



PII-DR

Digital Radiographic Examination

PNDT-DR

Revision 05

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Revision / Change Summary

Revision/Change	No.	Date	Description
Initial	0	4/12/2020	Initial Issue
Revision	01	8/12/2021	Code Review; updated for ASME Section V 2021 Edition
Revision	02	1/1/2024	Code Review; updated for ASME Section V 2023 Edition; added DDA system qualification requirements
Revision	03	1/1/2025	Code Review; updated for API 1104 21st Edition; added Ir-192 source qualification; added 3E Bendable DDA Panel
Revision	04	1/1/2026	Code Review; updated for ASME Section V 2025 Edition; added SNR and spatial resolution requirements per Appendix IV
Revision	05	9/5/2026	Complete rewrite to ASME Section V Article 2 Appendix IV (DDA) and API 1104 21st Edition Section 11; corrected IQI repair wording per API 1104 Interpretation 1104-I-0419-18; added acceptance criteria per Table 2 ($\leq 1/2$ in. wall) and Table 3 ($> 1/2$ in. wall); updated 3E Bendable DR Panel (200 μ m pixel pitch), XVu View software, Ir-192 source; added DDA system qualification, image processing, and SNR requirements

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1.0 SCOPE

1.1 This procedure establishes the minimum technique requirements for performing digital radiographic examination (DR) of welds and base materials using Digital Detector Array (DDA) technology for pipeline girth welds, fabricated welds, and applicable welder/welding operator performance qualifications. This procedure is written for Digital Radiography using DDA panels in accordance with ASME Section V, Article 2, Appendix IV and API 1104, 21st Edition, Section 11.

1.2 This procedure is applicable to carbon steel, austenitic stainless steel, duplex stainless steel, and other metallic pipeline and pressure-containing materials. It covers pipe diameters from 8 in. (203 mm) through 56 in. (1420 mm) with penetrated wall thickness ranges from 0.188 in. (4.8 mm) through 1.750 in. (44.5 mm) for single-wall exposure and 0.375 in. (9.5 mm) through 3.500 in. (89 mm) for double-wall exposure techniques.

1.3 The DDA system used under this procedure consists of the 3E Bendable Digital Radiographic Panel with a pixel pitch of 200 micrometers (μm), operated with XVu View software for image acquisition, processing, and evaluation. The radiation source shall be Iridium-192 (Ir-192) unless otherwise specified and qualified.

1.4 This procedure may be used with codes other than those listed in Section 2.0 if the requirements of those codes are met. The designated NDT Level III shall approve any additional systems, sources, or techniques to be used under this procedure.

1.5 This procedure does not cover computed radiography (CR) using phosphor imaging plates, film-based radiography, or real-time radiosopic examination. Those methods are covered under separate procedures.

2.0 REFERENCED DOCUMENTS

2.1 The following documents are referenced in this procedure. Current editions apply unless otherwise noted. Where a referenced document contains requirements that conflict with this procedure, the referencing code or contract specification shall govern.

2.2 Codes and Standards

2.2.1 ASME BPVC Section I, Power Boilers, 2025 Edition

2.2.2 ASME BPVC Section V, Nondestructive Examination, 2025 Edition, Article 2 – Radiographic Examination, including Mandatory Appendix II, Appendix IV (Digital Detector Arrays)

2.2.3 ASME BPVC Section VIII, Pressure Vessels, Divisions 1 and 2, 2025 Edition

2.2.4 ASME B31.1, Power Piping, 2024 Edition

2.2.5 ASME B31.3, Process Piping, 2024 Edition

2.2.6 ASME B31.4, Pipeline Transportation Systems for Liquids and Slurries, 2025 Edition

2.2.7 ASME B31.8, Gas Transmission and Distribution Piping Systems, 2025 Edition

2.2.8 API 1104, Welding of Pipelines and Related Facilities, 21st Edition

2.2.9 ASTM E94, Standard Guide for Radiographic Examination

2.2.10 ASTM E747, Standard Practice for Design, Manufacture, and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiography

2.2.11 ASTM E1027, Standard Practice for Design, Manufacture, and Use of Radiographic Hole-Type Image Quality Indicators (IQI)

2.2.12 ASTM E1254, Standard Guide to the manufacture of Hole-Type Image Quality Indicators (IQI)

2.2.13 ASTM E1316, Standard Terminology for Nondestructive Examinations

2.2.14 ASTM E2002, Standard Practice for Determining Total Image Unsharpness in Radiology

2.2.15 ASTM E2033, Standard Guide for Computed Radiology (Photostimulable Phosphor Method)

2.2.16 ASTM E2698, Standard Practice for Radiographic Examination Using Digital Detector Arrays

2.2.17 ASTM E2699, Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Digital Radiographic (DR) Test Methods

2.2.18 ASTM E2737, Standard Practice for Digital Detector Array Performance Evaluation and Long-Term Stability

2.2.19 ASTM E2597, Standard Practice for Manufacturing Characterization of Digital Detector Arrays (DDAs)

2.3 Company and Regulatory Documents

2.3.1 Code of Federal Regulations, Title 10, Parts 19, 20, 30, and 34 – Radiation Safety

2.3.2 Code of Federal Regulations, Title 49, Parts 107, 171, and 172 – Transportation of Radioactive Materials

2.3.3 ASNT SNT-TC-1A, 2020 Edition – Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

2.3.4 PII-WP-1, Written Practice for the Qualification and Certification of NDE Personnel, Current Revision

2.3.5 3E Bendable DR Panel Operating Manual, Current Edition

2.3.6 XVu View Software User Manual, Current Version

3.0 DEFINITIONS AND ABBREVIATIONS

3.1 DDA – Digital Detector Array: A solid-state radiation detection device consisting of an array of individual detector elements (pixels) that converts incident radiation into digital image data. The DDA used under this procedure is the 3E Bendable Digital Radiographic Panel with a pixel pitch of 200 μm .

3.2 SNR – Signal-to-Noise Ratio: The ratio of the mean signal value to the standard deviation of the signal in a specified region of interest. The minimum SNR for this procedure shall be 100:1 as measured in accordance with ASTM E2597.

3.3 SR■ (Spatial Resolution): The basic spatial resolution of the DDA, expressed as the effective pixel value in micrometers (μm). The spatial resolution shall be verified using a duplex wire type image quality indicator per EN 462-5 or ASTM E2002.

3.4 IQI – Image Quality Indicator: A device used to determine the radiographic quality and sensitivity of the radiographic image. Wire-type IQIs per ASTM E747 or hole-type IQIs per ASTM E1027 shall be used as applicable.

3.5 Ug – Geometric Unsharpness: A measure of the loss of definition in a radiographic image resulting from the finite size of the radiation source and the geometric relationships between source, object, and detector. Calculated as $U_g = F \times d / D$, where F is the source size, d is the source-to-object distance, and D is the source-to-detector distance.

3.6 DICONDE – Digital Imaging and Communication in Nondestructive Evaluation: A standard for the exchange of digital radiographic data.

3.7 ROI – Region of Interest: A user-defined area within the digital image used for measurement of pixel intensity values, SNR, or other image quality parameters.

