pitch, and diagonal view dimensions
- Display bit depth, gray mapping type, limits, and allowable inspector adjustments
- Background illumination requirements for electronic viewing area
- Imaging plate manufacturer and series
- Filter and screen materials, thicknesses, and placement (e.g., source outlet, outside cassette, inside cassette)
- Digital image processing methods and analysis techniques employed
- Requirements to determine if sufficient contrast exists at edge of pipe wall
- Requirements to determine if reference standard is properly located and oriented
- Minimum exposure and/or minimum pixel value requirements
- Digital image file requirements to convert file to Digital Imaging and Communications in Medicine (DICOM) or Digital Imaging and Communications in Nondestructive Evaluation (DICONDE)
- Image archiving requirement, including software/hardware requirements to review archived files
- Digital image archiving media requirements (e.g., magnetic, optical or flash)

8.4.2 Acoustic compatibility. Unless otherwise specified or approved, the acoustic compatibility between separate calibration standards and the material to be ultrasonically examined shall be as follows:

a. The areas of best and worst acoustic penetrability shall be determined by scanning selected passes over the material that are representative of the material cross section.

b. If the sound penetration in the calibration standard is better than that in the worst area of the production material, the gain (or dB) shall be increased to compensate for the difference (e.g., back reflections at the same thickness shall be set equal).

c. Gain compensation shall not be used if the sound penetration in the calibration standard is poorer than that in the worst area of the production material. It shall be at the option of the organization as to whether or not to use the calibration standard or obtain a calibration standard which is more acoustically compatible.

d. When identical parts are cut from a single forging, they may all be examined using calibration reflectors machined into one of the parts.

e. The acoustic compatibility requirements for calibration standards for pipe and tube are addressed by the controls of 8.4.4.3.

8.4.2.1 Longitudinal wave. Acoustic compatibility between the longitudinal wave calibration standard and the material to be examined shall be determined by one of the two methods outlined below. Alternate methods shall be submitted for approval.

8.4.2.1.1 Method 1 for same test metal distance. To determine acoustic compatibility, a direct comparison shall be made between the back reflections of the calibration standard and the material under examination. The amplitude of the back reflection of the calibration standard, at that multiple of the back reflection that represents thickness of the material under examination, shall be compared to the first back reflection of the material under examination. The same equipment and settings shall be used for measuring the back reflections of the calibration standard and the material to be examined.

8.4.2.1.2 Method 2 for different test metal distances. Back reflections in the far field of the search unit shall be used for determining the attenuation (dB/inch) for both the material under examination and the calibration standard materials, as described below.

For instruments with dB gain controls:

Step 1. Calculate the near field length for the search unit to be used during the examination using the equation below that corresponds to the search unit to be used, where D is the diameter of the active element of a round search unit in inches, L is the longest side dimension of the active element of a rectangular search unit in inches, k is a dimensionless constant based on the aspect ratio of a rectangular search unit from Table IX below, f is the frequency of the search unit in hertz, and V is the velocity of sound in the material in inches per second.

Round search unit Rectangular search unit

$$Near\ field = \frac{D^2 f}{4V} \qquad Near\ field = \frac{kL^2 f}{4V}$$

Table IX. Values of dimensionless constant k based on search unit aspect ratio

Aspect ratio 1/	k
1.0	1.37
0.9	1.25
0.8	1.15
0.7	1.09
0.6	1.04
0.5	1.01
0.4	1.00
0.3 and below	0.99

1/ The aspect ratio is the shortest side dimension of the active element of a rectangular search unit divided by its longest side dimension. An aspect ratio of 1.0 corresponds to a search unit with a square element.

Multiply this result by three. This is the minimum sound path for back reflections in the far field of the search unit.

Step 2. If the thickness of the material under examination is greater than or equal to the sound path calculated in Step 1, the first and second back reflections (as counted after the initial pulse) shall be used as BR#1 in Step 3 and BR#2 in Step 4, respectively.

If the thickness of the material under examination is less than the sound

path calculated in Step 1, divide the sound path calculated in Step 1 by the thickness of the material under examination (if necessary, this result shall be rounded up to the next whole number). This result is the numbered back reflection (as counted after the initial pulse) that shall be used as BR#1 in Step 3. Multiply the numbered back reflection used as BR#1 by two. This result is the numbered back reflection (as counted after the initial pulse) that shall be used as BR#2 in Step 4.

