



**Prime Inspections, Inc.**

# **Manual Ultrasonic (MUT) Examination Carbon-Steel Pipeline Girth Welds**

**Procedure No.: PII-TC-MUT | Revision: 0 | Effective: 2026-07-28**

Applicable Project: TC Energy (USA)

## **Technical Approval**

**Joshua de Monbrun, CEng -  
Consultant**

## **Quality Approval**

**Oscar Gonzales - VP of Quality**

## **Company Approval for Use**

### Code & Specification Basis

- API 1104, Welding of Pipelines and Related Facilities — 21st Edition (with current addenda) — §11.5; §9.6; Annex A (ECA); Annex B (Alternative UT Acceptance for Girth Welds).
- ASME BPVC Section V, Article 4 — Ultrasonic Examination Methods for Welds (2025 Edition).
- ASME BPVC Section V, Article 23 — SE-2491 (Linearity).
- ISO 17640 — Ultrasonic Testing — Techniques, Testing Levels, & Assessment.
- TC Energy TES-NE-MUT-G — Manual Ultrasonic Examination of Girth Welds (CAN-US-MEX), Item ID 004497443.
- TC Energy TEN-NE-NDE — Nondestructive Testing Standard (CDN-US-MEX), Item ID 1001828336.
- TC Energy Operator Qualification Program, Item ID 004504739 — Covered Task VF206 (NDT of Welds — Ultrasonic).
- ASNT SNT-TC-1A (2024); ANSI/ASNT CP-189; ISO 9712.

## Revision History

| Rev | Date       | Prepared / Approved         | Description of Change                                                                                                                                                                                                                                                                                                                                     |
|-----|------------|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0   | 2026-07-28 | J. de Monbrun / O. Gonzales | Initial issue of Prime Inspections, Inc. (PII) controlled procedure under the PII Quality Management System. Issued as Rev 0 — no prior PII revision history. Aligned with API 1104 21st Edition (with current addenda), ASME BPVC Section V (2025 Edition), and the current TC Energy TES/TEN/TEP series specifications applicable to the project scope. |

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## 1.0 Scope and Limitations

- 1.1. This procedure establishes the minimum requirements implemented by Prime Inspections, Inc. (PII) for performing Manual Ultrasonic Testing (MUT) on TC Energy projects, in accordance with TC Energy TES-NE-MUT-G (Manual Ultrasonic Examination of Girth Welds), API 1104 21st Edition, and ASME BPVC Section V Article 4.
- 1.2. Application
  - 1.2.1. Single-element manual contact shear-wave examination of weld metal and heat-affected zones, 0° longitudinal-wave wall-thickness measurement, and 0° lamination detection in pipe and associated components.
  - 1.2.2. This procedure applies to materials having a nominal wall thickness greater than or equal to  $\geq 6.4$  mm (0.250 in.).
  - 1.2.3. Examination of material less than  $< 6.4$  mm (0.250 in.) is outside the qualified scope of this procedure and shall be performed only under a separate, approved technique sheet or procedure authorized by the TC Energy Company NDE Subject Matter Expert before execution.
- 1.3. Qualification - This procedure is qualified for production use based on:
  - 1.3.1. TC Energy assets in the United States. The governing code, regulatory basis, project specification, weld configuration, and acceptance criteria shall be identified on the approved project Technique Sheet.
  - 1.3.2. Satisfactory demonstration on a project-specific mock-up containing known reflectors representative of the production weld configuration.
  - 1.3.3. Demonstration shall be conducted as described in API 1104 21st Ed. and shall be reviewed and consented to by the PII Level III in UT and the TC Energy Authorized Representative prior to the start of production work.
- 1.4. Out of Scope
  - 1.4.1. Automated Ultrasonic Testing (AUT) - covered by TC Energy TES-NE-AUT-GL (Item ID 1001828660).
  - 1.4.2. Phased Array (PAUT) and Time-of-Flight TOFD - covered by PII-TC-PAUT Rev0 / TES-NDT-PA.
  - 1.4.3. Structural Steel Welds fabricated to AWS D1.1.
  - 1.4.4. Austenitic-steel and nickel-alloy welds (ISO 22825) - require project-specific procedure with additional grain-noise and skew-angle qualification approved by Level III.
- 1.5. Where this procedure, API 1104, ASME Section V, or the applicable TC Energy specification does not explicitly address a required condition, PII shall identify the gap, notify TC Energy, apply the more conservative interpretation, and document the method used. Where requirements conflict, the more stringent shall govern.
- 1.6. Where a governmental, regulatory, code, project, or TC Energy requirement conflicts with this procedure, the more stringent requirement shall govern, except where regulation mandates use of an alternate requirement. The conflict and disposition shall be documented.

- 1.7. The Company reserves the right to perform additional NDE during or after welding and may require removal of a weld for destructive or other examination when deemed necessary.

## 2.0 References (Latest Editions Unless Stated)

### 2.1. Industry Codes and Standards

- 2.1.1. API 1104, 21st Edition (2021, with current addenda) §11.5; §9.6.
- 2.1.2. ASME BPVC Section V, Article 4 (2025 Ed.), Ultrasonic Examination Methods for Welds.
- 2.1.3. ASME BPVC Section V, Article 5 (2025 Ed.), Ultrasonic Examination Methods for Materials.
- 2.1.4. ISO 22232-1, 2, 3; Characterization and verification of ultrasonic test equipment.
- 2.1.5. ASNT SNT-TC-1A (2024); ANSI/ASNT CP-189; ISO 9712 — Personnel qualification.

### 2.2. TC Energy Specifications

- 2.2.1. TES-NE-MUT-G, Manual Ultrasonic Examination of Girth Welds (CAN-US-MEX), Item ID 004497443, Rev04.
- 2.2.2. TEN-NE-NDE, Nondestructive Testing Standard (CAN-US-MEX), Item ID 1001828336.
- 2.2.3. TEP-NE-TQ-G, Procedure for the Technical Qualification of Nondestructive Examination Providers, Item ID 004896672.
- 2.2.4. TEP-NE-ADT-G, Nondestructive Examination Audits (CAN-US-MEX), Item ID 003797402.
- 2.2.5. TC Energy Operator Qualification Program, Item ID 004504739, Covered Task VF206.
- 2.2.6. TC Energy Controlled Document Library Variance Procedure (CAN-US-MEX), Item ID 007728702.

