



PII-PAUT-02

Phased Array Ultrasonic Examination Storage Tanks & Pressure Vessels

PNDT-PAUT

Revision 02

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Revision / Change Summary

Revision/Change	No.	Date	Description
Initial	0	6/15/2020	Initial Issue — PAUT of pressure vessel welds per ASME Code Case 2235
Revision	01	12/11/2025	ASME Code review; new template format; incorporated ASME Section V Article 4 Mandatory Appendix V; added API 650 Annex U scope
Revision	02	9/30/2026	Complete rewrite to audit-ready format; extended scope to API 650 / API 653 storage tanks (shell, bottom, roof, nozzle welds) and ASME VIII Division 2 vessels; added Division 1 Mandatory Appendix 12 and Division 2 Table 7.8 fracture-mechanics acceptance; added API 650 Annex U acceptance; added zonal coverage for thick sections, encoder resolution, and Table T-421 essential variables; expanded calibration (Appendices I/II linearity, encoder), personnel demonstration per Appendix V, records retention per PII QMP; added six appendices; aligned with ASNT SNT-TC-1A 2020 Edition

Table of Contents

1.0 SCOPE

2.0 REFERENCED DOCUMENTS

3.0 DEFINITIONS AND ABBREVIATIONS

4.0 RESPONSIBILITY

5.0 PERSONNEL QUALIFICATIONS

6.0 EQUIPMENT AND MATERIALS

7.0 CALIBRATION BLOCKS

8.0 SURFACE PREPARATION AND TEMPERATURE

9.0 SCAN PLANNING

10.0 CALIBRATION AND SYSTEM VERIFICATION

11.0 EXAMINATION TECHNIQUE

12.0 DATA ANALYSIS AND EVALUATION

13.0 ACCEPTANCE CRITERIA

14.0 PROCEDURE QUALIFICATION AND DEMONSTRATION

15.0 DOCUMENTATION AND RECORDS

16.0 SAFETY

17.0 REVISION HISTORY

TABLE T-421 – ESSENTIAL AND NONESSENTIAL VARIABLES

APPENDICES

Appendix A – PAUT Scan Plan Template

Appendix B – Calibration Block Drawings and Requirements

Appendix C – ASME VIII Division 1 Mandatory Appendix 12 Acceptance Criteria

Appendix D – ASME VIII Division 2 Table 7.8 Fracture-Mechanics Acceptance Criteria

Appendix E – API 650 Annex U Acceptance Criteria

Appendix F – PAUT Indication Report Form

1.0 SCOPE

1.1 This procedure establishes the minimum requirements for shop and field phased array ultrasonic examination (PAUT) of full-penetration welds in pressure vessels constructed to ASME Boiler and Pressure Vessel Code Section VIII, Division 1 and Division 2, and in aboveground welded storage tanks constructed, repaired, or altered to API 650 and API 653. The technique uses phased array transducers with electronic beam steering and focusing, encoded scanning, and computer-based data acquisition to provide full volumetric coverage of the weld and heat-affected zone, and to dimension indications for comparison with the applicable acceptance standard.

1.2 This procedure applies to the following weld categories: (a) longitudinal and circumferential shell seams (Category A and B) of pressure vessels; (b) nozzle-to-shell and nozzle-to-head attachment welds (Category D) where geometry permits; (c) head-to-shell welds (Category B/C); (d) storage tank shell vertical and horizontal butt welds; (e) tank annular plate and bottom plate butt welds where full-penetration groove welds are specified; (f) tank roof-to-shell and roof plate butt welds; and (g) tank shell nozzle and manway reinforcing plate attachment welds where PAUT is specified in lieu of or as a supplement to radiography.

1.3 Materials covered are carbon steel and low-alloy steel (P-No. 1, 3, 4, 5A, 5B, and 9A/9B) with nominal thicknesses from 0.25 in. (6 mm) through 4.0 in. (100 mm). Thicknesses outside this range, austenitic or duplex stainless steels, nickel alloys, and clad or dissimilar-metal welds may be examined only after a successful demonstration on a representative mock-up approved by the PII UT Level III and the Owner/User or Authorized Inspector as applicable.

1.4 This procedure covers contact scanning from the O.D. surface (and I.D. surface where accessible) using linear phased array probes on refracting wedges producing shear waves between 40° and 70° and, where specified in the scan plan, longitudinal waves between 0° and 70°. Both sectorial (S-scan) and linear/electronic (E-scan) focal law sets are covered. Manual, semi-automated (encoded), and fully automated scanning are covered; encoded scanning is mandatory when PAUT is applied in lieu of radiography.

1.5 When PAUT is used in lieu of radiography for ASME Section VIII Division 1 vessels, the requirements of Mandatory Appendix 12 (Ultrasonic Examination of Welds — UT) and UW-53 apply. When used for ASME Section VIII Division 2 vessels under Part 7, paragraph 7.5.5, the fracture-mechanics-based acceptance criteria of Table 7.8 apply together with the flaw sizing and characterization requirements of this procedure. ASME Code Cases 2235 and 181 are cited for legacy reference only; their provisions have been incorporated into the Code and shall not be invoked as the governing document unless required by the contract.

1.6 When PAUT is used in lieu of radiography for API 650 storage tanks, the requirements of API 650 Section 8.3 and Annex U (Ultrasonic Examination in Lieu of Radiography) apply, including the requirement that the Purchaser approve the use of UT in lieu of RT and that the procedure be qualified per ASME Section V Article 4 Mandatory Appendix V (or Annex U.4 by reference). For in-service tanks, the repair and alteration examination requirements of API 653 Section 12 apply.

1.7 This procedure conforms to ASME Section V, Article 4, 2023 Edition, including Mandatory Appendix V (Phased Array E-Scan and S-Scan Linear Scanning Examination Techniques), and where applied in lieu of RT, the flaw-sizing techniques of Mandatory Appendix III and the workmanship-based or fracture-mechanics-based flaw evaluation of Nonmandatory Appendix N (Time of Flight Diffraction) is referenced only where TOFD is used as a supplementary technique.

1.8 This procedure is qualified for use based on successful calibration on a calibration block meeting Section 7.0 and a demonstration per Section 14.0. Any change to an essential variable listed in Table T-421 requires requalification of the procedure.

1.9 This procedure does not cover ultrasonic thickness measurement (see PII-UTT), manual UT (see PII-MUT), PAUT of piping systems (see PII-PAUT-01), or high-temperature hydrogen attack (HTHA) screening.

2.0 REFERENCED DOCUMENTS

2.1 The following documents are referenced in this procedure. The edition specified in the Owner/User contract or the referencing Code Section shall govern; where none is specified, the editions listed apply. Where a referenced document contains requirements that conflict with this procedure, the referencing Code Section or contract specification shall govern.

2.2 Codes and Standards

2.2.1 ASME BPVC Section V, Nondestructive Examination, 2023 Edition — Article 1 (General Requirements), Article 4 (Ultrasonic Examination Methods for Welds) including Mandatory Appendix I (Screen Height Linearity), Mandatory Appendix II (Amplitude Control Linearity), Mandatory Appendix III (Time of Flight Diffraction), Mandatory Appendix IV (Phased Array Manual Raster), Mandatory Appendix V (Phased Array E-Scan and S-Scan Linear Scanning), Mandatory Appendix VII (Ultrasonic Examination Requirements for Workmanship Based Acceptance Criteria), Mandatory Appendix VIII (Ultrasonic Examination Requirements for a Fracture Mechanics Based Acceptance Criteria), Mandatory Appendix IX (Procedure Qualification Requirements for Flaw Sizing and Categorization), Nonmandatory Appendix N (Time of Flight Diffraction Interpretation), and Article 23 (SE-2491 Evaluating Phased Array Systems)

2.2.2 ASME BPVC Section VIII, Division 1, Rules for Construction of Pressure Vessels, 2023 Edition — UW-11, UW-51, UW-53, and Mandatory Appendix 12 (Ultrasonic Examination of Welds — UT)

2.2.3 ASME BPVC Section VIII, Division 2, Alternative Rules, 2023 Edition — Part 7 (Examination Requirements), paragraphs 7.5.4 and 7.5.5 (Ultrasonic Examination in Lieu of Radiography), Table 7.8 (Flaw Acceptance Criteria for Surface and Subsurface Flaws), Table 7.9, and Annex 7.A

2.2.4 ASME Code Case 2235-9 (Use of Ultrasonic Examination in Lieu of Radiography) and Code Case 181 — legacy reference only; superseded by ASME VIII Div 1 Mandatory Appendix 12 and Div 2 paragraph 7.5.5

2.2.5 API Standard 650, Welded Tanks for Oil Storage, 13th Edition — Section 8.3 (Ultrasonic Examination of Welds), Section 8.1 (Radiographic Method — extent of examination), and Annex U (Ultrasonic Examination in Lieu of Radiography), including Table U-1 and U.6 acceptance criteria

2.2.6 API Standard 653, Tank Inspection, Repair, Alteration, and Reconstruction, 5th Edition — Section 12 (Examination and Testing), paragraph 12.1 (NDE) and 12.2 (Radiographs / UT in lieu of RT)

2.2.7 ASME BPVC Section IX, Welding, Brazing, and Fusing Qualifications, 2023 Edition

2.2.8 ASTM E2491, Standard Guide for Evaluating Performance Characteristics of Phased-Array Ultrasonic Testing Instruments and Systems (adopted as ASME SE-2491)

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

2.2.10 ASTM E1065, Standard Guide for Evaluating Characteristics of Ultrasonic Search Units

2.2.11 ASNT SNT-TC-1A, Recommended Practice, 2020 Edition — Personnel Qualification and Certification in Nondestructive Testing

2.2.12 ASME BPVC Section II, Part A — Ferrous Material Specifications (calibration block material)

2.3 Prime Inspections Inc. Documents

2.3.1 PII-QMP, Quality Management Program, Latest Revision

2.3.2 PII-WP-1, Written Practice for NDT Personnel Qualification and Certification, Latest Revision

2.3.3 PII-PAUT-01, Phased Array Ultrasonic Examination — Piping Systems, Rev 02

- 2.3.4 PII-MUT, Manual Ultrasonic Examination of Welds, Latest Revision
- 2.3.5 PII-UTT, Ultrasonic Thickness Measurement, Latest Revision
- 2.3.6 PII-HSE-01, Health, Safety and Environmental Manual, Latest Revision

3.0 DEFINITIONS AND ABBREVIATIONS

3.1 The following definitions and abbreviations apply throughout this procedure. Terms not defined herein have the meanings given in ASME Section V, Article 1, Mandatory Appendix I (Glossary of Terms) and ASTM E1316.

