



DEPARTMENT OF THE NAVY  
NAVAL SEA SYSTEMS COMMAND  
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IN REPLY REFER TO  
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Ser 05P/191  
28 Jun 24

From: Commander, Naval Sea Systems Command (SEA 05P2)  
To: Distribution

Subj: REQUIREMENTS FOR COMPUTED RADIOGRAPHY AS AN ALTERNATIVE TO FILM  
RADIOGRAPHY FOR WELDS

Ref: (a) NAVSEA T9074-AS-GIB-010/271, Rev. 1 of 11 Sep 14, Requirements for Nondestructive Testing Methods  
(b) NAVSEA ltr 4855 Ser 05P/117 of 27 Mar 18  
(c) NAVSEA 250-1500-1 Rev. 19 of August 2020, Welding Standard  
(d) MIL-STD-2132F(SH) of 27 Jun 22, Nondestructive Examination Requirements for Special Applications  
(e) NAVSEA 392-0775 Rev. 15 of May 2022, Information Notes on Welding and Nondestructive Testing

Encl: (1) NAVSEA Requirements for Computed Radiography of Welds using T9074-AS-GIB-010/271 Applications

1. Purpose. The purpose of this letter is to authorize the use of Computed Radiography (CR) weld inspection methods as an alternative to film radiography, per reference (a), in accordance with the requirements provided in Enclosure (1).

2. Background. Reference (b) provided direction for an implementation trial phase and review of CR process and procedures prior to final Naval Sea Systems Command (NAVSEA) approval. The trial phase for developers and initial users of the draft CR requirements included in enclosure (1) of reference (b) was to assist with their assessment of implementation at their individual activities. The reference (b) trial test period also provided an opportunity to identify technical modifications needed for reference (a) and reference (b) enclosure (1) based on field experience.

3. Discussion

a. Enclosure (1) has incorporated feedback obtained from the reference (b) trial period. The CR requirements are included in enclosure (1) of this letter until incorporation into the next reference (a) revision. End users may use CR in lieu of film radiography per enclosure (1).

b. Government and shipbuilder oversight by activities such as Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP), Regional Maintenance Centers (RMC), public shipyards, commercial shipyards, etc. is required to support the implementation of CR.

c. CR does not change acceptance criteria, which remains the same for CR and film radiography.

4. NAVSEA Action. NAVSEA approves enclosure (1) for the use of CR as an alternative to film radiography for reference (a) applications subject to the following limitations.

a. Approval of CR programs and inspection procedures shall be in accordance with enclosure (1), sections 1.1.4 and 1.1.5. Enclosure (1) is intended for use on weldments; however, CR procedures for castings may be submitted to NAVSEA for approval following similar guidelines.

b. If alternate certification requirements are invoked with reference (c) or reference (d), paragraph 1.6.5 in revision 1 of reference (a) shall be used.

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c. Enclosure (1) Appendix A contains a CR submission checklist that aligns with reference (e) to result in consistent submittals for CR program authorization for Naval Nuclear and Non-nuclear projects.

5. The NAVSEA point of contact regarding this action is Dr. Pranaam Haldipur, SEA 05P2, (202) 781-3856 or Pranaam.haldipur.civ@us.navy.mil.

6. The requirements of this letter do not authorize any change in terms, conditions, delivery schedule, or price or amount of the subject contract of any other Government contract. In the event that you consider these requirements represent a change in which you consider these requirements represent a change in which you are entitled to an equitable adjustment, you are to comply with the requirements of the "Notification of Changes" clause of the contract.

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PRANAAM HALDIPUR, PH.D.  
Technical Warrant Holder for Nondestructive  
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# NAVSEA REQUIREMENTS FOR COMPUTED RADIOGRAPHY OF WELDS IN T9074-AS-GIB- 010/271 APPLICATIONS

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**28 JUNE 2024**

1.1 SCOPE.

This document provides requirements for using Computed Radiography (CR) as an alternative to film radiography when volumetrically inspecting metal and other materials. Use of CR per this document is an acceptable form of radiography in accordance with reference (a) and specifications that invoke reference (a) for radiography. This document is intended for use on weldments; however, CR procedures for castings also require submittal to NAVSEA for approval, following similar guidelines.

