



Prime Inspections, Inc.

Digital Radiographic (DR) Examination of Welds

Digital Detector Array (DDA) Technique — ISO 17636-2 / ASME V Article 2

Procedure No.: PII-TC-DR | Revision: 1 | Effective: 2026-07-28

Applicable Project: TC Energy (USA)

Technical Approval

**Joshua de Monbrun, CEng -
Consultant**

Quality Approval

Oscar Gonzales - VP of Quality

Company Approval for Use

Code & Specification Basis

- API 1104, Welding of Pipelines and Related Facilities — 21st Edition (with current addenda).
- ASME BPVC Section V, Article 2 — Radiographic Examination (2025 Ed.), including Mandatory Appendix IX (Digital Image Acquisition, Display, Interpretation and Storage).
- ASME BPVC Section V, Article 1, Mandatory Appendix II — Personnel training and certification for digital radiography.
- ISO 17636-2 — Non-destructive Testing of Welds — Radiographic Testing — Part 2: X- and gamma-ray techniques with digital detectors.
- ISO 19232-1 (wire IQIs) and ISO 19232-5 (duplex-wire IQIs — spatial resolution).
- ASTM E2698 — Standard Practice for Radiologic Examination Using DDAs.
- ASTM E2737 — DDA Performance Evaluation and Long-Term Stability.
- ASTM E2597 / SE-2597 — Standard Practice for Manufacturing Characterization of DDAs.
- ASTM E2002 — Standard Practice for Determining Total Image Unsharpness.
- ASTM E2339 — DICONDE.
- ASTM E2699 — DICONDE for DR Test Methods.
- ASTM E1475 — Data Fields for Computerized Transfer of Digital Radiological Examination Data.
- TC Energy TES-NE-RT-GL — Radiographic Examination of Welds (CAN-US-MEX), Rev. 07 — Appendix A (Digital Radiography).
- 10 CFR Parts 19, 20, 30, 34 (USNRC); 49 CFR Parts 107, 171, 172 (DOT).

Revision History

Rev	Date	Prepared / Approved	Description of Change
0	2026-07-28	J. de Monbrun / O. Gonzales	Initial issue of Prime Inspections, Inc. (PII) controlled procedure under the PII Quality Management System. Issued as Rev 0 — no prior PII revision history. Aligned with API 1104 21st Edition (with current addenda), ASME BPVC Section V (2025 Edition), and the current TC Energy TES/TEN/TEP series specifications applicable to the project scope.
1	2026-07-28	J. de Monbrun / O. Gonzales	Revised to align with TC Energy TES-NE-RT-G Rev. 08. Updated scope, controlled references, Company NDE SME approval and Approved-for-Use requirements, personnel qualification and annual vision controls, technique-selection requirements, supplementary UT requirements for GMAW/MCAW welds, area-of-interest definition, interpretation and reporting requirements, and controlled report and technique-sheet forms. For digital radiography, added manufacturer-specific training, project-experience verification, fully automated system requirements, redundant equipment, software-version control, calibration triggers, unstitched-image storage, 15%-80% grey-scale evaluation, remote data access and two-device backup requirements.

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1.0 Scope

1.1. This procedure establishes the requirements for digital radiographic examination of welds in natural-gas pipeline applications on TC Energy projects in the United States using Company-qualified and Company-consented digital detector systems. This procedure is written for DR using Digital Detector Array (DDA) panels for API 1104 radiography and meets the requirements of ISO 17636-2.

1.2. Equipment Covered

Only fully automated digital radiographic weld examination systems qualified and consented by the TC Energy NDE SME are within the approved scope of this procedure.

NOTE: *No manual DR system may be used under this procedure until it has been reviewed by the PII Level III, qualified by documented demonstration, and consented to for project use by the TC Energy NDE SME.*

- 1.2.1. 3ENDT Xpress Scan-GW automated digital RT system — pipe diameters 17 in. (tie-in / HDD) and 27 in. (mainline production) scanning.
 - 1.2.2. 3ENDT Xpress Flex bendable-panel DDA — manual or automated systems — pipe diameters 8 in. (203 mm) through 56 in. (1420 mm).
 - 1.2.3. CarestreamNDT HPX-ARC bendable-panel DDA - 1025 & 1043 manual systems - pipe diameters 2 in. (60mm) through flat (for the 1025) or 4 in. (114mm) through flat (for the 1043).
 - 1.2.4. YXLON X-ray tube and 3ENDT VXu software as integrated subsystems. The production software version shall be the exact version qualified during the initial project technique qualification. Updates, patches, build changes, or version changes require prior written Company approval.
 - 1.2.5. No additional DR system may be used under this procedure until it has been reviewed by the PII Level III, qualified by documented demonstration, and consented to for project use by the TC Energy NDE SME.
- 1.3. Application — Procedure qualification welds, welder/welding-operator performance qualification welds, and production welds.
- 1.4. Computed Radiography (CR) is prohibited for pressure-containing components. CR in any other application requires prior written TC Energy NDE SME approval and documented system validation.
- 1.5. Where this procedure, API 1104, ASME Section V, ISO 17636-2, or the applicable TC Energy specification does not explicitly address a required condition, PII shall identify the gap, notify TC Energy, apply the more conservative interpretation, and document the method used. Where requirements conflict, the more stringent shall govern.

2.0 References (Latest Editions Unless Stated)

2.1. Industry Codes and Standards

- 2.1.1. API 1104, 21st Edition (2021, with addenda).

- 2.1.2. ASME BPVC Section V, Article 2 (2025 Ed.), Radiographic Examination, Mandatory Appendix IX (Digital Image Acquisition, Display, Interpretation and Storage).
- 2.1.3. ASME BPVC Section V, Article 1, Mandatory Appendix II, Training, Experience, and Examination Requirements for Personnel Performing DR / RTR.
- 2.1.4. ASME BPVC Section V, Article 22, SE-2698 (DR with DDAs), SE-2737 (DDA Performance), SE-2597 (DDA Manufacturing Characterization), SE-2002 (Total Image Unsharpness), SE-2339 (DICONDE), SE-2699 (DICONDE for DR).
- 2.1.5. ISO 17636-2, Non-destructive testing of welds, Radiographic Testing, Part 2: X- and gamma-ray techniques with digital detectors.
- 2.1.6. ISO 19232-1, Wire IQIs; ISO 19232-5, Duplex-wire IQI for basic spatial resolution.
- 2.1.7. ASTM E2698, E2737, E2597, E2339, E2699, E2002, E1475, E747.
- 2.1.8. ASTM E94, General radiographic examination guidance.
- 2.1.9. ASNT SNT-TC-1A (2024); ANSI/ASNT CP-189; ISO 9712.

2.2. Regulatory References

- 2.2.1. 10 CFR Parts 19, 20, 30, 34; USNRC radiation safety and industrial radiography licensing.
- 2.2.2. 49 CFR Parts 107, 171, 172, 173; DOT radioactive material transport.
- 2.2.3. 49 CFR Part 192 (PHMSA gas).
- 2.2.4. ASME B31.3 (2024) and B31.8 (2025) as applicable.

2.3. TC Energy Specifications

- 2.3.1. TES-NE-RT-G, Radiographic Examination of Welds, Appendix A (Digital Radiography), Item ID 003671368, Rev. 08.
- 2.3.2. TEN-NE-NDT-GL, Nondestructive Testing Standard, Item ID 1001828336, Rev. 01.
- 2.3.3. TEP-NE-ADT-GLE, Nondestructive Examination Audits, Item ID 003797402.
- 2.3.4. TC Energy Operator Qualification Program, Item ID 004504739.
- 2.3.5. TC Energy Controlled Document Library Variance Procedure, Item ID 007728702.

2.4. PII Internal & Vendor Manuals

- 2.4.1. PII-WP-1, Written Practice (SNT-TC-1A 2024 Ed.).
- 2.4.2. PII-RT-OEP-1, Operating & Emergency Procedures for Industrial Radiography (radiation safety plan).
- 2.4.3. PII-QM-01, Quality Manual.
- 2.4.4. 3ENDT Xpress Scan-GW Operating Manual.
- 2.4.5. 3ENDT Xpress Flex Bendable DR Panel Operating Manual.
- 2.4.6. YXLON X-Ray Tube Operating Manual.
- 2.4.7. 3ENDT VXu Software User Manual (exact qualified version).

3.0 Definitions and Acronyms

Term	Definition
BSR	Basic Spatial Resolution - duplex-wire IQI measurement on the digital image (ISO 19232-5).
CKP	Cluster Kernel Pixel — group of contiguous bad pixels on a DDA (per ASME SE-2597).
DDA	Digital Detector Array - an array of radiation-sensitive pixels (amorphous silicon, CMOS, etc.) producing a digital signal directly.
DICONDE	Digital Imaging and Communication in Nondestructive Evaluation (ASTM E2339).
DR	Digital Radiography.
Duplex IQI	ISO 19232-5 duplex-wire pair used for basic spatial resolution and unsharpness measurement.
DDL	Digital Driving Level — display digital value.
RTR	Real-Time Radiography — in-motion DR.
SNR / SNR_N	Signal-to-Noise Ratio / Normalized SNR per ISO 17636-2 Class A / Class B.
Ug	Geometric Unsharpness.

