



PII-CRT

Computed Radiographic Examination

PNDT-CRT

Revision 03

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Revision / Change Summary

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Initial	0	4/12/2020	Initial Issue
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Revision	02	1/1/2024	Code review; updated for ASME Section V 2023 Edition
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1.0 SCOPE

1.1 This procedure establishes the minimum technique requirements for performing computed radiographic examination (CR) of welds and base materials using phosphor imaging plate (PIP) technology as an alternative to conventional film radiography. This procedure is applicable to pipeline girth welds, fabricated welds, and applicable welder/welding operator performance qualifications. This procedure is written for Computed Radiography using phosphor imaging plates in accordance with ASME Section V, Article 2, Appendix IV and Appendix VIII, 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 2 in. (50 mm) through 56 in. (1420 mm) with penetrated wall thickness ranges from 0.0625 in. (1.6 mm) through 1.500 in. (38 mm) for single-wall exposure and 0.125 in. (3.2 mm) through 3.000 in. (76 mm) for double-wall exposure techniques.

1.3 The CR system used under this procedure consists of phosphor imaging plates (PIP) with a pixel size no greater than 200 micrometers (μm), a compatible CR scanner (digitizer), and image acquisition/review software that retains raw images. 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 digital radiography (DR) using Digital Detector Arrays (DDA panels), conventional film-based radiography, or real-time radiosopic examination. Those methods are covered under separate procedures (PII-DR for DDA-based digital radiography, PII-RT for film-based radiography).

1.6 Where the requirements of this procedure conflict with the referencing code, standard, or specification, the referencing code shall govern. Where this procedure is more stringent than the referencing code, this procedure shall govern.

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), and Appendix VIII (Radiography Using Phosphor Imaging Plate)

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 E1475, Standard Guide for Data Fields for Computerized Transfer of Digital Radiological Test Data

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

2.2.16 ASTM E2033, Standard Practice for Computed Radiography (Photostimulable Luminescence Method)

2.2.17 ASTM E2445, Standard Practice for Classification of Computed Radiography Systems for Industrial Applications

2.2.18 ASTM E2446, Standard Practice for Manufacturing Qualification of Computed Radiography Systems for Industrial Applications

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

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

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

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

2.2.23 EN 462-5, Non-destructive Testing – Image Quality of Radiographs – Part 5: Image Quality Indicators (Duplex Wire Type)

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 PII-RT, Radiographic Examination Procedure (Film), Current Revision
- 2.3.6 PII-DR, Digital Radiographic Examination Procedure (DDA), Current Revision
- 2.3.7 CR Scanner Operating Manual, Current Edition (as applicable to the scanner in use)
- 2.3.8 CR Image Acquisition Software User Manual, Current Version (as applicable to the software in use)

3.0 DEFINITIONS AND ABBREVIATIONS

3.1 CR – Computed Radiography: A radiographic technique that uses a phosphor imaging plate (PIP) to capture a latent image produced by X-ray or gamma radiation passing through the object being examined. The latent image is subsequently read by a laser scanner (digitizer) to produce a digital radiographic image. CR is distinguished from digital radiography (DR) by the use of a removable phosphor plate rather than a fixed digital detector array.

3.2 PIP – Phosphor Imaging Plate: A flexible or rigid plate coated with photostimulable phosphor that stores a latent radiographic image upon exposure to ionizing radiation. The stored image is read by stimulating the phosphor with a laser in a CR scanner. Also referred to as an imaging plate (IP) or storage phosphor plate.

3.3 DDA – Digital Detector Array: A solid-state radiation detection device consisting of an array of individual detector elements (pixels) that converts incident radiation directly into digital image data. While this procedure uses CR (phosphor plates) rather than a DDA, the DDA requirements of ASME Section V Article 2 Appendix IV are applied to the CR system where applicable per Appendix VIII.

3.4 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 or an equivalent methodology applicable to CR systems.

3.5 SR■ (Spatial Resolution): The basic spatial resolution of the CR system, 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. The CR system shall have a pixel size no greater than 200 μm.

