



Prime Inspections, Inc.

Phased Array and TOFD Ultrasonic (PAUT / TOFD) Examination Encoded Mechanized Scanning — Carbon-Steel Pipeline Girth Welds

Procedure No.: PII-TC-PAUT | 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), Mandatory Appendix IV (PAUT) and Mandatory Appendix V (TOFD).
- ASME BPVC Section V, Article 23 — SE-2491 (Linearity), SE-1961 (PAUT), SE-2700 (TOFD).
- ISO 13588 — Ultrasonic testing — Use of automated phased array technology.
- ISO 10863 — Ultrasonic testing — Time-of-flight diffraction technique (TOFD).
- ISO 22825 — Testing of welds in austenitic steels and nickel-based alloys (PAUT/TOFD).
- TC Energy TES-NDT-PA — Phased Array and TOFD Inspections of Welds and Materials (CAN-US-MEX), Item ID 009219103.
- TC Energy TEN-NE-NDT-GL — Nondestructive Testing Standard (CAN-US-MEX), Rev. 01.
- 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; with PAUT/TOFD-specific qualification documentation.

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 Phased Array Ultrasonic Testing (PAUT) and Time-of-Flight Diffraction (TOFD) examination on TC Energy projects, in accordance with TC Energy TES-NDT-PA (Phased Array and TOFD Inspections of Welds and Materials), API 1104 21st Edition (and Annex B Alternative Acceptance Standards when invoked), and ASME BPVC Section V Article 4 (with Mandatory Appendix IV for PAUT and Mandatory Appendix V for TOFD).
- 1.2. Application
- 1.2.1. Carbon-steel piping girth welds, using manual, semi-automatic, or encoded mechanized scanning with computer-based data acquisition and analysis.
 - 1.2.2. Contact scanning from the ID or OD surface, using PAUT transducers and wedges capable of generating shear-wave and longitudinal-wave beams between 0° and 75° per the approved scan plan.
 - 1.2.3. Pre-weld manual PAUT transverse scanning and 0° lamination scanning of base material adjacent to the weld.
- 1.3. Qualification - This procedure is qualified for production use based on:
- 1.3.1. Successful calibration on an acceptable API 1104 reference standard, and
 - 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. §11.5.2 and Annex B (when invoked) 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. Manual contact UT (single-element angle-beam) - covered by PII-TC-MUT Rev 0 / TES-NE-MUT-GL.
 - 1.4.3. 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.

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; Annex A (ECA); Annex B (Alternative UT Acceptance Mandatory).

- 2.1.2. ASME BPVC Section V, Article 4 (2025 Ed.), Ultrasonic Examination Methods for Welds, including Mandatory Appendix IV (PAUT) and Mandatory Appendix V (TOFD).
- 2.1.3. ASME BPVC Section V, Article 5 (2025 Ed.), Ultrasonic Examination Methods for Materials.
- 2.1.4. ASME BPVC Section V, Article 23, SE-2491 (Standard Practice for Evaluating Performance Characteristics of PAUT Instruments and Systems), SE-1961 (PAUT Contact Examination), SE-2700 (TOFD Contact Examination).
- 2.1.5. ISO 13588, Ultrasonic testing — Use of automated phased array technology.
- 2.1.6. ISO 10863, Ultrasonic testing — Time-of-flight diffraction technique.
- 2.1.7. ISO 22825, Testing of welds in austenitic steels and nickel-based alloys.
- 2.1.8. ISO 22232-1, 2, 3; Characterization and verification of ultrasonic test equipment.
- 2.1.9. ISO 18563-1, 2, 3; Characterization and verification of PAUT equipment (instrument/probes / combined).
- 2.1.10. ASTM E2491, Standard Guide for Evaluating Performance Characteristics of PAUT Instruments and Systems.
- 2.1.11. ASNT SNT-TC-1A (2024); ANSI/ASNT CP-189; ISO 9712 — Personnel qualification.

2.2. TC Energy Specifications

- 2.2.1. TES-NDT-PA, Phased Array and Time-of-Flight Diffraction Inspections of Welds and Materials (CAN-US-MEX), Item ID 009219103.
- 2.2.2. TES-NE-MUT-GL, Manual Ultrasonic Examination of Girth Welds (CAN-US-MEX), Item ID 004497443.
- 2.2.3. TEN-NE-NDT-GL, Nondestructive Testing Standard (CAN-US-MEX), Item ID 1001828336.
- 2.2.4. TEP-NE-ADT-GLE, 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) and Part 195 (PHMSA Hazardous Liquid).