### 2.3. Regulatory References

- 2.3.1. 49 CFR Part 192 (PHMSA Natural Gas).

### 2.4. PII Internal Documents

- 2.4.1. PII-WP-1, Written Practice (SNT-TC-1A 2024 Ed.), including PAUT-specific qualification topics.
- 2.4.2. PII-MUT-CAL-01, MUT Calibration Record.
- 2.4.3. PII-MUT-RPT-01, MUT Examination Report Template.
- 2.4.4. PII-QM-01, Quality Manual.

## 3.0 Definitions and Acronyms

| Term | Definition                                                      |
|------|-----------------------------------------------------------------|
| AUT  | Automated Ultrasonic Testing — out of scope for this procedure. |

| Term                | Definition                                                                                                                                                                                     |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Company             | TC Energy and its affiliates for whom the work is being performed.                                                                                                                             |
| Company NDE SME     | The TC Energy technical authority responsible for regional NDE oversight, compliance, and approval.                                                                                            |
| Contractor          | Prime Inspections, Inc., the ultrasonic inspection provider performing work under this procedure.                                                                                              |
| DAC                 | Distance Amplitude Correction.                                                                                                                                                                 |
| Evaluation Level    | The calibrated sensitivity used to investigate and characterize indications.                                                                                                                   |
| FSH                 | Full Screen Height of the A-scan display.                                                                                                                                                      |
| HAZ                 | Heat-Affected Zone.                                                                                                                                                                            |
| MUT                 | Manual Ultrasonic Testing using conventional single-element contact techniques.                                                                                                                |
| Reference Level     | The calibrated response established from the applicable reference reflector.                                                                                                                   |
| Scanning Level      | The gain used to search the examination volume, normally the reference level plus 6 dB for amplitude-based examination.                                                                        |
| Technique Sheet     | A project- and configuration-specific written instruction defining the weld geometry, thickness range, equipment, calibration, scan paths, sensitivity levels, coverage, and acceptance basis. |
| Transfer Correction | A dB correction applied when acoustic response differs between the calibration block and the production component.                                                                             |

## 4.0 Personnel Qualifications

- 4.1. Before performing manual ultrasonic testing on TC Energy projects, PII shall be technically qualified in accordance with TEP-NE-TQ-G, Item ID 004896672, as applicable to the contract.
- 4.2. MUT Technicians shall be currently qualified and certified to Level II or Level III in the ultrasonic method in accordance with PII-EP-1, ASNT SNT-TC-1A, ANSI/ASNT CP-189, ISO 9712, or an equivalent standard acceptable to TC Energy. Current qualification evidence shall be available to the Company.
- 4.3. **Personnel Qualification**
  - 4.3.1. Level I personnel may perform only 0° lamination scanning and/or wall-thickness measurements under the direction of a Level II or III MUT Technician. Level I personnel shall use written work instructions and shall refer all indication disposition to a Level II or III UT authority.

- 4.3.2. Level II personnel may perform calibration, examination, evaluation, interpretation, and reporting within the scope of their certification and the approved Technique Sheet.
- 4.3.3. Level III personnel must be qualified to the ANSI/ACCP Standard CP-189 in the UT method and must submit their records of current certification to TC Energy.
- 4.4. TC Energy may review personnel qualification records, directly observe work, and exclude individuals who lack the required training or experience or who demonstrate an inability to perform the prescribed examination.
- 4.5. When required by TC Energy, a minimum of one-day training for Company Inspectors will be provided before production begins.
- 4.6. Training records shall be retained by PII and made available for TC Energy to audit.
- 4.7. Mock-Up Demonstration

When required by the client or referencing code, the technician shall have participated in and successfully demonstrated detection and evaluation of flaws in mock-up(s) representative of the production weld type. Mock-up qualification records shall be on file and shall be re-qualified per the interval specified in PII-WP-1 or the project specification, whichever is more stringent.

#### 4.8. Operator Qualification (TC Energy U.S.)

Personnel shall hold a current qualification on Covered Task VF206 (Non-Destructive Testing of Welds — Ultrasonic) per the TC Energy Operator Qualification Program (Item ID 004504739) before performing work on TC Energy U.S. assets.

- 4.9. Vision — Annual Jaeger J-1 (or equivalent) near-vision examination at  $\geq 12$  in. (corrected or uncorrected, one eye) and color-contrast examination shall be documented for all NDT personnel.

## 5.0 Safety

- 5.1. PII personnel shall comply with all TC Energy site-specific safety rules. A Job Hazard Analysis (JHA) shall be completed and signed by all crew members each day prior to commencing work; a pre-job safety brief shall be held.
- 5.2. Minimum PPE: hard hat, ANSI Z87.1 eyewear, FR coveralls (as required), ASTM F2412/F2413 footwear, cut-resistant gloves, hearing and respiratory protection per site posting.
- 5.3. Couplant Handling: Per the manufacturer's SDS. Methanol additives used for cold-weather operations shall be recovered and disposed of in accordance with TC Energy's environmental requirements.
- 5.4. Electrical Hazards: Instruments shall be inspected for damaged cables/connectors before each shift; GFCI protection on all 120 VAC power sources; instrument grounding verified.
- 5.5. Should clarification of any safety requirement be needed, work shall be stopped, and the PII Site Supervisor or Project Manager contacted before resuming.

## 6.0 Equipment — Instrument, Transducers, Wedges, and Accessories

### 6.1. Instrument Requirements

- 6.1.1. A calibrated portable pulse-echo ultrasonic flaw detector with a linear A-scan presentation shall be used. The instrument shall meet ASME BPVC Section V, Article 4, Paragraphs T-431 and T-461, when applicable.
- 6.1.2. The instrument shall operate over at least 2.25 MHz to 7.5 MHz and shall provide stepped gain control in increments of 2 dB or less.
- 6.1.3. Reject or suppression shall remain off unless it has been demonstrated that its use does not affect examination linearity or required sensitivity. Filters and damping shall be maintained in the same positions during calibration and examination.