4.0 Responsibilities

- 4.1. PII VP of Quality — Owns preparation, control, and issuance of this procedure.
- 4.2. PII ASNT Level III (RT, with documented digital radiography qualification per ASME V Art. 1 App. II) - The PII Level III performs internal technical review and recommends systems and techniques for submission. Final project use requires TC Energy NDE SME qualification, consent, and Approved-for-Use status.
- 4.3. Site Supervisor / Technical Lead - Verifies certifications, OQ, equipment calibration, and current radioactive materials license/reciprocity for the work jurisdiction. The Technical Lead or Supervisor shall coordinate daily operations

with the Company-designated Welding Inspector and NDE Auditor and shall confirm that only Company-approved procedures and techniques are used.

- 4.4. Level II/III RT (DR) Technician – Performs DR per this procedure, completes calibration/examination records, performs IQI and duplex-IQI placement and sensitivity validation, interprets and reports.
- 4.5. Level I/1 Personnel – Level I personnel may assist only under direct Level II or III supervision and shall not independently perform exposures, interpret or disposition radiographic images, or sign examination reports.

5.0 Personnel Qualifications

- 5.1. Personnel performing digital image acquisition, processing, interpretation, evaluation, or reporting shall be certified to at least Level II under ISO 9712 or ANSI/ASNT CP-189 in the applicable method.
- 5.2. Each technician shall complete a minimum of 16 documented hours of manufacturer-specific hardware and software training for each system and each software product used.
- 5.3. **Required Training Topics (ASME V Article 1 Mandatory App. II)**
 - 5.3.1. Detector physics and operation (DDA, sensitivity, dynamic range, latitude).
 - 5.3.2. Image acquisition parameters (kV, mA, integration time, frame averaging, gain, offset, bad-pixel correction).
 - 5.3.3. Image quality (BSR, SNR, contrast, unsharpness, artifacts, aliasing).
 - 5.3.4. Calibration (offset, gain, bad pixel map, spatial resolution).
 - 5.3.5. Image processing (filters, window/level, contrast/brightness, magnification).
 - 5.3.6. Storage (DICOM format, metadata, file integrity).
 - 5.3.7. Acceptance criteria and reporting for DR.
- 5.4. Each technician shall have verifiable prior digital-radiography project experience. Certification, training, manufacturer-specific training, project-experience evidence, annual eye-examination results, and OQ records shall be submitted to the Company before work.
- 5.5. Minimum Certification Level — Level II/2 (with documented DR/DDA training) for image interpretation and reporting; Level III/3 (with ACCP or equivalent) for procedure approval and Level II evaluations.
- 5.6. Operator Qualification (TC Energy U.S.) — Personnel shall complete the applicable Covered Tasks per the TC Energy OQ Program (Item ID 004504739) prior to performing work on TC Energy projects.
- 5.7. Vision — Personnel performing final interpretation or signing radiographic reports shall have a valid, documented, annual Jaeger J-1 (near vision at ≥ 12 in.) or equivalent acuity examination and color-contrast examination.

6.0 Safety Requirements

- 6.1. A minimum of two (2) qualified people shall be present during any DR exposure operation (per 10 CFR §34.41).
- 6.2. All personnel operating X-ray or gamma equipment shall: protect and monitor each person near the radiation source; comply with USNRC (or CNSC / NOM-025-NUCL-2015) for safety, transport, and certification; always maintain a written Radiation Safety Plan on-site and available upon request.
- 6.3. Prior to commencement of work, all personnel must review and understand the Job Hazard Analysis (JHA), site-specific safety rules, and Personnel Protective Equipment (PPE) per project requirement; controlled-area boundary established per 10 CFR §20.1601 (2 mR/hr).
- 6.4. Personnel dosimetry: TLD/OSL badge + electronic alarming ratemeter + pocket dosimeter, and survey meter(s); dose records per 10 CFR §20.2106.

7.0 Equipment — DR System, DDA, and X-Ray / Gamma Source

7.1. X-Ray / Gamma Source

- 7.1.1. X-ray: constant-voltage capable up to 360 kV (Yxlon or equivalent).
- 7.1.2. Ir-192 gamma: source activity ≥ 20 Ci and ≤ 90 Ci. Source activity exceeding 90 Ci risks DDA pixel saturation and IS PROHIBITED unless a revised technique demonstrating acceptable image quality (including IQI sensitivity compliance) is submitted to TC Energy for approval.
- 7.1.3. Source type, activity, and date of exposure shall be recorded on every report.
- 7.1.4. Other isotopes (Se-75, Co-60) require prior Company consent before use.

7.2. Digital Detector Array (DDA)

- 7.2.1. Active area: flat panel or bendable configurations shall have a minimum active area of 100mm (4 in) × 250mm (10 in) or larger.
- 7.2.2. Detector resolution: shall be between 98-140 μm pixel pitch (per the system in use).
- 7.2.3. DDA shall meet the performance requirements of ASTM E2737 (long-term stability) and the BSR / SNR requirements of ISO 17636-2 Class A (or better).
- 7.2.4. DDA shall convert ionizing radiation into a digital signal directly.
- 7.2.5. DDA surface shall be kept free of dirt, scratches, and other mechanical defects to keep the area of interest free of system-induced artifacts.

7.3. X-Ray Source Size and Focal Spot Verification

- 7.3.1. For X-ray machines ≤ 500 kV, the source size may be determined by the manufacturer's data, a written statement, or the pinhole method.
- 7.3.2. For gamma sources, source-size verification per manufacturer's technical manuals, decay curves, or written statements.

7.3.3. Source type, size, and curie strength shall be recorded on each radiographic report.

7.4. Software

7.4.1. Software supplier, product, version, build and configuration shall be documented on each technique sheet. The production version shall match the qualified version. Any change requires prior written Company approval and requalification as directed.

7.4.2. Only DDA image-acquisition and review software that retains the RAW image shall be used.

7.4.3. The original RAW image format shall be saved BEFORE applying any filters; processed images shall be stored separately and tagged with the applied processing parameters.

7.4.4. System Capability — Each DR system shall be capable of acquiring, storing, and displaying digital images and shall comply with the data and metadata requirements of §19.0.

7.5. Automated System & Redundancy

7.5.1. PII shall use a fully automated digital radiographic weld examination system(s) that transfers data to the computer in real time. Redundant essential equipment, including backup detectors, X-ray tubes and critical components, shall be maintained at the work site.

7.6. Remote Access

7.6.1. When not furnished by the Company, PII shall provide reliable internet access and remote data-transfer capability for timely Company review and audit in a Company-acceptable format.

8.0 DDA Performance Qualification and Calibration

8.1. Calibration Required At

Detector calibrations shall be performed in accordance with the manufacturer's recommended practice.

8.1.1. Commencement of the qualification of each examination procedure.

8.1.2. Start of daily production for each pipe diameter and thickness.

8.1.3. Change in material.

8.1.4. Change in source activity (Ci) or X-ray energy (kV) — specifically: change in kV by more than the range stated on the technique sheet or, if not stated, ± 5 kV.

8.1.5. Change in equipment used (Table A-1 below).

8.1.6. Change in alignment between the X-ray tube and detector.

8.1.7. Change in detector temperature beyond manufacturer's recommended range; in the absence of specific guidance, any change greater than 25°F (14°C).

8.1.8. Change in technique parameters.

8.1.9. Increase in scan speed beyond the calibrated speed.

8.1.10. Failure to achieve required image quality.

8.1.11. At the discretion of the radiographer.

8.2. Essential Equipment Items (TES-NE-RT-GL Appendix A, Table A-1)

Item	Essential?
X-Ray Control Unit	Yes
X-Ray Tube	Yes
Digital Detector	Yes
Scanner Frame	Yes
X-Ray Computing System	Yes
Software Version (requires Company approval)	Yes

8.3. Bad-Pixel Map

- 8.3.1. DDA shall be supplied with the manufacturer's original bad-pixel map, including the process and methodology used to develop the map.
- 8.3.2. Non-functioning pixels (pixel dropout) shall NOT exceed 2% of the total active-area pixels AND shall NOT interfere with interpretation.
- 8.3.3. Static-detector DDAs shall NOT have Cluster Kernel Pixels (CKPs) within the area of interest. An overlay may be used for verification (ref. ASME SE-2597).
- 8.3.4. Multi-overlap pixel-data DDAs: CKPs are not relevant, provided acquired image data does not mask a relevant indication or create an artifact.

8.4. BSR (Basic Spatial Resolution) Calibration

- 8.4.1. Detector calibrations shall include a spatial resolution check.
- 8.4.2. A duplex-wire IQI (ISO 19232-5) shall be used to determine the BSR of the digital image, meeting ISO 17636-2 Class A (or better).
- 8.4.3. The compensation principle (e.g., averaging) shall NOT be used to achieve Class A.
- 8.4.4. The duplex IQI may be placed on the detector side and shall have a skew of 2° to 5° (off-parallel with the weld/scanner path) to avoid aliasing.

9.0 Surface Preparation

- 9.1. Material surfaces shall meet the applicable material specification, with additional conditioning where surface irregularities would mask or be confused with discontinuity images.
- 9.2. Weld ripples and surface irregularities (ID, where accessible, and OD) shall be removed to a degree that the resulting digital image cannot be confused with discontinuity images.
- 9.3. Reinforcement shall not exceed the limits specified by the governing code; the finished surface may be flush with the base material or have a reasonably uniform crown within the code limit.