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-TC-MUT Rev 0, Manual Ultrasonic Examination of Girth Welds.
- 2.4.3. PII-PAUT-CAL-01, PAUT Instrument / Probe / Wedge Calibration Record.
- 2.4.4. PII-PAUT-RPT-01, PAUT Examination Report Template.
- 2.4.5. PII-QM-01, Quality Manual.

3.0 Definitions and Acronyms

Term	Definition
AUT	Automated Ultrasonic Testing — out of scope for this procedure.
Compound Scan	Combined E-Scan and S-Scan in a single acquisition.
DAC	Distance Amplitude Correction.
Dead Element	Probe element returning no signal or out-of-tolerance signal during element check.
E-Scan (Electronic Scan)	Sequential firing of phased array elements producing parallel beams at a fixed angle.
ECA	Engineering Critical Assessment per API 1104 Annex A.
Encoded Scan	A scan in which the probe position is acquired by an encoder synchronized with UT data.
FSH	Full Screen Height of the A-scan or sectorial display.
Focal Law	A set of time delays is applied to the PAUT array elements to create a beam at a specified angle / focal depth.
Lateral Wave	Surface-following longitudinal wave between TOFD probes — defines the top of the TOFD examination zone.
PAUT	Phased Array Ultrasonic Testing.
S-Scan (Sectorial Scan)	Sweeping the beam angle across an angular range from a fixed probe position.
TCG	Time-Corrected Gain — equivalent to TVG (Time-Varied Gain) — replaces DAC by adjusting gain over time.
TOFD	Time-of-Flight Diffraction — uses tip-diffracted ultrasound and lateral / back-wall waves between two probes in pitch-catch.
Zone	Defined depth segment of the weld for which a specific PAUT or TOFD setup is established (e.g., upper, middle, lower zone).

4.0 Personnel Qualifications (PAUT/TOFD-Specific)

4.1. Personnel performing PAUT and TOFD examinations under this procedure shall be qualified and certified to Level II or Level III in accordance with PII-WP-1 (implementing ASNT SNT-TC-1A 2024 Ed.), to ANSI/ASNT CP-189, or ISO 9712, in the PAUT method; and as required by contract.)

4.2. Personnel Qualification

4.2.1. Level I personnel may not perform any independent duties under this procedure.

- 4.2.2. Level II or Level III in UT with documented minimum 80 hours of formal classroom PAUT/TOFD training, covering hands-on examination, data collection, evaluation, interpretation, and reporting.
- 4.2.3. 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.
- 4.3. In addition to the qualification(s) above, technicians shall have documented hardware/software training on the specific PAUT instrument model in use.
- 4.4. When required by TC Energy, a minimum of one-day training for Company Inspectors will be provided before production begins.
- 4.5.** Training records shall be retained by PII and made available for TC Energy to audit.
- 4.6. 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.
- 4.7. 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.
- 4.8. Vision — Annual Jaeger J-1 (or equivalent) near-vision examination at ≥ 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, Probes, Wedges, Encoders

6.1. Instrument Requirements

- 6.1.1. Inspection system capable of performing phased array, TOFD, and conventional pulse-echo UT with encoded scans.
- 6.1.2. Equipment linearity calibration per ASME SE-2491; interval not to exceed 12 months. Calibration documentation shall be on-site and available for TC Energy review.
- 6.1.3. Minimum digital sampling frequency: ≥ 100 MHz AND/OR at least 5 $\times$ probe nominal frequency.
- 6.1.4. Scanning resolution ≥ 1.0 mm (0.04 in.).
- 6.1.5. Data storage capacity ≥ 1.0 GB; external storage media per the Company-consented scan plan.
- 6.1.6. All data is backed up daily on media separate from the inspection equipment.

6.2. Phased Array Probes

- 6.2.1. Probes shall not use an active aperture greater than the instrument can pulse and receive.
- 6.2.2. Each probe clearly identified; part number and serial number recorded on the scan plan.
- 6.2.3. PAUT probe frequencies shall be between 2.25 MHz and 15.0 MHz (other frequencies require Company consent for specific testing).
- 6.2.4. Probes characterized by ISO 18563-2.