3.8 Frame Averaging: The process of acquiring multiple image frames and mathematically averaging them to reduce random noise and improve the SNR.

3.9 Integration Time: The time period during which the DDA collects radiation to produce a single image frame.

3.10 Bad Pixel Map: A software-based map identifying individual detector elements (pixels) that do not respond correctly to radiation. The bad pixel map is supplied by the DDA manufacturer and is used to correct the acquired image.

3.11 CKP – Cluster Kernel Pixel: A group of adjacent underperforming pixels. CKPs shall not be present in the area of interest for static DDA examinations.

3.12 Ir-192 – Iridium-192: A radioactive isotope used as a gamma radiation source for radiographic examination. Ir-192 emits gamma radiation with a mean energy of approximately 0.38 MeV.

3.13 DWE/SWV – Double-Wall Exposure / Single-Wall Viewing: A radiographic technique in which the radiation passes through both walls of a pipe but only one wall is viewed and evaluated.

3.14 SWE/SWV – Single-Wall Exposure / Single-Wall Viewing: A radiographic technique in which the radiation passes through one wall and that wall is viewed and evaluated.

3.15 Pixel Pitch: The center-to-center spacing between adjacent detector elements in the DDA array. The 3E Bendable DR Panel has a pixel pitch of 200 μm .

4.0 RESPONSIBILITY

4.1 The Quality Manager of Prime Inspections Inc. is responsible for the preparation, review, approval, and control of this procedure. The designated NDT Level III is responsible for the technical review, approval, and qualification of this procedure.

4.2 The designated NDT Level III in the radiographic method is responsible for the review, approval, and qualification of this procedure and for ensuring that all personnel performing radiographic examination under this procedure are qualified and certified in accordance with PII-WP-1.

4.3 Technicians are responsible for complying with this procedure and completing all required records and reports. At any time while performing work under this procedure, should it become evident that procedure requirements cannot be met, the technician shall immediately contact the supervisor or lead technician for resolution.

4.4 Prior to beginning work, all personnel shall read, understand, and follow the requirements of the applicable Job Hazard Analysis (JHA) and all site-specific safety requirements.

4.5 Any questions regarding safety concerns or requirements shall be directed to the lead technician, supervisor, or facility representative before beginning or resuming work.

4.6 The radiographer shall be responsible for the protection and monitoring of every person working with or near radiation sources. Protection and monitoring shall comply with all applicable federal, state, and local regulations as well as Prime Inspections Inc. company procedures.

4.7 It shall be the responsibility of the Customer to determine applicable codes, standards, and acceptance criteria. The Customer is also responsible for providing access to the cloud-based data storage system for retention of digital radiographic images and reports.

4.8 Level I radiographers and radiographer's assistants (operator-helpers) shall report to the Level II or Level III radiographer and shall have the required level of training for the duties performed.

5.0 PERSONNEL QUALIFICATIONS

5.1 Personnel performing radiographic examinations under this procedure shall be qualified and certified in accordance with PII-WP-1, which complies with ASNT SNT-TC-1A, 2020 Edition.

5.2 Personnel performing evaluations and/or reporting results in accordance with this procedure shall be certified Level II as a minimum in the radiographic test method in accordance with PII-WP-1.

5.3 All personnel performing radiography shall have completed radiation safety training and shall be in compliance with applicable regulatory requirements, including 10 CFR Part 34 or equivalent state regulatory requirements.

5.4 Level I radiographers and radiographer's assistants (operator-helpers) shall report to and work under the supervision of a Level II or Level III certified radiographer. The assistant shall have the required training for the duties performed and shall not operate radiation-producing equipment without direct supervision.

5.5 Near-vision acuity shall be verified annually in accordance with SNT-TC-1A. Personnel shall be capable of reading Jaeger No. 1 (or equivalent) at a minimum distance of 12 inches (300 mm).

5.6 Color vision shall be verified annually. Personnel shall be capable of distinguishing and differentiating the colors used in the radiographic method as applicable.

5.7 Personnel shall be trained on this specific procedure and its applicable safety requirements prior to performing examinations under this procedure. Training records shall be maintained in accordance with PII-WP-1.

5.8 Personnel performing digital radiographic evaluation shall be trained on the XVu View software, the 3E Bendable DR Panel operation, and DICONDE image data management. Training shall be documented and maintained in personnel training records.

6.0 EQUIPMENT AND MATERIALS

6.1 The digital radiographic examination system shall consist of the following major components:

6.1.1 3E Bendable Digital Radiographic Panel (DDA) with a pixel pitch of 200 μm and a sensitive area sufficient to cover the pipe diameters specified in Section 1.0.

6.1.2 XVu View software for image acquisition, processing, display, and DICOM-compliant archiving.

6.1.3 Radiation source: Iridium-192 (Ir-192) gamma-ray source in a shielded exposure device (projector) with applicable transfer and storage containers.

6.1.4 Radiation survey instruments: A calibrated radiation survey meter and personal dosimetry devices (dosimeters and/or film badges/TLDs) as required by 10 CFR Part 20.

6.1.5 Image Quality Indicators (IQIs): Wire-type IQIs per ASTM E747 or hole-type IQIs per ASTM E1027, as applicable to the referencing code.

6.1.6 Duplex wire IQI per EN 462-5 or ASTM E2002 for verification of total image unsharpness (spatial resolution).

6.1.7 Location markers, lead letters, and identification numbers for radiographic image identification.

6.1.8 Measuring scale comparator or dimensional calibration based on detector pixel size for dimensional measurement from the digital image.

6.2 DDA Specifications

6.2.1 The 3E Bendable DR Panel shall have the following minimum specifications:

(a) Pixel pitch: 200 μm

(b) Bit depth: 14-bit or 16-bit (minimum 14-bit)

(c) Radiation source: Ir-192 gamma-ray compatible

(d) Bendable form factor for pipe diameters from 8 in. (203 mm) through 56 in. (1420 mm)

(e) DICOM-compliant image output

(f) Manufacturer-supplied bad pixel map and calibration data

6.3 Software Requirements

6.3.1 The XVu View software shall be used for all image acquisition, processing, and evaluation under this procedure. The software version shall be documented in the radiographic report.

6.3.2 The software shall retain a raw image (unprocessed) in addition to any processed images. Raw images shall be retained for the record retention period specified in Section 17.0.

6.3.3 The software shall support DICOM-compliant image storage and metadata embedding per ASTM E2699.

6.4 The DDA surface shall be kept free of any dirt, scratches, or other mechanical defects to the extent that the area of interest on the digital image is free of system-induced artifacts that could mask or be confused with the image of any discontinuity.

7.0 RADIATION SOURCE

7.1 The radiation source used under this procedure shall be Iridium-192 (Ir-192), a gamma-ray source with a mean energy of approximately 0.38 MeV. The source shall be housed in an approved shielded exposure device (projector) in compliance with 10 CFR Part 34 or applicable state regulations.

7.2 The source size (physical dimension of the active pellet) shall be documented and shall be used in the calculation of geometric unsharpness (U_g). Source sizes typically used are 0.5 mm × 0.5 mm (0.020 in. × 0.020 in.) or 1.0 mm × 1.0 mm (0.040 in. × 0.040 in.), or as specified by the source manufacturer.