Step 3. Adjust the instrument gain or dB attenuator controls to bring BR#1 to approximately 50 percent of the full screen height and record the instrument dB setting.

Step 4. On the same material, using the dB gain or attenuator controls, bring BR#2 to approximately 50 percent of the full screen height and record the instrument dB setting.

Step 5. Calculate the attenuation (dB/inch) using the following equation:

$$dB/_{inch} = \frac{BR\ \#2\ dB\ (Step\ 4) - BR\ \#1\ (Step\ 3) - 6dB}{material\ thickness\ x\ h}$$

Where h is the numbered back reflection (as counted after the initial pulse) used as BR#2 and material thickness is the thickness of the material under examination.

If the dB/inch value is less than zero, round up to zero.

Step 6. Repeat Steps 2 through 5 for each of the calibration standard materials, using the thickness of each calibration standard material where the thickness of material under examination is identified.

Step 7. Compare the attenuation of the material under examination with the calibration standard material with the lowest attenuation.

(a) If the dB/inch for the calibration standard material is less than that for the material under examination, compensation is required in accordance with 8.4.2(b). The minimum gain compensation shall be as determined by the following equation:

dB Compensation (min.) = [dB/inch(material under examination) - dB/inch(calibration standard material)] x 2 x thickness (material under examination)

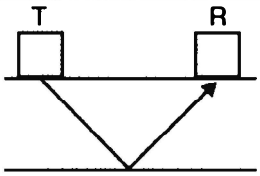
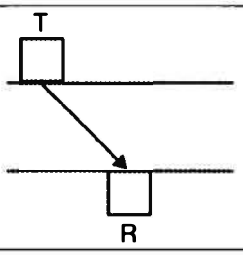
(b) If the dB/inch for the calibration standard material is greater than that of the material under examination, no gain compensation is permitted, per 8.4.2(c).

NOTE: For those instruments calibrated in dB attenuation, the dB values obtained for BR#1 and BR#2 are interchanged in the Step 5 calculation.

8.4.2.2 Shear wave. Acoustic compatibility between the production material and the shear wave calibration standard material shall be determined as follows:

a. Two shear mode search units of the same frequency and angle as those used for examination shall be located at the full-node or half-node on the material under measurement, and connected to the instrument as a dual element system. The transmitted signals for the calibration standard material and the production material shall be compared for the same total metal distance (within 10 percent) and adjusted per paragraph 8.4.2. The gain measured by this technique is increased by the compensation factor shown in Table X.

Table X. Compensation factor based on technique used and examination performed

Acoustic compatibility technique 1/	Examination	Compensation factor
	1-1/2 Node	3X
	Full-node	2X
	half-node	1X
	1-1/2 node	6X
	Full node	4X
	Half-node	2X

1/ T = transmitting search unit; R = receiving search unit.

b. Where part geometry or other factors preclude the use of this method, alternate methods may be submitted for approval.

8.4.3 Longitudinal wave calibration. Unless otherwise specified or approved, longitudinal wave calibration standards shall meet the following requirements. Longitudinal wave standards shall have flat-bottom holes (FBH) in accordance with Table XI. FBHs shall be drilled into the examination material or separate calibration standards normal to the examination surface. Test metal distances (TMDs) shall be as specified in Table XII for the multiple FBH calibration method or Table XIII for the single FBH calibration method.

As an alternative only for forgings (including forged bar and rod) greater than 24 inches as offered for acceptance, a TMD of T/2 + 1 inch may be used for the single FBH method (and Table XIII does not apply); for the multiple FBH method, TMDs of 1, 3, T/4, 3T/8, and T/2 + 1 inches may be used (and Table XII does not apply). Use of these TMDs shall require the examination to be performed from two opposite surfaces.

APPENDIX E

STANDARD PROCEDURE FOR ULTRASONIC EXAMINATION
(EXCLUDING THICKNESS MEASUREMENTS)

ORGANIZATION _____

PROCEDURE NUMBER _____

REVISION AND DATE _____

PREPARED BY _____

TITLE _____

EXAMINER SIGNATURE: _____

APPENDIX E

STANDARD PROCEDURE FOR ULTRASONIC EXAMINATION
(Excluding Thickness Measurements)

E.10 Scope. This procedure shall be used to perform ultrasonic examination of base material in accordance with the requirements of MIL-STD-2132. The addendum attached to this procedure identifies specific test details for the particular examination.