6.3. TOFD Probes — Selection by Wall Thickness

Wall Thickness	Frequency Range	Probe Diameter
6.0 mm (0.236 in.) to < 10.0 mm (0.394 in.)	10.0 to 20.0 MHz	3 to 6 mm (0.118 to 0.236 in.)
≥ 10.0 to 25.0 mm (0.394 to 1.0 in.)	5.0 to 15.0 MHz	3 to 6 mm (0.118 to 0.236 in.)
> 25.0 to 50.8 mm (1.0 to 2.0 in.)	2.25 to 7.5 MHz	3 to 6 mm (0.118 to 0.236 in.)

6.4. Wedge

- 6.4.1. Wedges clearly identified; part number, serial number, and natural refracted angle recorded on the scan plan.
- 6.4.2. Focal laws $\geq \pm 20^\circ$ or within suggested manufacturer limits, whichever is less.
- 6.4.3. For scanning curvatures $\leq$ NPS 20, the wedge radius shall not result in a material-to-wedge gap ≥ 0.5 mm (0.02 in.).

6.5. Scan Types

- 6.5.1. E-Scan: Overlap between adjacent active apertures $\geq 50\%$ of effective aperture height.
- 6.5.2. S-Scan: Angle variation $\leq 1.0^\circ$ between adjacent beams across the full sweep.
- 6.5.3. Compound Scan: Shall satisfy the requirements of both E-Scan and S-Scan.
- 6.5.4. TOFD: When implemented, scans shall be focused at $2/3$ the thickness of the material (single zone), or multiple zones for thicker materials.
- 6.5.5. 0° couplant monitoring shall be implemented for the active aperture on all encoded scans.
- 6.5.6. Transverse scans: 0° to 45° perpendicular to the weld axis, using manual PA raster scanning per the scan plan.
- 6.5.7. Lamination (0°) scans: performed BEFORE angle-beam inspections, at a minimum distance of 125 mm (5 in.) from the weld (or the documented stand-off in the scan plan), using a 0° manual PA scan.
- 6.5.8. Thickness surveys: performed before any angle-beam inspections; may be combined with lamination scans when proper calibration is on file.

6.6. Encoders

- 6.6.1. Encoder resolution ≥ 4 ticks per 1 mm (0.04 in.).
- 6.6.2. Encoder calibration interval ≤ 1 month; calibration by moving the encoder ≥ 500 mm (20 in.) and verifying $\pm 1\%$ of actual distance.
- 6.6.3. Daily / once-per-shift verification at $\pm 1\%$ of 200 mm (8 in.).

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 ≤ 250 ppm with a manufacturer's Certificate of Conformance retained.

8.0 Calibration Blocks (API 1104 Reference Standard) and Reflectors

8.1. Calibration Blocks vs. Reference Blocks

- 8.1.1. Calibration blocks (e.g., NAVSHIP V1, ISO V1/V2, or equivalent) are used to establish initial calibration parameters (wedge delay, velocity, TCG). "Reference blocks" are used to establish the required examination sensitivity (gain) or primary reference response.

- 8.1.2. For examination of material with a surface diameter $\leq$ NPS 20 (508 mm), a curved calibration block must be used. Curved calibration blocks must be 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. 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.
- 8.1.5. TOFD calibration blocks must meet ASME V, Mandatory Appendix III, III-434 requirements.

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)

The API 1104 reference standard shall be manufactured from project-specific production pipe as approved by TC Energy. Dimensions:

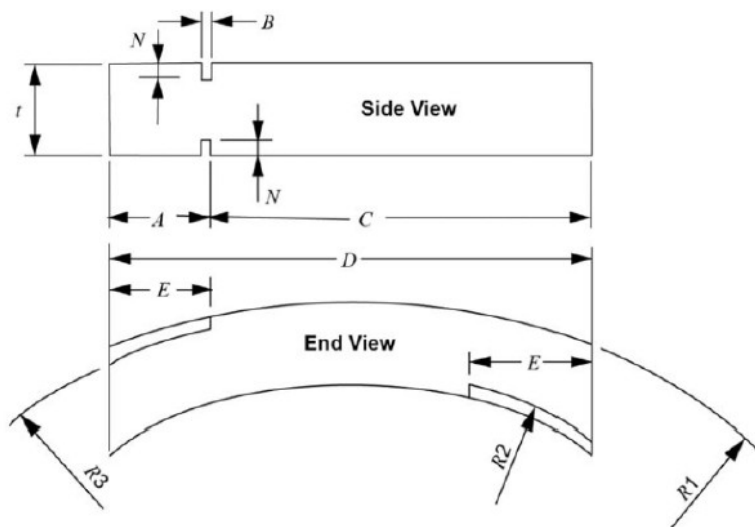


Figure 1: Example of Reference Standard for Ultrasonic Testing

Symbol	Description
t	Specified pipe wall thickness.
N	Notch depth $\pm 10\% t \pm 10\%$ of notch depth