3.6 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.

3.7 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 distance from source side of object to detector, and D is the source-to-object distance.

3.8 DICONDE – Digital Imaging and Communication in Nondestructive Evaluation: A standard for the exchange of digital radiographic data per ASTM E2699.

3.9 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.

3.10 Frame Averaging: The process of acquiring multiple image frames and mathematically averaging them to reduce random noise and improve the SNR. Applicable to CR when multiple scans or integrations are performed.

3.11 Bad Pixel Map: A software-based map identifying individual detector elements (pixels) in the CR scanner or imaging plate that do not respond correctly to radiation or laser stimulation. The bad pixel map is used to correct the acquired image and is supplied or generated by the scanner manufacturer or software.

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

3.13 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 and has a half-life of 73.83 days.

3.14 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.

3.15 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.

3.16 Pixel Pitch: The center-to-center spacing between adjacent detector elements in the CR scanner or imaging plate. For this procedure, the pixel pitch shall not exceed 200 μm (0.200 mm).

3.17 Backscatter: Scattered radiation that reaches the detector from the opposite side of the object being radiographed. Backscatter is detected using a lead letter "B" placed behind the imaging plate; its presence indicates insufficient backscatter protection.

3.18 CR Scanner (Digitizer): A laser-based device that reads the latent image stored on a phosphor imaging plate and converts it into a digital image. The scanner shall have a minimum bit depth of 12 bits (4096 gray levels) and shall be capable of resolving the required pixel size for the imaging plate in use.

3.19 Latent Image: The stored radiographic image on the phosphor imaging plate prior to scanning (digitization). The latent image is released by laser stimulation in the CR scanner.

3.20 Erase Cycle: The process of exposing the phosphor imaging plate to bright light (typically from a sodium vapor lamp or equivalent) after scanning to remove any residual image and prepare the plate for reuse.

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 computed 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 or other 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 computed 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 computed radiographic evaluation shall be trained on the CR scanner operation, the image acquisition/review software, and DICOM image data management. Training shall be documented and maintained in personnel training records.

6.0 EQUIPMENT AND MATERIALS

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

6.1.1 Phosphor Imaging Plates (PIP) with a pixel size no greater than 200 μm and a sensitive area sufficient to cover the pipe diameters specified in Section 1.0. Approved imaging plates are listed in Appendix V.

6.1.2 CR Scanner (digitizer) with a minimum bit depth of 12 bits (4096 gray levels) and the ability to read the required pixel size for the imaging plate in use. Approved scanners are listed in Appendix VI.

6.1.3 Image acquisition and review software that retains raw (unprocessed) images and supports DICOM-compliant image storage. Approved software is listed in Appendix VII.

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

6.1.5 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.

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

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

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

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

6.1.10 Lead screens (front and back) appropriate to the radiation source, and cassettes compatible with the imaging plates in use.

6.1.11 Backscatter "B" marker (lead letter) for verification of backscatter protection when required.

6.2 Phosphor Imaging Plate Specifications

6.2.1 The phosphor imaging plates used under this procedure shall have the following minimum specifications:

- (a) Pixel size: $\leq 200 \mu\text{m}$ (0.200 mm)
- (b) Bit depth: minimum 12-bit (4096 gray levels) scanner readout
- (c) Radiation source: Ir-192 gamma-ray compatible
- (d) DICOM-compliant image output from the scanner/software
- (e) Erasable and reusable (photostimulable phosphor)
- (f) Compatible with the approved CR scanner in use

6.3 Scanner Specifications

6.3.1 The CR scanner (digitizer) shall have the following minimum specifications:

- (a) Bit depth: minimum 12-bit (4096 gray levels)
- (b) Spatial resolution: capable of resolving the pixel size of the imaging plate in use ($\leq 200 \mu\text{m}$)
- (c) Laser wavelength and power appropriate for the phosphor imaging plate type
- (d) Integrated plate eraser for residual image removal
- (e) DICOM-compliant digital image output

6.4 Monitor Requirements

6.4.1 Monitors used for viewing and interpreting CR images shall have a resolution between 1 and 5 megapixels (MP). Viewing conditions shall be optimized with no glare or indirect lighting affecting interpretation. Monitor performance shall be accomplished in accordance with the applicable appendix of the referencing code.