E.20 Personnel. Personnel performing the examination shall be qualified in accordance with the requirements of MIL-STD-2132.

E.30 Equipment. The following equipment that meets the requirements of MIL-STD-2132 shall be used:

(Organization to list equipment to be used here.)

E.30.1 Instrument horizontal and vertical linearity. The ultrasonic equipment shall have horizontal and vertical linearity within ± 5 percent for the usable portion of the screen as measured in accordance with ASTM E317 or other approved method. The linearity requirements shall also apply to all auxiliary circuits, such as back reflection attenuator gates, distance amplitude correction, etc., over the entire range of operation used for the examination.

E.30.1.1 Voltage regulation. External voltage fluctuations shall not produce a noticeable effect on the calibration of the ultrasonic equipment. If the ultrasonic equipment does not have effective internal voltage regulation, the external power supplied to the ultrasonic equipment shall be voltage regulated to ± 1 percent.

E.30.1.2 Attenuator accuracy. Calibrated signal attenuators, if used, shall be accurate to ± 10 percent of the nominal attenuation ratio at the examination frequency and range. The decibel (dB) attenuation value shall be converted to an amplitude ratio by use of tables with dB-versus-voltage ratios. Alternatively, it may be calculated from the relationship:

$$Amplitude\ Ratio = 10^{(\frac{dB}{20})}$$

E.30.1.3 Equipment stability. The equipment manufacturer's instructions for equipment warm-up shall be followed prior to calibration. If the manufacturer does not specify a time, then a minimum of 10 minutes shall be used.

E.30.2 Search unit frequency and method. The minimum ultrasonic frequency for the longitudinal and shear wave tests shall be 2.25 megahertz (MHz) and 1.0 MHz, respectively. If penetration cannot be achieved when using 2.25 MHz in longitudinal wave or if a back reflection from full thickness cannot be maintained, then a longitudinal test frequency of 1.0 MHz shall be used. If full-node shear wave calibration at 1.0 MHz cannot be achieved, the test shall be performed using a half-node shear wave calibration and scanning in two opposing directions from two opposite surfaces. Use of these alternatives is permitted only if necessitated by uncontrollable conditions such as grain size, and not by controllable conditions such as surface

finish. Use of these alternatives shall be documented in the test report and justified. Frequencies lower than 1.0 MHz shall not be used.

E.30.3 Shear wave test mode. When shear wave testing is specified, the shear mode of wave propagation shall be used. The ultrasonic refracted angle in the material shall be approximately 45 degrees, unless part geometry, such as hollow round shapes, precludes the use of this angle.

E.30.4 Search unit contact area and calibration standard curvature. The search unit contact area on the production part shall be equal to or greater than the search unit contact area on the calibration standard.

a. For examining convex production surfaces, the calibration standard shall be convex, with a radius of curvature equal to or less than the production surface to be examined.

b. For examining concave production surfaces, the calibration standard shall be concave, with a radius of curvature equal to or less than the production surface to be examined.

c. For convex or concave surfaces, when a wedge or shoe is used, it shall be shaped to the approximate curvature of the surface to be examined, and such that the contact area on the production part equals or exceeds the contact area on the calibration standard.

d. Curvatures over 90 inches in diameter can be considered flat.

E.40 Product form. Ultrasonic testing of product shall be performed in the form as offered for acceptance or as specified in the addendum.

E.50 Ultrasonic couplant and scanning aids. The couplant for ultrasonic testing shall be petroleum-based motor oil (SAE-10, -20, or -30) or water. Other couplants may be used provided the couplant does not violate the requirements of MIL-STD-2041, when applicable, and one or more of the following conditions exist:

a. The tests are performed after final liquid penetrant testing or liquid penetrant testing is not required.

b. The test surfaces will be steam cleaned prior to liquid penetrant testing.

c. If glycerin or similar couplants are used, test surfaces will be cleaned with a 50 percent water and 50 percent alcohol solution prior to liquid penetrant testing.

d. If ultrasonic testing is performed prior to required liquid penetrant examination, approval is obtained for alternate couplants and cleaning methods.

Material such as search unit facing (e.g., tape or rubber faces on search units) or matting (on the part surface) may be used to facilitate scanning and reduce search unit wear. Calibration shall be done with the scanning aid in place.