9.4. Any surface conditioning process beyond routine preparation shall be approved by the Company / Authorized Representative before use.

10.0 Backscatter Radiation Control

- 10.1. A lead letter 'B', minimum 1/2 in. (13 mm) high × 1/16 in. (1.6 mm) thick, shall be attached to the back of the DDA during each exposure, in an area representing the area of viewing interest.
- 10.2. If a LIGHT image of a 'B' appears on a darker background of the image, backscatter protection is insufficient, and the resulting radiographic image is considered unacceptable.
- 10.3. A backscatter test shall be performed by placing a lead filter on one half of the back of the DDA, exposing, then repeating with the lead moved to the other half. If backscatter is detected, the back of the detector shall be shielded, and the test shall be repeated.
- 10.4. If a backing lead causes poor image results, a sheet of copper may be placed between the back of the panel and the backing lead, and the test shall be repeated.

11.0 Image Identification

- 11.1. Each radiograph shall be uniquely identified to establish a permanent correlation between the part radiographed and the image. At a minimum, the image shall include:
 - 11.1.1. Weld identifier.
 - 11.1.2. Diameter and thickness.
 - 11.1.3. Code of construction.
 - 11.1.4. Date.
 - 11.1.5. Project ID.
 - 11.1.6. Any additional information requested by the Company.
 - 11.1.7. Repaired area identification using the letter 'R' followed by -1, -2, etc. for repair sequence number.
- 11.2. Identification shall not obscure the area of interest.

12.0 Viewing and Display Requirements

- 12.1. Viewing facilities shall provide subdued background lighting at an intensity that will not cause reflections, shadows, or glare on the monitor that interfere with interpretation.
- 12.2. **Display Performance Minimum Requirements (TES-NE-RT-G Appendix A-4 and ASME V Art. 2 App. IX):**
 - 12.2.1. Brightness ≥ 250 cd/m² (measured at maximum Digital Driving Level off the display).

- 12.2.2. Contrast ratio $\geq 250:1$ (max DDL $\div$ min DDL).
 - 12.2.3. Capable of displaying linear patterns of alternating pixels at full contrast in both horizontal and vertical directions without aliasing.
 - 12.2.4. Free of discernible geometric distortion and screen flicker.
 - 12.2.5. Capable of displaying a 5% DDL block on a 0% background AND simultaneously a 95% DDL block on a 100% background, both clearly perceptible.
 - 12.2.6. Display ≥ 256 shades of grey with contrast adjustments; weld images on a 1920×1080 resolution viewing area minimum.
 - 12.2.7. Capable of discriminating horizontal and vertical low-contrast (1%) modulation patterns at the display center and all four corner locations.
 - 12.2.8. Alternate test patterns may be used, provided they include the features described in SMPTE RP 133 for the quality tests above.
- 12.3. Full-access viewing software shall be provided to TC Energy for auditing and review, with interpretation tools to validate conformance to this specification and the governing code.

13.0 Examination Technique

- 13.1. A single-wall exposure technique shall be used whenever practical. When not practical, a double-wall technique shall be used. Sufficient exposures (steps) shall demonstrate that required coverage has been achieved. Repairs shall be re-examined using the same technique used to identify the defect. Technique selection shall consider weld type, bevel geometry, weld configuration, wall thickness, and the applicable requirements of TES-NE-RT-G Table 4-1.
- 13.2. Welds completed using GMAW or Metal Core Arc Welding require supplementary volumetric UT. DR does not replace this additional UT requirement.
- 13.3. Scanner clearance and coating-cutback requirements shall be established and documented in the approved technique before production welding begins.
- 13.4. Exposure Geometries**
- 13.4.1. SWE/SWV — single-wall exposure, single-wall view.
 - 13.4.2. DWE/SWV — double-wall exposure, single-wall view (for DWE-SWV, the scanner mounts the X-ray tube on one side of the pipe band and the detector 180° opposite; full coverage by synchronized rotation maintaining 180° spacing).
 - 13.4.3. DWE/DWV — double-wall exposure, double-wall view.
- 13.5. The direction of the central beam shall be centered on the area of interest whenever possible. The maximum permitted radiation-angle deviation is 5° .

13.6. Geometric Unsharpness (Ug) Recommended Maxima

Material Thickness (t)	Recommended Maximum Ug
Under 2 in.	0.020 in.
2 in. through 3 in.	0.030 in.
Over 3 in. through 4 in.	0.040 in.
> 4 in.	0.070 in.

$U_g = f \times d / D$, where f = source size (effective focal spot), d = distance from source side of weld to detector, D = source-to-weld distance. D and d shall be determined at the approximate center of the area of interest.

NOTE: Recommended U_g values are guidance — final acceptance depends on satisfying the IQI image requirements (§16).

13.7. Location Markers (See Figure 1)

- 13.7.1. Markers shall appear as radiographic images on the digital image; their locations shall be permanently marked on the part surface when permitted (or on a map) for the required retention period.
- 13.7.2. First location identified with '0' or 'A'.
- 13.7.3. Markers should not be closer than 1/4 in. to the weld.
- 13.7.4. Whenever more than one image is used, identification markers shall appear on each image, and adjacent images shall overlap, with the last reference marker on each end appearing on the adjacent image, demonstrating no omission.
- 13.7.5. Reference markers on the DS side shall be read clockwise; spacing 2 in. for $\leq$ NPS 16, 6 in. for $>$ NPS 16.
- 13.7.6. Where practicable, at least 25 mm (1 in.) of coverage on each side of the weld cap. In situations where 25 mm (1 in.) is not achievable, the minimum distance between the toe of the weld cap and the detector/image boundary must be $\geq$ 6.4 mm (0.250 in.).

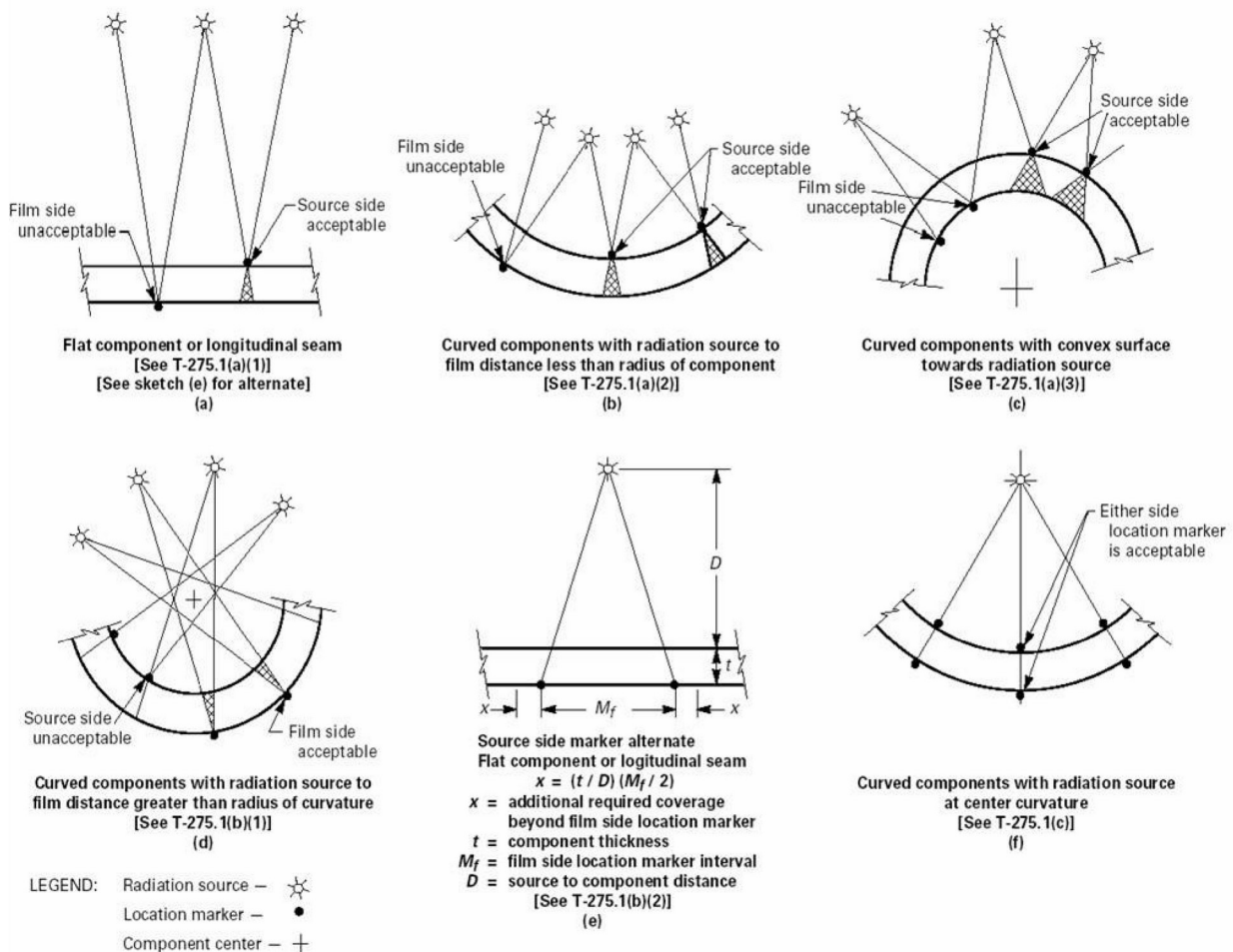


Figure 1: Location Markers

NOTE: The drawings/sketches and paragraph numbers in Figure 1 are for illustrative purposes and are the same as depicted in ASME Section V Article 2.