7.3 The equipment manufacturer's or supplier's publications, such as technical manuals, decay curves, or written statements documenting the actual or maximum source size, shall be acceptable as source size verification. The source type, size, and curie strength shall be noted in the radiographic report.

7.4 The source activity (in curies or gigabecquerels) shall be documented at the time of exposure. Source decay shall be accounted for in the calculation of exposure time. The Ir-192 half-life is 73.83 days.

7.5 If an X-ray tube source is used in lieu of Ir-192, the determination of the focal spot for X-ray machines at 500 kV and below may be made by the manufacturer's data, a written statement documenting size, or the pinhole method. When such data is not available, the designated Level III shall be contacted for resolution on determining the focal spot size.

7.6 Radiation filters or masking may be used to equalize the radiation intensity reaching the DDA when significant thickness variations exist across the examination area. When used, the type and dimensions of the filter or masking shall be documented in the radiographic report.

8.0 SURFACE PREPARATION

8.1 The surface of the material to be radiographed shall be prepared such that surface irregularities, weld reinforcement, spatter, or other conditions do not interfere with the interpretation of the radiographic image. Surface preparation may include grinding, machining, or other methods as necessary.

8.2 Weld reinforcement shall not exceed the maximum permitted by the referencing code section. For API 1104 applications, the weld reinforcement shall not exceed the limits specified in the applicable edition of API 1104. Excessively high weld reinforcement may reduce radiographic sensitivity and should be reduced to the maximum permitted.

8.3 Grinding marks, if present, shall not be oriented in a direction that could mimic or mask relevant indications on the radiographic image. Weld crowns may be left as-welded if surface irregularities do not mask indications.

8.4 The DDA panel surface shall be kept clean and free of dirt, dust, moisture, or other contaminants that could affect image quality. The panel shall be handled in accordance with the manufacturer's operating manual to prevent damage to the sensitive surface.

8.5 Backing rings or strips, if used, shall not be considered as part of the material thickness in IQI selection. The actual measurement of weld reinforcement is not required; the estimated reinforcement shall be added to the nominal wall thickness for IQI selection.

9.0 EXPOSURE GEOMETRY

9.1 The radiographic technique used shall be either Single-Wall Exposure / Single-Wall Viewing (SWE/SWV) or Double-Wall Exposure / Single-Wall Viewing (DWE/SWV), as applicable to the pipe diameter, wall thickness, and access conditions.

9.2 For DWE/SWV techniques, the radiation source shall be positioned such that the central beam passes through both walls of the pipe and only the film-side (detector-side) wall is evaluated. The source offset shall be sufficient to prevent superimposition of the source-side wall onto the area of interest.

9.3 For SWE/SWV techniques, the radiation source shall be positioned on the inside of the pipe (panoramic or center-line technique) or on the outside with the DDA on the opposite side. The source-to-object distance shall be sufficient to achieve the required geometric unsharpness.

9.4 Geometric Unsharpness (Ug): The Ug shall not exceed the following recommended values based on material thickness:

Material Thickness (t)	Maximum Ug
Under 2 in. t	0.020 in. (0.51 mm)
2 in. through 3 in. t	0.030 in. (0.76 mm)
Over 3 in. through 4 in. t	0.040 in. (1.02 mm)
All material greater than 4 in. t	0.070 in. (1.78 mm)

9.5 Note: The above are recommended values. Final acceptance of the radiographic technique is dependent on satisfying the IQI image requirements. The material thickness (t) used for Ug determination shall be the thickness on which IQI selection is based.

9.6 Geometric Unsharpness (Ug) formula:

$$U_g = F \times d / D$$

where: Ug = Geometric Unsharpness; F = Source size (maximum projected dimension of the radiating source); d = Distance from source side of the object to the detector; D = Distance from source of radiation to the object being radiographed. D and d shall be determined at the approximate center of the area of interest.

9.7 The direction of the central beam of radiation should be centered on the area of interest whenever possible. The source-to-detector distance and source-to-object distance shall be documented in the radiographic report or technique sheet.

9.8 The minimum source-to-detector distance (SDD) for the 3E Bendable DR Panel with 200 µm pixel pitch and Ir-192 source shall be calculated to maintain Ug within the limits specified above. For panoramic (center-line) exposures, the SDD shall equal the inside pipe radius plus the DDA standoff distance.

10.0 DDA SYSTEM REQUIREMENTS

10.1 This section addresses the DDA system requirements in accordance with ASME Section V, Article 2, Appendix IV, including spatial resolution, signal-to-noise ratio (SNR), system qualification, and image quality.

10.2 Spatial Resolution (Basic Spatial Resolution – SR■)

10.2.1 The basic spatial resolution of the DDA shall be determined in accordance with ASTM E2597 or EN 462-5 using a duplex wire type IQI. The measured spatial resolution shall be documented for each DDA system and shall not exceed 200 µm for the 3E Bendable DR Panel.

10.2.2 The spatial resolution shall be verified at the commencement of each examination procedure qualification and whenever the DDA system is changed. The verification shall be performed using a duplex wire IQI placed adjacent to the weld on the first image produced each day or at the start of each examination campaign.

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

(a) Aliasing: Artifacts that appear in an image when the spatial frequency of the input is higher than the output is capable of reproducing. Aliasing often appears as jagged or stepped sections in a line or as moiré patterns.

10.3 Signal-to-Noise Ratio (SNR)

10.3.1 The signal-to-noise ratio (SNR) of the DDA system shall be a minimum of 100:1 as measured in a region of interest (ROI) in accordance with ASTM E2597. The SNR shall be measured at the radiation energy, source-to-detector distance, and integration time used for the examination.

10.3.2 The SNR shall be determined by the following method:

(a) Select a region of interest (ROI) in the homogeneous area of the digital image adjacent to the area of examination.

(b) Record the mean pixel value (signal) and the standard deviation (noise) of the pixel values within the ROI.

(c) Calculate $SNR = \text{Mean} / \text{Standard Deviation}$. The calculated SNR shall be $\geq 100:1$.

10.3.3 If the required SNR of 100:1 is not achieved, the radiographer shall adjust the integration time, frame averaging, or source-to-detector distance until the required SNR is obtained. The SNR value shall be documented in the technique sheet.

10.4 Underperforming Pixel Management

10.4.1 Digital detectors shall be supplied with the detector manufacturer's original bad pixel map, including the process and methodology used by the manufacturer to develop the bad pixel map. Bad pixels are underperforming detector elements and shall be addressed as follows:

(a) DDAs using static detectors shall not have cluster kernel pixels (CKPs) in the area of interest. An overlay may be used for verification. Refer to ASME SE-2597.

(b) For DDAs that use multiple overlapping pixel data arrangements, CKPs are not relevant provided acquired image data does not mask a relevant indication or create an image artifact.

10.4.2 All DDAs require a software-based calibration to determine the underperforming pixel map in accordance with the manufacturer's guidelines. System calibration for procedure-approved systems and image acquisition instructions are addressed in the 3E Bendable DR Panel Operating Manual.