E.60 Surface finish of examination surfaces. The maximum surface finish roughness of all test surfaces shall not exceed 250 micro inches roughness height rating (Ra) measured in accordance with ASME B46.1. The surfaces shall be sufficiently free from waviness, burrs,

roughness, and other irregularities to permit an adequate and uniform test over the required area.

E.70 Calibration requirements.

E.70.1 Calibration standards. The calibration standards to be used are detailed in the addendum to this procedure. The surface finish of the calibration blocks shall not be smoother than the production test surface.

E.70.1.1 Acoustic compatibility. The acoustic compatibility between separate calibration standards and the material to be ultrasonically tested shall be as follows:

E.70.1.1.1 Longitudinal wave. Longitudinal wave acoustic compatibility between the calibration standard and the production material to be tested shall be established by one of the two methods outlined below. The addendum shall identify the applicable method.

E.70.1.1.1.1 Method 1 for same test metal distance. A direct comparison shall be made between the back reflection of the calibration standard material and the material under test to determine the acoustic compatibility. The amplitude of the back reflection obtained at that multiple back reflection of the calibration standard that represents the same test metal distance (TMD) as the first back reflection of the production material under test shall be compared. The same equipment and settings shall be used for measuring the responses from both the calibration standard and the material to be tested. Gain compensation to adjust for differences in acoustic compatibility shall be determined in accordance with E.70.1.1.3.

E.70.1.1.1.2 Method 2 for different test metal distances. Back reflections in the far field of the search unit shall be used for determining the attenuation (dB/inch) for both the material under examination and the calibration standard materials as follows:

For instruments with dB gain controls:

Step 1. Calculate the near field length for the search unit to be used during the examination using the equation below that corresponds to the search unit to be used, where D is the diameter of the active element of a round search unit in inches, L is the longest side dimension of the active element of a rectangular search unit in inches, k is a dimensionless constant based on the aspect ratio of a rectangular search unit from Table E-1 below, f is the frequency of the search unit in hertz, and V is the velocity of sound in the material in inches per second.

Round search unit	Rectangular search unit
$Near\ field = \frac{D^2 f}{4V}$	$Near\ field = \frac{kL^2 f}{4V}$

Table E-1. Values of dimensionless constant k based on search unit aspect ratio

Aspect ratio 1/	k
1.0	1.37
0.9	1.25
0.8	1.15
0.7	1.09
0.6	1.04
0.5	1.01
0.4	1.00
0.3 and below	0.99

1/ The aspect ratio is the shortest side dimension of the active element of a rectangular search unit divided by its longest side dimension. An aspect ratio of 1.0 corresponds to a search unit with a square element.

Multiply this result by three. This is the minimum sound path for back reflections in the far field of the search unit.

Step 2. If the thickness of the material under examination is greater than or equal to the sound path calculated in Step 1, the first and second back reflections (as counted after the initial pulse) shall be used as BR#1 in Step 3 and BR#2 in Step 4, respectively.

If the thickness of the material under examination is less than the sound path calculated in Step 1, divide the sound path calculated in Step 1 by the thickness of the material under examination (if necessary, this result shall be rounded up to the next whole number). This result is the numbered back reflection (as counted after the initial pulse) that shall be used as BR#1 in Step 3. Multiply the numbered back reflection used as BR#1 by two. This result is the numbered back reflection (as counted after the initial pulse) that shall be used as BR#2 in Step 4.

Step 3. Adjust the instrument dB gain or attenuator controls to bring BR#1 to 50 percent of the full screen height and record the instrument dB setting.

Step 4. On the same material, using the dB gain or attenuator controls, bring BR#2 to 50 percent of the full screen height and record the instrument dB setting.

Step 5. Calculate the attenuation (dB/inch) using the following formula:

$$dB/_{inch} = \frac{BR\#2\ dB\ (Step\ 4) - BR\#1\ dB\ (Step\ 3) - 6\ dB}{material\ thickness\ x\ h}$$

Where h is the numbered back reflection (as counted after the initial pulse) used as BR#2 and material thickness is the thickness of the material under examination.

If the dB/inch value is less than zero, round up to zero.

Step 6. Repeat Steps 2 through 5 for each of the calibration standard materials, using the thickness of each calibration standard material where the thickness of the material under examination is identified.

Step 7. Compare the attenuation of the material under examination with the calibration standard material with the lowest attenuation.