### 6.2. Instrument Linearity and Performance

- 6.2.1. Screen-height linearity, amplitude-control linearity, and instrument performance shall be verified in accordance with the applicable ASME Section V requirements.
- 6.2.2. Linearity checks shall be performed at intervals not exceeding three months for analog instruments and one year for digital instruments, or before first use after the interval.

### 6.3. Transducers and Wedges

- 6.3.1. Transducers shall comply with BS EN ISO 22232-2 and shall have a nominal frequency between 2.25 MHz and 7.5 MHz unless an alternate frequency is defined in the approved Technique Sheet and approved by the Company NDE SME.
- 6.3.2. Materials with coarse-grained structure may require an alternate frequency to achieve adequate penetration and resolution. Any alternate shall be demonstrated and approved before use.
- 6.3.3. The active crystal dimension shall not exceed 12.7 mm (0.500 in.) unless specifically defined and approved in the Technique Sheet.
- 6.3.4. Angle-beam transducers shall be mounted on wedges producing measured refracted angles within 1.5° of 45°, 60°, or 70°. Fixed or removable wedge designs are permitted.
- 6.3.5. The exit point and actual refracted angle shall be determined on an IIW block or equivalent and marked or otherwise traceably identified for each search unit.
- 6.3.6. Examinations on pipe less than NPS 14 shall use wedges contoured to the examination surface. The contour shall provide stable coupling without rocking and shall be recorded on the Technique Sheet.

### 6.4. Straight-Beam Transducers

- 6.4.1. Straight-beam transducers suitable for wall-thickness measurement and lamination detection shall be available for all examinations.
- 6.4.2. For wall thickness less than 10.0 mm (0.394 in.), delay-line or dual-element transducers are preferred when they improve near-surface resolution and measurement reliability.

## 6.5. Identification and Accessories

- 6.5.1. Instrument, transducers, wedges, cables, and calibration blocks shall be uniquely identified and recorded on the calibration record or Technique Sheet.
- 6.5.2. A calibrated temperature-measurement device, suitable markers, cleaning materials, and any contour gauges or dimensional tools required by the Technique Sheet shall be available.
- 6.5.3. For component temperatures above the normal range of the transducer or wedge, equipment rated for the examination temperature shall be used and documented.

## 7.0 Couplant

- 7.1. Couplant shall be water or water-based gel. Oil-based couplants are PROHIBITED.
- 7.2. Couplant shall not be detrimental to the materials being examined and shall be completely removed from the work surface upon completion of inspection.
- 7.3. For cold-weather operations, methanol may be added. The methanol-water mixture shall be recovered and disposed of in accordance with TC Energy's environmental requirements.
- 7.4. The couplant used for examinations shall be the same as that used for calibration.
- 7.5. For austenitic / nickel-alloy applications, couplant chloride + sulfur content shall be verified  $\leq 250$  ppm with a manufacturer's Certificate of Conformance retained.

## 8.0 Calibration Blocks, Reference Standards, and Reflectors

### 8.1. Calibration Blocks & Reference Blocks

- 8.1.1. Calibration blocks (e.g., IIW Type-2, multi-step, etc.) are used to establish initial calibration parameters (delay, velocity). "Reference blocks" are used to establish the required examination sensitivity (gain, DAC) or primary reference response.
- 8.1.2. For examination of material with a surface diameter  $\leq$  NPS 20 (508 mm), a curved reference standards must be used. Curved reference standards must be between 0.9 to 1.5 times the nominal pipe diameter being inspected and within 25% of the nominal wall thickness being inspected.
- 8.1.3. Basic calibration blocks may be used for materials  $>$  NPS 20 (508 mm) as per ASME V, Article 4.
- 8.1.4. A multi-step thickness block of similar material shall be used for thickness calibration. The block shall include thicknesses above and below the expected production thickness.

8.1.5. Transfer correction must be performed on the calibration block that meets ASME V requirements and on the examination component for each different material and thickness.

## 8.2. Reflectors

Specified reflectors (side-drilled holes, flat-bottom holes, notches) shall be used to establish the primary reference response of the equipment.

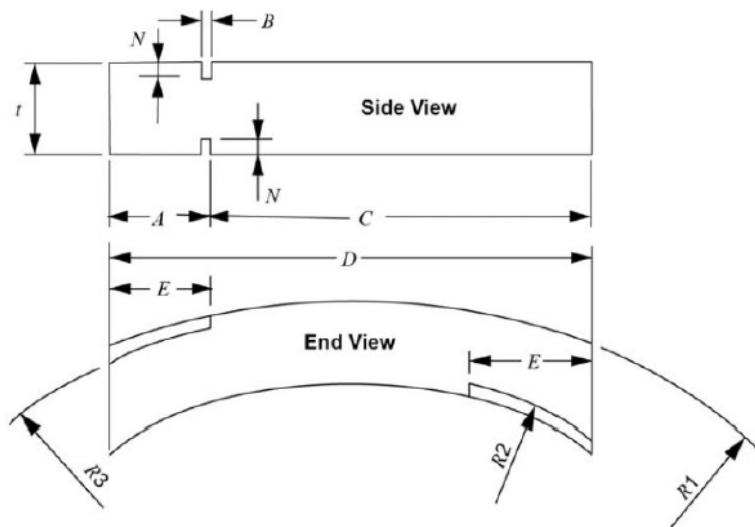
## 8.3. Material

Block material shall be of the same product form and material specification — or equivalent ASME P-Number grouping — as the production material. ASME P-Nos. 1, 3, 4, 5A through 5C, and 15A through 15F are considered equivalent.