13.8. Marker Placement — Single-Wall Viewing

13.8.1. Source-Side Markers — Required on the source side for: piping components with concave side toward the source AND source-to-material distance less than the inside radius; curved or spherical components with concave side toward the source.

13.9. Marker Placement — Double-Wall Viewing

13.9.1. At least one location marker shall be placed on the outside surface adjacent to the weld for each image.

13.10. DDA-Side Markers

13.10.1. Placed on the DDA side for piping components with the concave side toward the source AND source-to-material distance greater than the inside radius.

13.10.2. As an alternative to source-side placement, markers may be placed on the DDA side where the image shows coverage beyond the location

markers (per ASME V Art. 2 Figure for marker placement), and the alternative is documented per §19.0.

13.10.3. Either-Side Markers — Either source or DDA side permitted on curved/spherical components where source-to-material distance equals the inside radius.

13.10.4. Where inaccessibility prevents stipulated placement, a dimensioned map of actual marker placement shall accompany the images and shall demonstrate that full coverage has been obtained.

13.11. Data Collection — Additional Requirements per TES-NE-RT-GL Appendix A

13.11.1. The digital scan start shall be located at the top of the pipe and physically marked for reference.

13.11.2. Resulting weld image(s) shall ensure full-circumference coverage with a data overlap of 25.4 mm (1 in.) in which a location marker is visible.

13.11.3. In-motion imaging systems shall use the same scanning speed and exposure parameters during inspection as during calibration.

13.11.4. Static-image techniques shall permit viewing in stitched and unstitched formats. The unstitched images shall be saved as part of the permanent examination record.

13.11.5. If the weld inspection image quality is determined unacceptable per the Company-consented procedure, a rescan shall be performed.

13.11.6. Encoder deviation shall NOT exceed 10 mm throughout the entire weld circumference.

13.11.7. Fully automated DR systems shall transfer digital information to the computer for presentation, analysis, and storage in real time.

14.0 Image Quality Indicator (IQI) Selection and Placement

14.1. Wire IQI

14.1.1. IQIs shall be selected from the same material group/grade as identified in ASTM E747 or ISO 19232-1, or from a group/grade of lesser radiation absorption than the test material.

14.1.2. ASTM E747 IQI: six (6) wires of increasing diameter. ISO 19232-1 IQI: seven (7) wires of increasing diameter.

14.1.3. Essential wire diameter shall be selected per the thickness tables in §22.0 (Tables 3A and 3B). Smaller wire diameters may be used at PII's option, provided the required sensitivity is obtained.

14.1.4. Images of IQI identifying style number, ASTM set letter, or ISO designation shall appear clearly. The essential wire diameter image shall appear clearly across the entire area of interest.

14.1.5. For welds with reinforcement, the IQI thickness is based on nominal single-wall thickness plus the estimated reinforcement (not exceeding

code maximum). Backing rings/strips are not part of the IQI-selection thickness.

14.1.6. For dissimilar metal welds, when weld-metal radiation attenuation differs from base metal, IQI material selection shall be based on the weld metal.

14.1.7. Additional IQIs may be required for thickness variations or dissimilar-metal applications.

14.2. Wire IQI Placement

14.2.1. For welds radiographed in a single exposure (panoramic), wire IQIs shall be placed on the detector (DDA) side of the part. At a minimum, four (4) IQIs shall be positioned at the 1, 4, 7, and 11 o'clock positions. The IQI at 1 o'clock shall be within 130 mm (5 in.) of the circumferential distance from the 12 o'clock reference position.

14.2.2. Where inaccessibility prevents source-side placement, the IQI shall be placed on the DDA side in contact with the part.

14.2.3. Wire length shall be perpendicular to the length of the weld. The identification numbers and (when used) the lead letter 'F' shall NOT be in the area of interest except where geometric configuration makes it impractical.

14.2.4. For non-weld materials, the IQI with identification number(s) and the 'F' (if used) may be placed in the area of interest.

14.2.5. For DWE/SWV or SWE/SWV multi-exposure techniques where the length to be interpreted exceeds 130 mm (5 in.): two IQIs across the weld, on the film/detector side, one within 25 mm (1 in.) of either end of the interpreted length, and the other at the center.

14.2.6. When a repaired weld is radiographed, an additional IQI shall be placed across each repaired area.

14.2.7. Alternative placement on a separate block of the same / radiographically similar material is permitted where geometry or size prevents direct placement; image brightness at the IQI body shall be equal to or greater than at the area of interest for negative format (reverse for positive). Variations up to 2% are permitted in determining 'equal to' by pixel intensity.

14.3. Duplex Wire IQI (ISO 19232-5) Basic Spatial Resolution

14.3.1. Each weld shall have at a minimum one Duplex IQI placed on the detector on TC Energy projects.

14.3.2. Position the duplex IQI at a slight angle, ~ 2° to 5° off parallel from the weld (scanner path), to avoid aliasing effects.

14.3.3. Duplex IQI placement shall be at the outer extremities of the projected image within 50 mm of the location marker(s).

14.3.4. Duplex IQI shall achieve Class A (per ISO 17636-2) WITHOUT compensation.

14.4. Number of IQIs (Multiple)

- 14.4.1. If multiple IQIs are used, one shall be representative of the lightest area of interest and another of the darkest.
- 14.4.2. When an array of objects in a circle is radiographed, at least one IQI shall be shown on each object image.

15.0 Image Quality and SNR

- 15.1. The digital image shall be free of system-induced artifacts in the area of interest that could mask or be confused with a discontinuity image.
- 15.2. The digital image shall display the required level of sensitivity of the IQI(s) for the material thickness being examined.
- 15.3. The image shall be post-processed to the point where the required level of IQI sensitivity and weld contrast is acceptable for final interpretation. The ORIGINAL (raw) format shall be saved before applying filters.
- 15.4. Additional tools may be used to verify interpretations; however, with the exception of any filters that are noted in the report, the final interpretation shall be made without the use of those tools.

15.5. Image Brightness

- 15.5.1. The image brightness adjacent to the designated wire of the wire-type IQI shall be judged equal to or greater than the image brightness in the area for a negative format. If verified by measurement, pixel-intensity variations of up to 30% are permitted when determining 'equal to'. Localized pixel averaging may be used to determine pixel-intensity variations, provided the number of pixels averaged does not exceed the total that would fit within a circle 0.125 in. (3 mm) in diameter. The image-brightness requirement is reversed for a positive format.

15.6. SNR — Signal-to-Noise Ratio

- 15.6.1. Digital systems shall meet the signal-to-noise requirements defined in ISO 17636-2 Class A (or better) for all DW and SW techniques. The ISO 17636-2 compensation rule shall not be used to satisfy Class A signal-to-noise requirements.

[Reference: ISO 17636-2 §6.5 and Table 6/7; ASME V Art. 2 Mandatory App. IX-3.3.]

16.0 IQI Sensitivity Requirements

- 16.1. Radiographic testing shall be performed with a technique of sufficient sensitivity to display the essential wire of the wire-type IQI. The radiograph shall also display the IQI identifying numbers and letters. The image of the essential wire diameter shall appear clearly across the entire area of interest.
- 16.2. The duplex wire IQI shall achieve ISO 17636-2 Class A WITHOUT applying the compensation rule.

- 16.3. IQI sensitivity shall be selected per the wall-thickness / essential-wire tables in §22.0 (Tables 3A — ASTM E747 and 3B — ISO 1027/19232-1 mapping).

17.0 Image Processing, Interpretation, and Evaluation

- 17.1. Before image-quality evaluation, the technician shall optimize contrast and brightness. The low-pass and high-pass limits shall be set to evaluate between 15% and 80% of the system's maximum grey-scale range (for a 16-bit system: 15% = 9,831 / 80% = 52,428).
- 17.2. Final radiographic interpretation of the area of interest shall be performed within the identified IQI image contrast and brightness values, or, if multiple IQIs are used, the overlapping portions of the identified contrast and brightness values for the intervening thickness ranges.
- 17.3. The IQI and the area of interest shall be of the same image format (positive OR negative). Independent areas of the same image may be displayed and evaluated in differing formats, provided the IQI and the area of interest are viewed in the same format.
- 17.4. The IQI shall extend all the way through the weld. If this cannot be achieved due to the weld width, two IQIs from each side shall be used.
- 17.5. Stitched and unstitched images shall be saved as part of the exam record.
- 17.6. Software image-analysis tools shall provide, at a minimum:
- 17.6.1. Zoom functions.
 - 17.6.2. Grey-level display and measurements.
 - 17.6.3. Contrast and brightness adjustments.
 - 17.6.4. Linear and circular defect measurement tools.
 - 17.6.5. Defect selection type and comment box.
 - 17.6.6. Spatial resolution measurement tool using the duplex-wire IQI
 - 17.6.7. Verification that the software version matched the qualified version for the project technique
- 17.7. Digital image zoom shall NOT be increased more than a 1:4 zoom factor. For example, images viewed at 1920 × 1080 shall have a range of interpretation and defect marking between 0.74 and 2.97 zoom factor. Contractor's interpretation guidelines specifying limits outside this range require prior Company consent.
- 17.8. Evaluation of indications shall be performed in accordance with the referencing code/standard/specification as referenced in the Project documents. All observed imperfections shall be reported. For each imperfection exceeding 50% of the allowable flaw dimension, the weld record shall include the flaw type and measured size. Customer (TC Energy) shall determine the final disposition of the weld.