3.2 Definitions

Term	Definition
Active Aperture	The total length of the group of elements pulsed together to form a single focal law (virtual probe), equal to the number of active elements multiplied by the element pitch.
Annular Plate	The ring of bottom plates directly beneath the tank shell (API 650 5.5) whose butt welds are subject to volumetric examination requirements.
A-Scan	A display of signal amplitude versus time (sound path) for a single focal law.
B-Scan	A cross-sectional (side) view of the test object constructed from A-scans acquired along the scan axis, showing depth versus scan position.
C-Scan	A plan (top) view showing amplitude or depth as a function of scan and index position.
D-Scan (End View)	A cross-sectional view perpendicular to the scan axis showing depth versus index position.
Encoder	A position-sensing device (wheel, string, or magnetic) that records probe position along the scan axis so that data may be indexed to a weld reference datum.
E-Scan (Linear / Electronic Scan)	A scan in which the same focal law is multiplexed across a group of active elements stepped along the array, producing a set of parallel beams at a fixed angle.
Focal Law	The set of delays applied to individual elements to steer and/or focus the beam to a specified angle and depth.
Fracture-Mechanics-Based Acceptance	Acceptance criteria expressed in terms of flaw height (a), flaw length (l), and component thickness (t), as in ASME VIII Div 2 Table 7.8, requiring flaw sizing and surface/subsurface categorization.
Indication	The response or evidence of a reflector obtained by ultrasonic examination, prior to evaluation.
Line Scan	A single pass of the probe parallel to the weld axis at a fixed stand-off with the beam directed toward the weld; also called a linear scan or one-line scan.
Merged (Composite) View	A software presentation combining data from multiple focal laws, probes, or scans into a single true-depth image, corrected for wedge geometry and refracted angle.
Raster Scan	Scanning with probe motion perpendicular to the weld (index) combined with incremental movement along the weld (scan) to build volumetric coverage.
Reference Datum	The physical mark on the component (e.g., 0° / TDC / 12 o'clock or a stamped station) from which encoder positions are referenced.
Scan Plan	A documented plan, approved by the UT Level III, showing probe positions, focal laws, beam angles, coverage of the weld volume and HAZ by ray tracing, and calibration/sensitivity settings for a specific weld configuration.
S-Scan (Sectorial Scan)	A scan in which the same active aperture is used to generate a sweep of beams over a range of refracted angles (e.g., 40°–70°) producing a fan-shaped image.

Term	Definition
Surface Flaw	A flaw whose nearest point to a surface is at a distance of less than 0.5 times the flaw height (ASME VIII Div 2 7.5.5 / Section V Appendix VIII); subsurface otherwise.
TCG (Time Corrected Gain)	Electronic gain compensation applied as a function of time (depth) so that equal reflectors at different depths produce equal amplitude; the phased array equivalent of a DAC curve and required for each focal law.
Workmanship-Based Acceptance	Acceptance criteria expressed in terms of amplitude relative to the reference level and indication length, as in ASME VIII Div 1 Mandatory Appendix 12 and API 650 Annex U.6.
Zonal Coverage	Division of a thick weld into depth zones, each addressed by a dedicated focal law set / probe position, such that every zone is interrogated at near-optimum angle and sound path.

3.3 Abbreviations

Abbreviation	Meaning
AI	Authorized Inspector (ASME VIII)
DAC	Distance Amplitude Correction
FSH	Full Screen Height
HAZ	Heat-Affected Zone
LW / SW	Longitudinal Wave / Shear Wave
PAUT	Phased Array Ultrasonic Testing
RT	Radiographic Testing
SDH	Side-Drilled Hole
SNR	Signal-to-Noise Ratio
TDC	Top Dead Center
TOFD	Time of Flight Diffraction
UT	Ultrasonic Testing
UW	Section VIII Div 1 Part UW (Welded Vessels) paragraph prefix

4.0 RESPONSIBILITY

4.1 The PII Managing Director is responsible for approval of this procedure and for provision of the resources (personnel, equipment, and calibration standards) necessary for its implementation.

4.2 The PII Corporate Quality Manager is responsible for control, distribution, and periodic review of this procedure per PII-QMP; for ensuring that personnel certifications are current; and for ensuring that examination records are retained in accordance with Section 15.0.

4.3 The PII UT Level III is responsible for the technical content of this procedure; for preparing or approving all scan plans; for approving calibration block designs; for conducting or witnessing procedure demonstrations per Section 14.0; for approving mock-ups for materials or configurations outside Section 1.3; for resolving disputed interpretations; and for final review of examination reports when PAUT is applied in lieu of radiography.

4.4 The PAUT Level II examiner is responsible for verifying equipment calibration and linearity status; performing the examination in accordance with the approved scan plan; acquiring encoded data with adequate coverage and coupling; analyzing data and characterizing, sizing, and categorizing indications; recording results; and reporting any condition that prevents compliance with this procedure to the UT Level III before proceeding.

4.5 The PAUT Level I trainee or assistant may set up scanners, apply couplant, prepare surfaces, and operate equipment under the direct supervision of a Level II or Level III, but shall not interpret, evaluate, or accept/reject results.

4.6 The Client / Owner-User / Fabricator is responsible for identifying the referencing Code Section and edition, the acceptance standard (workmanship or fracture-mechanics), the extent of examination, weld joint details (WPS, joint geometry, thickness), access and surface condition, and for obtaining Authorized Inspector or Purchaser acceptance of UT in lieu of RT where required by ASME VIII UW-11(a)(8), Div 2 7.5.5, or API 650 U.1.

4.7 Where the Authorized Inspector or Client representative elects to witness calibration or examination, PII shall provide reasonable notice and access to data files.

5.0 PERSONNEL QUALIFICATIONS

5.1 Personnel performing examinations to this procedure shall be qualified and certified in accordance with PII-WP-1, which meets or exceeds ASNT SNT-TC-1A, 2020 Edition, and the referencing Code Section (ASME Section V Article 1, T-120(e) and (f); API 650 U.3 and 8.3.2).

5.2 Personnel who acquire and analyze PAUT data shall be certified UT Level II or Level III and shall hold a PAUT-specific endorsement documented in their certification record. The PAUT endorsement requires, as a minimum, 40 hours of formal phased array training, 320 hours of documented PAUT experience (which may be concurrent with UT Level II experience), and successful completion of a PAUT-specific practical examination including data acquisition and analysis of encoded scans on flawed specimens.

5.3 In addition to certification, personnel performing PAUT in lieu of radiography (ASME VIII Div 1 App 12, Div 2 7.5.5, API 650 Annex U) shall have successfully demonstrated their ability to detect, characterize, and size flaws in a blind performance demonstration per ASME Section V Article 4, Mandatory Appendix V, paragraph V-471 and Section 14.0 of this procedure. The demonstration shall be on a specimen set representative of the thickness range, joint geometry, and flaw types expected, and shall be witnessed and documented by the UT Level III.

5.4 Only Level II or Level III personnel shall interpret, evaluate, and report results. Level I personnel shall not perform examinations independently.

5.5 Personnel shall have a current near-vision acuity examination (Jaeger J-1 or equivalent at not less than 12 in.) and color perception examination in accordance with PII-WP-1. Vision examinations shall be repeated annually.

5.6 Personnel shall be familiar with the specific make and model of phased array instrument, analysis software, scanner, and encoder used. Familiarization training on new equipment shall be documented before that equipment is used for Code examinations.

5.7 Certification records, including training hours, experience, examination scores, vision test, and PAUT endorsement / demonstration records, shall be available for review by the Client and Authorized Inspector.

Requirement	PAUT Level II	UT Level III
UT Method Training (SNT-TC-1A 2020, Table 6.3.1A)	80 hours cumulative (40 Level I + 40 Level II)	Per SNT-TC-1A 6.3 / ASNT NDT Level III certificate
PAUT-Specific Training	40 hours minimum	40 hours minimum or documented equivalent
UT Experience	1,680 hours cumulative in UT (210 hrs min Level I, 630 hrs Level II) per Table 6.3.1A	Per SNT-TC-1A 6.3.2
PAUT Experience	320 hours documented in PAUT data acquisition & analysis	—
Written Examinations	General, Specific, and Practical (PAUT) — 70% min each, 80% composite	ASNT Basic + Method + Specific
Performance Demonstration (in lieu of RT)	Blind demonstration per App V-471 / Section 14.0	Witnesses and approves

Requirement	PAUT Level II	UT Level III
Vision	Jaeger J-1 near vision, color perception; annual	Jaeger J-1 near vision, color perception; annual
Recertification Interval	5 years maximum	5 years maximum

6.0 EQUIPMENT AND MATERIALS

6.1 Phased Array Instrument

6.1.1 The instrument shall be a computerized phased array ultrasonic system capable of generating, receiving, and displaying focal laws for sectorial and linear scanning; storing all A-scan data (full waveform capture) as a function of encoded position; and applying TCG independently to each focal law. Minimum configuration is 16 pulser channels / 64 receive channels (16:64); 32:128 or greater is preferred for thicknesses above 2.0 in.

6.1.2 The instrument shall operate at a nominal frequency range of at least 1 MHz to 10 MHz and shall provide calibrated gain in steps of 1 dB or less over a range of at least 0 to 80 dB. Pulser voltage, pulse width, digitizing frequency (minimum 5 times the probe nominal frequency, 100 MHz preferred), and filter settings shall be recorded in the scan plan and shall not be changed between calibration and examination.

6.1.3 The instrument shall have been evaluated for screen height linearity and amplitude control linearity within the preceding 3 months per ASME Section V Article 4, Mandatory Appendices I and II, and for the phased array-specific characteristics of ASME Section V Article 23 SE-2491 (element activity, beam steering, focusing) at intervals not exceeding 12 months or following repair. Evidence of linearity shall be maintained on the PII Equipment Linearity Record and shall be available at the job site.

6.1.4 Acceptable instruments include, but are not limited to: Olympus/Evident OmniScan MX2, X3, X3 64, Zetec TOPAZ 16/32/64, Sonatest Veo3, and Eddyfi Gekko. Substitution of an instrument model is a nonessential variable provided the linearity checks and array characterization have been performed and the model has been used in the procedure demonstration or has demonstrated equivalent sensitivity on the calibration block.

6.2 Phased Array Probes

6.2.1 Probes shall be linear (1-D) arrays of 16, 32, or 64 elements with nominal center frequencies of 2.25, 3.5, 5, or 7.5 MHz. Nominal frequency, element count, pitch, elevation, and active aperture shall be selected from the table below based on thickness and shall be recorded in the scan plan. Dual-linear (TRL) arrays may be used for near-surface or clad applications when approved in the scan plan.

6.2.2 Each probe shall have a manufacturer's certificate of conformance documenting center frequency (within $\pm 20\%$ of nominal), bandwidth, and element activity. Element activity shall be verified per Section 10.2 before each calibration; probes with more than 25% of elements inoperative, or with two or more adjacent dead elements within any active aperture, shall not be used.

6.2.3 Probe frequency is an essential variable within $\pm 20\%$ of nominal; a change beyond this requires requalification.

Nominal Thickness (in.)	Frequency (MHz)	Elements (typ.)	Pitch (mm)	Active Aperture (min.)	Typical Wedge / Angles
0.25 – 0.50	7.5 / 5.0	16 – 32	0.5 – 0.6	8 mm	SW 55° nominal; S-scan 45°–70°
0.50 – 1.00	5.0	32	0.6 – 1.0	16 mm	SW 55° nominal; S-scan 40°–70°
1.00 – 2.00	5.0 / 3.5	32 – 64	1.0	24 mm	SW 55°; S-scan 40°–70°; 2 zones
2.00 – 3.00	3.5 / 2.25	32 – 64	1.0 – 1.5	32 mm	SW 45°/60°; S-scan 40°–65°; 3 zones; LW for root

Nominal Thickness (in.)	Frequency (MHz)	Elements (typ.)	Pitch (mm)	Active Aperture (min.)	Typical Wedge / Angles
3.00 – 4.00	2.25	64	1.5	48 mm	SW 45°/60°; S-scan 40°–60°; 4 zones; LW 0° supplement

6.3 Wedges

6.3.1 Wedges shall be of a material (Rexolite or equivalent) and geometry that produce refracted shear waves in steel over the full angular range specified in the scan plan (40° to 70°) or longitudinal waves (0° to 70°) where specified, without excessive internal reverberation within the examination range. The wedge natural refracted angle, wedge velocity, height of first element, and roof/squint angles shall be entered into the instrument and verified by wedge delay calibration.