6.5 Software Requirements

6.5.1 The image acquisition and review software shall be used for all image scanning, processing, and evaluation under this procedure. The software version shall be documented in the radiographic report. Approved software is listed in Appendix VII.

6.5.2 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. Only software that retains raw images shall be used under this procedure.

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

6.6 Equipment Handling and Storage

6.6.1 When the scanner is not in use or during transportation and shipment, the slot where the imaging plate is fed in and the eraser tray door shall be covered to prevent the entry of foreign material, dirt, and dust. This is best accomplished using masking tape and the plastic cover for the feed slot.

6.6.2 The scanner shall always be transported in a protective case. The cassette shall be removed and the sliding door secured before transport. The scanner shall not be jarred or bumped, as this may lead to misalignment of the laser.

6.6.3 The phosphor imaging plate 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 (Ug). 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 imaging plate 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.

7.7 As with film radiography, lead screens (front and back) should be used with phosphor imaging plates. Different sources of radiation may require different thicknesses of screens. Due care must be taken to control scatter in the same manner as with film radiography.

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

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

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 CR system with $\leq 200 \mu\text{m}$ pixel size 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 imaging plate standoff distance.

9.9 Physical positioning of the imaging plate should be the same as for film techniques. The imaging plate shall be placed in a cassette with lead screens (front and back) and positioned in contact with the surface being examined.

10.0 CR SYSTEM REQUIREMENTS (ASME V ARTICLE 2 APPENDIX IV)

10.1 This section addresses the CR system requirements in accordance with ASME Section V, Article 2, Appendix IV and Appendix VIII, including spatial resolution, signal-to-noise ratio (SNR), system qualification, and image quality. The requirements of Appendix IV for Digital Detector Arrays (DDA) are applied to the CR system where applicable per the provisions of Appendix VIII for phosphor imaging plates.

10.2 Spatial Resolution (Basic Spatial Resolution – SR■)

10.2.1 The basic spatial resolution of the CR system shall be determined in accordance with ASTM E2445, ASTM E2597, or EN 462-5 using a duplex wire type IQI. The measured spatial resolution shall be documented for each CR system and shall not exceed 200 μm for the imaging plate/scanner combination used under this procedure.

10.2.2 The spatial resolution shall be verified at the commencement of each examination procedure qualification and whenever the CR system is changed (imaging plate type, scanner, or software). 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.

10.2.4 Scanner resolution shall be matched to expected indications. As a guide, weld quality examination should use $\leq 50 \mu\text{m}$ resolution, and profile or information-only examination may use $\leq 100 \mu\text{m}$ resolution. The operator shall be aware that smaller resolution settings (finer pixel pitch) produce greater noise in the image.

10.3 Signal-to-Noise Ratio (SNR)

10.3.1 The signal-to-noise ratio (SNR) of the CR system shall be a minimum of 100:1 as measured in a region of interest (ROI) in accordance with ASTM E2597 or an equivalent methodology applicable to CR systems. The SNR shall be measured at the radiation energy, source-to-detector distance, and exposure conditions 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 $\text{SNR} = \text{Mean} / \text{Standard Deviation}$. 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 exposure dose, scanner gain setting, or source-to-detector distance until the required SNR is obtained. As a general rule, a dose of 0.25 R to 0.5 R will result in an excellent image and is the best starting point for technique development. The SNR value shall be documented in the technique sheet.

10.4 Underperforming Pixel Management

10.4.1 CR scanners and imaging plates shall be evaluated for underperforming pixels (bad pixels). Bad pixels are underperforming detector elements and shall be addressed as follows:

(a) CR systems using static scanning configurations shall not have cluster kernel pixels (CKPs) in the area of interest. An overlay may be used for verification. Refer to ASTM E2445 and ASTM E2446.