- 17.9. Repair Scans — Repair scans utilizing DR shall use the same start mark as the original weld scan AND shall achieve image-quality requirements as prescribed by this procedure for the entire circumference.

18.0 Measurement / Scale Calibration

- 18.1. The measurement scale used for interpretation shall be capable of providing dimensions of the projected image. The measurement-scale tool shall be based on a known dimensional comparator placed on or adjacent to the detector side of the part near the area of interest during exposure. A screenshot image showing the measurement scale from the known comparator shall be included in the technique sheet.
- 18.2. As an alternative to a measuring-scale comparator, dimensional calibration of the measuring function based on detector pixel size may be used (and shall be documented on the technique sheet).

19.0 Documentation and Data Storage (DICONDE)

19.1. Technique Sheet — Project-Specific (Microsoft Excel)

Must be a Company-approved form.

- 19.1.1. Software version, system ID
- 19.1.2. Type of material being radiographed
- 19.1.3. Joint bevel design
- 19.1.4. Radiographic method (e.g., single-wall or double-wall exposure)
- 19.1.5. Material thickness range for which the procedure is suitable
- 19.1.6. Source type and strength (curies or Ma/Kv)
- 19.1.7. OFD, SFD or FFD, Geometric Unsharpness Factor (Ug Factor), and radiation angle with respect to the weld and film
- 19.1.8. ASTM or ISO IQI: type of material, identification of ASTM or ISO set, essential wire, diameter, number, and location
- 19.1.9. Position of radiation source (external or internal)
- 19.1.10. Type, thickness, and position of intensifying screens and filters
- 19.1.11. Sketch showing the geometric arrangement for the production of the radiographs, and showing the minimum SFD and radiation angle with respect to the weld
- 19.1.12. Panel type and brand
- 19.1.13. Number of images per weld
- 19.1.14. Exposure conditions in milliamperes minutes or curie minutes
- 19.1.15. Exposure time
- 19.1.16. Indication of manual or automatic
- 19.1.17. Grey-scale evaluation range, BSR, SNR, and image quality results
- 19.1.18. Sensitivity (%)
- 19.1.19. Heat shields: material, thickness, and the distance from the detector side of the heat shield to the pipe surface

19.2. Data File Requirements — Minimum Content (TES-NE-RT-G Appendix A-9)

Must contain correct information within the file or program meta data and be backed up after every weld on two independent storage devices.

- 19.2.1. Weld identification.
- 19.2.2. Object inspected (e.g., girth weld).
- 19.2.3. Material type (e.g., carbon steel).
- 19.2.4. Material thickness.
- 19.2.5. Specification of examination, including acceptance requirements.
- 19.2.6. Digital radiographic technique.
- 19.2.7. Magnification (max 4×).
- 19.2.8. System of marking used (metric units).
- 19.2.9. Radiation source, type and size of focal spot, equipment identification.
- 19.2.10. Detector, screens, filters, and detector basic spatial resolution (for first weld scanned as daily calibration).
- 19.2.11. Detector temperature.
- 19.2.12. Scan speed, frames per second.
- 19.2.13. Tube voltage used and current.
- 19.2.14. Source-to-detector distance.
- 19.2.15. Type of image quality indicators.

19.3. Daily Inspection Report Requirements — Per TES-NE-RT-G Appendix A-10, the report accompanying each group of images shall contain:

- 19.3.1. Contract, component, and weld identification (and chainage, if available).
- 19.3.2. Material type and thickness.
- 19.3.3. Detector identification.
- 19.3.4. Technique (single wall or double wall).
- 19.3.5. Date of examination.
- 19.3.6. Technician name, certification, and signature.
- 19.3.7. Number and revision of PII procedure.
- 19.3.8. Weld acceptance disposition.
- 19.3.9. Imperfection classification (per code).
- 19.3.10. Applicable codes and standards.
- 19.3.11. Equipment identification.
- 19.3.12. Acceptance criteria.

19.4. Storage

Digital files shall be stored and backed up as soon as practicable following completion of each weld examination on two independent storage devices. Cloud storage may form one copy only when the second copy is independent.

- 19.4.1. All digital images shall be uploaded to cloud-based data storage as agreed with TC Energy.
- 19.4.2. Final retention format: DICONDE (ASTM E2339 / E2699).
- 19.4.3. Digital radiographic techniques shall produce a permanent radiographic image record in its original, unaltered format.

- 19.4.4. Electronic records are categorized in a logical file structure agreed upon between TC Energy and PII.
- 19.4.5. Retention shall meet 49 CFR §192.709 (minimum 7 years, or asset life if longer).

20.0 Acceptance Standards

- 20.1. Unless otherwise specified by the project, weld acceptance shall be per API 1104, 21st Edition, §9.6 (Acceptance Standards for Nondestructive Testing).
- 20.2. Indications shall be classified using the API 1104 indication types (IP, IPD, ICP, IF, IFD, IC, BT, SI, PIP, HB, CP, CR, UC, AHC, and pipe/fitting imperfections per §9.7).
- 20.3. For ASME B31.3: ASME B31.3 §344.5 (with §341.3.2 severity classification when invoked).
- 20.4. A Project-Specific Acceptance Addendum shall be developed where required by the customer; without such guidance, TC Energy shall be consulted.

20.5. API 1104 Accept/Reject Criteria

20.5.1. Inadequate Penetration without High-Low

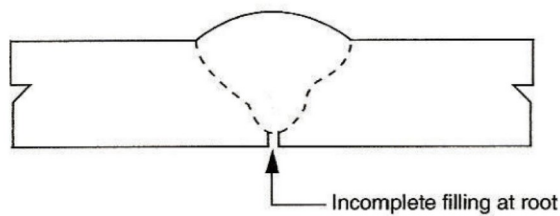
Inadequate penetration without high-low (IP) is defined as the incomplete filling of the weld root. This condition is shown schematically in Figure 2 shall be considered a defect should any of the following conditions exist:

- a. The length of an individual indication of IP exceeds 1in (25mm).
- b. The aggregate length of indications of IP in any continuous 12in (300mm) of weld exceeds 1in (25mm).
- c. The aggregate length of indications of IP exceeds 8% of the weld length in any weld less than 12in (300mm) in length.

20.5.2. Inadequate Penetration Due to High-Low

Inadequate penetration due to high-low (IPD) is defined as the condition in which one edge of the root is exposed (or unbonded) because adjacent pipe or fitting joints are misaligned. This condition is shown schematically in Figure 3. IPD shall be considered a defect should any of the following conditions exist:

- a. The length of an individual indication of IPD exceeds 2in (50mm).
- b. The aggregate length of indications of IPD in any continuous 12in (300mm) length of weld exceeds 3in (75mm).



**Figure 2: Inadequate Penetration (IP)
High-Low (IPD)**

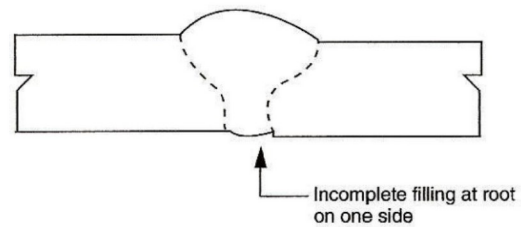


Figure 3: IP Due to

20.5.3. Inadequate Cross Penetration

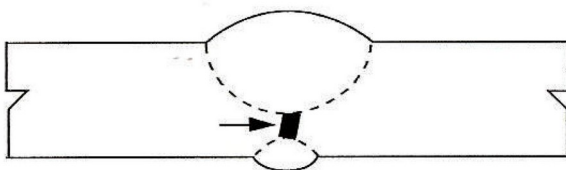
Inadequate cross penetration (ICP) is defined as a subsurface imperfection between the first inside pass and the first outside pass that is caused by inadequately penetrating the vertical land faces. This condition is shown schematically in Figure 4. ICP shall be considered a defect should any of the following conditions exist:

- The length of an individual indication of ICP exceeds 2in (50 mm).
- The aggregate length of ICP in any continuous 12in (300mm) length of weld exceeds 2in (50mm).

20.5.4. Incomplete Fusion

Incomplete fusion (IF) is defined as a surface imperfection between the weld metal and the base material that is open to the surface. This condition is shown schematically in Figure 5. IF shall be considered a defect should any of the following conditions exist:

- The length of an individual indication of IF exceeds 1in (25mm).
- The aggregate length of indications of IF in any continuous 12in (300mm) length of weld exceeds 1in (25 mm).
- The aggregate length of indications of IF exceeds 8% of the weld length in any weld less than 12in (300mm) in length.