6.3.2 For curved surfaces with a radius less than 20 in. (nozzles, small-diameter vessels, tank shell courses of small tanks scanned circumferentially), wedges shall be contoured to the surface when the gap between the wedge and surface exceeds 0.020 in. (0.5 mm) at any point. Axially oriented scans on tank shells (vertical seams) and large-diameter vessels normally require flat wedges. Contoured wedges are a nonessential variable provided the calibration block curvature requirement of Section 7.4 is met.

6.3.3 Wedges shall be equipped with carbide wear pins or shall be inspected for wear before each calibration. A wedge worn such that the wedge delay calibration cannot be achieved within ± 0.5 mm of the theoretical exit point shall be replaced.

6.3.4 Wedges shall have irrigation ports for couplant feed when used on scanners.

6.4 Scanners and Encoders

6.4.1 Encoded scanning shall use a manual or motorized scanner that maintains probe orientation (skew) within $\pm 2^\circ$ of the scan plan and stand-off within ± 2 mm. Magnetic-wheel scanners (e.g., Olympus HSMT-Flex / Compact, Jireh Navic / Skoot, Zetec Paintbrush) are acceptable on ferritic vessels and tank shells. Band, chain, or ring scanners are acceptable on nozzles and small-diameter components.

6.4.2 Encoders shall have a resolution of at least 20 counts/mm and shall be calibrated per Section 10.6 to within $\pm 1\%$ of true distance over a minimum of 20 in. (500 mm). Encoder resolution setting (data recording increment) shall not exceed the values of Section 11.4.

6.4.3 For line scans on large tank shells, a straight-edge guide or magnetic strip shall be used to maintain constant stand-off from the weld centerline.

6.5 Couplant

6.5.1 Couplant shall be a water-based gel, glycerin, water with wetting agent, or equivalent commercial ultrasonic couplant. The same couplant type shall be used for calibration and examination.

6.5.2 Couplants used on nickel alloys, austenitic or duplex stainless steels, or titanium shall be certified to contain not more than 250 ppm halogens (chlorides plus fluorides) and 250 ppm sulfur, and certification shall be on file.

6.5.3 For surface temperatures above 125°F (52°C), a high-temperature couplant rated for the surface temperature shall be used and high-temperature wedges shall be specified in the scan plan.

6.6 Analysis Software

6.6.1 Data analysis software (e.g., OmniPC, TomoView, UltraVision, Sonatest UTstudio, Eddyfi Capture) shall be capable of displaying A-, B-, C-, D- and S-scan views; true-depth corrected merged

views; overlaying the weld profile; measuring indication length along the encoded axis, depth, and height; performing amplitude-drop (6 dB) sizing; and generating reports. Software version shall be recorded on the examination report.

6.6.2 The original acquired data file shall not be modified; analysis shall be performed on a copy or with software that preserves the raw data and records analysis gain and gates separately.

7.0 CALIBRATION BLOCKS

7.1 Basic calibration blocks shall conform to ASME Section V, Article 4, T-434.1 (general), T-434.2 (non-piping calibration blocks, Fig. T-434.2.1), and Mandatory Appendix V (V-434) as applicable. Block material shall be of the same product form and P-Number grouping (P-No. 1, 3, 4, 5A, 5B, 9A, 9B, 10 are considered equivalent per T-434.1.2) as the component, shall have received at least the minimum tempering treatment of the material specification, and shall be examined by straight beam prior to fabrication of reflectors to confirm freedom from indications exceeding the remaining back-wall reflection.

7.2 Block thickness (T) shall be selected per Table T-434.2.1 for the weld thickness (t) range being examined. Block thickness and hole diameter are listed in Appendix B. A block qualifies for weld thicknesses from $t/2$ to $2t$ up to the maximum thickness of the block's applicable range; alternatively, a block of thickness $t \pm 25\%$ may be used. The block shall be long enough to allow full sound path for the maximum refracted angle at the maximum depth (minimum $3T$ for 70°).

7.3 Reflectors shall be side-drilled holes (SDH) of the diameter specified in Table T-434.2.1(a) (Appendix B), located at $T/4$, $T/2$, and $3T/4$ depth as a minimum. For blocks over 2 in. thick, additional SDHs shall be provided so that reflector spacing does not exceed 1 in. of depth. Surface notches (square or 60° V-notch, depth $2\% T$ maximum 0.1 in., width not exceeding 0.25 in., length minimum 1 in.) shall be provided on both surfaces for near-surface and far-surface sensitivity verification when required by the scan plan or when Division 2 fracture-mechanics sizing is applied.

7.4 Curvature: For examination surfaces with a diameter of 20 in. (500 mm) or less (nozzles, small vessels), the block shall be curved with a diameter between 0.9 and 1.5 times the component diameter per T-434.1.7.2. Surfaces with diameter greater than 20 in. — including all API 650 tank shells and most vessel shells — are considered flat for calibration purposes and a flat block may be used.

7.5 Cladding: For clad components where the examination is performed through the cladding, the block shall be clad by the same welding procedure or a demonstrated equivalent per T-434.1.4.

7.6 Encoded PAUT (Appendix V) reference sensitivity for TCG shall use the SDHs of the basic block. Where the referencing Code requires a fracture-mechanics evaluation, the block shall additionally contain at least one reflector (SDH or notch) within the upper and lower 25% of the thickness for height-sizing verification.

7.7 Calibration blocks shall be uniquely identified with a permanent serial number, material specification, heat/lot traceability, and thickness. A dimensional drawing and material test report or certificate of conformance shall be on file for each block. Blocks shall be visually inspected for corrosion, mechanical damage, or plugged holes before each use.

7.8 An IIW Type 1 or Type 2 block, or equivalent, may be used for velocity and wedge delay verification but shall not be used as the primary sensitivity reference.

7.9 Where a blind demonstration specimen (flawed plate) is used for procedure or personnel demonstration per Section 14.0, it shall be separate from the calibration block and shall be documented with a flaw map controlled by the UT Level III.

8.0 SURFACE PREPARATION AND TEMPERATURE

8.1 The examination surface on each side of the weld shall be free of weld spatter, loose scale, rust, paint (unless tightly adherent, uniform, and accounted for in the calibration/transfer correction), dirt, oil, and surface irregularities that would interfere with coupling or probe movement. The prepared band shall extend from the weld toe a distance sufficient for the maximum stand-off in the scan plan plus the scanner footprint, but not less than $1.5T + 2$ in. on each side of the weld where access permits.

8.2 Weld crowns shall be ground flush or dressed to a smooth contour when the scan plan requires scanning over the weld (e.g., zero-degree LW supplement or when single-side access requires beams to be transmitted through the cap). Where the cap is not ground, the scan plan shall demonstrate by ray tracing that full coverage of the weld volume and HAZ is achieved from the stand-off positions without transmitting through the cap.

8.3 Surface roughness shall not exceed $250\text{ }\mu\text{in.}$ ($6.3\text{ }\mu\text{m}$) Ra for encoded scanning. Grinding marks shall be oriented parallel to the direction of probe motion where practical. Surface waviness or weld toe undercut that causes loss of coupling exceeding 6 dB shall be corrected before scanning.

8.4 Tank shells and vessel surfaces coated with a tightly adherent paint or thin coating up to 0.020 in. (0.5 mm) may be examined through the coating provided a transfer correction per Section 10.5 is performed on the coated component and the correction does not exceed 6 dB. Coatings greater than 0.020 in., thermal spray, or loose coatings shall be removed in the scan band.

8.5 Temperature: The temperature difference between the calibration block and the examination surface shall not exceed 25°F (14°C) per T-461.1. The standard temperature range for this procedure is 40°F to 125°F (4°C to 52°C). For surfaces from 125°F to 300°F (52°C to 150°C), high-temperature wedges and couplant shall be used, the calibration block shall be heated to within 25°F of the surface, and probe dwell time shall be limited per the wedge manufacturer's rating. Examination above 300°F requires a UT Level III-approved technique.

8.6 The weld shall be uniquely identified and a reference datum (zero point) and scan direction shall be permanently marked (paint stick or low-stress stamp as permitted by the Owner) on the component prior to encoded scanning. For vertical tank shell seams, the datum is the bottom of the seam (top of lower course) and the scan direction is upward. For horizontal tank seams and vessel circumferential seams, the datum is a stamped or marked station (0° / TDC / North) and the scan direction is clockwise viewed from the designated reference end. For nozzles, the datum is the 12 o'clock position with respect to the vessel axis.

8.7 Hi-lo (misalignment), weld width, cap height, and root condition shall be recorded on the scan plan, and any deviation from the assumed weld profile exceeding $1/16$ in. shall be evaluated by the examiner for its effect on coverage.

9.0 SCAN PLANNING

9.1 A written scan plan shall be prepared for each weld joint configuration (thickness, joint geometry, diameter, and material grouping) before examination and shall be approved by the PII UT Level III. The scan plan shall be documented on the template in Appendix A (or an equivalent software-generated report containing the same information) and shall be attached to, or referenced by, the examination report. A scan plan may cover a group of welds of identical configuration.

9.2 Scan plans shall be developed using ray-tracing / beam-modeling software (e.g., ESBeamTool, Olympus NDT SetupBuilder, Zetec UltraVision Scan Plan, Eddyfi Capture) that models the actual weld bevel geometry, thickness, and probe/wedge combination. A screenshot or plot of the ray-traced coverage shall be included in the scan plan.

9.3 Minimum Content of the Scan Plan

9.3.1 Component identification: vessel/tank number, drawing, weld ID(s), material, nominal thickness, diameter or curvature, joint design (bevel angles, root face, root gap, land), WPS, and whether the cap is ground.

9.3.2 Equipment: instrument model, software version, probe model/serial, frequency, element count, pitch, wedge model/angle/serial, scanner and encoder model, couplant.

9.3.3 Focal laws: for each probe position — scan type (S-scan / E-scan), wave mode, angular range and step (S-scan, maximum 1° step), fixed angle and element step (E-scan), first element, number of active elements, focal depth/type (true depth, projection, half-path, or unfocused), and pulser/receiver settings.

9.3.4 Probe positions: index offset (stand-off) from the weld centerline for each probe position, skew angle, and side(s) of the weld. Coverage from both sides of the weld is required unless prevented by geometry, in which case the plan shall demonstrate equivalent coverage and the Client/AI shall be notified.

9.3.5 Coverage demonstration: ray-traced plot showing that the entire weld volume plus the HAZ (minimum 1/4 in. or 0.5T beyond the fusion line, whichever is less, on each side) is intersected by at least two beam angles, one of which is within $\pm 10^\circ$ of normal to the fusion face for detection of planar fusion-line flaws, and that the root and cap regions are covered.

9.3.6 Zonal breakdown for thicknesses above 1.0 in. per Section 9.5.

9.3.7 Encoder resolution (data recording increment), scan speed limit, and overlap requirements per Section 11.4.

9.3.8 Calibration block identification, TCG reflectors, reference sensitivity, scanning sensitivity, and transfer correction method.

9.3.9 Acceptance standard (referencing Code, workmanship or fracture-mechanics table).

9.3.10 Preparer, approver (UT Level III), date, and revision.

9.4 Beam Angle Selection

9.4.1 Sectorial scans shall span a minimum of 40° to 70° shear wave for thicknesses up to 2.0 in. For thicker sections, the upper angle may be reduced to 60°–65° to preserve SNR at long sound paths, provided the ray trace confirms coverage of the fusion faces. Beams above 70° shall not be relied upon for detection because of surface-wave generation and mode conversion.