10.5 DDA System Qualification

10.5.1 The DDA system shall be qualified in accordance with ASME Section V, Article 2, Appendix IV and ASTM E2737 prior to use in production examination. The qualification shall include:

- (a) Verification of spatial resolution (SR $\blacksquare$) using a duplex wire IQI per EN 462-5 or ASTM E2002
- (b) Verification of SNR $\geq$ 100:1 at the qualified exposure conditions
- (c) Verification of the manufacturer's bad pixel map and correction methodology
- (d) Verification of image quality using the required IQI at the qualified material thickness range
- (e) Long-term stability verification in accordance with ASTM E2737

10.5.2 DDA system qualification records shall be maintained and shall include the date of qualification, DDA serial number, software version, exposure parameters, and measured values of spatial resolution, SNR, and IQI sensitivity.

10.5.3 DDA system qualification shall be repeated when any of the following conditions occur:

- (a) A change in the DDA detector (replacement or repair)
- (b) A change in the radiation source type or energy
- (c) A change in the software version that affects image acquisition or processing
- (d) Damage to or degradation of the DDA panel
- (e) At intervals not exceeding 12 months, or as required by the referencing code or customer specification

10.6 Pixel Intensity and Gray Scale Range

10.6.1 The pixel intensity (gray scale) range for each radiographic image shall be documented. The minimum and maximum pixel values in the area of interest shall be within the qualified range for the DDA system. For the 3E Bendable DR Panel with 14-bit or 16-bit depth, the typical pixel intensity range shall be 800 to 60,000 (14-bit) or 800 to 60,000 (16-bit, scaled).

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

10.7 Technique Variables Documentation

10.7.1 The following technique variables shall be available for review either in the image metadata, the body of the radiographic report, or a combination of both:

- (a) Material type and thickness
- (b) Isotope type and curie strength, or X-ray voltage (kV) and current (mA)
- (c) Equipment manufacturer, make, model number, and serial number of the DDA
- (d) Minimum source-to-object distance
- (e) Distance from the source side of the object to the detector
- (f) Energy source focal spot size
- (g) Image display parameters, including filters used and window and level values
- (h) Storage media used
- (i) Radiation filters or masking used
- (j) Detector source alignment validation, if applicable

- (k) Pixel intensity / gray scale range (minimum to maximum)
- (l) Integration time and frame averaging

11.0 IMAGE PROCESSING

11.1 Image processing shall be performed using the XVu View software in accordance with the manufacturer's operating manual. The following image processing operations shall be applied as applicable:

11.2 Raw Image Retention

11.2.1 The raw image (unprocessed) shall be retained in addition to any processed images. The raw image shall be stored in DICOM format and shall be available for review for the record retention period specified in Section 17.0.

11.2.2 Only DDA image acquisition and image review software that retains a raw image shall be used under this procedure.

11.3 Image Enhancement

11.3.1 Image enhancement tools, including window/level adjustment (brightness and contrast), may be used to optimize the display of the radiographic image for interpretation. The enhancement parameters shall be documented in the radiographic report.

11.3.2 Spatial filters (e.g., smoothing, edge enhancement, sharpening) may be used for image enhancement. All filters used shall be documented in the report, including the filter type and parameters. Final interpretation of the radiograph shall be made using the documented filter settings.

11.3.3 Additional tools may be used for verification of interpretations; however, with the exception of filters used and noted in the report, final interpretation of the radiograph shall be made without the use of those tools.

11.4 Image Processing Specification

11.4.1 The following image processing steps shall be applied in sequence for each acquired image:

- (a) Bad pixel correction: Apply the manufacturer's bad pixel map to correct underperforming detector elements
- (b) Gain and offset correction: Apply the DDA calibration correction (dark current and flat-field correction)
- (c) Frame averaging: If multiple frames are acquired, apply frame averaging to improve SNR
- (d) Window and level adjustment: Adjust the display window (contrast) and level (brightness) to display the required IQI sensitivity
- (e) Filter application: If spatial filters are used, document the filter type and parameters

11.4.2 The image shall be post-processed to the point where the required level of IQI sensitivity and weld contrast is acceptable for final interpretation.

11.5 Digital Image Storage

11.5.1 All digital images shall be stored in DICOM-compliant format per ASTM E2699. The image metadata shall include the technique variables listed in Section 10.7.1.

11.5.2 Digital images shall be uploaded to a cloud-based data storage system for final retention. The Customer shall provide access to the storage location where digital files in DICOM format and test reports are to be stored.

11.5.3 Technique details may be embedded in the image data file. When this is done, ASTM E1475 may be used as a guideline for establishing data fields and information content.

12.0 CALIBRATION AND SYSTEM QUALIFICATION

12.1 System calibration is required for the DDA in accordance with the manufacturer's guidelines and ASME Section V, Article 2, Appendix IV. Calibration shall be performed at the following times:

12.1.1 At the commencement of the qualification of each examination procedure

12.1.2 When a change in material occurs

12.1.3 When a change in source quantity (curies) or energy of radiation occurs

12.1.4 When a change in the equipment used occurs (DDA, source, or software)

12.1.5 When a change in temperature occurs in accordance with manufacturer guidelines. In the absence of manufacturer information, any temperature change greater than 25°F (14°C) shall trigger recalibration.

12.1.6 When a change in technique parameters occurs

12.1.7 When failure to achieve image quality requirements occurs

12.1.8 At the discretion of the radiographer or Level III

12.2 Reference system calibration steps are provided in the 3E Bendable DR Panel Operating Manual and the XVu View Software User Manual.

12.3 Radiographs shall be acquired using the XVu View Digital System. The radiographer shall use the proper integration times and frame averaging to provide the IQI image quality and SNR required. This is accomplished by following the exposure using approved technique sheets.

12.4 Procedure Demonstration

12.4.1 Demonstration of IQI image requirements, in addition to the requirements noted in this procedure, on production or technique radiographs using the DDA shall be considered satisfactory evidence of compliance with this procedure.

12.4.2 For API 1104 radiography, a separate report with images shall be submitted to the Level III in the method for documented approval prior to beginning production radiography.

12.5 Measuring Scale Comparator

12.5.1 The measuring scale used for interpretation shall be capable of providing dimensions of the projected image. The measurement scale tool shall be based upon 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 of the digital image showing the measurement scale from a known dimensional comparator shall be included in the technique sheet.

12.5.2 As an alternative to a measuring scale comparator, a dimensional calibration of the measuring function based upon the detector pixel size (200 µm) may be used.

13.0 EXAMINATION

13.1 Radiographic examination shall be performed in accordance with the approved technique sheet for the specific project. The technique sheet shall specify the exposure parameters, source-to-detector distance, IQI type and placement, and all other variables necessary to achieve the required image quality.

13.2 Location markers (see Appendix V) shall be placed on the part. Their locations shall be permanently marked on the surface of the part being radiographed when permitted, or on a map, in a manner permitting the area of interest on the radiograph to be accurately traceable to its location on the part for the required retention period. The first location shall be identified with a "0" or an "A." Location markers shall not be placed closer than ¼ in. (6 mm) to the weld.