## 8.4. API 1104 Sensitivity Reference Standard (per API 1104 §11.5.4 / Figure 1)

When API 1104 requires a project-specific reference standard or procedure demonstration block, the standard shall be fabricated from approved project material and shall represent the production pipe and weld configuration, as approved by TC Energy. Before fabrication or use, reference-block beam paths shall be examined by straight beam. Areas containing indications that exceed the remaining back-wall response shall not be used for required sound paths

Dimensions:



**Figure 1: Example of Reference Standard for Ultrasonic Testing**

| Symbol | Description                                      |
|--------|--------------------------------------------------|
| t      | Specified pipe wall thickness.                   |
| N      | Notch depth $\pm 10\% t \pm 10\%$ of notch depth |
| A      | 2 in. (50 mm) minimum                            |
| a      | 0.125 in. (3.2 mm) maximum notch width           |
| b      | $11.35t + 2$ in. (50 mm) minimum length          |

| Symbol | Description                                                  |
|--------|--------------------------------------------------------------|
| c      | 3.1 in. (80 mm) minimum width                                |
| d      | 1 in. (25 mm) minimum notch length                           |
| R1     | Outside radius of pipe.                                      |
| R2     | Radius of inside notch $\geq R1 - 0.1t$                      |
| R3     | Radius of outside diameter notch at depth - $\geq R1 - 0.1t$ |

#### 8.5. Block Examination

Prior to use, the block material shall be completely examined with a straight-beam search unit. Areas containing indications exceeding the remaining back reflection shall be excluded from beam paths required to reach the reference reflectors.

#### 8.6. Heat Treatment

Block shall receive at least the minimum tempering treatment required by the material specification. If the production weld has been post-weld heat-treated, the block shall receive the same heat treatment.

#### 8.7. Surface Finish

The scanning surface of the block shall be representative of the production component's surface finish.

#### 8.8. Temperature

Block temperature during calibration, examination, and verification shall be within  $\pm 14^{\circ}\text{C}$  ( $25^{\circ}\text{F}$ ) of the component temperature. Block temperature shall be recorded at initial calibration and at each verification.

#### 8.9. Component Temperature

Surface temperature of the production component shall be recorded on the examination record prior to performing the examination. Ambient may be recorded when the component is at ambient temperature.

## 9.0 Technique Sheet Requirements

9.1. Manual ultrasonic examination shall be performed to a documented, detailed procedure and a written Technique Sheet that ensures the entire required weld volume and HAZ are examined.

9.2. A Technique Sheet shall be prepared for each qualified range of wall thickness and each variation in bevel or joint configuration. At a minimum, it shall identify:

9.2.1. Project, asset, job number, governing code, TC Energy specification revision, and acceptance basis.

9.2.2. Pipe diameter, nominal and measured wall thickness, material, product form, weld type, weld process, bevel geometry, root configuration, and cap condition.

- 9.2.3. Examination surface, access restrictions, scan directions, search-unit positions, and required coverage of weld, HAZ, and adjacent base metal.
- 9.2.4. Instrument, transducers, wedge identifiers, measured angles, frequencies, crystal sizes, wedge contour, cables, and couplant.
- 9.2.5. Calibration blocks, reference reflectors, range, material velocities, DAC points, reference gain, scanning gain, evaluation gain, transfer correction, and temperature limits.
- 9.2.6. 0° thickness and lamination technique; root scan; full-volume raster scan; transverse-reflector scan; scan speed; minimum overlap; and any supplemental 45° examination.
- 9.2.7. Indication evaluation and sizing methods, reporting threshold, acceptance criteria, and treatment of limited coverage.

### **9.3. Coverage Requirements**

- 9.3.1. The examination coverage shall include the weld, the heat-affected zone, and the adjacent base metal. At a minimum, the examination volume shall include the weld and 6 mm (0.250 in.) of the adjacent base metal on each side of the weld.
- 9.3.2. A critical examination of the root must be performed before completing a full weld volume and HAZ scan using a rastering (zigzag) scan pattern with the axis of the beam perpendicular to the weld.
- 9.3.3. Raster scanning must provide for a minimum 30% overlap of the beam width.
- 9.3.4. Where physical access or geometry limits volumetric coverage, the examination limitations must be clearly documented and reviewed with the Company prior to acceptance of results.

### **9.4. Scan Speed and Surface Preparation**

- 9.4.1. Acquisition speed shall not exceed 150 mm (6.0 in.) per second.
- 9.4.2. Manual transverse and lamination scanning speed  $\leq$  150 mm (6.0 in.) per second.
- 9.4.3. Scanning surface shall be free of obstructions and shall be buffed clean prior to inspection. The weld cap may require removal where applicable, according to the scan plan.

### **9.5. Scanning Sensitivity**

- 9.5.1. Scanning sensitivity shall be +6 dB above primary reference sensitivity, unless geometry or noise prevents readable data.
- 9.5.2. When noise > 20% FSH, a +6 dB scan AND a scan at reference sensitivity shall both be performed and recorded.

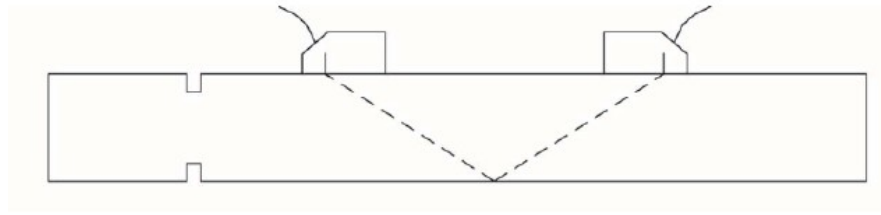
### **9.6. Gate Settings**

- 9.6.1. Gate amplitude threshold: 10% FSH (maximum 20% FSH when noise prevents useful data at 10%).

### **9.7. Transfer Correction**

- 9.7.1. When the calibration block is not of the same product form or heat treatment as the production component, transfer correction shall be determined by ASME V Article 4 T-451 by comparing the corresponding

reference-reflector responses, or by the pitch-catch sound-velocity method (see Figure 2). Transfer correction shall be applied to the primary reference level before the +6dB scanning sensitivity. The applied dB correction shall be captured on the PAUT report.



**Figure 2: Example, Attenuation and Transfer Procedure**

9.7.2. Refer to §23 “Attachment A” for Transfer Correction Procedure.

## **9.8. Temperature**

9.8.1. Temperature variations > 14°C (25°F) between the calibration block and the examination material are NOT permitted without prior Company consent.

## **10.0 Calibration — Straight Beam and Thickness Measurement**

10.1 Calibration shall be performed from a surface corresponding to the surface used for production examination. The same couplant, transducer, cable, and relevant instrument controls shall be used for calibration and examination.

10.2 For thickness measurement, select the appropriate step wedge and adjust the range so that at least three back-wall reflections from the thicker step are visible.