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

10.4.2 All CR systems require a software-based calibration to determine the underperforming pixel map in accordance with the scanner manufacturer's guidelines. System calibration for procedure-approved systems and image acquisition instructions are addressed in the scanner operating manual.

10.5 CR System Qualification

10.5.1 The CR system shall be qualified in accordance with ASME Section V, Article 2, Appendix IV and Appendix VIII, ASTM E2446, and ASTM E2737 prior to use in production examination. The qualification shall include:

- (a) Verification of spatial resolution (SR■) 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 CR system qualification records shall be maintained and shall include the date of qualification, scanner serial number, imaging plate type and serial number, software version, exposure parameters, and measured values of spatial resolution, SNR, and IQI sensitivity.

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

- (a) A change in the CR scanner (replacement or repair)
- (b) A change in the imaging plate type or manufacturer
- (c) A change in the radiation source type or energy
- (d) A change in the software version that affects image acquisition or processing
- (e) Damage to or degradation of the scanner or imaging plates
- (f) 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 CR system. For a 12-bit scanner (4096 gray levels), the typical pixel intensity range shall be appropriate for the exposure dose and scanner gain settings used.

10.6.2 As a general guide for technique development, a good starting point is half the maximum gray scale value of the scanner. For a 16-bit system, approximately 32,500 in the area of interest is a suitable starting point. Software can be optimized to aid in viewing images, and the manufacturer's manual should be referenced.

10.7 Monitoring Density Limitations

10.7.1 Densitometers, step wedge comparison films, and density limitation requirements are not applicable to phosphor imaging plate radiography. Image quality is verified through pixel intensity measurements, SNR, and IQI sensitivity rather than film density.

10.8 Technique Variables Documentation

10.8.1 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 scanner and imaging plates
- (d) Minimum source-to-object distance
- (e) Distance from the source side of the object to the imaging plate
- (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) Pixel intensity / gray scale range (minimum to maximum)
- (k) Scanner gain setting and resolution (pixel size)
- (l) Exposure dose (R or mR) at the imaging plate

11.0 IMAGE PROCESSING

11.1 Image processing shall be performed using the approved image acquisition and review 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 CR 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 Software filters may be used if applicable. Use of filters shall be utilized only when the possibility of masking or hiding of defects has been taken into consideration. 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 scanner/manufacturer's bad pixel map to correct underperforming detector elements
- (b) Gain and offset correction: Apply the CR scanner calibration correction (dark current and flat-field correction)
- (c) Window and level adjustment: Adjust the display window (contrast) and level (brightness) to display the required IQI sensitivity
- (d) 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. Final interpretation of the image shall be accomplished with a maximum zoom of 3X.

11.5 Imaging Plate Processing

11.5.1 The following general notes apply to imaging plate processing:

- (a) The scanner/workstation must be located in a temperature-controlled environment similar to a common office area. The room should be clean and free of dust. A room air filter should be considered to help maintain a clean environment.
- (b) The imaging plates are engineered to form an image with X-rays or gamma rays and are erased by sunlight, sodium vapor, yellow safelights, fluorescent, and ultra-violet light. Low wattage (less than 40 watts) incandescent light from a standard light bulb will not harm the image and will provide enough lighting to operate the system.

11.5.2 System Start-up: Turn on the scanner/workstation. Allow the system to boot and log on. Start the software. Allow the scanner a minimum of 15 minutes to warm up before scanning.