9.4.2 For single-V or double-V bevels with bevel angles of 30°–37.5° from vertical, the fusion face is best interrogated by beams of 52°–60° (perpendicular incidence); an E-scan at 55°–60° is

recommended in addition to the S-scan. For narrow-gap (J or U) preparations with near-vertical fusion faces, beams of 40°–50° with a second (full-skip or tandem) leg, or TOFD supplement, shall be used.

9.4.3 Where the weld is examined for transverse flaws (required by ASME VIII Div 2 7.5.5 and by API 650 Annex U when specified by the Purchaser), the scan plan shall include probe positions skewed 0°±15° to the weld axis on the ground cap or two positions at ±45° skew on the parent metal if the cap is not ground.

9.4.4 A 0° longitudinal-wave scan of the base metal in the scan band shall be performed prior to angle-beam examination to detect laminations that would interfere with the angle beams (T-472.1.1), and to record actual thickness at the scan positions.

9.5 Zonal Coverage for Thick Sections

9.5.1 For thicknesses above 1.0 in., the weld shall be divided into depth zones not exceeding 1.0 in. (25 mm) each, and the scan plan shall assign to each zone a focal law set (or probe position) whose focal depth lies within that zone and whose sound path does not exceed the range in which the TCG has been verified. Typical zoning: 1.0–2.0 in. — 2 zones; 2.0–3.0 in. — 3 zones; 3.0–4.0 in. — 4 zones.

9.5.2 Each zone shall be covered by beams from both sides of the weld. Adjacent zones shall overlap by at least 10% of the zone height. The lower zones (root region) of thick double-V welds shall be interrogated using first-leg beams from a larger stand-off or from the opposite surface where accessible, rather than second-leg beams, wherever geometry permits.

9.5.3 A separate TCG shall be established for each focal law set (each probe position / zone), using SDHs that span the depth range of that zone.

9.5.4 Where multiple probe positions are required for zonal coverage, the scanner shall carry the probes simultaneously in a fixed frame where practical so that all zones are recorded in a single encoded pass; otherwise each pass shall be separately encoded from the same datum and merged in analysis.

10.0 CALIBRATION AND SYSTEM VERIFICATION

10.1 Calibration shall include the complete ultrasonic system — instrument, probe, wedge, cable, scanner/encoder, couplant, and software settings — and shall be performed on the calibration block described in Section 7.0 with the same settings that will be used for the examination. Calibration shall be performed at the start of each examination shift, and verification per Section 10.8 shall be performed at the intervals specified. The block temperature shall be within 25°F of the component surface temperature.

10.2 Element Activity (Array Operability) Check

10.2.1 Before wedge delay and sensitivity calibration, an element-activity check shall be performed by pulsing each element individually (or in the smallest group the instrument allows) against a flat surface or the IIW block and recording the relative amplitude of the back-wall echo from each element. Elements with amplitude more than 6 dB below the average are considered inactive.

10.2.2 The probe is acceptable if not more than 25% of elements are inactive and no two adjacent elements within any active aperture are inactive. The result shall be recorded on the calibration record.

10.3 Velocity and Wedge Delay Calibration

10.3.1 Material velocity (shear and/or longitudinal) shall be verified on the calibration block or a block of the same material using two known sound paths (e.g., IIW 100 mm radius and 25 mm thickness) and entered into the focal law set.

10.3.2 Wedge delay shall be calibrated for every focal law (each angle of the S-scan or each element group of the E-scan) using a known radius (IIW 100 mm or 4 in. radius) or a SDH at known depth, such that the measured sound path or depth of the reflector is within ± 0.5 mm (± 0.020 in.) of the true value across all angles. Beam-exit-point verification shall confirm that the indexed position of a known reflector is within ± 1 mm of its true position.

10.3.3 Angle verification: the refracted angle of at least the lowest, middle, and highest angles of each S-scan shall be verified on the SDHs such that the plotted depth and surface distance agree with the true position within $\pm 2^\circ$ equivalent.

10.4 Sensitivity and TCG

10.4.1 A TCG shall be constructed for each focal law set using the SDHs of the basic calibration block at a minimum of three depths (T/4, T/2, 3T/4) spanning the examination depth range, plus additional points so that no interval between points exceeds 1.0 in. of sound-path depth for thicknesses above 2 in. Each SDH shall be maximized at each angle (or each element group) and the amplitude set to the primary reference level of 80% FSH ($\pm 5\%$).

10.4.2 After TCG construction, every SDH shall be re-scanned with each focal law and shall read 80% $\pm 10\%$ FSH (equivalently within ± 2 dB) at all angles; angles that do not meet this tolerance shall be excluded from evaluation or the TCG re-established. Per Appendix V, V-463.5, the TCG shall be established for the full angular range used.

10.4.3 Reference sensitivity is defined as the gain at which the TCG SDH responses are at 80% FSH. Scanning (acquisition) sensitivity shall be reference sensitivity plus at least 6 dB (T-472.1.2), or greater as needed to bring the noise floor to not less than 5% but not more than 20% FSH; the scanning gain shall be recorded so that analysis can be normalized to reference (evaluation) gain.

10.4.4 For workmanship-based acceptance (Div 1 Appendix 12, API 650 Annex U), the reference level is the TCG (DAC-equivalent) amplitude from the SDH; indications are evaluated as a percentage of the reference level.

10.4.5 Where notches are used for near-surface/far-surface verification, the notch responses shall be recorded on the calibration record for information; the notch shall not be used to set reference sensitivity.

10.5 Transfer Correction

10.5.1 Transfer correction shall be performed when the component surface condition, curvature, coating, or material attenuation differs from the calibration block, using two probes in pitch-catch (through-transmission) mode at the same angle on both the block and the component, or by comparison of back-wall reflection of a 0° focal law. The difference in dB shall be applied as additional gain (positive correction only unless approved by the UT Level III) and recorded. Transfer correction exceeding 6 dB requires surface improvement or UT Level III approval; correction exceeding 12 dB is not permitted.

10.6 Encoder Calibration

10.6.1 The encoder shall be calibrated at the start of each shift, after any change of scanner, wheel, or encoder, and whenever data positions are suspect, by moving the scanner a measured distance of at least 20 in. (500 mm) along a straight-edge and adjusting the encoder resolution such that the displayed distance is within $\pm 1\%$ of the true distance. Calibration shall be verified on the component surface (scanner wheels engaged) before acquisition. Encoder direction and datum offset shall be verified.

10.7 Instrument Linearity (Appendix I and II)

10.7.1 Screen height linearity shall be verified per ASME Section V Article 4, Mandatory Appendix I, at intervals not exceeding 3 months: two reflector signals set to 80% and 40% FSH shall maintain a 2:1 ratio within 5% FSH as gain is varied so that the larger signal ranges from 100% to 20% FSH. For phased array instruments, this shall be performed on at least one focal law from each active group (or per SE-2491 methodology).

10.7.2 Amplitude control linearity shall be verified per Mandatory Appendix II at intervals not exceeding 3 months: with a reflector set at 80% FSH, gain changes of -6 dB, -12 dB, +6 dB (from 40%), and -18 dB (from 80%) shall produce amplitudes of 32–48%, 16–24%, 64–96%, and 8–12% FSH respectively. Records shall be maintained on the PII Linearity Record and shall accompany the equipment.

10.7.3 Phased array system characterization per ASME Section V Article 23 (SE-2491) — including beam steering/angle accuracy, element activity, and focal law verification — shall be performed annually and after major repair.

10.8 Calibration Verification and Recalibration

10.8.1 Calibration shall be verified (sensitivity and sweep/depth) on the calibration block at the start and end of each examination shift, at least every 4 hours during the examination, upon any change of examiner, and at the completion of each weld or group of welds examined under one calibration data set. Verification shall be recorded.

10.8.2 Recalibration is required upon any change or substitution of instrument, probe, wedge, cable, scanner/encoder, couplant type, power source (battery to line), or software version, and upon any change to focal law parameters other than analysis gain.

10.8.3 If, during verification, any reference reflector amplitude has decreased by more than 20% or 2 dB, or any point on the depth/sweep has shifted by more than 10% of the sound path or 5% of full screen, the system shall be recalibrated and all data acquired since the last valid verification shall be re-acquired. If amplitude has increased by more than 20% or 2 dB, all recorded indications since the last valid verification shall be re-evaluated using the corrected calibration and their values changed on

the data sheets.

10.8.4 Verification may be performed on a simulator or check block of documented equivalence only for the intermediate 4-hour checks; the start and end verification shall be on the basic calibration block.

Calibration / Verification Item	Frequency	Tolerance	Reference
Screen height linearity	≤ 3 months	±5% FSH of 2:1 ratio	Art. 4 Mand. App. I
Amplitude control linearity	≤ 3 months	Per App. II table (±20% of expected)	Art. 4 Mand. App. II
Phased array system characterization	Annual / after repair	Per SE-2491	Art. 23 SE-2491
Element activity	Each calibration	≤ 25% dead; no 2 adjacent	App. V V-461; SE-2491
Wedge delay / velocity	Each calibration	±0.5 mm depth; ±1 mm index	T-461; App. V
TCG (all angles)	Each calibration	80% ±10% FSH on all SDHs	T-463; V-463.5
Encoder	Each shift / change	±1% over 500 mm	App. V V-461.3
Calibration verification	Start, ≤ 4 hr, end, changes	±20% / 2 dB; 10% sweep	T-467
Transfer correction	Each component / surface	≤ 6 dB (12 dB max w/ L-III)	Nonmand. App. S/U

11.0 EXAMINATION TECHNIQUE

11.1 Examination shall be performed in accordance with the approved scan plan using the calibrated system. The extent of examination (100% of designated welds, spot examination locations, or repair areas) shall be as specified by the referencing Code and the Client. When PAUT is applied in lieu of radiography, 100% of the length of each designated weld shall be examined, including the full weld volume and adjacent HAZ.

11.2 General

11.2.1 A 0° longitudinal-wave scan of the base metal in the scan band shall be performed before angle-beam scanning to detect laminar reflectors that would interfere with coverage and to record local thickness. Laminar indications exceeding 1 in. in any dimension shall be recorded and the scan plan adjusted (alternate stand-off or side) as necessary.

11.2.2 Angle-beam scanning for reflectors oriented parallel to the weld shall be performed from both sides of the weld on the same surface (or from both surfaces where required for coverage) with the beam directed perpendicular to the weld axis. Where access is available from only one side (e.g., nozzle-to-shell, tank shell-to-annular plate corner joint), the scan plan shall demonstrate coverage using additional angles, second-leg beams, or examination from the opposite surface, and the limitation shall be recorded on the report.

11.2.3 Scanning for transverse reflectors shall be performed when required by the referencing Code (ASME VIII Div 2 7.5.5; API 650 Annex U when specified) or Client, per Section 9.4.3.

11.2.4 Both S-scan and E-scan focal law sets defined in the scan plan shall be acquired. Where S-scan alone is used for detection, the scan plan shall demonstrate that all fusion faces are interrogated within $\pm 10^\circ$ of normal by at least one angle in the sweep.

11.3 Line (Linear) Scan vs. Raster Scan

11.3.1 Encoded line scanning (Appendix V technique) is the primary technique of this procedure: the probe(s) is/are held at the fixed stand-off(s) specified in the scan plan and moved parallel to the weld axis in a single pass per probe position, with the electronic S-scan/E-scan providing the through-thickness coverage that a raster would otherwise provide. Line scanning is required for PAUT in lieu of RT.

11.3.2 Manual raster scanning (Appendix IV technique) with the phased array probe may be used for supplementary investigation of indications, for nozzle welds or geometries where a scanner cannot be applied, or where specified by the Client, provided the raster index step does not exceed 0.5 times the active aperture width (or the -6 dB beam width, whichever is smaller) and scan speed does not exceed 6 in./s. Raster-scanned data without encoding shall not be used as the sole record for acceptance in lieu of RT.