10.3 Use the thinner step to establish zero offset (delay calibration) and the thicker step to establish material velocity (velocity calibration). Repeat adjustment until the A-Scan sweep and digital thickness reading agree with the certified step values within 0.05 mm (0.002 in.) or the instrument resolution, whichever is greater.

10.4 The calibrated range shall be sufficient to display the required material thickness and back-wall responses without ambiguity.

10.5 For lamination examination, set the second back-wall echo from the indication-free base material to 80% FSH. This sensitivity shall be used for scanning and evaluation, unless the approved Technique Sheet specifies a more sensitive setting.

10.6 Thickness calibration and the lamination reference setting shall be documented on the calibration record before examination.

## **11.0 Calibration — Angle Beam and DAC**

11.1 The search-unit exit point and actual refracted angle shall be verified before establishing distance calibration and DAC.

11.2 Ultrasonic inspection angles shall be selected in accordance with Table 1.

| Wall Thickness        | Examination Angles                           |
|-----------------------|----------------------------------------------|
| All wall thicknesses  | 0° lamination scan and thickness measurement |
| < 12.7 mm (0.500 in.) | 60° and 70°                                  |
| ≥ 12.7 mm (0.500 in.) | 45°, 60°, and 70°                            |

**Table 1: Transducer Selection Criteria**

### 11.3 Range

The calibrated screen range shall represent a minimum sound path of one and one-half skip in the material examined.

### 11.4 Distance Amplitude Correction (DAC) Curve

11.4.1 When amplitude-based criteria are used, a minimum three-point DAC curve shall be established using the applicable code reflectors. Gain shall be adjusted so that the peak response used to establish the DAC is 80% FSH at the maximum reflector response.

11.4.2 No DAC reference point shall be below 20% FSH. When a point would fall below 20% FSH, a split DAC shall be used and the first reference point on the second DAC shall be set to 80% FSH.

11.4.3 Reference sensitivity is the calibrated DAC level, including any applicable transfer correction. Scanning sensitivity shall be at least +6dB above reference sensitivity. Evaluation shall be performed at reference sensitivity unless the governing code or approved Technique Sheet specifies otherwise.

11.5 Transfer correction shall be determined and applied before the scanning gain is added. The correction shall be recorded on the calibration record and examination report.

11.6 For materials less than <12.7 mm (0.500 in.), locations containing indications that break the established reference level with 60° or 70° shall also be examined with a 45° search unit.

11.7 All calibration points, reference responses, distances, angles, gain levels, DAC curves, and applied corrections shall be recorded.

## 12.0 Calibration Verification, Sensitivity, Scan Speed, and Temperature

12.1 Calibration shall be performed or verified:

12.1.1 Before examinations begin.

12.1.2 At intervals not exceeding one hour during examinations.

12.1.3 After a transducer, wedge, or cable change.

12.1.4 After an instrument power cycle, equipment repair, or change of instrument.

12.1.5 At the end of the examination series or shift.

- 12.1.6 Whenever calibration validity is in doubt.
- 12.2 The manual scanning speed shall not exceed 150 mm/s (6 in./s), and shall be reduced when needed to maintain coupling, coverage, and reliable recognition of indications
- 12.3 For amplitude-based examination, scanning shall be performed at the established scanning level and evaluation at the established evaluation level. Instrument settings that affect response shall remain unchanged between calibration and examination.
- 12.4 For contact examination, the temperature difference between the calibration and examination surfaces shall remain within (14°C (25°F) of each other, unless an alternate range has been validated and approved by the Company NDE SME. Block and component temperatures shall be recorded at initial calibration and each verification.
- 12.5 If a distance-range point moves more than 10% of the sweep reading, or 5% of full sweep, whichever is greater, distance calibration shall be corrected and affected indications reexamined.
- 12.6 If sensitivity changes by more than 20% of amplitude or 2 dB, sensitivity shall be corrected. A decrease in sensitivity requires reexamination of all material examined since the last valid check. An increase requires reevaluation of recorded indications, since the last valid check.
- 12.7 If the instrument is found not to be functioning properly, all material examined since the last valid calibration shall be reexamined.
- 12.8 Calibration and verification times, results, temperatures, corrections, and required reexaminations shall be documented.

## **13.0 Base-Metal Examination (Lamination Scan)**

- 13.1 Before weld examination, wall-thickness measurements shall be completed in accordance with a Company-approved procedure and recorded.
- 13.2 A 0° compression-wave examination shall be performed on both sides of the weld and shall cover the greater of 100% of the material through which transverse and shear waves will pass, or 100 mm (4.0 in.) from the weld.
- 13.3 Transducer selection shall optimize detection. Delay-line or dual-element transducers are preferred for wall thickness less than 10.0 mm (0.394 in.) when they improve detection and resolution.
- 13.4 Using a longitudinal-wave transducer, the second back-wall echo shall be adjusted to at least 80% FSH. The base material shall be examined for laminar or stringer imperfections that could interfere with angle-beam examination.
- 13.5 Imperfections that can mask or impede transverse or shear-wave examination shall be documented on the examination record, marked on the component when practical, and reported to the Company representative.
- 13.6 Where practical, the transverse and shear-wave techniques shall be modified to compensate for recorded base-metal imperfections. The revised approach shall

remain within the approved Technique Sheet or receive Level III and Company approval.

- 13.7 Any unresolved loss of coverage shall be clearly documented and reviewed with the Company before examination results are accepted.