Symbol	Description
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
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°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 Scan Plan Requirements and Inspection Procedure

9.1. A complete written scan plan, signed by the PII Level III in UT and submitted to TC Energy for consent prior to production use, shall include:

- 9.1.1. Inspection equipment, software version, probe(s), wedge(s), encoder.
- 9.1.2. Search unit details — frequency, element sizes, pitch.
- 9.1.3. Scan type — E-Scan, S-Scan, Compound, TOFD, Conventional.

- 9.1.4. Sampling frequency.
- 9.1.5. Focal range / focal point.
- 9.1.6. Filter settings.
- 9.1.7. Element numbers used for focal laws.
- 9.1.8. Angular range of S-Scan.
- 9.1.9. Inspection increments (degrees between beams or distance between focal laws).
- 9.1.10. Material velocity (compression/shear).
- 9.1.11. Weld configuration to be examined — thickness, bevel design, base-material product form.
- 9.1.12. Surface curvature requiring contour wedges.
- 9.1.13. Calibration blocks and standards used.
- 9.1.14. Manual/semi-automatic/automated scanning designation.
- 9.1.15. Scan locations and directions — each scan has a unique identification.
- 9.1.16. Scanning speed.
- 9.1.17. Permitted temperature variation between block and component (typically $\leq 14^{\circ}\text{C} / 25^{\circ}\text{F}$).
- 9.1.18. Couplant information — manufacturer, type, mix, or additive (if applicable).

9.2. Coverage Requirements

- 9.2.1. Minimum coverage: 1 × wall thickness, up to a maximum of 25 mm (1.0 in.), beyond each weld toe.
- 9.2.2. Complete coverage of weld deposit.
- 9.2.3. Inspection angles within $\pm 10^{\circ}$ (perpendicular) of the intended target (bevel angles) when using S-Scans or E-Scans — except for base material and fillet weld inspections.
- 9.2.4. When multiple scans are required for full coverage, $\geq 25\%$ overlap between scans.
- 9.2.5. Single-sided access (limited by fitting or component geometry) is acceptable WITH an approved scan plan that includes full joint coverage, including the opposite-side HAZ; the Level III shall approve, and TC Energy shall consent prior to use.

9.3. Scan Speed and Surface Preparation

- 9.3.1. Acquisition speed shall not exceed the lesser of (a) the speed established during instrument setup, or (b) 150 mm (6.0 in.) per second.
- 9.3.2. Manual transverse and lamination scanning speed ≤ 150 mm (6.0 in.) per second.
- 9.3.3. 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.

9.4. Scanning Sensitivity

- 9.4.1. Scanning sensitivity shall be +6 dB above primary reference sensitivity, unless geometry or noise prevents readable data.

- 9.4.2. When noise > 20% FSH, a +6 dB scan AND a scan at reference sensitivity shall both be performed and recorded.

9.5. Gate Settings

- 9.5.1. Gate amplitude threshold: 10% FSH (maximum 20% FSH when noise prevents useful data at 10%).
- 9.5.2. Gate start: 25 mm (1.0 in.) before the weld-to-parent-material interface, with a minimum 5 mm (0.25 in.) beyond the weld center.
- 9.5.3. For one-sided weld scans, the gate shall be extended beyond the calculated HAZ.

9.6. Focal Point

- 9.6.1. True-depth focusing OR projection focusing may be used.
- 9.6.2. True-depth focusing: focal point set to 1.2 to 1.5 × nominal material thickness for single-group scanning.
- 9.6.3. Projection focusing: focal point at the weld-volume center; for multi-pass examination, focal point at the midpoint of the area of interest per scan.

NOTE: When indications exceed the established threshold, the beam focal point may be adjusted from the scan-plan default to the actual depth of the indication to improve flaw sizing accuracy.

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.