11.5.3 Imaging Plate (IP) Care and Handling:

- (a) The white side of the IP is the exposure side and the scanning side. Treating this surface properly will greatly extend the useful life of the IP.
- (b) Always wear cotton gloves when handling IPs to reduce the effects of fingerprints. When gloves are not available, the IP shall be held by the edges.
- (c) IPs must be kept clean by wiping with lint-free laboratory cloth (Kim-Wipes® or equivalent) and ethyl or 70% alcohol, no greater. The plate surface should be thoroughly wiped with a moistened cloth. The back (dark) side should also be cleaned. Plates should be examined by inspecting the edges for cracks and other damage, and inspecting the surface under reflected light to detect scratches or other marks. Prior to each scan, clean the IP with a microfiber cloth to remove any dirt, sand, lint, etc. that may damage the IP or scanner components.
- (d) The area or table where IPs are handled must also be kept clean to prevent dirt and grit from scratching the IP surface.
- (e) Cassettes and lead screens must also be kept clean and free of debris. Oxidized or kinked lead screens should not be used with IPs. A protective layer of thin plastic or other suitable material should cover the lead screen so that lead contamination or scratching of the IP is avoided. Replace lead screens as necessary.
- (f) When inserting or removing IPs from a cassette, to avoid scratches the IP must not scrape across the surface of the lead screen or any other surface. The IPs and lead screens should be carefully stacked and un-stacked outside of the cassette.
- (g) Prior to exposure, IPs can be handled in a brightly lit room. After exposure, the cassettes must only be opened and the IPs scanned with only dim lighting as stated above.
- (h) If it is uncertain whether an IP is erased, or if the IP has not been used recently, the technician shall erase the plate before use.

11.5.4 IP Scanning:

- (a) Reduce the lighting as described above before removing the IP from the cassette.
- (b) Remove the IP from the cassette and place it in the scan feed slot at the appropriate point for the scanner being used, with the white surface facing the scanner.
- (c) Follow the manufacturer's recommendation for scanner selection and utilization. Scanner resolution shall be matched to expected indications. Gain selection should be optimized to the energy source and may be optimized to decrease the "r" factor required depending on image resolution requirements. Refer to the specific manufacturer's manual to assist in gain selection.
- (d) The scanner feed surface shall be clean and dust free.
- (e) Optimize the scanner eraser option so that residual images do not remain after acquisition.

11.6 Digital Image Storage

11.6.1 All digital images shall be stored in DICOM-compliant format per ASTM E2699. The image metadata shall include the technique variables listed in Section 10.8.1.

11.6.2 A copy of the image data files shall be recorded and finalized on non-rewritable compact disk or write-protected files on mass data storage media (external hard drive) and shall be delivered with the report to the client's representative. The report can be generated in PDF format and added to the image data disc.

11.6.3 Digital images shall be uploaded to a cloud-based or other 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.

11.6.4 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.

12.0 CALIBRATION AND SYSTEM QUALIFICATION

12.1 System calibration is required for the CR scanner and imaging plates in accordance with the manufacturer's guidelines, ASME Section V, Article 2, Appendix IV and Appendix VIII, and ASTM E2446. 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 (scanner, imaging plate type, 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 scanner operating manual and the image acquisition software user manual.

12.3 Radiographs shall be acquired using the approved CR scanner and software. The radiographer shall use the proper exposure dose, scanner gain setting, and resolution 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 CR system 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 Dimensional Comparator

12.5.1 A device with known dimensions shall be placed in direct contact with the cassette or on the imaging plate prior to exposure (a hole-type IQI may be used as the dimensional comparator). The measuring scale used for interpretation shall be capable of providing dimensions of the projected image. 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 a verifiable scanned pixel size 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 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 Imaging Plate-Side Markers:

13.7.1 Location markers shall be placed on the imaging plate 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 imaging plate 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 imaging plate 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 Facilities for Viewing Radiographs

14.1.1 Viewing facilities shall provide subdued background lighting of an intensity that will not cause reflections, shadows, or glare on the monitor that interferes with the interpretation process.

14.2 Image Quality Indicator (IQI) Selection

14.2.1 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.

14.2.2 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.

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

14.2.4 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.

14.2.5 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.

14.2.6 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.

14.2.7 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.

14.3 Use of IQIs to Monitor Radiographic Examination

14.3.1 Placement of IQI(s)

(a) Source-Side IQI(s): When using separate blocks for IQI placement, as described in the applicable RT procedure, the thickness of the blocks shall be such that the image brightness at the body of the IQI is judged to be equal to or greater than the image brightness at the area of interest for a negative image format. If verified by measurement, pixel intensity variations up to 15% are permitted in the determination of "equal to." This image brightness requirement is reversed for a positive image format.