## 14.0 Weld Examination Requirements

- 14.1 Weld examination shall be performed in accordance with the governing code or standard, the approved Technique Sheet, and the additional requirements of this procedure.
- 14.2 For API 1104 examination, the qualified and documented reference, scanning, and evaluation sensitivity levels established during procedure demonstration shall be used.
- 14.3 A 100% volumetric examination of the weld metal and HAZ shall be performed over the required weld length.
- 14.4 A critical examination of the root shall be completed before the full-volume and HAZ scan. The root scan shall use a zigzag pattern with the beam axis perpendicular to the weld.
- 14.5 The full-volume raster scan shall provide a minimum 30% overlap of the effective beam width between adjacent passes.
- 14.6 The angles required by Table 1 shall be used. Supplemental 45° examination is required in the areas identified by §11.6.
- 14.7 For reflectors oriented parallel to the weld, the angle beam shall be directed approximately perpendicular to the weld axis from both sides of the weld and from two directions on the same examination surface when access permits.
- 14.8 For reflectors oriented transverse to the weld:
- 14.8.1 When the weld cap is not flush, scan from base material on both sides of the cap while directing the beam in both axial directions and skewing as required to cover the weld volume.
  - 14.8.2 When the weld cap is flush, scan through the weld surface in both axial directions and manipulate the search unit to cover the required volume.
- 14.9 The contact surface shall be uniform and free of loose scale, paint, weld spatter, surface irregularities, or foreign matter that interferes with probe movement or ultrasound transmission. Weld reinforcement may be locally removed only when authorized and documented.
- 14.10 Where physical access or geometry limits full volumetric coverage, the limitation shall be clearly documented, including the affected volume and attempted compensating techniques, and shall be reviewed with the Company before acceptance of results.

## 15.0 Evaluation and Sizing

- 15.1 All indications that exceed the evaluation threshold established by the approved Technique Sheet shall be investigated sufficiently to determine whether the response is caused by noise, geometry, metallurgy, or a relevant imperfection. For the existing amplitude-based technique, indications exceeding 20% of the reference level shall be investigated unless the governing code or Company specifies another threshold.
- 15.2 Evaluation shall include, as applicable, plotting reflector coordinates, comparison with weld and fabrication geometry, scanning from the opposite side or direction, use of multiple angles, beam skewing, and observation of echo dynamics.
- 15.3 Geometric or metallurgical responses exceeding 50% of reference level shall be documented with their identity, maximum amplitude, location, and extent unless the project criteria require a lower documentation threshold.
- 15.4 Indication length shall be determined from the examination side that provides the most reliable response. When multiple angles are used, the most conservative defensible length shall be reported.
- 15.5 For the current amplitude-drop length-sizing technique, maximize the indication response, adjust it to 80% FSH, and scan to the locations where the response falls to 40% FSH, a 6 dB drop. Another qualified sizing method may be used when identified on the approved Technique Sheet.
- 15.6 Indication depth shall be calculated from the calibrated sound path, measured refracted angle, probe index point, examination surface, and component thickness. Depth shall be reported from the outside surface to the bottom of the indication.
- 15.7 Vertical extent shall be determined by the qualified method specified on the Technique Sheet. The method and any demonstrated accuracy limitation shall be recorded.
- 15.8 When a response saturates the display or prevents reliable sizing, additional scans shall be performed at reduced gain without changing the calibrated time base. The report shall identify the gain used for final sizing.
- 15.9 All sized defects shall include maximum amplitude at reference sensitivity, applied transfer correction, classification, disposition, start and stop location, length, vertical extent, and depth from the OD surface.

## 16.0 Acceptance Standards (API 1104)

- 16.1 Non-Rejectable Indications (Imperfections)  
Indications that do not exceed the code of construction or the project ECA shall be classified as imperfections and documented in the report, including depth, vertical extent (height), length, and amplitude response.

- 16.2 Indications shall be considered defects should any of the following conditions exist:
- 16.2.1 Indications determined to be cracks (C).
  - 16.2.2 Individual indications with a vertical height (through-wall) dimension determined to be greater than one quarter of the wall thickness.
  - 16.2.3 Multiple indications at the same circumferential location with a summed vertical height (through-wall) dimension exceeding one-half the wall thickness.
- 16.3 Linear Surface (LS) indications (other than cracks) interpreted to be open to the I.D. or O.D. surface shall be considered defects, should any of the following conditions exist:
- 16.3.1 The aggregate length of LS indications in any continuous 300 mm (12.0 in.) length of weld exceeds 25 mm (1.0 in.).
  - 16.3.2 The aggregate length of LS Indications exceeds 8% of the weld length.
- 16.4 Linear Buried (LB) indications (other than cracks) interpreted to be subsurface within the weld and not I.D. or O.D. surface-connected shall be considered defects should any of the following conditions exist:
- 16.4.1 The aggregate length of LB indications in any continuous 300 mm (12.0 in.) length of weld exceeds 50 mm (2.0 in.).
  - 16.4.2 The aggregate length of LB indications exceeds 8% of the weld length.
- 16.5 Transverse (T) indications (other than cracks) shall be considered volumetric and evaluated using the criteria for volumetric indications. The letter T shall be used to designate all reported transverse indications.
- 16.6 Volumetric Cluster (VC) indications shall be considered defects when the maximum dimension of VC indications exceeds 13 mm (0.500 in.).
- 16.7 Volumetric Individual (VI) indications shall be considered defects when the maximum dimension of VI indications exceeds 3 mm (0.125 in.).
- 16.8 Volumetric Root (VR) indications interpreted to be open to the I.D. surface shall be considered defects, should any of the following conditions exist:
- 16.8.1 The maximum dimension of VR indications exceeds 6 mm (0.250 in.) or the nominal wall thickness, whichever is less.
  - 16.8.2 The total length of VR indications exceeds 13 mm (0.500 in.) in any continuous 300 mm (12.0 in.) length.
- 16.9 Any accumulation of relevant indications (AR) shall be considered a defect when any of the following conditions exist:
- 16.9.1 The aggregate length of indications above evaluation level exceeds 50 mm (2.0 in.) in any 300 mm (12.0 in.) length of weld.
  - 16.9.2 The aggregate length of indications above evaluation level exceeds 8% of the weld length.
- 16.10 Base-Material Imperfections — Reported to TC Energy. Disposition by the Company.

## 17.0 Marking of Defect Areas

- 17.1 Imperfections evaluated as rejectable shall be marked directly on the examination material with a permanent or paint marker.
- 17.2 Stainless-steel welds: indelible low-halogen / low-sulfur (chloride-free) ink marker only.
- 17.3 Rejected areas marked with an additional 13 mm (0.5 in.) on each side of the indication length; include depth, side of weld, and vertical extent.