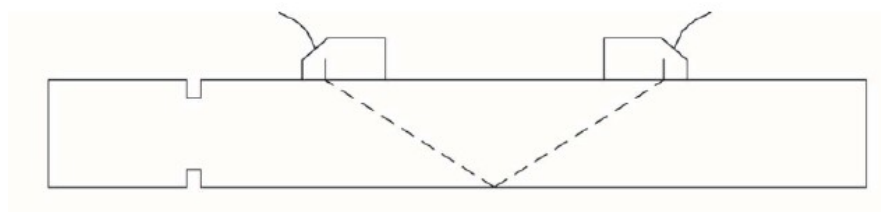


Figure 2: Example, Attenuation and Transfer Procedure

- 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 — PAUT (Element Check, Beam, TCG)

10.1 Calibration Frequency

- 10.1.1 Before daily inspection begins.
- 10.1.2 After any repair or maintenance to the equipment.
- 10.1.3 After any system power-down event.
- 10.1.4 At intervals not exceeding 1 hour during inspection.
- 10.1.5 At the end of each shift.
- 10.1.6 Whenever calibration validity is in doubt.

10.2 Each successful calibration shall include a verification screenshot retained in the project records.

10.3 PAUT Element Check

- 10.3.1 Performed before any inspection AND at least once per shift.
- 10.3.2 Maximum allowable Dead Elements: 10% of the array.
- 10.3.3 No two adjacent Dead Elements are permitted.
- 10.3.4 Element-check screenshots retained in the calibration record.

10.4 Straight-Beam (0°) Calibration

- 10.4.1 Ultrasonic range adjusted using an E-Scan at 0° so the display shows at least two plate thicknesses.
- 10.4.2 Sensitivity adjusted at a location free of indications such that the second back-wall reflection is 80% FSH; sensitivity may be adjusted for surface roughness.

10.5 Angle-Beam Calibration

- 10.5.1 Beam angles verified within $\pm 2^\circ$ of the minimum and maximum angles configured for S-Scans, or within $\pm 2^\circ$ of the first and last beams configured for E-Scans.
- 10.5.2 Horizontal sweep distance adjusted to the actual material-path distance across all configured angles using a PACS block or equivalent.
- 10.5.3 Screen range set to $3 \times$ the nominal material thickness at the minimum configured angle (true-depth display); larger screen ranges per scan plan when joint configuration requires.

10.6 Time-Corrected Gain (TCG)

- 10.6.1 TCG shall be established using the API 1104 reference standard N10 (10% T) notches across all configured angles, at a minimum of three points throughout the tested material range.
- 10.6.2 TCG shall balance all calibration points to within $\pm 5\%$ amplitude of each other.

11.0 Calibration — TOFD (Lateral Wave, Sensitivity, Multi-Zone)

11.1 Range

Adjusted to include 1.0 μ s before the lateral wave and 0.5 μ s after the mode-converted back-wall reflection.

11.2 Calibration Scan

Shall demonstrate the ability to detect the ID and OD notches.

11.3 Lateral Wave

Shall have a minimum response height of 40% FSH (Negative 20% + Positive 20% = 40%) at the reference sensitivity setting.

11.4 Zone Strategy

11.4.1 Single TOFD configuration: wall thickness $\leq$ 25.4 mm (1.0 in.).

11.4.2 Dual TOFD configuration: wall thickness $>$ 25.4 mm (1.0 in.).

11.5 Reference Sensitivity Setting

11.5.1 Single-zone OR uppermost zone of multi-zone exam: set gain so the lateral-wave amplitude is between 40% and 90% FSH and baseline noise level between 5% and 10% FSH.

11.5.2 Additional zones below the uppermost zone: set baseline noise level between 5% and 10% FSH (lateral wave not used as reference for these zones).

11.5.3 Calibration shall use the API 1104 reference standard.

11.6 Multi-Zone TOFD Verification

11.6.1 When the weld is broken into multiple zones, the above calibration steps shall be repeated for each TOFD probe pair.

11.6.2 The nearest side-drilled hole in the adjoining zone(s) shall also be detected during the calibration.

11.6.3 Two additional offset scans per zone shall be performed (offset to either side of the applicable zone's examination area). If the notches are not detected, two additional offset scans are required at the offset distance documented in the scan plan.

11.7 TOFD Sensitivity Confirmation

Scan the calibration block's notches, with the probes centered between the notches at the reference sensitivity level. The notch responses in the required zone shall be at least 6 dB above the grain noise and shall be apparent in the digitized greyscale display.

12.0 General Examination Requirements

12.1 Examination Coverage

12.1.1 Prior to angle beam examination, manual 0° longitudinal wave testing shall be performed on the parent material to a minimum distance of 1.25

times the longest skip distance used and shall be free of any full or partial beam reflectors that could influence production weld inspection. Welds completed without factory ends require parent material inspection. All interfering partial and full beam reflectors shall be recorded on the examination report, and the company shall be notified. Sensitivity applied for parent material inspection shall be defined and approved by TC Energy.