**Figure 4: Inadequate Cross Penetration (ICP)
Incomplete Fusion (IF)**

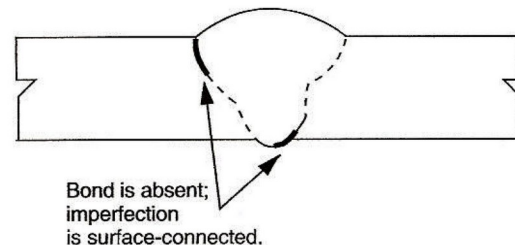


Figure 5:

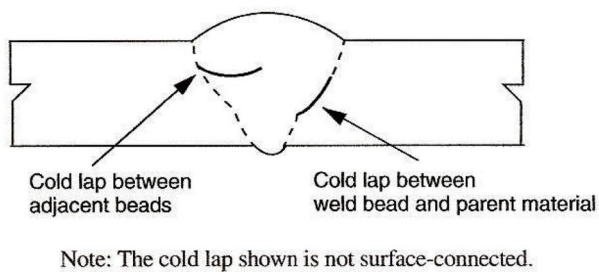
20.5.5. Incomplete Fusion Due to Cold Lap

Incomplete fusion due to cold lap (IFD) is defined as an imperfection between two adjacent weld beads or between the weld metal and the base metal that is not open to the surface. This condition is shown schematically in Figure 6. IFD shall be considered a defect should any of the following conditions exist:

- a. The length of an individual indication of IFD exceeds 2in (50mm)
- b. The aggregate length of indications of IFD in any continuous 12in (300mm) length of weld exceeds 2in (50mm)
- c. The aggregate length of indications of IF exceeds 8% of the entire weld length.

20.5.6. Internal Concavity

Internal concavity (IC) is shown schematically in Figure 7. Any length of internal concavity is acceptable, provided the density of the radiographic image of the internal concavity does not exceed that of the thinnest adjacent parent material. For areas that exceed the density of the thinnest adjacent parent material, the criteria for burn-through (see 20.6.7) are applicable.



**Figure 6: Incomplete Fusion Due to Cold Lap (IFD)
Concavity (IC)**

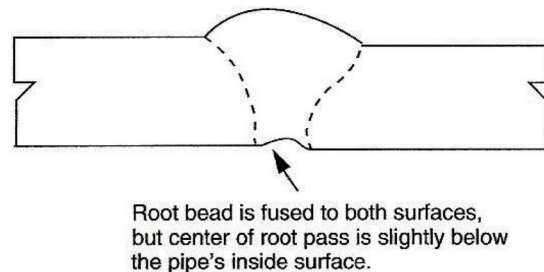


Figure 7: Internal

20.5.7. Burn-Through

A burn-through (BT) is defined as a portion of the root bead where excessive penetration has caused the weld puddle to be blown into the pipe.

20.5.7.1. For a pipe with an outside diameter greater than or equal to 2.375in (60.3mm), a BT shall be considered a defect should any of the following conditions exist:

- a. The maximum dimension exceeds 1/4in (6mm) and the density, in any portion of the BT's image, exceeds that of the thinnest adjacent parent material.

b. The maximum dimension exceeds the thinner of the nominal wall thicknesses joined, and the density, in any portion of the BT's image, exceeds that of the thinnest adjacent parent material.

c. The sum of the maximum dimensions of separate BT's whose image density, for any portion of BT's, exceeds that of the thinnest adjacent parent material and exceeds 1/2in (13 mm) in any continuous 12in (300 mm) length of weld, or the total weld length, whichever is less.

20.5.7.2. For a pipe with an outside diameter less than 2.375in (60.3mm), a BT shall be considered a defect when any of the following conditions exist:

a. The maximum dimension exceeds 1/4in (6 mm), and the density in any portion of the BT's image exceeds that of the thinnest adjacent parent material.

b. The maximum dimension exceeds the thinner of the nominal wall thicknesses joined, and the density in any portion of the BT's image exceeds that of the thinnest adjacent parent material.

c. More than one BT of any size is present, and the density in any portion of the BT's image exceeds that of the thinnest adjacent parent material.

20.5.8. Slag Inclusions

A slag inclusion is defined as a nonmetallic solid entrapped in the weld metal or between the weld metal and the parent material. Elongated slag inclusions (ESI's), continuous or broken slag lines, or wagon tracks are usually found at the fusion zone. Isolated slag inclusions (ISI's) are irregularly shaped and may be located anywhere in the weld. For evaluation purposes, when the size of a radiographic indication of slag is measured, the indication's maximum dimension shall be considered its length.

20.5.8.1. For a pipe with an outside diameter greater than or equal to 2.375in (60.3mm), slag inclusions shall be considered a defect should any of the following conditions exist:

a. The length of an individual indication of ESI exceeds 2in (50mm).

b. The aggregate length of indications of ESI in any continuous 12in (300mm) length of weld exceeds 2in (50mm).

c. The width of an ESI indication exceeds 1/16in (1.6mm)

d. The aggregate length of ISI indications in any continuous 12in (300mm) length of weld exceeds 1/2in (13mm)

- e. The width of the ISI indication exceeds 1/8in (3mm)
- f. More than four ISI indications with the maximum width of 1/8in (3mm) are present in any 12in (300mm) length of weld.
- g. The aggregate length of ESI and ISI indications exceeds 8% of the entire weld length.

20.5.8.2. For a pipe with an outside diameter less than 2.375in (60.3mm), slag inclusions shall be considered a defect should any of the following conditions exist:

- a. The length of an ESI indication exceeds three times the thinner of the nominal wall thicknesses joined.
- b. The width of an ESI indication exceeds 1/16in (1.6mm).
- c. The aggregate length of ISI indications exceeds two times the thinner of the nominal wall thicknesses joined, and the width exceeds one-half the thinner of the nominal wall thicknesses joined.
- d. The aggregate length of ESI and ISI indications exceeds 8% of the entire weld length.

NOTE: *Parallel ESI indications separated by approximately the width of the root bead (wagon tracks) shall be considered a single indication unless the width of either of them exceeds 1/32in (0.8 mm). In that event, they shall be considered separate indications.*

20.5.9. Porosity

Porosity is defined as gas trapped in the solidifying weld metal before it has a chance to rise to the surface of the molten puddle and escape. Porosity is generally spherical but may be elongated or irregular in shape, such as piping (wormhole) porosity. When the size of the radiographic indication produced by a pore is measured, the maximum dimension of the indication shall apply to the criteria given below:

20.5.9.1. Individual or scattered porosity (P) shall be considered a defect should any of the following conditions exist:

- a. The size of an individual pore exceeds 1/8in (3mm).
- b. The size of an individual pore exceeds 25% of the thinner of the nominal wall thicknesses joined.
- c. The distribution of scattered porosity exceeds the concentration permitted by Figures 8 or 9.

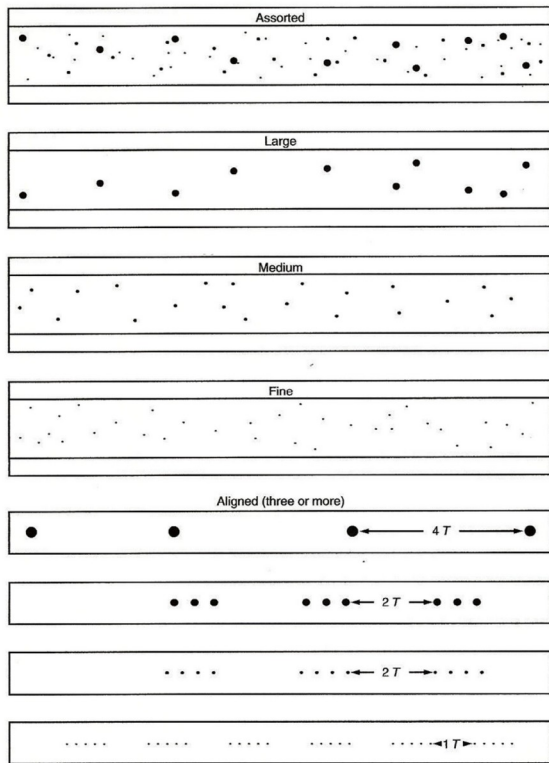


Figure 8: Max Distribution of Porosity ≤ 0.500 in (12.7mm)

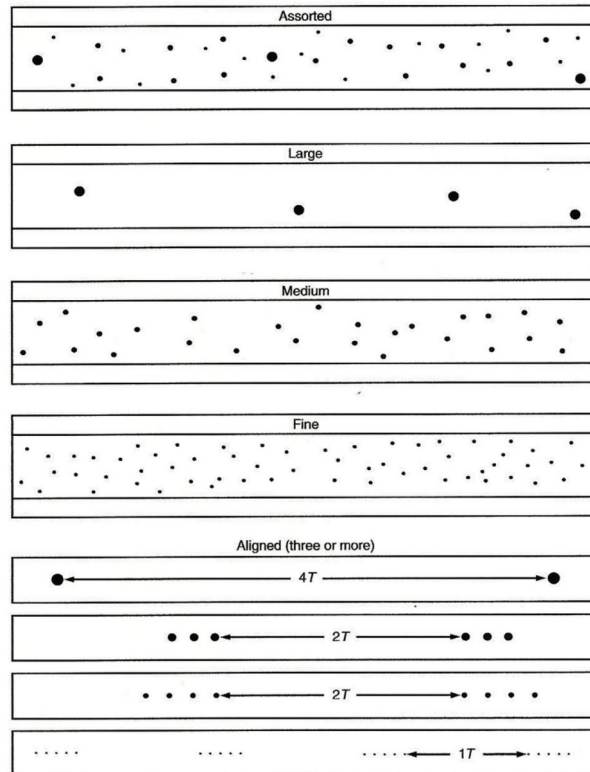


Figure 9: Max Distribution of Porosity > 0.500 in (12.7mm)

20.5.9.2. Cluster porosity (CP) that occurs in any pass except the finish pass shall comply with the criteria stated in 20.7.9.1. CP that occurs in the finished pass shall be considered a defect should any of the following conditions exist:

- a. The diameter of the cluster exceeds 1/2in (13mm).
- b. The aggregate length of CP in any continuous 12in (300mm) length of weld exceeds 1/2in (13mm).