11.3.3 For nozzle-to-shell welds, the preferred approach is an encoded line scan around the nozzle (ring or band scanner on the nozzle neck, or encoded manual scan on the shell) from both the shell side and the nozzle side where geometry permits, supplemented by manual raster scanning for the shell-side inside-corner region.

11.4 Encoder Resolution, Scan Speed, and Overlap

11.4.1 The data recording increment (encoder resolution) along the scan axis shall not exceed 0.04 in. (1 mm) for thicknesses up to 3 in. and 0.08 in. (2 mm) for thicknesses above 3 in. and shall in no case exceed 0.5 times the minimum flaw length to be recorded (V-471.2). The value used shall be recorded in the scan plan.

11.4.2 Scan speed shall not exceed the value at which the instrument's pulse repetition frequency and number of focal laws permit acquisition at every encoder increment; the instrument shall be configured to flag missed data lines. Data files containing more than 5% missed lines, or any missed lines over 2 consecutive increments within the weld length, shall be rescanned over the affected length plus 1 in. overlap at each end.

11.4.3 Where a weld is scanned in multiple segments (e.g., a horizontal tank seam scanned in 10 ft sections, or a vessel circumferential seam), adjacent segments shall overlap by at least 2 in. (50 mm) and each segment shall be referenced to the common datum. Where a scan is interrupted, it shall be restarted at least 2 in. before the interruption point.

11.4.4 Adjacent probe positions (index offsets) and zones shall overlap in coverage by at least 10% of the active aperture or zone height as demonstrated in the scan plan.

11.4.5 Coupling shall be monitored during acquisition (A-scan noise level, B-scan/C-scan continuity, or a coupling-check gate on a back-wall or wedge echo). Regions of coupling loss exceeding 0.1 in. along the scan axis shall be rescanned.

11.5 Component-Specific Requirements

11.5.1 Pressure vessel shell and head seams (Cat. A, B): Line scan from both sides at stand-offs per the scan plan. Long seams scanned axially; circumferential seams scanned circumferentially from a stamped 0° datum with clockwise convention. For heads, the knuckle curvature shall be considered in the scan plan and a contoured wedge or reduced aperture used where the gap exceeds 0.020 in.

11.5.2 Pressure vessel nozzle welds (Cat. D): Examine from the shell side (encoded around the nozzle) and from the nozzle neck outside surface where the neck length and diameter permit; where the inside of the nozzle is accessible, a 0°/low-angle scan from the bore may be used for the inner fusion face. Set-in versus set-on configuration and reinforcing pads shall be shown on the scan plan.

11.5.3 API 650 tank shell vertical seams: Datum at bottom of course, scan upward; scan from both sides of the seam. Where PAUT is in lieu of RT under Annex U, the number and location of examinations shall satisfy Section 8.1.2 (spot RT locations) as a minimum, or 100% as specified by the Purchaser; UT is normally applied 100% of vertical seams when substituted for RT.

11.5.4 API 650 tank shell horizontal seams: Datum at a marked station; scan from above and below the seam. For the first (bottom) course-to-annular-plate corner joint (T-joint fillet/penetration weld), PAUT is not a substitute for the vacuum-box / MT / PT examinations of 8.4 but may be applied as a supplementary volumetric examination with a Level III-approved technique.

11.5.5 API 650 annular plate and bottom plate butt welds: Full-penetration butt welds with backing strip (annular ring radial seams per 5.5.4) shall be scanned from the top surface only; the scan plan shall address the backing strip geometry and demonstrate that root indications can be discriminated from the backing-strip corner. Lap-welded bottom plates are not within the scope of PAUT.

11.5.6 API 650 roof welds: Roof plate butt welds (where specified as full penetration) and roof-to-shell compression ring welds may be examined from the roof surface with due regard for the thin plate (typically 3/16 in.–1/4 in.) using 7.5 MHz probes and high-angle S-scans; a demonstration on a representative thin-plate block is required before use.

11.5.7 API 653 repairs and alterations: Shell plate replacements, insert plates, door sheets, and repaired seams shall be examined per API 653 Section 12.1 and 12.2 with the acceptance criteria of API 650 (Annex U when UT in lieu of RT). The examination shall include the full length of new welds and, for door sheets and inserts, a minimum of 6 in. of existing weld on each side of the new weld intersections.

11.6 Data Quality Review at Acquisition

11.6.1 Before leaving the weld, the examiner shall review each data file for: complete coverage of the weld length from datum to datum plus overlap; absence of missed lines beyond 11.4.2; adequate coupling; correct datum and direction; geometry echoes (root, cap, backing) at expected positions confirming correct index offset; and noise level at 5–20% FSH. Deficient files shall be re-acquired before demobilizing from the weld.

12.0 DATA ANALYSIS AND EVALUATION

12.1 Analysis shall be performed by a PAUT Level II or Level III on the complete encoded data file, using the analysis software with the weld overlay, at the reference (evaluation) gain. Analysis shall consider all views (A, B, C, D, S, and merged) for each focal law set. The analyst shall be identified on the report; where the analyst is different from the acquisition examiner, both shall be recorded.

12.2 Recording Levels

12.2.1 Workmanship-based acceptance (ASME VIII Div 1 Mandatory Appendix 12; API 650 Annex U.6): All indications with amplitude greater than 20% of the reference level (TCG) shall be investigated to the extent necessary to determine the shape, identity, and location of the reflector and to evaluate against the acceptance standard. Indications exceeding 50% of reference level shall be recorded with location, length, depth, and maximum amplitude regardless of disposition.

12.2.2 Fracture-mechanics-based acceptance (ASME VIII Div 2 Table 7.8): All imaged indications that produce a response greater than 20% of the reference level, or that are identifiable as flaws by pattern (regardless of amplitude, e.g., tip-diffracted signals), shall be investigated, characterized as surface or subsurface, and sized for length and through-wall height. All flaws with height greater than the smaller of 0.05 in. or 10% of the Table 7.8 allowable shall be recorded.

12.2.3 All indications interpreted as cracks, lack of fusion, or incomplete penetration are recordable and rejectable regardless of amplitude or length under all acceptance standards of this procedure.

12.3 Discrimination of Geometric and Metallurgical Indications

12.3.1 Indications shall be evaluated to determine whether they originate from weld geometry (root, cap, backing strip, hi-lo, counterbore, weld toe, mode conversion) or from flaws. Geometric indications shall be plotted on the weld overlay and shall be correlated with the physical position of the geometric feature (within $\pm 1/16$ in.), shall be present continuously or in a regular pattern along the weld, shall behave consistently from both sides of the weld, and shall be confirmed by direct measurement of the surface profile where possible. Geometric indications so identified are non-relevant but shall be noted on the report with the basis for disposition.

12.3.2 Indications that cannot be positively attributed to geometry shall be treated as flaws. Where doubt remains, the UT Level III shall be consulted and supplementary techniques (manual UT with a different angle, TOFD, MT/PT of the surface, or profile gauging) may be used.

12.4 Length Sizing

12.4.1 Indication length shall be measured along the weld axis from the encoded C-scan or merged view using the 6 dB drop method: the length between the points at which the amplitude falls to 50% of the indication's maximum amplitude (for indications exceeding reference level) or, for workmanship criteria, the length over which the amplitude exceeds the applicable evaluation level (e.g., 20% or 50% of reference as required by the acceptance table). For indications with multiple peaks, the length shall be measured between the outermost points where amplitude falls to 50% of the smallest adjacent peak.

12.4.2 Indications on the same plane separated by less than the length of the shorter indication (Div 1 App 12) or by less than the spacing rules of Div 2 Annex 7.A / Section V App VIII (Appendix D of this procedure) shall be treated as a single indication with combined length.

12.5 Through-Wall Height Sizing and Surface/Subsurface Categorization (Div 2)

12.5.1 Flaw height (a) shall be measured using tip-diffraction (upper and lower tip signals) in the S-scan / B-scan where tip signals are resolvable; otherwise by the 6 dB drop method across the through-wall extent of the flaw using the S-scan or E-scan. The method used shall be recorded. For

flaws smaller than the beam dimension, the measured height shall not be reported as less than the value demonstrated in the procedure qualification (Section 14.0) for that probe frequency: 2.25 MHz — 0.100 in.; 3.5 MHz — 0.075 in.; 5 MHz — 0.060 in.; 7.5 MHz — 0.040 in.

12.5.2 Flaw depth (S) from the nearest surface shall be measured from the true-depth corrected view. A flaw is categorized as a surface flaw when $S < 0.5a$; otherwise as subsurface (ASME VIII Div 2 7.5.5.2 / Section V Appendix VIII). Surface flaws shall be evaluated with $a = \text{measured height} + S$ (i.e., extended to the surface).

12.5.3 Multiple flaws shall be evaluated for proximity using the rules of Div 2 Table 7.8 notes and Annex 7.A: flaws whose separation in the through-wall direction is less than the height of the larger flaw, or along the weld axis less than the length of the shorter flaw, shall be combined and the combined dimensions used for evaluation.

12.5.4 Aspect ratio a/l shall be computed and rounded down to the nearest tabulated value in Table 7.8 for determining the allowable a/t ; where $a/l > 0.5$, $a/l = 0.5$ shall be used.

12.6 Reporting of Evaluation

12.6.1 For each recordable indication, the report (Appendix F) shall include: weld ID; probe position/focal law set; start and end position along the weld from the datum; length; maximum amplitude (% reference) and the angle at which it occurred; depth to the reflector and, for Div 2, height and surface/subsurface category; indication type (flaw characterization: LOF, slag, porosity, crack-like, IP, geometric); acceptance standard applied; and disposition (accept/reject/repair). Screenshots of the merged view with the flaw measured shall be attached for all rejectable indications.

13.0 ACCEPTANCE CRITERIA

13.1 Acceptance criteria shall be those of the referencing Code Section and edition specified by the Client. The applicable standard shall be identified on the scan plan and report. The criteria are summarized below and tabulated in Appendices C, D, and E; the Code text governs in case of conflict with the summary.

13.2 **ASME Section VIII Division 1 — UW-53 and Mandatory Appendix 12 (workmanship):** Indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length. Other imperfections are unacceptable if the indication exceeds the reference level amplitude and has a length that exceeds: 1/4 in. for t up to 3/4 in.; 1/3 t for t from 3/4 in. to 2-1/4 in.; 3/4 in. for t over 2-1/4 in.; where t is the thickness of the weld excluding any allowable reinforcement (for a butt weld joining two members of different thickness, t is the thinner member; for a full-penetration weld including a fillet, the fillet throat is included in t). See Appendix C.

13.3 **ASME Section VIII Division 1 — UT in lieu of RT (UW-11(a)(8), Appendix 12-3 / 7.5.5 by reference):** Where the Division 1 vessel is examined by UT in lieu of RT per UW-11(a)(8) the fracture-mechanics acceptance criteria of Section VIII Division 2, 7.5.5 (Table 7.8) apply and the examination shall be performed per Appendix D of this procedure. This corresponds to the legacy Code Case 2235 methodology.

13.4 **ASME Section VIII Division 2 — Part 7, 7.5.5, Table 7.8 (fracture-mechanics):** Flaws characterized as cracks are unacceptable. Other flaws are evaluated for height-to-thickness ratio (a/t) against the allowable values of Table 7.8 as a function of aspect ratio (a/l) and surface/subsurface category for the thickness range ($t < 1$ in.; $1 \text{ in.} \leq t \leq 12 \text{ in.}$; $t > 12 \text{ in.}$ not applicable to this procedure). Flaws exceeding the allowable a/t, and all flaws whose length exceeds 4t ($t \leq 1 \text{ in.}$) or the tabulated limits, are unacceptable. Subsurface flaws with $S < 0.4d$ (where d is the flaw depth from the surface) shall be treated as surface flaws per the Table 7.8 notes. See Appendix D.