(b) All other applicable RT procedure requirements for placement of IQI(s) shall apply.

14.3.2 Number of IQIs

(a) Multiple IQIs: An IQI shall be used for each applicable thickness range specified in the applicable RT procedure spanned by the minimum-to-maximum thickness of the area of interest to be radiographed.

(b) As an alternative to (a) above, a minimum of two IQIs representing the minimum and maximum thicknesses of the area of interest may be used, provided the requirements of Section 14.7 are met.

(c) All other applicable RT procedure requirements for the number of IQIs shall apply.

14.3.3 Comparators such as digitized film strips, gray scale cards, etc., may be used to aid in judging displayed image brightness. When comparators are used to judge areas within the image, they need not be calibrated. Pixel intensity values may also be used to quantify image brightness comparisons.

14.3.4 Shims under Hole IQIs

(a) For welds with reinforcement or backing material, a shim of material radiographically similar to the weld metal and/or backing material shall be placed between the part and the IQIs, such that the image brightness at the body of the IQI is judged to be equal to or greater than the image brightness at the area of interest for a negative image format. If verified by measurement, pixel intensity variations up to 15% are permitted in the determination of "equal to." This image brightness requirement is reversed for a positive image format.

(b) The shim dimensions shall exceed the IQI dimensions such that the outline of at least three sides of the IQI shall be visible in the radiograph.

14.4 Placement of IQIs

14.4.1 The IQIs shall be placed on the source 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.

14.4.2 Where inaccessibility prevents hand-placing the IQIs on the source side, the IQI shall be placed on the imaging plate 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.

14.4.3 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.

14.5 Number of IQIs

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

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

14.6 IQI for Repaired Welds (API 1104 21st Edition, Section 11.1.6.1.a)

14.6.1 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.

14.6.2 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.

14.6.3 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 14.6.2) applies regardless of imaging media length.

14.6.4 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.

14.7 Quality of Digital Images

14.7.1 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.

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

14.7.3 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.

14.8 IQI Sensitivity

14.8.1 Radiographic testing shall be performed with a technique of sufficient sensitivity to display the essential wire of a wire-type IQI or the designated hole of a hole-type IQI. The radiographs 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.

14.9 Image Brightness

14.9.1 The image brightness through the body of the hole-type IQI or 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 2% are permitted in the determination of "equal to." This image brightness requirement is reversed for a positive image format. Radiographic density requirements for film radiography are not applicable to phosphor imaging plate radiography.

14.10 Sensitivity Range

14.10.1 The contrast and brightness range that demonstrates the required sensitivity shall be valid contrast and brightness values for interpretation. When multiple IQIs are utilized to cover different thickness ranges:

- (a) The contrast and brightness range that demonstrates the required IQI image of each IQI shall be determined.
- (b) Intervening thicknesses may be interpreted using the overlapping portions of the determined contrast and brightness ranges. When there is no overlap, an additional IQI(s) shall be used.

14.11 Excessive Backscatter

14.11.1 For a negative image format, if a light image of the backscatter "B" appears on a darker background of the image, protection from backscatter is insufficient and the radiographic image shall be considered unacceptable. A dark image of the "B" on a lighter background is not cause for rejection.

14.11.2 For a positive image format, if a dark image of the backscatter "B" appears on a lighter background of the image, protection from backscatter is insufficient and the radiographic image shall be considered unacceptable. A light image of the "B" on a darker background is not cause for rejection.

14.12 Interpretation

14.12.1 Prior to interpretation, the range of contrast/brightness values that demonstrate the required IQI sensitivity shall be determined. Final radiographic interpretation shall be made only after the data within this IQI sensitivity range has been evaluated. The IQI and the area of interest shall be of the same image format (positive or negative). Additionally, where applicable:

- (a) When more than one IQI is used to qualify a range of thicknesses, the overlapping portions of each IQI's established sensitivity range shall be considered valid for interpretation of intervening thicknesses.
- (b) The digital image may be viewed and evaluated in a negative or positive format.
- (c) Independent areas of interest of the same image may be displayed and evaluated in different image formats, provided the IQI and the area of interest are viewed and evaluated in the same image format.
- (d) Final interpretation of the image shall be accomplished with a maximum zoom of 3X.