(a) If the dB/inch for the calibration standard material is less than that for the material under examination, compensation is required in accordance with E.70.1.1.3. The minimum dB compensation shall be calculated per this equation:

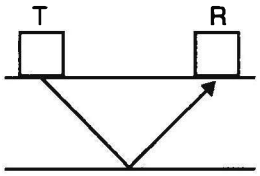
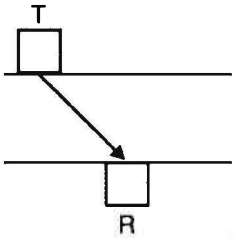
dB Compensation (min.) = [dB/inch(material under examination) - dB/inch(calibration standard material)] x 2 x thickness (material under examination)

(b) If the dB/inch for the calibration standard material is greater than that of the material under examination, no gain compensation is permitted in accordance with E.70.1.1.3.

NOTE: For those instruments calibrated in dB attenuation, the dB values obtained for BR#1 and BR#2 are interchanged in the Step 5 calculation.

E.70.1.1.2 Shear wave. Shear wave acoustic compatibility between the calibration standard and the production material to be tested shall be established as follows. Two shear wave search units of the same frequency and angle as those used for production examination shall be located at the full-node or half-node on the production material and connected to the instrument as a dual-element system. If the signal from the product is less than that from the calibration standard, additional gain shall be applied per E.70.1.1.3. The gain measured by this technique is increased by the compensation factor shown in Table E-2.

TABLE E-2. Compensation factor based on technique used and examination performed

Acoustic compatibility technique 1/	Examination	Compensation factor
	1-1/2 Node	3X
	Full-Node	2X
	Half-Node	1X
	1-1/2 Node	6X
	Full-Node	4X
	Half-Node	2X

1/ T=transmitting search unit; R = receiving search unit

E.70.1.1.3 Gain compensation. To determine whether gain compensation is required for acoustic compatibility:

a. Determine the areas of best and worst acoustic penetrability by scanning selected passes over the material that are representative of the material cross-section.

b. If the sound penetration in the calibration standard is better than that in the worst area of the production material, a change in the gain (or dB) controls shall be accomplished to compensate for the difference (e.g., back reflections at the same TMD shall be set equal).

c. Gain compensation shall not be used if the sound penetration in the calibration standard is poorer than that in the worst area of the production material. The ultrasonic examiner will determine whether to use the calibration standard or obtain a calibration standard that is more acoustically compatible.

E.70.1.1.4 Pipe and tube. Calibration standards for the ultrasonic testing of pipe and tube shall be made from ultrasonically defect-free pipe or tube of the same type, nominal wall thickness, and nominal outside diameter as the pipe or tube to be tested.

E.70.2 Calibration Methods.

E.70.2.1 Longitudinal wave. Longitudinal wave calibration shall be performed using one or both of the following methods as identified in the addendum.

E.70.2.1.1 Single flat-bottom hole method. The reference line for the longitudinal wave single flat-bottom hole (FBH) calibration method shall be constructed as follows:

a. Adjust the equipment so that the amplitude of the response from the FBH hole is between 80 and 100 percent of the full screen height.

b. At this gain setting, draw a line parallel to the sweep line over the full thickness range at the above amplitude height.

E.70.2.1.2 Multiple flat-bottom hole method. The reference line for the longitudinal wave multiple FBH calibration method shall be constructed as follows:

a. Adjust the ultrasonic equipment so that the response from the hole producing the lowest indication amplitude is at least twice the height of the production material noise level and at least 20 percent of the full screen height.

b. Draw straight line segments between the maximum amplitudes of the responses from the calibration FBHs.

c. Extend the line parallel to the sweep line in front of the first point to the zero depth position, and after the last point to the full thickness position.

d. When the reference line for the entire thickness range does not fall within the screen display using one gain setting, the reference line may be segmented using different gain settings provided there are overlaps between the segments. Overlaps are provided by using the longest TMD from the shorter thickness range as the first (shortest) TMD of the next (longer) thickness range.

e. If used, specific instructions for use of an electronically generated distance amplitude correction (DAC) curve, or automatic gain compensation which equalizes the responses from the required calibration FBHs shall be detailed in the addendum.

E.70.2.2 Shear wave. Except as permitted by E.70.2.2.2 and E.70.2.2.3, or as identified in the addendum, the full-node calibration method below for shear wave testing shall be used.