## 18.0 Repairs

- 18.1 When this procedure is used for pipeline girth-weld repair, the examination method originally used to detect the defect shall verify defect removal before manual ultrasonic examination is performed.
- 18.2 Final examination of a repaired area shall use the same approved Technique Sheet and sensitivity levels used for the original examination when that technique provides complete coverage of the repair.
- 18.3 Repaired areas shall be re-tested using the same scan plan and techniques used for the original inspection, unless the original plan does not provide coverage of the repaired area; in that case, a new scan plan shall be developed for the repair area and approved by the PII UT Level III, and the Company NDE SME before final examination.
- 18.4 Inspection of repair areas shall include the full length of the repair PLUS, a minimum of 75 mm (3.0 in.) on each end.
- 18.5 The repair location, repair limits, verification of defect removal, final examination results, and any remaining limitations shall be documented on the examination report.

## 19.0 Reporting Requirements

- 19.1 At the end of each day or shift, PII shall provide TC Energy with details of all ultrasonic examinations completed during that period using the Company-approved reporting format.
- 19.2 **The Manual Ultrasonic Examination Report shall include, at a minimum:**
  - 19.2.1 Contractor name
  - 19.2.2 Procedure number and revision.
  - 19.2.3 TC Energy specification number and revision.
  - 19.2.4 Governing code and acceptance basis.
  - 19.2.5 Weld information, including diameter, nominal and measured wall thickness, weld type, weld or part identification, and material.
  - 19.2.6 Job number, location, date, and time.
  - 19.2.7 Measured wall thickness.
  - 19.2.8 Side of weld, including upstream/downstream or equivalent orientation.

- 19.2.9 Angles used for examination.
  - 19.2.10 Transfer-correction value, when applied.
  - 19.2.11 Instrument, transducers, wedges, cables, and calibration blocks used.
  - 19.2.12 Equipment settings, including reference dB, scanning dB, evaluation dB, range, velocity, and DAC identification.
  - 19.2.13 MUT Technician name, certification level, OQ Status, signature, and date.
  - 19.2.14 Sketch or photograph.
  - 19.2.15 Examination coverage, inaccessible areas, and limitations.
  - 19.2.16 Disposition of reportable indications and defects.
- 19.3 When a defect is sized, the report shall include:**
- 19.3.1 Maximum amplitude response at reference sensitivity, including the applied transfer correction.
  - 19.3.2 Defect classification and disposition.
  - 19.3.3 Defect length and start/stop location.
  - 19.3.4 Defect vertical extent and depth to the bottom of the defect from the OD surface.
  - 19.3.5 Sizing method and any stated limitation.
- 19.4 All observed defects and all base-metal conditions that impede examination shall be documented and reported to the Company representative.
- 19.5 Reports shall be legible, complete, signed, and traceable to the applicable calibration record and Technique Sheet.

## 20.0 Data Management, Audits, and Records

- 20.1 The controlled record set shall include the approved procedure, project Technique Sheets, procedure-demonstration records, calibration records, examination reports, indication sketches or photographs, personnel qualification records, and variance approvals.
- 20.2 Records shall be retained in accordance with the governing code, contract requirements, TC Energy direction, and the PII record-retention policy, whichever is more stringent.
- 20.3 Electronic records shall use a systematic file-naming convention that identifies the project, weld or part, date, procedure revision, Technique Sheet, and record type.
- 20.4 Records shall be protected from unauthorized alteration and shall be available to TC Energy for review or audit.
- 20.5 All NDE operations are subject to periodic Company audit in accordance with TEP-NE-ADT-G, Item ID 003797402. PII personnel shall provide access to procedures, reports, equipment, systems, and qualification records requested by the Authorized Representative or Company Auditor.

20.6 When a Company audit identifies a required corrective action, PII shall report the finding internally and to the Company within 48 hours of identification. Corrective actions shall be developed and implemented in coordination with the Company Quality team, and closure shall be formally documented upon Company acceptance.

20.7 Any reexamination, report correction, or disposition resulting from an audit or calibration finding shall remain traceable to the original record.

## 21.0 Variances

Any deviation from this procedure or from TES-NDT-PA shall be processed through the TC Energy Controlled Document Library Variance Procedure (CAN-US-MEX), Item ID 007728702. Internal PII variances shall additionally be recorded in PII-QM-VAR with Level III concurrence.

## 22.0 Compliance Cross-Reference Matrix

| Procedure §     | Subject                                                                           | TES-NE-MUT-G Reference     |
|-----------------|-----------------------------------------------------------------------------------|----------------------------|
| 1.2-1.5         | Scope, minimum 6.4 mm wall thickness, 0° and shear-wave methods, excluded methods | TES-NE-MUT-G Purpose/Scope |
| 1.5, 2.0, 16.0  | Code, regulatory, and more-stringent requirement hierarchy                        | TES 2.1.1-2.1.4; 5.3.1     |
| 1.8, 9.0, 25.0  | Detailed procedure, wall-thickness/bevel Technique Sheet, Company SME approval    | TES 2.2.1                  |
| 1.7             | Company right to additional NDE and destructive examination                       | TES 2.2.2                  |
| 19.1, 19.4      | Daily/shift report and reporting of observed defects                              | TES 2.2.3; 6.1.1           |
| 18.1            | Original examination method verifies defect removal before MUT                    | TES 2.2.4                  |
| 1.2, 10.0, 13.0 | 0° wall-thickness verification and lamination detection                           | TES 2.2.5; 5.1             |

| Procedure §    | Subject                                                                                | TES-NE-MUT-G Reference       |
|----------------|----------------------------------------------------------------------------------------|------------------------------|
| 20.5-20.7      | Audits, 48-hour corrective-action reporting, Company acceptance of closure             | TES 2.3                      |
| 4.1-4.9        | Contractor qualification, technician certification, Level I limits, OQ, Company review | TES 3.1-3.4                  |
| 6.0            | Instrument, frequency, crystal size, angles, contour wedges                            | TES 4.1.1                    |
| 7.0            | Water-based couplant, no oil, methanol recovery, cleanup, same calibration couplant    | TES 4.1.1 Couplants          |
| 8.0, 10.0-12.0 | Calibration blocks, temperature, verification, and traceability                        | TES 4.2.1-4.2.2; 4.2.7-4.2.8 |
| 11.2-11.7      | Required angles, 45° follow-up, 1.5 skip, three-point DAC, split DAC                   | TES 4.2.3-4.2.6              |
| 13.0           | Base-metal thickness and lamination examination, reporting and compensation            | TES 5.1                      |
| 14.0           | 100% weld/HAZ coverage, root-first zigzag, 30% overlap, limited-coverage review        | TES 5.2                      |
| 16.0           | Applicable code/project acceptance criteria and more-stringent rule                    | TES 5.3.1                    |
| 19.0, 24.0     | Required report fields and defect-sizing information                                   | TES 6.1.2-6.1.3              |
| 21.0           | Formal variance process                                                                | TES 7                        |
| 1.11, 20.0     | Company and Contractor responsibilities and recordkeeping                              | TES 8 and 10                 |

## 23.0 Attachment A: Transfer Correction Procedure

When the item examined and the reference block are the same thickness:

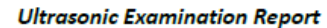
23.1 Place angle beam probes of the same size, nominal frequency, and nominal refracted angle on the calibration block or mock-up to be used in the position shown below.