13.5 **API 650 Section 8.3 (UT, shop or field, when RT is also performed) — acceptance per ASME VIII UW-53 / Appendix 12** as invoked by 8.3.2. **API 650 Annex U (UT in lieu of RT) — acceptance per U.6:** Indications interpreted as cracks, incomplete fusion, or incomplete penetration are unacceptable. Other indications are evaluated against the length and amplitude limits of Table U-1 (Appendix E), which depend on thickness and include an allowance based on amplitude relative to the reference level (indications with amplitude below 50% reference may be longer than those exceeding reference). Where the Purchaser specifies, the fracture-mechanics criteria of ASME VIII Div 2 Table 7.8 may be used in lieu of U.6 with the sizing requirements of this procedure.

13.6 **API 653 Section 12:** Repair and alteration welds shall meet the acceptance standards of API 650 (8.1.5 for RT; 8.3 / Annex U for UT) as invoked by API 653 12.1 and 12.2, unless the Owner specifies more stringent criteria.

13.7 Indications exceeding the acceptance criteria shall be reported to the Client and, where applicable, the Authorized Inspector. Repairs shall be re-examined over the full repair length plus 2 in. beyond each end using this procedure with the same scan plan and acceptance standard as the original examination.

13.8 Where Client specifications impose criteria more stringent than the Code, the Client criteria shall be identified on the scan plan and applied.

14.0 PROCEDURE QUALIFICATION AND DEMONSTRATION

14.1 This procedure is written to ASME Section V Article 4 and Mandatory Appendix V and is qualified for workmanship-based acceptance (ASME VIII Div 1 Appendix 12; API 650 Annex U.6) by successful calibration on the basic calibration block and demonstration of the scan plan's coverage on that block. The essential variables are listed in Table T-421 (following Section 17.0); a change to any essential variable outside its stated range requires requalification.

14.2 When this procedure is applied for fracture-mechanics-based acceptance (ASME VIII Div 2 Table 7.8, or Div 1 UT in lieu of RT), the procedure shall be qualified in accordance with ASME Section V Article 4 Mandatory Appendix VIII and Mandatory Appendix IX, and the demonstration requirements of Mandatory Appendix V paragraph V-471 shall be met, as follows: (a) The qualification specimen set shall contain flaws (a minimum of three per specimen, including at least one surface-connected and one embedded planar flaw and one volumetric flaw) in welds representative of the joint geometry, thickness range ($\pm 25\%$ or the range being qualified, whichever is smaller), material grouping, and surface condition; (b) The demonstration shall detect all flaws; (c) Length shall be sized within ± 0.25 in. or $\pm 10\%$ of true length, whichever is greater; (d) Height shall be sized within RMS error not exceeding 0.125 in. (or the value specified by the referencing Code, e.g., Div 2 Annex 7.A) and the height under-sizing shall not exceed the tolerance that would cause a rejectable flaw to be accepted; (e) Surface/subsurface categorization shall be correct for all flaws; (f) The specimen flaw map shall be controlled by the UT Level III and the demonstration shall be blind to the examiner.

14.3 Personnel demonstration (V-471): Each PAUT Level II who acquires or analyzes data for acceptance in lieu of RT shall successfully complete a blind demonstration on the qualification specimen set (or an equivalent set approved by the UT Level III) before performing production examinations, and thereafter whenever the Level III has cause to question performance. Acceptance of the personnel demonstration is: detection of all flaws exceeding the recording threshold, no false calls that would be rejectable, and sizing within the tolerances of 14.2(c)–(e). Results shall be documented on the PII Performance Demonstration Record and filed with the certification record.

14.4 Mock-ups: For configurations outside Section 1.3 (austenitic/duplex/nickel alloys, clad, dissimilar metal, thicknesses outside 0.25–4.0 in., or unusual joint geometry), a mock-up with representative welds and reflectors (SDHs, notches, or implanted flaws) shall be examined per the proposed scan plan and the results reviewed and approved by the UT Level III and the Client/AI before production examination.

14.5 Qualification records shall include: specimen drawings and flaw maps, scan plan(s) used, data files, analysis results versus true state, statistical summary, names of personnel, equipment identification, and approval signatures. Records shall be retained for the life of the procedure revision.

14.6 The qualification remains valid for the ranges of the essential variables demonstrated. Extending the thickness range, changing the wave mode, frequency beyond $\pm 20\%$, or changing the acceptance methodology (workmanship to fracture-mechanics) requires additional qualification.

15.0 DOCUMENTATION AND RECORDS

15.1 A complete examination record shall be generated for each weld or group of welds examined under one scan plan and calibration. The record shall consist of the examination report (Appendix F format), the scan plan (Appendix A), the calibration record, the equipment linearity records, personnel certifications, and the electronic data files.

15.2 Examination Report Content (T-490 / V-490 / API 650 U.7)

15.2.1 Procedure identification and revision (PII-PAUT-02 Rev 02); scan plan number and revision; referencing Code and acceptance standard.

15.2.2 Component identification: Client, project, vessel/tank number, drawing, weld ID(s), material specification and grade, nominal thickness, diameter, joint design, WPS, surface condition, and surface temperature.

15.2.3 Equipment: instrument make/model/serial and software version; probe(s) make/model/serial, frequency, element count, pitch; wedge(s) model/angle/serial; scanner and encoder model/serial; couplant brand and batch (where halogen/sulfur control applies); calibration block identification.

15.2.4 Focal law settings: scan type, angular range/step or fixed angle/element step, active aperture, focal depth, pulser voltage, filter, digitizing frequency, PRF, TCG reference gain, scanning gain, transfer correction applied.

15.2.5 Calibration and verification times and results; encoder calibration; element activity result.

15.2.6 Scan details: datum location, scan direction, probe positions (index offsets), skew, encoder resolution, segments and overlaps, coverage limitations and areas not examined with reason.

15.2.7 Indication data per Section 12.6 for each recordable indication, including screenshots for rejectable indications.

15.2.8 Data file names (raw and analysis/processed), storage location, and file checksum or software-generated file identifier.

15.2.9 Examiner (acquisition) and analyst names, certification levels, and signatures; UT Level III review signature when in lieu of RT; date(s) of examination and analysis.

15.2.10 Results summary: accept / reject / repair-and-re-examine, per weld.

15.3 Electronic Data

15.3.1 The raw (unprocessed, full A-scan) data file for every scan, and the analysis (processed) file including analyst annotations, gates, measurements, and gain, shall both be archived. Raw files shall not be overwritten. File naming shall include: project, component, weld ID, probe position, and date/sequence (e.g., PRJ1234_V-101_W-03_P1_20260930_01.opd).

15.3.2 Data shall be copied from the instrument to PII secure storage (server or encrypted portable media) at least daily during field work, and to the PII project archive at completion. A copy of the data files shall be furnished to the Client with the report when PAUT is applied in lieu of RT (required by ASME VIII Div 2 7.5.5 and API 650 U.7 for the Manufacturer's/Purchaser's records), in a format readable with freely available viewer software or with the viewer software supplied.

15.4 Retention

15.4.1 All records listed in 15.1 shall be retained by PII for a minimum of one (1) year from the date of the report in accordance with the PII Quality Management Program (PII-QMP), or longer where required by the contract, Client specification, or the referencing Code (ASME VIII Div 1 UW-51(a)(4)/Appendix 12-4 and Div 2 7.5.5.3 require the Manufacturer to retain UT-in-lieu-of-RT

records until the Manufacturer's Data Report is signed by the Inspector, and the data shall be made available to the Owner; API 650 U.7 requires records be retained by the Manufacturer and furnished to the Purchaser). The Client is the long-term custodian of the records; PII shall furnish complete copies to the Client with the final report.

15.4.2 Calibration block drawings, material certifications, and equipment linearity/characterization records shall be retained for the life of the block/equipment plus one year.

15.4.3 Procedure qualification and personnel demonstration records shall be retained for the life of the procedure revision and the personnel certification respectively.

16.0 SAFETY

16.1 All work shall be performed in accordance with PII-HSE-01, the Client site safety requirements, and applicable OSHA 29 CFR 1910 / 1926 regulations. A job safety analysis (JSA) shall be completed before commencing work at each new location.

16.2 Tank and vessel work frequently involves elevated work (scaffolding, aerial lifts, tank shell climbing), confined space entry (vessel interiors, tank interiors, floating roofs), and hot work permits. Personnel shall hold current training for fall protection, confined space entry (attendant/entrant), and site-specific permits before performing these activities. Confined space entry requires a permit, atmospheric monitoring, attendant, and rescue plan per 29 CFR 1910.146.

16.3 Magnetic-wheel scanners exert strong attractive forces; pinch-point hazards shall be controlled by proper handling technique and gloves. Scanners used on vertical or overhead surfaces shall be tethered to prevent falls. Scanners shall be removed from the component when not in use.

16.4 Battery-operated instruments shall be used where line power presents a hazard; when line power is used, GFCI protection and inspected cords are required. Instruments shall not be operated in classified (hazardous) areas without a hot work / electrical permit or intrinsically safe equipment.

16.5 Hot-surface examinations (Section 8.5) require heat-resistant gloves, limited contact time, and awareness of burn hazard; couplant on hot surfaces may produce vapors — ensure ventilation.

16.6 Couplant spills shall be cleaned promptly to prevent slip hazards, particularly on tank roofs and scaffolds. Couplant and cleaning solvents shall have Safety Data Sheets on site and shall be disposed of per site requirements.

16.7 Personnel shall be aware of simultaneous operations, including radiography in progress by other crews, and shall observe radiation area boundaries.

16.8 Any injury, near miss, or unsafe condition shall be reported immediately to the site supervisor and PII management per PII-HSE-01.

17.0 REVISION HISTORY

17.1 This procedure shall be reviewed at intervals not exceeding three years, upon issue of a new edition of the referencing Code(s), or upon identification of a deficiency, per PII-QMP. Revisions shall be approved by the UT Level III and the Managing Director and shall be issued through controlled distribution.

Rev	Date	Section(s)	Description of Change	Approved
0	6/15/2020	All	Initial issue — PAUT of pressure vessel welds per Code Case 2235	B. Champion
01	12/11/2025	All	Template update; Section V Article 4 Appendix V; API 650 Annex U scope	B. Champion
02	9/30/2026	All	Complete rewrite to audit-ready format: added API 650/653 tank welds, Div 2 Table 7.8 fracture-mechanics, Div 1 App 12 tables, Annex U tables, zonal coverage, encoder resolution, Table T-421, calibration block appendix, indication report form; SNT-TC-1A 2020	B. Champion

**TABLE T-421 — REQUIREMENTS OF AN ULTRASONIC EXAMINATION
PROCEDURE**

Per ASME Section V, Article 4, T-421 and Table T-421, and Mandatory Appendix V, Table V-421. The following variables are addressed in this procedure. A change in an essential variable beyond the range specified requires requalification of the procedure per Section 14.0. Changes to nonessential variables do not require requalification but shall be documented in a procedure revision or scan plan.