13.3 Whenever more than one image is used to inspect a weld, identification markers shall appear on each image, and adjacent images shall overlap. The last reference marker on each end of the image shall appear on the appropriate adjacent images in a way that establishes that no part of the weld has been omitted.

13.4 Evidence shall be seen on each radiograph that the required coverage of the area of interest radiographed has been achieved.

13.5 For Single-Wall Viewing (SWE/SWV):

13.5.1 Source-side markers shall be placed on the source side when performing radiography on piping components whose concave side is toward the source and when the source-to-material distance is less than the inside radius of the component, or on curved/spherical components whose concave side is toward the source.

13.6 For Double-Wall Viewing (DWE/SWV):

13.6.1 At least one location marker shall be placed on the outside surface adjacent to the weld (or on the material in the area of interest) for each radiograph.

13.7 DDA-Side Markers:

13.7.1 Location markers shall be placed on the DDA side when performing radiography on piping components whose concave side is toward the source and when the source-to-material distance is greater than the inside radius.

13.7.2 As an alternative to source-side placement, markers may be placed on the DDA side when the radiograph shows coverage beyond the location markers and when this alternative is documented in accordance with Section 17.0.

13.7.3 Either-side markers may be placed on either the source side or DDA side when performing radiography on curved or spherical components whose concave side is toward the source and the source-to-material distance equals the inside radius of the component.

13.7.4 When inaccessibility or other limitations prevent the placement of markers as stipulated, a dimensioned map of the actual marker placement shall accompany the radiographs and shall show that full coverage has been obtained.

14.0 EVALUATION

14.1 Image Quality Indicator (IQI) Selection

14.1.1 IQIs shall be selected from either the same alloy material group or grade as identified in ASTM E747 (wire-type) or ASTM E1027 (hole-type), as applicable, or from an alloy material group or grade with less radiation absorption than the material being radiographed.

14.1.2 The IQI shall consist of either a series of six (6) wires for ASTM E747 wire type or a series of seven (7) wires for ISO wire type, arranged in order of increasing diameter. The essential wire diameter to be used, based on the thickness of the weld, is shown in Appendix II, Table 3A for ASTM E747 wire type and Table 3B for ISO wire type.

14.1.3 At the radiographic contractor's option, smaller wire diameter IQIs than those specified may be used, provided the required sensitivity is obtained.

14.1.4 For welds with reinforcement, the thickness of the IQI is based on the nominal single-wall thickness plus the estimated weld reinforcement, not to exceed the maximum permitted by the referencing code section. Backing rings or strips are not considered as part of the thickness in IQI selection. The actual measurement of the weld reinforcement is not required.

14.1.5 For welds without reinforcement, the thickness of the IQI is based on the nominal single-wall thickness. Backing rings or strips are not considered as part of the weld thickness in IQI selection.

14.1.6 For welds joining dissimilar materials, when the weld metal is of an alloy group or grade which has a radiation attenuation that differs from the base material, the 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. All IQI selections shall be based on the selection tables noted in Appendix II.

14.2 Placement of IQIs

14.2.1 The IQIs shall be placed on the detector side of the part being examined. As a minimum, four (4) IQIs shall be placed at the 1, 4, 7, and 11 o'clock positions. The placement of the IQI located at the 1 o'clock position shall be within 5 in. (125 mm) of the circumferential distance from the 12 o'clock reference position of the pipe.

14.2.2 Where inaccessibility prevents hand-placing the IQIs on the source side, the IQI shall be placed on the DDA side in contact with the part being examined. A lead letter "F," at least as high as the IQI identification number(s), shall be placed adjacent to or on the IQI but shall not mask the essential hole when hole-type IQIs are used.

14.2.3 Wire-type IQIs shall be placed on the weld so that the length of the wires is 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 when geometric configuration makes it impractical.

14.2.4 For IQI location for materials other than welds, the IQIs with the IQI identification number(s) and the lead letter "F," if used, may be placed in the area of interest.

14.3 Number of IQIs

14.3.1 If multiple IQIs are used, one shall be representative of the lightest area of interest and the other the darkest area of interest.

14.3.2 When an array of objects in a circle is radiographed, at least one IQI shall be shown on each object image.

14.4 IQI for Repaired Welds (API 1104 21st Edition, Section 11.1.6.1)

14.4.1 For DWE/SWV or SWE/SWV procedures requiring multiple exposures for complete inspection of the weld, and where the length of film/imaging media to be interpreted is greater than 5 in. (130 mm), two IQIs placed across the weld and located on the film side shall be used. One shall be within 1 in. (25 mm) of the end of the film/imaging media length to be interpreted and the other shall be at the center of the film/imaging media.

14.4.2 When a repaired weld is radiographed, an additional IQI shall be placed across each repaired area. The additional IQI shall be positioned such that it spans the full width of the repair area, ensuring that the essential wire is visible across the repaired region on the radiographic image.

14.4.3 When the length of imaging media to be interpreted is 5 in. (130 mm) or less, only one IQI per image is required in accordance with API 1104 Interpretation 1104-I-0419-18. The additional IQI requirement for repaired areas (Section 14.4.2) applies regardless of imaging media length.

14.4.4 The IQI may be placed above the surface of the pipe or held in position between the surface of the pipe and the imager by a fixture attached to the imager or scanning device. Acceptability of such IQI placement shall be demonstrated during procedure qualification.

14.5 Quality of Digital Images

14.5.1 The digital image shall be free of system-induced artifacts in the area of interest that could mask or be confused with the image of any discontinuity.

14.5.2 The digital image shall, as a minimum, display the required level of sensitivity of the IQIs for the thickness of material being examined.

14.5.3 The radiographic images of the IQI identifying style number and ASTM set letter or ISO designation shall appear clearly. The image of the essential wire diameter shall appear clearly across the entire area of interest.

14.6 IQI Sensitivity

14.6.1 Radiographic testing shall be performed with a technique of sufficient sensitivity to display the essential wire of a wire-type IQI. The radiographs should also display the IQI identifying numbers and letters. The image of the essential wire diameter shall appear clearly across the entire area of interest.

14.7 Interpretation and Evaluation

14.7.1 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.

14.7.2 The IQI and the area of interest shall be of the same image format (positive or negative). The contrast and brightness range that demonstrates the required IQI sensitivity shall be used for interpretation.

14.7.3 The digital image may be viewed and evaluated in a negative or positive image format. Independent areas of interest of the same image may be displayed and evaluated in differing image formats, provided the IQI and the area of interest are viewed and evaluated in the same image format.

14.7.4 Evaluation of Indications: All evaluations shall be performed in accordance with the referencing code, standard, or specification as referenced in the project documents. All observed imperfections shall be reported. The Customer shall determine final disposition of the weld.

15.0 STANDARDS OF ACCEPTANCE

15.1 Unless otherwise specified, code-specific radiographic acceptance criteria shall be used for evaluation as applicable. A project-specific addendum shall be developed to address project-specific acceptance criteria as required by the customer.

15.2 For API 1104, 21st Edition applications, the acceptance criteria shall be in accordance with Section 9 of API 1104, using Table 2 for wall thickness $\leq 1/2$ in. (13 mm) or Table 3 for wall thickness $> 1/2$ in. (13 mm), as applicable. The acceptance criteria tables are reproduced in Appendix III of this procedure.