14.12.2 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 computed radiographic examination using phosphor imaging plates 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	
CR scanner type, model, or manufacturer	X	
Imaging plate type, model, or manufacturer	X	
Pixel size (spatial resolution) of scanner/imaging plate	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	
Exposure dose range	X	
Scanner gain setting	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
Lead screen thickness		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) Scanner make, model, and serial number
- (c) Imaging plate type, manufacturer, and pixel size ($\leq 200 \mu\text{m}$)
- (d) Exposure geometry (DWE/SWV or SWE/SWV)
- (e) Exposure conditions (curie-hours or milliampere-minutes)
- (f) Pipe diameter, material specification/grade, and wall thickness
- (g) Type of material, identifying ASTM or ISO set, and essential wire diameter
- (h) Geometric unsharpness (U_g) calculation
- (i) Scanner gain setting and resolution (pixel size)
- (j) Exposure dose (R or mR) at the imaging plate
- (k) Screenshot image showing the measuring scale from a known dimensional comparator
- (l) SNR value measured for the qualified exposure conditions
- (m) Spatial resolution (SR $\blacksquare$) verification result

17.2 The record of the examination is to be reported on a Radiographic Examination Report. As a minimum, the following information shall be provided:

- (a) Identification as required by the applicable procedure
- (b) A dimensioned map (if used) of marker placement per the applicable RT procedure
- (c) Number of exposures
- (d) X-ray voltage or isotope type and curie strength used
- (e) Source size (diagonal or maximum projected dimension)
- (f) Base material type and thickness, weld reinforcement thickness, as applicable
- (g) Source-to-object distance
- (h) Distance from source side of object to imaging plate
- (i) Storage phosphor (imaging plate) manufacturer and designation
- (j) Image acquisition (digitizing) equipment manufacturer, model, and serial number
- (k) Single or double wall exposure
- (l) Single or double wall viewing
- (m) Procedure and addendum identification and revision numbers
- (n) Examination results
- (o) Date of examination, name and qualification level of examiner
- (p) Imaging software version and revision
- (q) Numerical values of the final image processing parameters, to include filters, window (contrast), and level (brightness), for each view
- (r) SNR value and spatial resolution verification results

17.3 Storage of Digital Images: A copy of the image data files shall be recorded and finalized on non-rewritable compact disk or write-protected files on mass data storage media (external hard drive) and

shall be delivered with the report to the client's representative. The report can be generated in PDF format and added to the image data disc.

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 CR 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

CR System Qualification Test Procedure

This appendix provides the procedure for qualification of the CR system in accordance with ASME Section V, Article 2, Appendix IV and Appendix VIII, ASTM E2446, and ASTM E2737.

1.0 Purpose: To verify that the CR system (phosphor imaging plate, CR scanner, image acquisition/review software, Ir-192 source) meets the requirements for spatial resolution, SNR, and image quality for production radiographic examination.

2.0 Equipment Required: Phosphor imaging plates ($\leq 200 \mu\text{m}$ pixel size), CR scanner (12-bit minimum), 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, lead screens, and cassettes.

3.0 Spatial Resolution Verification: Place the duplex wire IQI on the imaging plate 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 $200 \mu\text{m}$ for the CR system used under this procedure.

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 scanner/manufacture's bad pixel map is active in the image acquisition 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 CR System Qualification Record. The record shall include: date, scanner serial number, imaging plate type and serial number, software version, source type and activity, exposure parameters (SDD, exposure dose, scanner gain, resolution), 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: CR 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)

Wall or Weld Thickness	Essential Wire Diameter	ASTM Set Letter
------------------------	-------------------------	-----------------

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 – API 1104)

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

Pixel Resolution Chart

The following chart provides the pixel resolution (PPI and PPL) for various micron sizes and imaging plate widths. Choose the micron size desired and cross-reference with the imaging plate width to determine pixels per inch (PPI) and pixels per line (PPL) across the width of the imaging plate.