Requirement (as applicable)	Essential	Nonessential	Procedure Section
Weld configurations to be examined, including thickness dimensions and base material product form (pipe, plate, etc.)	X		1.2, 1.3, 9.3
The surfaces from which the examination shall be performed	X		1.4, 9.3.4, 11.2
Technique(s) (straight beam, angle beam, contact, and/or immersion)	X		1.4, 11.3
Angle(s) and mode(s) of wave propagation in the material	X		6.2, 9.4
Search unit type(s), frequency(ies), and element size(s)/shape(s)	X		6.2
Special search units, wedges, shoes, or saddles, when used	X		6.3
Ultrasonic instrument(s)	X		6.1
Calibration [calibration block(s) and technique(s)]	X		7.0, 10.0
Directions and extent of scanning	X		11.1, 11.2, 11.5
Scanning (manual vs. automatic)	X		11.3
Method for discriminating geometric from flaw indications	X		12.3
Method for sizing indications	X		12.4, 12.5
Computer enhanced data acquisition, when used	X		6.1, 6.6, 11.4
Scan overlap (decrease only)	X		11.4.3, 11.4.4
Personnel performance requirements, when required	X		5.3, 14.3
Personnel qualification requirements		X	5.0
Surface condition (examination surface, calibration block)		X	8.0
Couplant: brand name or type		X	6.5
Post-examination cleaning technique		X	16.6
Automatic alarm and/or recording equipment, when applicable		X	6.1, 6.6
Records, including minimum calibration data to be recorded (e.g., instrument settings)		X	15.0

Requirement (as applicable)	Essential	Nonessential	Procedure Section
<i>Appendix V additions (Table V-421):</i> Focal law parameters (aperture, element step, angular range and step, focal depth)	X		9.3.3
Search unit index offset / stand-off (scan plan)	X		9.3.4
Encoder resolution (increase) / data recording increment	X		11.4.1
Scanning speed (increase)	X		11.4.2
Scanner / encoder type and fixturing		X	6.4
Analysis software (version)		X	6.6

APPENDIX A — PAUT SCAN PLAN TEMPLATE

The following template defines the minimum content of a PAUT scan plan prepared under Section 9.0. A software-generated scan plan report (ESBeamTool, SetupBuilder, UltraVision, Capture) containing the same information and the ray-traced coverage plot may be substituted. Each scan plan shall be uniquely numbered (SP-[Project]-[Seq]) and approved by the PII UT Level III.

Part 1 — Component and Weld

Parameter	Value
Scan Plan No. / Rev.	
Project / Job No. / Client	
Vessel / Tank No. and Drawing	
Weld ID(s) Covered	
Weld Category / Type (Cat A/B/C/D; shell vert./horiz.; annular; roof; nozzle)	
Material Spec. / Grade / P-No.	
Nominal Thickness t (in.) / Range	
Diameter / Curvature (in.) — flat if > 20 in.	
Joint Design (bevel angle, root face, root gap, land, backing) — attach sketch	
WPS No. / Process	
Cap Ground? (Y/N) / Hi-Lo (in.)	
Surface Condition / Coating (in.)	
Surface Temperature Range (°F)	
Referencing Code / Acceptance Standard	

Part 2 — Equipment and Calibration

Parameter	Value
Instrument Model / S/N / Software Version	
Probe(s) Model / S/N / Frequency (MHz) / Elements / Pitch (mm)	
Wedge(s) Model / Nominal Angle / S/N / Contoured?	
Scanner / Encoder Model / S/N / Resolution (counts per mm)	
Couplant Type / Brand	
Calibration Block ID / Thickness / SDH Dia. / Curvature	

Parameter	Value
TCG Reflectors (depths) / Reference Level	
Scanning Gain (dB above reference)	
Transfer Correction Method / Value (dB)	
Pulser Voltage / Pulse Width / Filter / Digitizing Freq. / PRF	

Part 3 — Focal Law Sets and Probe Positions (one row per probe position / zone)

Pos .	Side	Scan Type	Wave Mode	Angle Range / Step (or Fixed Angle)	First El. / No. Active	Focus (typ e/depth)	Index Offset (mm)	Skew (°)	Zone / Depth Range (in.)
1									
2									
3									
4									
5									
6									

Part 4 — Scanning Parameters and Coverage

Parameter	Value
Reference Datum Location / Scan Direction	
Encoder Resolution / Data Recording Increment (mm)	
Maximum Scan Speed (in./s)	
Segment Length / Overlap (in.)	
Transverse Scan Required? / Positions	
0° LW Lamination Scan Performed? / Band Width	
Coverage Verification (attach ray-trace plot): Weld volume + HAZ covered by ≥ 2 angles; fusion faces within $\pm 10^\circ$ normal	
Coverage Limitations / Areas Not Examined	
Prepared By (Level II/III) / Date	
Approved By (UT Level III) / Date	
Client / AI Review (if required) / Date	

Requirement	Specification	Reference
Material	Same P-No. grouping and product form as component; P-1, 3, 4, 5A, 5B, 9A, 9B, 10 equivalent for carbon/low-alloy; heat treated to at least min. temper of spec.	T-434.1.2, T-434.1.3
Straight-beam pre-examination	Block examined at 0° before drilling; areas with indications exceeding remaining back-wall reflection excluded from reflector positions	T-434.1.1
Curvature	Component OD ≤ 20 in.: curved block 0.9–1.5 × component OD. OD > 20 in.: flat block acceptable	T-434.1.7.2
Cladding	Block clad by same process when examining through clad	T-434.1.4
Surface finish	Representative of component; ≤ 250 μin. Ra	T-434.1.5
Identification	Permanent S/N, material, T, drawing no.; MTR / CoC on file	PII-QMP
Height-sizing verification (Div 2)	At least one reflector within upper 25% and lower 25% of T (SDH or notch)	App. VIII / Sec. 7.6
Thick-section TCG	SDH spacing ≤ 1 in. depth for T > 2 in.	Sec. 10.4.1
IIW / DSC block	Velocity and wedge delay verification only	Sec. 7.8

Table B-3 — PII Standard Calibration Block Set for Tanks and Vessels

Block ID	T (in.)	Qualifies t (in.)	SDH Dia. (in.)	SDH Depths (in.)	Notches	Material
PII-CB-075	0.75	0.25 – 1.00	3/32	0.19, 0.375, 0.56	Both surfaces	SA-516-70
PII-CB-150	1.50	1.00 – 2.00	1/8	0.375, 0.75, 1.125	Both surfaces	SA-516-70
PII-CB-300	3.00	2.00 – 4.00	3/16	0.75, 1.50, 2.25 (+0.375, 1.125, 1.875, 2.625)	Both surfaces	SA-516-70 N
PII-CB-400	4.00	3.00 – 4.00 (t ±25%)	3/16	1.0, 2.0, 3.0 (+0.5, 1.5, 2.5, 3.5)	Both surfaces	SA-516-70 N
PII-CB-025R	0.25	0.19 – 0.375 (roof/thin plate)	3/32	0.0625, 0.125, 0.1875	Both surfaces	A36 / A283-C

APPENDIX C — ASME SECTION VIII DIVISION 1, MANDATORY APPENDIX 12 ACCEPTANCE CRITERIA

Applicable when PAUT is performed on Division 1 vessels under UW-53 (UT of welds where required or as a supplement to RT) with the acceptance standards of Mandatory Appendix 12, paragraph 12-3, and when invoked by API 650 8.3.2 for UT of tank welds. These are workmanship-based (amplitude and length) criteria evaluated at the TCG reference level. Where UT is performed in lieu of RT under UW-11(a)(8), the Division 2 Table 7.8 criteria of Appendix D apply instead.

Table C-1 — Appendix 12-3 Acceptance Standards

Indication Type	Amplitude Condition	Acceptance Limit	Disposition
Cracks, lack of fusion, incomplete penetration	Any amplitude	Not permitted regardless of length	Reject
Other imperfections — t up to 3/4 in.	Exceeds reference level (100% TCG)	Length not to exceed 1/4 in.	Reject if length > 1/4 in.
Other imperfections — t from 3/4 in. to 2-1/4 in.	Exceeds reference level	Length not to exceed 1/3 t	Reject if length > t/3
Other imperfections — t over 2-1/4 in.	Exceeds reference level	Length not to exceed 3/4 in.	Reject if length > 3/4 in.
Other imperfections (any t)	Between 20% and 100% of reference	Investigate to characterize; record if > 50%	Accept unless characterized as crack / LOF / IP

Note 1: t = thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members of different thickness, t is the thinner of the two. If a full-penetration weld includes a fillet weld, the throat of the fillet is included in t.

Note 2: Indication length is measured per Section 12.4 (6 dB drop or extent above reference level). Aligned indications on the same plane separated by less than the length of the shorter indication are evaluated as a single indication.

Note 3: Per 12-2, the examination shall be performed in accordance with ASME Section V Article 4 with the procedure qualified per T-421; indications greater than 20% reference shall be investigated (12-3).

Note 4: UW-53 also permits UT of welded joints at the option of the Manufacturer; when UT is the required examination under UW-11(a)(7) or (a)(8), the additional requirements of those paragraphs apply.

Table C-2 — Worked Length Limits by Thickness (Appendix 12-3)

Weld Thickness t (in.)	Governing Rule	Maximum Acceptable Length of Indication Exceeding Reference (in.)
0.25	1/4 in.	0.250
0.375	1/4 in.	0.250
0.50	1/4 in.	0.250
0.75	1/4 in.	0.250
1.00	t/3	0.333
1.25	t/3	0.417
1.50	t/3	0.500

Weld Thickness t (in.)	Governing Rule	Maximum Acceptable Length of Indication Exceeding Reference (in.)
1.75	t/3	0.583
2.00	t/3	0.667
2.25	t/3	0.750
2.50	3/4 in.	0.750
3.00	3/4 in.	0.750
3.50	3/4 in.	0.750
4.00	3/4 in.	0.750

APPENDIX D — ASME SECTION VIII DIVISION 2, TABLE 7.8 FRACTURE-MECHANICS ACCEPTANCE CRITERIA

Applicable when PAUT is performed under Division 2 Part 7, paragraph 7.5.5 (UT in lieu of RT), or under Division 1 UW-11(a)(8) which invokes the Division 2 criteria (legacy ASME Code Case 2235). Flaws are sized for through-wall height (a), length (l), and depth below the nearest surface (S), categorized as surface or subsurface per Section 12.5, and compared with the allowable a/t as a function of aspect ratio a/l. The examination and procedure shall be qualified per ASME Section V Article 4 Mandatory Appendices VIII and IX (Section 14.2). Values below are reproduced from Table 7.8 for carbon and low-alloy steel welds; the Code table governs.

Table D-1 — Flaw Acceptance Criteria for Surface Flaws (Table 7.8)

Aspect Ratio a/l	Allowable a/t — $t < 1$ in. (25 mm)	Allowable a/t — $1 \text{ in.} \leq t \leq 12 \text{ in.}$
0.00	0.031	0.020
0.05	0.033	0.020
0.10	0.036	0.031
0.15	0.041	0.034
0.20	0.047	0.038
0.25	0.055	0.043
0.30	0.064	0.049
0.35	0.074	0.057
0.40	0.083	0.066
0.45	0.085	0.078
0.50	0.087	0.090

Table D-2 — Flaw Acceptance Criteria for Subsurface Flaws (Table 7.8)

Aspect Ratio a/l	Allowable a/t — $t < 1$ in. (25 mm)	Allowable a/t — $1 \text{ in.} \leq t \leq 12 \text{ in.}$
0.00	0.034	0.032
0.05	0.038	0.033
0.10	0.043	0.036
0.15	0.049	0.044
0.20	0.057	0.050
0.25	0.066	0.056
0.30	0.078	0.064

Aspect Ratio a/l	Allowable a/t — $t < 1$ in. (25 mm)	Allowable a/t — 1 in. $\leq t \leq 12$ in.
0.35	0.090	0.073
0.40	0.105	0.083
0.45	0.123	0.095
0.50	0.143	0.109

Note 1: t = thickness of the weld excluding allowable reinforcement; for members of different thickness, the thinner. a = flaw height (through-wall); l = flaw length; S = distance from nearest surface to the nearest flaw edge.