15.3 API 1104, 21st Edition – Radiographic Acceptance Criteria

15.3.1 Radiographic indications are not necessarily imperfections. Machining marks, scratches, surface conditions, and image artifacts may produce indications that are similar to those produced by imperfections but that are not relevant to acceptability. The following criteria shall apply when indications are evaluated.

15.3.2 Classification of Indications:

- (a) Any indication with a maximum dimension of $1/16$ in. (1.6 mm) or less shall be classified as non-relevant. Any larger indication believed to be non-relevant shall be regarded as relevant until re-examined by radiographic or another NDT method to determine whether or not an actual imperfection exists. The surface may be ground or otherwise conditioned before re-examination.
- (b) Relevant indications are those caused by imperfections. Linear indications are those in which the length is more than three (3) times the width. Rounded indications are those in which the length is three (3) times the width or less.

15.4 Acceptance Standards – Wall Thickness $\leq 1/2$ in. (13 mm) [API 1104 Table 2]

15.4.1 For welds with wall thickness $\leq 1/2$ in. (13 mm), the following imperfections shall be considered defects:

Imperfection Type	Unacceptable If:
Crack (all types)	Any crack, regardless of length
Crater crack (star crack)	Length $> 5/32$ in. (4 mm)
Incomplete fusion (IF)	Total length > 1 in. (25 mm) in a continuous 12 in. (300 mm) length of weld, or $> 8\%$ of weld length
Incomplete penetration (IP)	Total length > 1 in. (25 mm) in a continuous 12 in. (300 mm) length of weld, or $> 8\%$ of weld length
Internal concavity (suck-back)	Any depth greater than the lesser of $1/32$ in. (0.8 mm) or 25% of the wall thickness
Burn-through	Any depth greater than the lesser of $1/32$ in. (0.8 mm) or 25% of the wall thickness
Slag inclusion (elongated)	Length $> 1/3 \times$ wall thickness or $1/8$ in. (3 mm), whichever is less
Slag inclusion (isolated)	Maximum dimension $> 1/8$ in. (3 mm)
Porosity (scattered)	Per API 1104 Figure 9, as applicable to wall thickness
Porosity (cluster)	Cluster dimension $> 3/4$ in. (19 mm) or per API 1104 Figure 11
Tungsten inclusion	Per API 1104 Figure 12, maximum dimension $> 1/8$ in. (3 mm) for $\leq 1/2$ in. wall
Undercut (internal)	Depth $> 1/32$ in. (0.8 mm) or $> 25\%$ of wall thickness

Undercut (external)	Depth > 1/32 in. (0.8 mm) or > 12-1/2% of wall thickness
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15.5 Acceptance Standards – Wall Thickness > 1/2 in. (13 mm) [API 1104 Table 3]

15.5.1 For welds with wall thickness > 1/2 in. (13 mm), the following imperfections shall be considered defects:

Imperfection Type	Unacceptable If:
Crack (all types)	Any crack, regardless of length
Crater crack (star crack)	Length > 5/32 in. (4 mm)
Incomplete fusion (IF)	Total length > 2 in. (51 mm) in a continuous 12 in. (300 mm) length of weld, or > 16% of weld length
Incomplete penetration (IP)	Total length > 2 in. (51 mm) in a continuous 12 in. (300 mm) length of weld, or > 16% of weld length
Internal concavity (suck-back)	Any depth greater than the lesser of 1/16 in. (1.6 mm) or 25% of the wall thickness
Slag inclusion (elongated)	Length > 1/4 in. (6 mm) or > 1/2 × wall thickness, whichever is less
Slag inclusion (isolated)	Maximum dimension > 1/4 in. (6 mm)
Slag inclusion (transverse)	Per API 1104 Section 9.3.6.3 as applicable
Porosity (scattered)	Per API 1104 Figure 9, as applicable to wall thickness
Porosity (cluster)	Cluster dimension > 3/4 in. (19 mm) or per API 1104 Figure 11
Tungsten inclusion	Per API 1104 Figure 12, maximum dimension > 1/8 in. (3 mm)
Undercut (internal)	Depth > 1/32 in. (0.8 mm) or > 25% of wall thickness
Undercut (external)	Depth > 1/32 in. (0.8 mm) or > 12-1/2% of wall thickness

15.6 Base Material Imperfections

15.6.1 Imperfections in the base material detected by radiographic testing shall be reported to the Customer. The disposition of these imperfections shall be as directed by the Customer.

15.7 When doubt exists about the type of imperfection being disclosed by an indication, verification may be obtained by using other NDT methods such as ultrasonic testing (UT), magnetic particle testing (MT), or liquid penetrant testing (PT) as applicable.

16.0 PROCEDURE QUALIFICATION

16.1 When procedure qualification is required, any change to a requirement identified as an essential variable (see the essential variables table below) shall require requalification of this procedure by demonstration. Where a range is specified for an essential variable, the bounding values of the range shall be qualified by demonstration. A change of a requirement identified as a non-essential variable does not require requalification of the written procedure.

16.2 All changes of essential or non-essential variables from those in this procedure shall require a revision of, or an addendum to, the procedure. The essential and non-essential variables for digital radiographic examination using DDAs are listed in the table below.

Variable	Essential	Non-Essential
Radiation source type (Ir-192, Co-60, X-ray)	X	
Radiation source energy or isotope	X	
Source size (focal spot dimension)	X	
DDA type, model, or manufacturer	X	
DDA pixel pitch (spatial resolution)	X	
Minimum SNR (100:1)	X	
Image processing software type or version	X	
Material type or thickness range	X	
Exposure technique (SWE/SWV vs. DWE/SWV)	X	
Source-to-detector distance range	X	
Integration time	X	
Frame averaging (number of frames)	X	
IQI type (wire vs. hole)	X	
IQI material group	X	
Radiation filter or masking type	X	
Acceptance criteria (code or standard)	X	
Image display parameters (window/level range)		X
Application method of IQI		X
Location marker placement method		X
Measuring scale comparator type		X
Personnel qualification		X

17.0 RECORDS

17.1 Technique Sheet: A technique sheet (in Microsoft Excel or equivalent) shall be developed for each specific project. The technique sheet shall contain, as a minimum, the following information:

- (a) Size of effective focal spot and voltage rating of the X-ray equipment, or isotope type and source size
- (b) Digital detector resolution (pixel pitch: 200 μm)
- (c) Exposure geometry (DWE/SWV or SWE/SWV)
- (d) Exposure conditions (curie-hours or milliampere-minutes)
- (e) Pipe diameter, material specification/grade, and wall thickness
- (f) Type of material, identifying ASTM or ISO set, and essential wire diameter
- (g) Geometric unsharpness (U_g) calculation
- (h) Integration time and frame averaging values
- (i) Screenshot image showing the measuring scale from a known dimensional comparator
- (j) SNR value measured for the qualified exposure conditions
- (k) Spatial resolution (SR $\blacksquare$) verification result