20.5.9.3. Hollow-bead Porosity (HB) is defined as elongated linear porosity that occurs in the root pass. HB shall be considered a defect should any of the following conditions exist:

- a. The length of an individual indication of HB exceeds 1/2in (13mm).
- b. The aggregate length of indications of HB in any continuous 12in (300mm) length of weld exceeds 2in (50mm).
- c. Individual indications of HB, each greater than 1/4in (6mm) in length, are separated by less than 2in (50mm).
- d. The aggregate length of all indications of HB exceeds 8% of the entire weld length.

20.5.10. Cracks

Cracks (C) shall be considered a defect should any of the following conditions exist:

- a. The crack, of any size or location in the weld, is not a shallow crater crack or star crack.
- b. The crack is a shallow crater crack or star crack with a length that exceeds 5/32in (4mm)

NOTE: *Shallow crater cracks or star cracks are located at the stopping point of weld beads and are the result of weld metal contraction during solidification.*

20.5.11. Undercutting

Undercutting is defined as grooves melted into the parent material adjacent to the toe or root of the weld and left unfilled by weld metal. Undercutting adjacent to the cover pass (EU) or root pass (IU) shall be considered a defect should any of the following conditions exist:

- a. The aggregate length of indications of EU and IU, in any combination, in any continuous 12in (300mm) length of weld exceeds 2in (50mm).
- b. The aggregate length of indications of EU and IU, in any combination, exceeds 1/8 of the weld length.

NOTE: *See Visual Inspection Procedure for acceptance standards for undercutting when visual and mechanical measurements are employed.*

20.5.12. Accumulation of Imperfections

Excluding incomplete penetration due to high-low and undercutting, any accumulation of imperfections (AI) shall be considered a defect should any of the following conditions exist:

- a. The aggregate length of indications in any continuous 12in (300mm) length of weld exceeds 2in (50mm).
- b. The aggregate length of indications exceeds 8% of the entire weld length.

20.5.13. Pipe or Fitting Imperfections

Imperfections in the pipe or fittings detected by radiographic testing shall be reported to the customer. Their disposition shall be as directed by the customer.

20.6. 20.8 ASME B31.3 Accept/Reject Criteria

Criteria (A to M) for Types of Welds and for Service Conditions - Note (1)										Weld Imperfections
Normal and Category M Fluid Service			Severe Cyclic Conditions			Category D Fluid Service				
Girth, Miter Groove, and Branch Connection Welds Note (2)	Longitudinal Groove Weld Note (3)	Fillet Weld Note (4)	Girth, Miter Groove, and Branch Connection Welds Note (2)	Longitudinal Groove Weld Note (3)	Fillet Weld Note (4)	Girth & Miter Groove Welds	Longitudinal Groove Weld Note (3)	Fillet Weld Note (4)	Branch Connection Weld Note (2)	
A	A	A	A	A	A	A	A	A	A	Crack
A	A	A	A	A	A	C	A	NA	A	Lack of Fusion
B	A	NA	A	A	NA	C	A	NA	B	Incomplete Penetration
E	E	NA	D	D	NA	N/A	N/A	N/A	N/A	Rounded Indications
G	G	NA	F	F	NA	N/A	N/A	N/A	N/A	Linear indications
H	A	H	A	A	A	I	A	H	H	Undercutting
A	A	A	A	A	A	A	A	A	A	Surface porosity or exposed slag inclusion Note (5)
NA	NA	NA	J	J	J	NA	NA	NA	NA	Surface Finish
K	K	NA	K	K	NA	K	K	NA	K	Concave surface, concave root, or burn-through
L	L	L	L	L	L					Weld reinforcement or internal protrusion

General Notes:

(a) Weld imperfections are evaluated by one or more of the types of examination methods given, as specified in B31.3 paragraphs. 341.4.1, 341.4.2, 341.4.3, and M341.4, or by the engineering design.

(b) "N/A" indicates the Code does not establish acceptance criteria or does not require evaluation of this kind of imperfection for this type of weld.

(c) Check (✓) indicates examination method generally used for evaluating this kind of weld imperfection.

(d) Ellipsis (. . .) indicates examination method not generally used for evaluating this kind of weld imperfection.

Notes:

(1) Criteria given are for required examination. More stringent criteria may be specified in the engineering design. See also ASME B31.3, paras. 341.5 and 341.5.3.

(2) Branch connection weld includes pressure-containing welds in branches and fabricated laps.

(3) Longitudinal groove weld includes straight and spiral (helical) seam. Criteria are not intended to apply to welds made in accordance with a standard listed in ASME B31.3 Table A-1, Table A-1M, or Table 326.1. Alternative Leak Test requires examination of these welds; see ASME B31.3 para. 345.9.

(5) These imperfections are evaluated only for welds $3/16\text{in} \leq 5\text{ mm}$ ($\leq 5\text{ mm}$) in nominal thickness.

(4) Fillet weld includes socket and seal welds, and attachment welds for slip-on flanges, branch reinforcement, and supports.

Criterion		Acceptable Value Limits - Note (1)
Symbol	Measure	
A	Extent of imperfection	Zero (no evident imperfection)
B	Cumulative length of incomplete penetration	$\leq 1.5\text{in}$ (38mm) in any 6in (150mm) weld length or 25% of total weld length, whichever is less
C	Cumulative length of lack of fusion and incomplete penetration	$\leq 1.5\text{in}$ (38mm) in any 6in (150mm) weld length or 25% of total weld length, whichever is less
D	Size and distribution of rounded indications	See Appendix 1 and Figures 4, 5, and 6.0 - 6.5. Note (2)
E	Size and distribution of rounded indications	For $T_w \leq 1/4\text{in}$ (6mm), limit is same as D - Note (2) For $T_w > 1/4\text{in}$ (6mm), limit is 1.5D - Note (2)
F	Linear indications Individual length Individual width Cumulative length	$\leq T_w / 3$ $\leq 3/32\text{in}$ (2.5mm) and $\leq T_w / 3$ $\leq T_w$ in any 12 T_w weld length - Note (2)
G	Linear indications Individual length Individual width Cumulative length	$\leq 2T_w$ $\leq 1/8\text{in}$ (3mm) and $\leq T_w / 2$ $\leq 4T_w$ in any 6in (150mm) weld length - Note (2)
H	Depth of undercut Cumulative length of internal and external undercut	$\leq 1/32\text{in}$ (1mm) and $\leq T_w / 4$ $\leq 1.5\text{in}$ (38mm) in any 6in (150mm) weld length or 25% of total weld length, whichever is less
I	Depth of undercut Cumulative length of internal and external undercut	$\leq 1/16\text{in}$ (1.5mm) and $\leq [T_w / 4 \text{ or } 1/32\text{in} (1\text{mm})]$ $\leq 1.5\text{in}$ (38mm) in any 6in (150mm) weld length or 25% of total weld length, whichever is less
J	Surface roughness	$\leq 500\text{ }\mu\text{in}$ (12.5 μm) Ra in accordance with ASME B46.1
K	Depth of surface concavity, root concavity, or burn-through	Total joint thickness, including weld reinforcement $\geq T_w$ Notes (3) and (4)
L	Height of reinforcement or internal protrusion in any plane through the weld shall be within limits of the applicable height value in the tabulation shown in Appendix 2 for ASME B31.3. Weld metal shall merge smoothly into the component surfaces.	See Appendix 2: Maximum Permissible Weld Reinforcement
M	Height of reinforcement or internal protrusion as described in L.	See Appendix 2: Maximum Permissible Weld Reinforcement

NOTES:

(1) Where two limiting values are separated by “and,” the lesser of the values determines acceptance. Where two sets of values are separated by “or,” the larger value is acceptable. T_w is the nominal wall thickness of the thinner of the two components joined by a butt weld.

(2) Porosity and inclusions such as slag or tungsten are defined as rounded indications where the maximum length is three times the width or less. These indications may be circular, elliptical, or irregular in shape; may have tails; and may vary in density. Indications where the length is greater than three times the width are defined as linear indications and may also be slag, porosity, or tungsten.

(3) For circumferential groove welded joints in pipe, tube, and headers made entirely without the addition of filler metal, external concavity shall not exceed the lesser of 1/32in or 10% of the joint nominal thickness. The contour of the concavity shall blend smoothly with the base metal. The total joint thickness, including any reinforcement, shall not be less than the minimum wall thickness, tm.

(4) For radiography, acceptability may be determined by comparing the density of the image through the affected area to the density through the adjacent base metal (Tw).

21.0 Variances

Any deviation from this procedure or from TES-NE-RT-G Rev.08 Appendix A shall be processed through the TC Energy Controlled Document Library Variance Procedure (CAN-US-MEX), Item ID 007728702. Internal PII variances shall be recorded in PII-QM-VAR with Level III concurrence.