E.70.2.2.1 Full-node calibration method. The reference line for the shear wave full-node calibration method shall be constructed as follows:

a. Adjust the gain such that the indication from the notch producing the lowest amplitude is at least 20 percent of the full screen height and at least twice the height of the material noise. Where possible, the response from the notches shall be checked for symmetry by positioning the search unit in opposing directions. If a difference is noted, the smaller signal amplitudes shall be used to construct the reference line.

b. Draw a straight line between the half-node and full-node peaks of the first reflections obtained from the two notches.

c. Extend the line parallel to the sweep line in front of the first point to the zero depth position.

d. An electronically generated DAC curve or automatic gain compensation that equalizes the responses from the required calibration notches may be used.

E.70.2.2.2 Half-node calibration method. If the indication from the full-node notch cannot be obtained at least 20 percent of the full screen height and twice the height of the material noise level, the reference line for the shear wave half-node calibration method shall be constructed as follows:

a. Adjust the equipment so that the amplitude of the response from the half-node notch is between 80 and 100 percent of the full screen height. Where possible, the response from the notch shall be checked for symmetry by positioning the search unit in opposing directions. If a difference is noted, the smaller signal amplitude shall be used to construct the reference line.

b. At this gain setting, draw a line parallel to the sweep line, at the above amplitude height, from the zero depth position to the half-node peak.

c. Scanning shall be performed from both (opposite) surfaces in two opposing scanning directions.

E.70.2.2.3 Calibration for pipe and tube. The reference line for pipe and tube shall be constructed as follows:

a. For immersion, adjust the ultrasonic beam refracted angle to equalize the peak response from both the inside diameter (ID) (half-node) and outside diameter (OD) (full-node) notches, and set as the reference line.

b. For contact, the smaller of the peak ID and OD responses shall be set as the reference line, as long as the peak responses are within 2 dB of each other. If the peak responses are not within 2 dB, the refracted angle may be adjusted to bring the peak responses within 2 dB. If the peak response difference is greater than 2 dB, the use of an alternate ultrasonic test procedure is permitted, if approved.

c. Adjust the ultrasonic instrument gain such that the reference line is at least 50 percent but not more than 90 percent of the full screen height.

d. Draw a straight line from the half-node to the full-node peaks of the first reflections obtained from the two notches.

e. Extend the line parallel to the sweep in front of the half-node signal to the zero depth position.

f. After establishing the refracted angles and equalization per (a) or (b), an electronic DAC curve may be used.

E.70.2.3 Calibration gain. Calibration gain shall be the instrument gain used to establish the reference line, plus any acoustic compatibility gain compensation required by E.70.1.1.3(b).

E.70.2.4 Frequency of calibration checks. A check of the calibration shall be performed at the following stages of testing, or whenever one of the following conditions exists.

a. Beginning of the testing.

b. At intervals not exceeding 4 hours.

c. When the equipment has been left unattended.

d. Whenever there is a change in test personnel.

e. When there is a change in equipment or accessories that may affect test results.

f. When changes in the electrical power supply system that affect the ultrasonic test are noted.

g. At the end of a shift.

h. At the completion of the test.

E.70.2.4.1 Frequency of recalibration. Any realignment of the search unit with respect to the material, or any change in the search unit, couplant, instrument settings, or scanning speed from that used for calibration shall require recalibration.

E.70.2.4.1.1 Loss of response. If during the calibration check a 15 percent or greater loss in the response from the flat-bottom hole or notch is noted, the required calibration shall be re-established and all the material tested since the last calibration shall be re-tested. Where calibration requires multiple TMDs, the calibration check may be accomplished by verifying the response from the near and far TMDs.

E.80 Scanning.

E.80.1 Scanning surfaces and directions. Specific information regarding the test surfaces and scanning directions is identified in the addendum.

E.80.2 Manual scanning. Manual scanning speeds shall not exceed a surface speed of six inches per second and shall have a minimum overlap of 25 percent of the dimension inscribed on the search unit, or the contact area of the active element, whichever is less. Scanning shall be accomplished with a gain at least double the calibration gain (see E.70.2.3). For instruments calibrated in dB, an increase of 6 dB doubles the gain. However, where the general noise level precludes scanning at 2X, scanning shall be performed at a gain as high as possible but in no case shall scanning be performed at a gain less than the calibration gain.

E.80.3 Automatic scanning. For automatic scanning, the part or search unit movement and rotation shall be maintained at a uniform speed. The scanning gain, alarm level, index increment, and speed of the part or search unit shall be set so that the indication amplitude from

the calibration holes or notches is above the reference line on two adjacent scans at production speed.