17.2 To aid in proper interpretation of radiographs, details of the radiographic examination technique used shall accompany each group of radiographs. As a minimum, the information shall include:

- (a) Date of examination
- (b) Name and/or identity and certification level (if applicable) for personnel performing the examination
- (c) Identification of the weld, part, or component examined including weld number, serial number, or other identifier
- (d) Examination method, technique, procedure identification, and revision
- (e) Results of the examination
- (f) Number of exposures
- (g) Dimension map (if used) of marker placement in accordance with Section 13.0
- (h) X-ray voltage or isotope type and curie strength used
- (i) Effective focal spot of energy source
- (j) Base material type and thickness, weld reinforcement thickness, as applicable
- (k) Source-to-object distance
- (l) Distance from source side of object to DDA
- (m) DDA manufacturer, model designation, and serial number
- (n) Image acquisition (digitizing) equipment and manufacturer
- (o) Single- or double-wall exposure
- (p) Single- or double-wall viewing
- (q) Procedure identification and revision level
- (r) Image software version and revision
- (s) Numerical values of the final image processing parameters, to include filters, window (contrast), and level (brightness) for each view
- (t) Underperforming pixel evaluation for each image
- (u) Computer monitor resolution

(v) SNR value and spatial resolution verification results

17.3 Storage of Digital Images: All digital images shall be uploaded to a cloud-based data storage system for final retention. The Customer shall provide access to these locations where the data, including digital files in DICOM format and test reports, are to be stored.

17.4 Technique details may be embedded in the image data file. When this is done, ASTM E1475 may be used as a guideline for establishing data fields and information content.

17.5 Unless otherwise specified, all DR records and reports shall be maintained in accordance with Prime Inspections Inc. retention policies and the referencing code section requirements.

17.6 Documentation of Personnel and Procedure Demonstrations

17.6.1 Personnel or procedure demonstrations performed shall be performed and documented as specified by the referencing code section.

17.6.2 When documentation requirements for personnel or procedure demonstrations are not specified by the referencing code section, the following information shall be recorded as a minimum:

- (a) Name of the organization responsible for preparation and approval of the examination procedure
- (b) Examination method applied
- (c) Procedure number and designation
- (d) Number and date of most recent revision
- (e) Date of the demonstration
- (f) Name and certification level (if applicable) of personnel performing the demonstration

18.0 SAFETY

18.1 All radiographic work performed under this procedure shall comply with applicable federal, state, and local radiation safety regulations, including 10 CFR Part 20 (Standards for Protection Against Radiation) and 10 CFR Part 34 (Radiological Safety Requirements for Radiographic Operations).

18.2 Personnel performing radiography shall have completed radiation safety training and shall hold a current radiographer certification or radiographer's assistant designation as required by 10 CFR Part 34.

18.3 A calibrated radiation survey meter shall be used at all times during radiographic operations. The survey meter shall be checked for proper operation before each use and shall be calibrated at intervals not exceeding 6 months or as required by regulation.

18.4 Personal dosimetry (film badge, TLD, or OSL dosimeter) shall be worn by all personnel performing radiography. Dosimetry records shall be maintained in accordance with 10 CFR Part 20.

18.5 A restricted area shall be established around each radiographic exposure site. The boundary shall be posted with appropriate radiation warning signs and barricaded to prevent unauthorized entry. The boundary shall be established at the point where the radiation dose rate does not exceed 2 mR/hr (0.02 mSv/hr).

18.6 Prior to beginning work, all personnel shall read, understand, and follow the requirements of the applicable Job Hazard Analysis (JHA) and all site-specific safety requirements, including the use of appropriate personal protective equipment (PPE).

18.7 Any questions regarding safety concerns or requirements shall be directed to the lead technician, supervisor, or facility representative before beginning or resuming work.

18.8 Transportation of radioactive materials shall comply with 49 CFR Parts 107, 171, and 172. All radioactive source transport shall be performed in approved Type A or Type B packages as applicable.

APPENDIX I

DDA System Qualification Test Procedure

This appendix provides the procedure for qualification of the DDA system in accordance with ASME Section V, Article 2, Appendix IV and ASTM E2737.

1.0 Purpose: To verify that the DDA system (3E Bendable DR Panel, 200 μm pixel pitch, XVu View software, Ir-192 source) meets the requirements for spatial resolution, SNR, and image quality for production radiographic examination.

2.0 Equipment Required: 3E Bendable DR Panel, Ir-192 source, duplex wire IQI (EN 462-5 or ASTM E2002), ASTM E747 wire-type IQI, calibration block of same material and thickness range as production parts.

3.0 Spatial Resolution Verification: Place the duplex wire IQI on the DDA surface at a slight angle (2° to 5° off parallel). Acquire an image at the qualified exposure conditions. Determine the basic spatial resolution (SR $\blacksquare$) from the duplex wire image. The measured SR $\blacksquare$ shall not exceed 200 μm for the 3E Bendable DR Panel.

4.0 SNR Verification: Select a region of interest (ROI) in the homogeneous area of the image adjacent to the calibration block. Measure the mean pixel value (signal) and the standard deviation (noise). Calculate $\text{SNR} = \text{Mean} / \text{Standard Deviation}$. The calculated SNR shall be $\geq 100:1$.

5.0 IQI Sensitivity Verification: Place the required wire-type IQI (per ASTM E747) on the calibration block at the qualified position. Acquire an image at the qualified exposure conditions. Verify that the essential wire is clearly visible across the entire area of interest. Document the IQI type, essential wire diameter, and the image.

6.0 Bad Pixel Map Verification: Verify that the manufacturer's bad pixel map is active in the XVu View software. Confirm that no cluster kernel pixels (CKPs) are present in the area of interest. If CKPs are detected, contact the Level III for resolution before proceeding.

7.0 Documentation: Record all qualification results on the DDA System Qualification Record. The record shall include: date, DDA serial number, software version, source type and activity, exposure parameters (SDD, integration time, frame averaging), measured SR $\blacksquare$, measured SNR, IQI type and essential wire, and the name and certification level of the person performing the qualification.

8.0 Qualification Interval: DDA system qualification shall be performed at intervals not exceeding 12 months, or whenever any of the conditions listed in Section 10.5.3 occur.

APPENDIX II

IQI Selection and Placement Tables (API 1104)

Table 2A – ASTM E747 Wire IQI Designation and Wire Diameter

ASTM Set – Wire No.	Wire Diameter (in.)	Wire Diameter (mm)
A-1	0.0032	0.08
A-2	0.004	0.10
A-3	0.005	0.13
A-4	0.0063	0.16
A-5	0.008	0.20
A-6	0.010	0.25
B-6	0.010	0.25
B-7	0.013	0.33
B-8	0.016	0.41
B-9	0.020	0.51
B-10	0.025	0.64
B-11	0.032	0.81
C-11	0.032	0.81
C-12	0.040	1.02
C-13	0.050	1.27
C-14	0.063	1.60
C-15	0.080	2.03
C-16	0.100	2.54
D-16	0.100	2.54
D-17	0.126	3.20
D-18	0.160	4.06
D-19	0.200	5.05
D-20	0.250	6.35
D-21	0.320	8.13

Table 3A – Material Thickness, IQI Designation, and Essential Wire (ASTM E747 – API 1104)

Pipe Wall or Weld Thickness	Essential Wire Diameter	ASTM Set Letter		
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inches	mm	inches	mm	
0 – 0.250	0 – 6.35	0.008	0.20	A
> 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 3B – Material Thickness, IQI Designation, and Essential Wire (ISO 1027 – API 1104)

Pipe Wall or Weld Thickness	Essential Wire Diameter	Wire Identity		
inches	mm	inches	mm	
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

APPENDIX III

Acceptance Criteria Tables (API 1104, 21st Edition)

The following tables reproduce the acceptance criteria from API 1104, 21st Edition, Section 9, for radiographic examination of welds. Table 2 applies to wall thickness $\leq 1/2$ in. (13 mm). Table 3 applies to wall thickness $> 1/2$ in. (13 mm). These criteria are provided for reference; the applicable edition of API 1104 shall govern in case of any discrepancy.