- 12.1.2 The weld shall be examined throughout its entire length, and the coverage shall include the weld, the heat-affected zone, and the adjacent base metal. At a minimum, the Parallel and Transverse examination volume shall include the weld and the lesser of 15mm (0.590 in.) or T, of the adjacent base metal on each side of the weld.

12.2 Calibration

- 12.2.1 Phased array testing shall utilize a minimum of a 2-point TCG.
12.2.2 A transfer correction shall be performed between the calibration block and the component in accordance with §9.7.

12.3 Reference, Scanning, and Evaluation Levels

- 12.3.1 0° Longitudinal wave testing of parent material shall be performed with the second backwall signal adjusted to at least 80% FSH on the part examined. This level shall be used for scanning and evaluation.
12.3.2 The reference level for phased array examination of the weld shall be at the minimum 2-point TCG derived from the “N” 10% notch on the calibration block detailed in Figure 1. The scanning level shall be the TCG reference level +6dB. The evaluation sensitivity shall also be the TCG reference level +6dB. All indications exceeding 20% of the TCG screen height shall be evaluated.

13.0 Coupling Monitoring and Data-Loss Limits

- 13.1 Wedge-to-parent-material coupling shall be monitored continuously during production testing.
13.2 On loss of coupling, the probe/scanner shall be moved back to the position prior to loss; adequate coupling shall be re-established before proceeding.
13.3 Total coupling loss shall NOT exceed either (a) 5.0 mm (0.25 in.) in any full scan distance, or (b) 3.0 mm (0.125 in.) consecutively.
13.4 Data loss noted shall NOT exceed 1% of recorded data.
13.5 No two consecutive lines of data may be incomplete, with no more than two data transfers missing in any 25 mm (1.0 in.) of scan length.

14.0 Evaluation Requirements

- 14.1 Evaluations shall be performed at calibrated reference sensitivity. Indications exceeding the 20% FSH threshold shall be evaluated, unless otherwise instructed by the project specification or TC Energy.

14.2 Indications shall be evaluated against the code of construction and/or the project-specific Engineering Critical Assessment (ECA) when invoked.

14.3 Geometric / Metallurgical Indications

Indications produced by ultrasonic testing are not necessarily defects. Changes in the weld geometry due to alignment offset of abutting pipe ends, changes in weld reinforcement profile of I.D. root and O.D. capping passes, internal chamfering, and ultrasonic wave mode conversion due to such conditions may cause geometric indications that are similar to those caused by weld imperfections but that are not relevant to acceptability.

14.4 Linear indications are defined as indications with their greatest dimension in the weld length direction. Typical linear indications may be caused by, but are not limited to, the following types of imperfections:

14.4.1 Inadequate penetration without high-low (IP)

14.4.2 Inadequate penetration due to high-low (IPD)

14.4.3 Inadequate cross penetration (ICP)

14.4.4 Incomplete fusion (IF)

14.4.5 Incomplete fusion due to cold lap (IFD)

14.4.6 Elongated slag inclusion (ESI)

14.4.7 Cracks (C)

14.4.8 Undercutting adjacent to the cover pass (EU) or root pass (IU)

14.4.9 Hollow bead porosity (HB).

14.5 Transverse indications are defined as indications with their greatest dimension across the weld. Typical transverse indications may be caused by, but are not limited to the following types of imperfections:

14.5.1 Cracks (C)

14.5.2 Isolated slag inclusions (ISI)

14.5.3 Incomplete fusion due to cold lap (IFD) at start/stops in the weld passes.

14.6 Volumetric indications are defined as three-dimensional indications. Such indications may be caused by single or multiple inclusions, voids, or pores. Partially filled voids, pores, or small inclusions at start/stops in weld passes may cause larger indications in the transverse direction than in the weld length direction. Typical volumetric indications may be caused by, but are not limited to, the following types of imperfections:

14.6.1 Internal concavity (IC)

14.6.2 Burn-through (BT)

14.6.3 Isolated slag inclusions (ISI)

14.6.4 Porosity (P)

14.6.5 Cluster porosity (CP)

14.7 Relevant indications are those caused by imperfections. Relevant indications shall be evaluated at the evaluation level given in §12.3.2. to the acceptance standards given in §16.0.