22.0 Tables — Energy / Material / Pixel and IQI Designations

Table 22-1: Energy, Material, and Pixel-Value Range (per the qualified PII DR systems)

Manufacturer	Energy Source	Min Res (μm)	Technique	Modality	Material Group	Bit Depth	Thickness Range (in.)	Min Pixel Value	Max Pixel Value
3ENDT / YXLON	X-ray	127	SW	DR	1	14 or 16	0.19 – 1.77	800	60000
3ENDT / YXLON	X-ray	127	DW	DR	1	14 or 16	0.39 – 3.34	800	60000
3ENDT	X-ray	100	DW	DR	1	16	0.39 – 3.34	800	60000
3ENDT	Gamma	140	DW	DR	1	16	0.39 – 3.34	800	60000

Table 22-2A: ASTM E747 Wire IQI Designation and Diameter

ASTM Set-Wire #	Wire Diameter (in. / mm)
A-1	0.0032 / 0.08
A-2	0.0040 / 0.10
A-3	0.0050 / 0.13
A-4	0.0063 / 0.16
A-5	0.0080 / 0.20
A-6	0.0100 / 0.25
B-6	0.0100 / 0.25
B-7	0.0130 / 0.33
B-8	0.0160 / 0.41
B-9	0.0200 / 0.51
B-10	0.0250 / 0.64
B-11	0.0320 / 0.81
C-11	0.0320 / 0.81
C-12	0.0400 / 1.02
C-13	0.0500 / 1.27
C-14	0.0630 / 1.60
C-15	0.0800 / 2.03
C-16	0.1000 / 2.54
D-16	0.1000 / 2.54
D-17	0.1260 / 3.20
D-18	0.1600 / 4.06
D-19	0.2000 / 5.05
D-20	0.2500 / 6.35
D-21	0.3200 / 8.13

Table 22-2B: ISO 19232-1 Wire IQI Designation and Diameter (selected sets)

IQI Set	ISO Wire #	Wire Diameter mm (in.)
1-ISO-7	1	3.20 (.125)
	2	2.54 (.100)
	3	2.03 (.080)
	4	1.60 (.063)

IQI Set	ISO Wire #	Wire Diameter mm (in.)
	5	1.25 (.050)
	6	1.00 (.040)
	7	0.80 (.032)
6-ISO-12	6	1.00 (.040)
	7	0.80 (.032)
	8	0.63 (.025)
	9	0.50 (.020)
	10	0.40 (.016)
	11	0.32 (.013)
	12	0.25 (.010)
10-ISO-16	10	0.40 (.016)
	11	0.32 (.013)
	12	0.25 (.010)
	13	0.20 (.008)
	14	0.16 (.0063)
	15	0.127 (.005)
	16	0.10 (.004)
13-ISO-19	13	0.20 (.008)
	14	0.16 (.0063)
	15	0.127 (.005)
	16	0.10 (.004)
	17	0.08 (.0032)
	18	0.063 (.0025)
	19	0.051 (.0020)

Table 22-3A: Material Thickness, Penetrameter Designation, Essential Wire (ASTM E747 — API 1104)

Wall / Weld Thickness (in.)	Wall / Weld Thickness (mm)	Essential Wire Diameter (in. / mm)	ASTM Set Letter
0 - 0.250	0 - 6.35	0.008 / 0.20	A

Wall / Weld Thickness (in.)	Wall / Weld Thickness (mm)	Essential Wire Diameter (in. / mm)	ASTM Set Letter
> 0.250 - 0.375	> 6.35 - 9.5	0.010 / 0.25	A or B
> 0.375 - 0.500	> 9.5 - 12.7	0.013 / 0.33	B
> 0.500 - 0.750	> 12.7 - 19.05	0.016 / 0.41	B
> 0.750 - 1.000	> 19.05 - 25.4	0.020 / 0.51	B
> 1.000 - 2.000	> 25.4 - 50.8	0.025 / 0.64	B

Table 22-3B: Material Thickness, Penetrameter Designation, Essential Wire (ISO 19232-1 / 1027 — API 1104)

Wall / Weld Thickness (in.)	Wall / Weld Thickness (mm)	Essential Wire Diameter (in. / mm)	ISO Wire Identity
0 - 0.250	0 - 6.35	0.008 / 0.20	13
> 0.250 - 0.375	> 6.35 - 9.5	0.010 / 0.25	12
> 0.375 - 0.500	> 9.5 - 12.7	0.013 / 0.33	11
> 0.500 - 0.750	> 12.7 - 19.05	0.016 / 0.41	10
> 0.750 - 1.000	> 19.05 - 25.4	0.020 / 0.51	9
> 1.000 - 2.000	> 25.4 - 50.8	0.025 / 0.64	8

23.0 Compliance Cross-Reference Matrix

Procedure §	Subject	Governing Code / Specification Reference
5.0	DR Personnel Training & Certification	ASME V Art. 1 Mandatory App. II; SNT-TC-1A 2024; ANSI/ASNT CP-189; ISO 9712
6.0	Radiation Safety / Two-Person Rule	10 CFR §20 / §34.41; CNSC NSRDR; NOM-025-NUCL-2015
7.1	Source Activity (≤ 90 Ci for Ir-192)	TES-NE-RT-GL App. A-1; ISO 17636-2 §6
7.2	DDA Performance	ASTM E2737, E2698; ASME SE-2597; ISO 17636-2 §5
8.3	Bad-Pixel Map (CKP < 2%)	ASME SE-2597; TES-NE-RT-GL App. A-3-4

Procedure §	Subject	Governing Code / Specification Reference
8.4	BSR via Duplex IQI (Class A no comp.)	ISO 19232-5; ISO 17636-2 Class A; TES-NE-RT-GL App. A-5
12.0	Display Performance (250 cd/m ² , 250:1)	TES-NE-RT-GL App. A-3-3; ASME V Art. 2 App. IX; SMPTE RP 133
13.0	Exposure Geometry / Coverage	API 1104 §11.1.4; ASME V Art. 2 T-271; TES-NE-RT-GL App. A-4
13.4	Geometric Unsharpness	ASTM E2002; ASME V Art. 2 T-274.2
14.0	Wire & Duplex IQI	ASTM E747; ISO 19232-1 & -5; ASME V Art. 2 T-276; TES-NE-RT-GL App. A-5
15.5	Image Brightness $\pm 30\%$ Pixel	ASME V Art. 2 Mandatory App. IX-3.4
15.6	SNR per ISO 17636-2 Class A	ISO 17636-2 §6.5; TES-NE-RT-GL App. A-6-4
17.7	Max 4× Zoom	TES-NE-RT-GL App. A-7-3
19.0	Documentation & DICONDE Storage	ASTM E2339, E2699, E1475; 49 CFR §192.709; TES-NE-RT-GL App. A-8/A-9
20.0	Acceptance Standards	API 1104 §9.6); ASME B31.3 §344.5;
21.0	Variance Process	TC Energy Item ID 007728702

25.0 Radiographic Examination Technique Sheet



Radiographic Procedure Qualification Record (Digital)

1621 Primewest Parkway | Katy, TX 77449 | P: (281) 578-6523; info@rae.com

primeinspections.com

Client: _____ Date: _____ Page: _____ of _____
 AFE/IR/PO No: _____
 Location: _____ UTQ Job No: _____

Code/Specification	Procedure & Rev	Acceptance Criteria
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Material Type: _____ Weld Joint Type: _____ Bevel: _____ Diameter (NPS): _____ Thickness: _____ Reinforcement (Est.): _____	IQI Type: ☐ Wire ☐ Plaque Designation: _____ Material: _____ Placement: ☐ Source Side ☐ Detector Side Essential Wire / Hole: _____	Screens Material: _____ Thickness Front: _____ Back: _____ Back Scatter Indicator: _____ Backing Material: _____
Radiation Source Type: ☐ Ir ¹⁹² ☐ Co ⁶⁰ ☐ Se ⁷⁵ ☐ X-Ray Strength: _____ (Ci) _____ (kV) _____ (mA) Focal Size: _____		
Detector Panel Manufacturer: _____ Type & Size: _____ Serial No: _____ Limit of Coverage: _____ No. of Exposures _____	Setup Source to Film Distance: _____ Dist. Source Side of Object to Film: _____ Source to Object Distance: _____ Ug (Geometric Unsharpness): _____ Exposure Time: _____ mA Minute: _____	Image Density Verification Window/Contrast: _____ Brightness/Level: _____ Focus: _____ Linearity: _____ Sensitivity (%): _____

Technique ☐ SWE/SWV (Panoramic) ☐ SWE/SWV (Single Wall) ☐ DWE/SWV (Contact) ☐ DWE/DWV (External Offset) 	Sketch
Image Processing Imaging System Manufacturer: _____ Type: _____ Serial No: _____ Imaging Software Version: _____ Revision: _____ File Type: _____ Monitor Resolution: _____	Other Acquisition: ☐ Manual ☐ Automated Scan Speed (FPS): _____ Detector Temperature: _____ Spatial Resolution: _____
Comments _____ _____ _____ _____	Heat Shields Type: _____ Material: _____ Thickness: _____ Distance (Detector Side of HS to Object): _____

Technician 	Client Representative:
Print Name & Level _____ Sign _____ Date _____	Print Name & Title _____ Sign _____ Date _____

Radiographic Procedure Qualification [RPQ]

PII-DRFORM-TS-Rev0 – 7/28/2026

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