Sample Size (µm)	PPI	14" Plate	10" Plate	8" Plate	7" Plate	5" Plate	4.5" Plate
87	292	4088	2920	2336	2044	1460	1346
90	282	3948	2820	2256	1974	1410	1269
95	267	3738	2670	2136	1869	1335	1202
100	254	3556	2540	2032	1778	1270	1143
105	242	3388	2420	1936	1694	1210	1089
110	231	3234	2310	1848	1617	1155	1040
115	221	3094	2210	1768	1547	1105	995
120	212	2968	2120	1696	1484	1060	954
125	203	2842	2030	1624	1421	1015	914
130	195	2730	1950	1560	1365	975	878
135	188	2632	1880	1504	1316	940	846
140	181	2534	1810	1448	1267	905	815
145	175	2450	1750	1400	1225	875	788
150	169	2366	1690	1352	1183	845	761
155	164	2296	1640	1312	1148	820	738
160	159	2226	1590	1272	1113	795	716
165	154	2156	1540	1232	1078	770	693
170	149	2086	1490	1192	1043	745	671
175	145	2030	1450	1160	1015	725	653
180	141	1974	1410	1128	987	705	635
185	137	1918	1370	1096	959	685	617
190	134	1876	1340	1072	938	670	603
195	130	1820	1300	1040	910	650	585
200	127	1778	1270	1016	889	635	572

PPI = Pixels per Inch; PPL = Pixels per Line across the width of the imaging plate. To formulate: Divide 25,400 by the micron size desired (e.g., $25,400 \div 100 \mu\text{m} = 254 \text{ PPI}$). Then take the PPI and multiply by the width of



the imaging plate in inches. The result is pixels per line. Note: The Pixel Resolution Chart is not applicable to VMI units.

APPENDIX V

Approved Imaging Plates

Manufacturer	Model / Designation
GE Inspection Technologies	IPU (Image Plate Ultrasharp)
GE Inspection Technologies	IPS (Image Plate Sharp)
GE Inspection Technologies	IPCII (Image Plate Common)
Carestream	HR
Carestream	XL
Carestream	XL Blue
Carestream	GP
Fujifilm	CR-ST-VI (Standard Plate)
Fujifilm	CR-UR-1 (High Resolution Plate)

Note: Other imaging plates may be approved and are required to be listed in this procedure prior to use. This may be accomplished by a Temporary Change Request (TCR) upon Level III approval.

APPENDIX VI

Approved Scanners

Manufacturer	Model
VMI	5000 series
Kodak	ACR-2000i
Carestream	HPX1
Carestream	HPX-PRO
Fujifilm	Dynamix HR2-25
GE Inspection Technologies (GEIT)	CRxFlex
GE Inspection Technologies (GEIT)	CRxVision
GE Inspection Technologies (GEIT)	CRSOP
GE Inspection Technologies (GEIT)	CR25P

Note: Other processing systems may be approved and are required to be listed in this procedure prior to use. This may be accomplished by a Temporary Change Request (TCR) upon Level III approval.



APPENDIX VII

Approved Software

Manufacturer	System
VMI	StarViewFX
GE Inspection Technologies (GEIT)	Acquire and Review
Carestream	Industrex
Fujifilm	Dynamix VU

Note: Other processing systems may be approved and are required to be listed in this procedure prior to use. This may be accomplished by a Temporary Change Request (TCR) upon Level III approval.

APPENDIX VIII

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-CRT Rev 03
Radiation Source Type	Ir-192
Source Size (mm × mm)	
Source Activity (Ci / GBq)	
Scanner Manufacturer / Model	
Scanner Serial Number	
Imaging Plate Type / Manufacturer	
Imaging Plate Serial Number	
Pixel Size (μm)	≤ 200
Software / Version	
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)	
Exposure Dose (R / mR)	
Scanner Gain Setting	
Scanner Resolution (μm / PPI)	
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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