15.0 Length, Height, and Depth Sizing

15.1 Length

15.1.1 Indication length determined by the 6 dB drop method.

15.1.2 For saturated indications where the true peak amplitude cannot be obtained, additional scans at lower gain levels shall be performed; the length may be determined from the stored data files (all scans saved).

15.2 Height (Through-Wall)

15.2.1 Defined by analyzing the echo-dynamic characteristics and signal drop-off in the A-scan presentation.

15.2.2 If the indication's signal saturates the vertical screen height for encoded scans, the height shall be determined by all continuous channel responses above 50% FSH.

15.3 Depth

The depth of an indication shall be the through-wall distance from the outside surface of the examination material to the bottom of the defect.

16.0 Acceptance Standards (API 1104 §9.6 and Annex B; ECA when invoked)

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.
- 16.11 Engineering Critical Assessment (ECA)
Where API 1104 Annex A (Alternative Acceptance Standards for Girth Welds) or Annex B (Alternative UT Acceptance) is invoked, the project-specific ECA shall govern. ECA shall be issued by the Company, appended to the project Technique Sheet, and define the critical flaw height and length applicable to the project.
[Reference: API 1104 §9.6; API 1104 Annex A & Annex B; TES-NDT-PA §5.]
- 16.12 TOFD Acceptance Criteria shall be determined by TC Energy. This may be in the form of a critical flaw size, documentation of all detected flaws, or all detected flaws of a given type, depending on the application.

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 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 Level III.
- 18.2 Inspection of repair areas shall include the full length of the repair PLUS, a minimum of 75 mm (3.0 in.) on each end.

19.0 Reporting Requirements

- 19.1 The PAUT/TOFD Examination Report shall include, as a minimum:
- 19.1.1 Inspection equipment, software version, probe(s), wedge(s), encoder serial numbers.
 - 19.1.2 Scan type (E-Scan, S-Scan, Compound Scan, TOFD, Conventional).
 - 19.1.3 Procedure number and revision (PII-TC-PAUT Rev0) and scan plan implemented.
 - 19.1.4 Angular range of S-Scan; element numbers used for focal laws.
 - 19.1.5 Temperature of block and component at each calibration/verification.
 - 19.1.6 Weld configuration examined — thickness, bevel design, base material product form.
 - 19.1.7 Specification and code implemented (e.g., API 1104 §9.6 or Annex B; project ECA).
 - 19.1.8 Calibration blocks and standards used; reference sensitivity established.
 - 19.1.9 Scanning results — rejectable, non-rejectable, and non-relevant indications.
 - 19.1.10 Sizing details of indications — length (6 dB drop), height (echo-dynamic / multi-channel), depth, amplitude.
 - 19.1.11 Operator name and certifications (PAUT Level II/III, OQ status).
 - 19.1.12 Date and time of examination.

20.0 Data Management and Records

- 20.1 A data management plan consistent with project scope shall be established prior to mobilization.
- 20.2 All project data shall be backed up daily (or at the end of each shift) on media separate from the inspection equipment.
- 20.3 PII shall provide review software with unrestricted access to project data for TC Energy auditing.
- 20.4 File Naming — A systematic file naming convention shall be established to manage calibration data, setup files, and PAUT/TOFD data files. The convention shall align with the scan plan.

20.5 Raw Data — PAUT data shall be saved in the original raw A-scan format. Any review or evaluation shall not change or affect the original A-scan data.

20.6 Retention — Records shall be retained per the prevailing Code Section and 49 CFR §192.709 / §195.404 (minimum 7 years, or asset life if longer).