E.80.4 Separate test for loss of back reflection. When a separate test for loss of back reflection is necessary, a search unit no larger than 1-1/8 inch in diameter shall be used. The first back reflection in an indication-free area of the production material, in the area of worst penetrability as determined in E.70.1.1.3(a), shall be between 80 and 100 percent of the full screen height, and the part scanned for loss of back reflection. Loss of back reflection shall be evaluated as to percent loss, provided the loss is not caused by nonparallel surfaces, change in part geometry, surface irregularities, or penetrability differences. Complete (100 percent) loss of back reflection is when the back reflection is no longer discernible above the base line or material noise level, if present.

E.80.5 Sound penetration monitoring. A back reflection obtainable while testing at production scanning speed shall be monitored to ensure adequate couplant and search unit surface contact conditions. Where no back reflection exists because of nonparallel surfaces, or with shear wave testing, sound penetration into the material shall be confirmed by monitoring the material noise level, if possible.

E.80.6 Automatic alarming devices. For examination using automatic alarming devices, the alert level shall be based on the lowest response amplitude of the reference line and shall be calibrated to detect the specified reportable conditions.

E.90 Ultrasonic evaluation.

E.90.1 Instrument gain for evaluation of indications. All indications shall be evaluated against the reference line using the calibration gain of E.70.2.3. In the event that an indication occurs in an area other than that of poorest penetrability, the back reflection in the area adjacent to the indication may be compared to the calibration standard back reflection and the gain adjusted in accordance with E.70.1.1.3 for the evaluation of the indication to the reference line.

E.90.2 Indications. All indications equal to or greater than the specified reporting level shall be maximized and evaluated to the acceptance criteria using the maximized response. Reinspection of rejectable indications using other approved parameters is prohibited, with the following exceptions:

a. A smaller search unit of the same frequency may be used, and the final evaluation may be adjusted accordingly, if the search unit is calibrated and included in the approved standard addendum.

b. Indications detected with scanning aids in place may be reevaluated with the original search unit (or a smaller search unit of the same frequency per (a) above) and scanning aids either removed or left in place. Search units with scanning aids removed shall be calibrated and included in the approved standard addendum.

E.90.3 Loss of back reflection. When the material/process specification contains acceptance criteria for defect and loss of back reflection evaluation, the material shall be examined for both indications and loss of back reflection. Evaluation for loss of back reflection is not limited to areas where there are reportable indications. When inspecting for indications only to the material mid-thickness, monitoring and evaluation for loss of back reflection is still

required and shall be a separate scan per E80.4. If the examination for loss of back reflection cannot be performed due to uncontrollable conditions such as grain size, it shall be documented in the examination report and justified therein. Any indications greater than or equal to the reporting level shall also be evaluated for the percent loss of back reflection from each test direction. Losses attributable to nonparallel surfaces, changes in part geometry, or surface irregularities need not be evaluated or reported. The loss of back reflection may be evaluated against the specified acceptance criteria using back reflections other than the first reflection, provided it is within the usable portion of the screen and does not interfere with the defect examination. Alternatively, a separate scan or electronic compensation shall be used to evaluate the loss of back reflection.

E.90.3.1 Reportable loss of back reflection. Areas producing loss of back reflection, regardless of the presence or absence of a reportable indication or discontinuity, shall be reported when the back reflection falls to within 25 percent of the full screen height above the rejectable loss of back reflection screen height (e.g., if the acceptance criteria specifies that complete or 100 percent loss of back reflection be rejected, back reflections 25 percent or less of the full screen height shall be reported).

E.90.4 Traveling indications. When acceptance or reporting criteria for traveling indications is specified in the addendum, reportable longitudinal wave indications shall be evaluated to determine if they are traveling. A traveling indication is a reportable indication that moves in depth a distance equal to or greater than 10 percent of the material thickness being tested, or 1 inch, whichever is less (as measured by horizontal movement on the instrument screen), with movement of the search unit.

E.100 Test report. A test report in accordance with MIL-STD-2132 shall be completed. Reporting levels and acceptance criteria are identified in the addendum. If the noise level precludes meeting the specified reporting level, the reporting level shall be established to be 15 percent of the full screen height above the noise level provided that the noise level does not exceed 50 percent of the reference line. The noise level shall be reported when the specified reporting level cannot be met.