Note 2: A subsurface flaw is one for which $S \geq 0.5a$ (Section 12.5.2 / 7.5.5.2); if $S < 0.5a$ the flaw is a surface flaw and a is taken as the measured height plus S . Note that Table 7.8 also requires subsurface flaws with $S < 0.4d$ (d = depth of the flaw center) to be evaluated as surface flaws.

Note 3: For intermediate values of a/l , linear interpolation is permitted; alternatively round a/l down to the next lower tabulated value. For $a/l > 0.5$, use 0.5.

Note 4: Flaws characterized as cracks are unacceptable regardless of size. Where PAUT cannot positively characterize a planar flaw as non-crack-like, it shall be treated as a crack unless additional NDE (MT/PT at surface, TOFD, or destructive examination of a repair excavation) demonstrates otherwise.

Note 5: Multiple flaws shall be evaluated for interaction using the proximity rules of Annex 7.A (or ASME Section V Article 4 Mandatory Appendix VIII, Figure VIII-472) before comparison with Table 7.8; combined flaws use the envelope dimensions.

Note 6: Flaw length limits: In addition to the a/t limits, Table 7.8 does not permit acceptance of flaws with $l > 4t$ when $t \leq 1$ in. unless $a/t \leq$ the $a/l = 0$ value; the procedure shall apply the $a/l = 0$ row for all flaws with $l/t > 4$.

Note 7: The sizing accuracy demonstrated per Section 14.2 shall be considered: where the measured a is within the demonstrated RMS height error of the allowable, the flaw shall be treated as exceeding the allowable unless resized with a qualified higher-resolution technique.

Table D-3 — Example Allowable Flaw Heights for Common Vessel Thicknesses (Surface Flaw, derived from Table D-1)

t (in.)	$a/l = 0.0$ (long flaw)	$a/l = 0.1$	$a/l = 0.25$	$a/l = 0.5$ (short flaw)
0.50	0.015 in.	0.018 in.	0.028 in.	0.043 in.
0.75	0.023 in.	0.027 in.	0.041 in.	0.065 in.
1.00	0.020 in.	0.031 in.	0.043 in.	0.090 in.
1.50	0.030 in.	0.046 in.	0.065 in.	0.135 in.
2.00	0.040 in.	0.062 in.	0.086 in.	0.180 in.
3.00	0.060 in.	0.093 in.	0.129 in.	0.270 in.
4.00	0.080 in.	0.124 in.	0.172 in.	0.360 in.

Example values are for guidance; the analyst shall compute a/t from measured dimensions and compare with Tables D-1/D-2.

APPENDIX E — API 650 ANNEX U ACCEPTANCE CRITERIA (UT IN LIEU OF RADIOGRAPHY)

Applicable when the Purchaser has approved ultrasonic examination in lieu of radiography for API 650 tank shell butt welds and annular plate butt welds under Annex U (U.1), and for API 653 repairs and alterations invoking API 650 acceptance. Annex U requires: a written procedure per ASME Section V Article 4 qualified by performance demonstration (U.4 / Mandatory Appendix V-471), automated or encoded data acquisition with full A-scan storage (U.5), 100% examination of the welds designated for UT in lieu of RT, personnel qualified per U.3, and acceptance per U.6 as summarized below. The Standard text governs.

Table E-1 — U.6 Acceptance Criteria: Rejectable Indications Regardless of Size

Indication Characterization	Disposition
Cracks	Reject
Incomplete fusion (lack of fusion)	Reject
Incomplete penetration	Reject
Surface-connected planar flaws (any length) in the root or cap region confirmed by supplementary surface NDE	Reject

Table E-2 — U.6 / Table U-1 Acceptance Criteria for Other Indications (Workmanship, Amplitude-Based)

Weld Thickness t (in.)	Indication Amplitude	Maximum Acceptable Length of Indication	Basis
$t \leq 3/4$	> 100% reference (TCG)	1/4 in.	ASME VIII App. 12 / U.6
$3/4 < t \leq 2-1/4$	> 100% reference	1/3 t	ASME VIII App. 12 / U.6
$t > 2-1/4$	> 100% reference	3/4 in.	ASME VIII App. 12 / U.6
All t	50% to 100% reference	Investigate and record; length not to exceed 2 × the limits above unless characterized as crack / LOF / IP	U.6.4 (Table U-1)
All t	20% to 50% reference	Investigate to characterize; acceptable unless crack / LOF / IP	U.6.4
All t	Aligned indications (same plane) separated by < shorter indication length	Evaluate as single indication of combined length	U.6.5
Annular plate butt welds	As above	Same limits as shell welds; root/backing-strip signals discriminated per Section 12.3	U.1.2 / 7.2.4

Note 1: When the Purchaser specifies fracture-mechanics acceptance per U.6.6 (alternative), the criteria of ASME Section VIII Division 2 Table 7.8 (Appendix D) shall be used together with the flaw sizing and procedure qualification requirements of Section 12.5 and 14.2.

Note 2: Annex U requires the examination record to include the data files and be furnished to the Purchaser (U.7); see Section 15.3.2.

Note 3: For welds that also receive radiography per 8.1 (i.e., UT is supplementary, not in lieu), the UT acceptance criteria of 8.3.2 apply, which invoke ASME Section VIII UW-53 / Appendix 12 (Appendix C of this procedure).

Note 4: API 653 12.1.1 requires NDE of repairs and alterations by the methods and acceptance criteria of API 650; where the Owner/User approves UT in lieu of RT for shell repairs, this Appendix applies.

Table E-3 — Extent of Examination (API 650 Section 8.1 / 8.3 / Annex U)

Weld	RT Extent per 8.1.2 (baseline)	UT in Lieu of RT (Annex U)
Shell vertical joints, $t \leq 3/8$ in.	One spot per 10 ft of first course; one per 100 ft thereafter; +1 per plate in first course	100% of designated joints unless Purchaser specifies spot locations; PAUT normally 100%
Shell vertical joints, $3/8 < t \leq 1$ in.	Spots as above plus all junctions of vertical and horizontal joints	100%
Shell vertical joints, $t > 1$ in.	100% (full length)	100%
Shell horizontal joints	One spot per 10 ft; one per 200 ft thereafter	100% of designated joints or as specified by Purchaser
Annular plate radial butt welds	One spot per each 10 ft (7.2.4 / 8.1.2.9), or RT of each weld as specified	100% of each weld where UT substituted
Nozzle / manway attachment welds	RT not typically required (MT/PT/UT per Purchaser)	Per Purchaser; PAUT supplementary technique with L-III approved scan plan

APPENDIX F — PAUT INDICATION REPORT FORM

Form PII-PAUT-02-F1. One form (or software-generated equivalent containing the same fields) per weld or group of welds examined under a single scan plan and calibration. Attach scan plan, calibration record, and merged-view screenshots of all rejectable indications. Data file names shall be listed for every scan.

Client:		Project / Job No.:		Report No.:	
Vessel / Tank No.:		Drawing No.:		Date of Exam:	
Weld ID(s):		Weld Type / Category:		Scan Plan No. / Rev:	
Material / Grade:		Nominal t (in.):		Diameter (in.):	
Referencing Code / Edition:		Acceptance Standard:		Surface Temp (°F):	
Procedure:	PII-PAUT-02 Rev 02	Surface Condition:		Coating (in.):	

Equipment and Calibration

Instrument / S/N / SW Ver.:		Probe / S/N / MHz / El. / Pitch:	
Wedge / Angle / S/N:		Scanner / Encoder / S/N:	
Cal Block ID / T / SDH:		Couplant:	
Ref. Gain (dB) / Scan Gain (dB):		Transfer Corr. (dB):	
Encoder Cal (±1%) Time / Result:		Element Activity Result:	
Cal Verif. Times (start / 4 hr / end):		Linearity Record No. / Date:	

Scan Data Files

Scan #	Weld ID	Probe Pos. / Side	Datum / Direction	Start-End (in.)	Resolution (mm)	Data File Name (raw)	Missed Lines %
1							
2							
3							
4							

Indications

Ind. #	Weld ID	Start (in.)	End (in.)	Length l (in.)	Depth S (in.)	Height a (in.)	Max Amp (% Ref)	Angle (°)	Surf / Sub	Type (LOF/Slag/ Por/Crack/IP/Geo)	Accept / Reject
1											
2											
3											
4											
5											
6											
7											

8											
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Coverage Limitations / Remarks:

Results Summary: ■ ACCEPT ■ REJECT — Repair and Re-examine ■ Partial Coverage — See Remarks

Examiner (Acquisition) / Level / Cert. No.	Analyst / Level / Cert. No.	PII UT Level III Review	Client / AI Review
Signature / Date	Signature / Date	Signature / Date	Signature / Date

Appendix F — Instructions for Completing Form PII-PAUT-02-F1

F-1 Header: Enter the Client, project/job number, and a unique report number in the format PII-[Job]-PAUT-[Seq]. Identify the vessel or tank and drawing. List all weld IDs covered by the report; where several welds are reported, attach a continuation sheet for the Indications table with the weld ID in each row.

F-2 Referencing Code and Acceptance Standard: State the Code, Division/Standard, edition, and the specific acceptance table (e.g., "ASME VIII Div 1 2023, App. 12-3", "ASME VIII Div 2 2023, Table 7.8", "API 650 13th Ed., Annex U.6"). This determines which appendix (C, D, or E) the analyst applies.

F-3 Equipment and Calibration: Record the serial numbers of every system component. Record the reference gain (TCG at 80% FSH on SDHs) and the scanning gain actually used for acquisition. Record the encoder calibration result and all calibration verification times with pass/fail. Reference the current Linearity Record for the instrument.

F-4 Scan Data Files: List every data file acquired, including rescans, with the probe position (from the scan plan), the datum and scan direction, encoded start and end positions, the encoder resolution used, and the percentage of missed lines reported by the instrument. Files with missed lines exceeding Section 11.4.2 shall be identified as superseded by a rescan.

F-5 Indications: Enter each recordable indication (Section 12.2) with positions measured from the datum along the weld axis. Length is per Section 12.4. Depth S is the distance from the scanning surface to the nearest edge of the indication; Height a is required for Division 2 / fracture-mechanics evaluations and shall be entered with the sizing method (tip diffraction "TD" or 6 dB drop "6dB") noted in the Type column. Max Amp is the amplitude as a percentage of the TCG reference level at evaluation gain, with the angle at which it occurred. Surf/Sub categorization per Section 12.5.2. Type: LOF (lack of fusion), Slag, Por (porosity), Crack, IP (incomplete penetration), Geo (geometric, non-relevant; state feature in Remarks).

F-6 Coverage Limitations: Describe any portion of the weld volume not fully covered (single-side access, obstructions, surface condition), with weld positions affected and the reason. Where coverage is incomplete, the report shall not be marked ACCEPT without Client/AI concurrence and the limitation noted.

F-7 Signatures: The acquisition examiner and analyst (if different) shall sign. For PAUT in lieu of RT, the PII UT Level III shall review and sign before the report is issued. The Client / Authorized Inspector signature block is provided for witnessing or acceptance where required.

F-8 Attachments: Scan plan (Appendix A format), calibration record, merged-view screenshots for each rejectable indication (with measurement cursors shown), and a data file index. Electronic copies of raw and analysis files shall be transmitted to the Client per Section 15.3.2.