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	Governing Code / Specification Reference
4.0	PAUT/TOFD Personnel + Mock-Up Demo	SNT-TC-1A 2024; PII-WP-1; API 1104 §11.5.2; TC Energy OQ VF206; TES-NDT-PA §3
6.1	Instrument Linearity	ASME V Art. 4 Mand. App. IV/V; ASME SE-2491; ISO 18563-1
6.2	PAUT Probes	ISO 18563-2; ASME V Art. 4 Mand. App. IV
6.3	TOFD Probe Selection	ISO 10863; ASME V Art. 4 Mand. App. V; TES-NDT-PA
6.5	E-Scan / S-Scan / Compound / TOFD	ASME V Art. 4 Mand. App. IV §IV-432 & V §V-432; TES-NDT-PA
6.6	Encoders	TES-NDT-PA §5; ISO 13588
8.4	API 1104 Reference Standard	API 1104 §11.5.4; Annex B
9.0	Scan Plan	ASME V Art. 4 T-471/T-472; TES-NDT-PA §7; ISO 13588
10.3	Dead-Element Limits ($\leq 10\%$; no 2 adjacent)	TES-NDT-PA §8.2; ISO 18563-1
10.6	TCG ($\pm 5\%$ balance, ≥ 3 points)	ASME V Art. 4 Mand. App. IV §IV-432; TES-NDT-PA
11.0	TOFD Calibration (lateral wave, zones)	ASME V Art. 4 Mand. App. V; ISO 10863; TES-NDT-PA §8.6
13.0	Coupling-Loss Limits	TES-NDT-PA §7.9
15.0	Length / Height / Depth Sizing	API 1104 §11.5.8 & Annex B; ASME V Art. 4 Mand. App. V
16.0	Acceptance Standards	API 1104 §9.6 & Annex B; TES-NDT-PA §10

Procedure §	Subject	Governing Code / Specification Reference
19.0	Reporting	ASME V Art. 4 T-490; TES-NDT-PA §10; 49 CFR §192.709/§195.404
21.0	Variance Process	TC Energy Item ID 007728702

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.

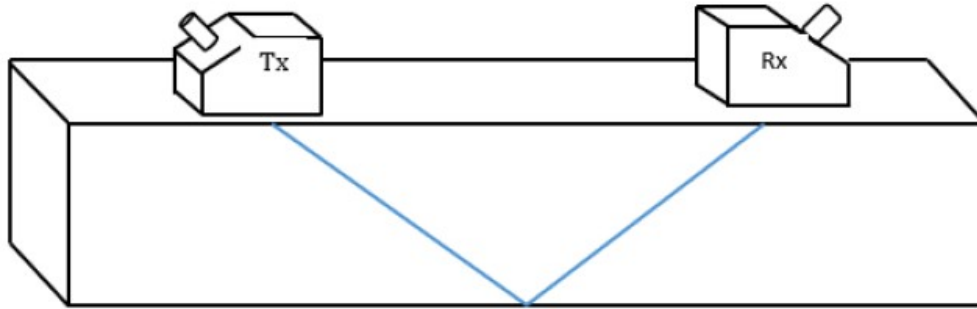


Figure 3: Transfer Correction Probe Placement

24.0 Phased Array Examination Report



Phased Array Examination Report

Form No: PII-PAUTFORM-Rev0
Report No: _____
Date: 7/28/2026
Page: 1 of _____
Job #: _____

[illegible]

25.0 Phased Array Calibration & Scan Plan



PAUT Equipment Calibration and Scan Plan

Prime inspection was contracted to	
Material	65
Part Temperature	95°F
Nominal Thickness	1.04
Performed From	1°F
Surface Condition	Buffed Smooth
RIG K	
Technique	42"0.780"
Acceptance Criteria	API 1104
Procedure	PII-PAUT Piping Rev4
Test Instrument	
Manufacturer:	Olympus
Model:	MX3 32-128
Serial #:	77046
Calibration Standards	
Ref. Block	42x0.780" MFIPI 036
Material	C/S
Linearity Reflector	SD Hole
Temperature	75
Sensitivity Cal Std	PACS Block
Sensitivity Reflector	0.047 @ .400D



System Settings:	Group 1	Group 2	Group 3	Group 4
Law Configuration	Shear	Shear	Longitudinal	
Beam Delay				
Beam Start	0.2	0.2		
Beam Range	1.00	65		
PRF	Auto	Auto		
Gain	31.30	31.1		
Mode	Half Path	Half Path		
Sound Velocity	.1276 in/Us	.1276 in/Us		
Pulse Width	100 ns	100 ns		
Scan Offset				
Index Offset	1.25	1.25		
# of Elements Used	32.00	32		
First Element	1	1		
Last Element	32.00	32		
Material Velocity	.1276 in/Us	.1276 in/Us		
Start Angle	38.00	38		
Stop Angle	72	72		
Angle Resolution	1.00	1		
Focal Depth	0.75	0.75		
Probe Skew	90.00	270		
Probe Information	Group 1	Group 2	Group 3	Group 4
Manufacture	Vernon NDT	Vernon NDT		
Probe Type	A-31 5L32	A-31 5L32		
Probe Mode	SW	SW		
Size	0.5	0.5		
Frequency	5	5		
Serial #	2077AD1066	2077AD1064		

— END OF DOCUMENT —