23.2 Using through-transmission methods, maximize the indication obtained and obtain a dB value of the indication.

- 23.3 Measure the surface distance between the probe exit points.  $\frac{1}{2} SD / t = \tan \Theta_2$ .
- 23.4 Transfer the same two search probes to the part to be examined, orient them in the same direction in which scanning will be performed, and obtain a dB value of indications as explained above from at least three locations.
- 23.5 The difference in dB between the calibration block or mock-up and the average of that obtained from the part to be examined should be recorded and used to adjust the standard sensitivity.



**Figure 3: Transfer Correction Probe Placement**



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## 25.0 Manual UT Calibration Record

|                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Ultrasonic Calibration Verification Record |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
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| 1621 Primewest Parkway   Katy, TX 77449   P: (281) 944-3840; info@primeinspections.com                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Date:                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Instrument Found:                          | <input type="checkbox"/> In-tolerance <input type="checkbox"/> Out of tolerance |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Instrument:                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Serial Number:                             |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Transducer:                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Serial Number:                             |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Reference Block:                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Serial Number:                             |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Procedure:                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Next Due Date:                             |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| <b>A. Screen Height Linearity</b> Per ASTM E317                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                       | Higher Signal                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Lower Signal                               | Accepted Limits                                                                 | Ideal Lower Signal |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                            | 100                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                            | 46-55                                                                           | 50%                |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 2                                                                                                                                                                                                                                                                                                                                                                                                                            | 90                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            | 41-50                                                                           | 45%                |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 3                                                                                                                                                                                                                                                                                                                                                                                                                            | 80                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            | 37-44                                                                           | 40%                |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 4                                                                                                                                                                                                                                                                                                                                                                                                                            | 70                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            | 32-38                                                                           | 35%                |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 5                                                                                                                                                                                                                                                                                                                                                                                                                            | 60                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 30                                         | 28-33                                                                           | 30%                |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 6                                                                                                                                                                                                                                                                                                                                                                                                                            | 50                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            | 23-27                                                                           | 25%                |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 7                                                                                                                                                                                                                                                                                                                                                                                                                            | 40                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            | 19-22                                                                           | 20%                |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 8                                                                                                                                                                                                                                                                                                                                                                                                                            | 30                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            | 14-16                                                                           | 15%                |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 9                                                                                                                                                                                                                                                                                                                                                                                                                            | 20                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            | 9.1-11                                                                          | 10%                |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| <b>B. Amplitude Control Linearity</b>                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Initial Amplitude                                                                                                                                                                                                                                                                                                                                                                                                            | dB Change                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Result                                     | Limit                                                                           |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 80                                                                                                                                                                                                                                                                                                                                                                                                                           | -6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            | 37% – 43%                                                                       |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 80                                                                                                                                                                                                                                                                                                                                                                                                                           | -12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                            | 17% – 23%                                                                       |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 40                                                                                                                                                                                                                                                                                                                                                                                                                           | +6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                            | 76% – 84%                                                                       |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 20                                                                                                                                                                                                                                                                                                                                                                                                                           | +12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                            | 76% – 84%                                                                       |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| <b>C. Horizontal Linearity</b>                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
|                                                                                                                                                                                                                                                                                                                                                                                                                              | <table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <tr><td>10</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>9</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>8</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>6</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td></td> <td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td> </tr> </table> |                                            |                                                                                 |                    |   |   |   |                                      |           |      | 10 |  |  |  |  |  |  |  |  |  |  | 9 |  |  |  |  |  |  |  |  |  |  | 8 |  |  |  |  |  |  |  |  |  |  | 7 |  |  |  |  |  |  |  |  |  |  | 6 |  |  |  |  |  |  |  |  |  |  | 5 |  |  |  |  |  |  |  |  |  |  | 4 |  |  |  |  |  |  |  |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |  |  |  | 0 |  |  |  |  |  |  |  |  |  |  |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 10                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 9                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 8                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 7                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 6                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 5                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 4                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 3                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 2                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 0                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
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| <b>D. Resolution</b>                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Near Surface:                                                                                                                                                                                                                                                                                                                                                                                                                | <input type="checkbox"/> Satisfactory <input type="checkbox"/> Unsatisfactory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Far Surface:                                                                                                                                                                                                                                                                                                                                                                                                                 | <input type="checkbox"/> Satisfactory <input type="checkbox"/> Unsatisfactory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Comments<br><div style="border: 1px solid black; height: 150px; width: 100%;"></div>                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Evaluated By: <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <tr> <td style="width: 40%; height: 40px;"></td> <td style="width: 30%; height: 40px;"></td> <td style="width: 30%; height: 40px;"></td> </tr> <tr> <td style="font-size: 8px;">Technician Name and UT Level (print)</td> <td style="font-size: 8px;">Signature</td> <td style="font-size: 8px;">Date</td> </tr> </table> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   | Technician Name and UT Level (print) | Signature | Date |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
|                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| Technician Name and UT Level (print)                                                                                                                                                                                                                                                                                                                                                                                         | Signature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Date                                       |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| PII-MUTFORM-CAL-Rev0 - Ultrasonic Calibration Verification Record                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |
| 07/28/2026                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                            |                                                                                 |                    |   |   |   |                                      |           |      |    |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |   |   |   |   |   |   |   |   |   |    |

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