Table 2 – Acceptance Criteria for Wall Thickness $\leq 1/2$ in. (13 mm)

Imperfection	Unacceptable If:
Crack (all types)	Any crack, regardless of length
Crater crack or star crack	Length $> 5/32$ in. (4 mm)
Incomplete fusion (IF)	Total length > 1 in. (25 mm) in 12 in. (300 mm) of weld, or $> 8\%$ of weld length
Incomplete penetration (IP)	Total length > 1 in. (25 mm) in 12 in. (300 mm) of weld, or $> 8\%$ of weld length
Internal concavity / suck-back	Depth $> 1/32$ in. (0.8 mm) or $> 25\%$ of wall thickness
Burn-through	Depth $> 1/32$ in. (0.8 mm) or $> 25\%$ of wall thickness
Slag inclusion (elongated)	Length $> 1/3 \times$ wall thickness or $> 1/8$ in. (3 mm), whichever is less
Slag inclusion (isolated)	Maximum dimension $> 1/8$ in. (3 mm)
Porosity (scattered)	Per API 1104 Figure 9
Porosity (cluster)	Cluster dimension $> 3/4$ in. (19 mm); per API 1104 Figure 11
Tungsten inclusion	Maximum dimension $> 1/8$ in. (3 mm); per API 1104 Figure 12
Undercut (internal)	Depth $> 1/32$ in. (0.8 mm) or $> 25\%$ of wall thickness
Undercut (external)	Depth $> 1/32$ in. (0.8 mm) or $> 12-1/2\%$ of wall thickness

Table 3 – Acceptance Criteria for Wall Thickness $> 1/2$ in. (13 mm)

Imperfection	Unacceptable If:
Crack (all types)	Any crack, regardless of length
Crater crack or star crack	Length $> 5/32$ in. (4 mm)
Incomplete fusion (IF)	Total length > 2 in. (51 mm) in 12 in. (300 mm) of weld, or $> 16\%$ of weld length
Incomplete penetration (IP)	Total length > 2 in. (51 mm) in 12 in. (300 mm) of weld, or $> 16\%$ of weld length
Internal concavity / suck-back	Depth $> 1/16$ in. (1.6 mm) or $> 25\%$ of wall thickness
Slag inclusion (elongated)	Length $> 1/4$ in. (6 mm) or $> 1/2 \times$ wall thickness, whichever is less

Slag inclusion (isolated)	Maximum dimension > 1/4 in. (6 mm)
Slag inclusion (transverse)	Per API 1104 Section 9.3.6.3
Porosity (scattered)	Per API 1104 Figure 9
Porosity (cluster)	Cluster dimension > 3/4 in. (19 mm); per API 1104 Figure 11
Tungsten inclusion	Maximum dimension > 1/8 in. (3 mm); per API 1104 Figure 12
Undercut (internal)	Depth > 1/32 in. (0.8 mm) or > 25% of wall thickness
Undercut (external)	Depth > 1/32 in. (0.8 mm) or > 12-1/2% of wall thickness

APPENDIX IV

DDA Bad Pixel Map and Calibration Verification

This appendix provides the requirements for verification of the DDA bad pixel map and calibration in accordance with ASME Section V, Article 2, Appendix IV and ASTM E2737.

1.0 Bad Pixel Map: The 3E Bendable DR Panel shall be supplied with the manufacturer's original bad pixel map, which identifies individual detector elements (pixels) that do not respond correctly to radiation. The bad pixel map shall include the process and methodology used by the manufacturer to develop the map.

2.0 Software-Based Calibration: All DDAs require a software-based calibration to determine the underperforming pixel map in accordance with the manufacturer's guidelines. The calibration shall be performed using the XVu View software in accordance with the 3E Bendable DR Panel Operating Manual.

3.0 Calibration Verification: At the commencement of each examination procedure qualification, and whenever calibration is required per Section 12.0, the following shall be verified:

- 3.1 Dark current (offset) correction is active and correct
- 3.2 Flat-field (gain) correction is active and correct
- 3.3 Bad pixel map is loaded and applied to the acquired image
- 3.4 No cluster kernel pixels (CKPs) are present in the area of interest
- 3.5 Image is free of system-induced artifacts in the area of interest

4.0 If CKPs are detected in the area of interest, the DDA shall not be used for production examination until the issue is resolved. Contact the Level III and the DDA manufacturer for resolution.

5.0 For DDAs that use multiple overlapping pixel data arrangements (scanning mode), CKPs are not relevant provided the acquired image data does not mask a relevant indication or create an image artifact.

6.0 Long-term stability of the DDA shall be verified in accordance with ASTM E2737 at intervals not exceeding 12 months. The stability verification shall include repeated measurements of spatial resolution, SNR, and bad pixel count over time.

APPENDIX V

Technique Sheet Template

The following template shall be used for the project-specific technique sheet. A separate technique sheet shall be developed for each project or weld configuration.

Parameter	Value
Project Name / Number	
Procedure Number / Revision	PII-DR Rev 05
Radiation Source Type	Ir-192
Source Size (mm × mm)	
Source Activity (Ci / GBq)	
DDA Manufacturer / Model	3E Bendable DR Panel
DDA Serial Number	
DDA Pixel Pitch (μm)	200
Software / Version	XVu View / ____
Pipe Diameter (in. / mm)	
Wall Thickness (in. / mm)	
Material Specification / Grade	
Exposure Technique	DWE/SWV or SWE/SWV
Source-to-Object Distance (in. / mm)	
Object-to-Detector Distance (in. / mm)	
Source-to-Detector Distance (in. / mm)	
Geometric Unsharpness (Ug) (in. / mm)	
Integration Time (seconds)	
Frame Averaging (number of frames)	
IQI Type (ASTM E747 / ISO)	
IQI Set / Essential Wire	
SNR (measured)	≥ 100:1
Spatial Resolution SR■ (μm)	≤ 200 μm
Min Pixel Value / Max Pixel Value	
Image Processing Filters Used	
Window (Contrast) / Level (Brightness)	
Number of Exposures per Weld	

Acceptance Criteria (Code / Table)	API 1104 21st Ed. / Table 2 or 3
Radiographer Name / Cert. Level	
Date of Examination	

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