For purposes of this document, CR should be considered an integral part of reference (a) for film radiography. For example, a “radiograph” should be considered either a radiographic film or CR digital image, and wherever “film” appears in reference (a), such as in Figures 7 through 15, it shall be read as “film or imaging plate”. Finally, wherever “density” is referenced, “pixel value” shall be substituted for CR applications. In addition, the section numbers in this document align with, and contain modifications or additions to, the related section numbers in reference (a).

1.1.2 NON-GOVERNMENT PUBLICATIONS.

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM INTERNATIONAL

- ASTM E746 Standard Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems
- ASTM E1025 Standard Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology
- ASTM E1316 Standard Terminology for Nondestructive Testing
- ASTM E1453 Standard Guide for Storage of Media that Contains Analog or Digital Radioscopic Data
- ASTM E2002 Standard Practice for Determining Total Unsharpness in Radiology
- ASTM E2007 Standard Guide for Computed Radiography
- ASTM E2033 Standard Practice for Radiographic Examination using Computed Radiography
- ASTM E2339 Standard Practice for Digital Imaging and Communications in Nondestructive Evaluations (DICONDE)
- ASTM E2445 Standard Practice for Performance Evaluation and Long Term Stability of Computed Radiography Systems
- ASTM E2446 Standard Practice for Manufacturing Characterization of Computed Radiography Systems
- ASTM E2738 Standard Practice for Digital Imaging and Communication Nondestructive Evaluation (DICONDE) for Computed Radiography (CR) Test Methods

AMERICAN SOCIETY FOR NONDESTRUCTIVE TESTING, INC. (ASNT)

## Computed Radiography (CR) for Welds - T9074-AS-GIB-010/271

SNT-TC-1A Recommended Practice No. SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing

### SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS (SMPTE)

RP-133 Specifications for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard Copy Recording Cameras

### AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE (AAPM)

AAPM TG18 Test Pattern AAPM On-Line Report No. 3 "Assessment of Display Performance for Medical Imaging Systems"

#### 1.1.3 REFERENCES.

- a. T9074-AS-GIB-010/271, Requirements for Nondestructive Testing Methods
- b. Recommended Practice No. SNT-TC-1A; Personnel Qualification and Certification in Nondestructive Testing

#### 1.1.4 ACTIVITY APPROVAL.

The following approvals are required for CR inspection procedures and techniques, including revisions, CR systems, CR data management plans, and other related documents for inspecting weldments:

- Government shipyards and activities (including Regional Maintenance Centers, Warfare Centers, Fleet, etc.): NAVSEA approval is required.
- For commercial shipyards: Authorized representative approval is required.
- For commercial shipyard supplier base: Procuring shipyard activity approval is required.

CR used for inspection of castings shall require NAVSEA approval.

#### 1.1.5 PROCEDURE APPROVAL.

CR inspection procedures and representative techniques, including revisions, shall be approved per paragraph 1.1.4 prior to any inspection. The submittal shall include film radiographs of the same weld meeting the requirements of reference (a) for production radiography. All requests for CR technique approval shall reference the associated digital archive and shall include the performance evaluation data used to characterize the signal-to-noise (SNR) plateau and minimum pixel value (PV).

A minimum of three test samples (including film and corresponding digital images using the minimum specified pixel value) per technique shall be submitted for approval; each technique shall include representative indications for materials and geometries in the program. CR program, procedures and techniques submitted shall meet the requirements of this document and Appendix A checklists, "CHECKLISTS FOR SUBMISSIONS REQUESTING AUTHORIZATION TO USE COMPUTED RADIOGRAPHY IN LIEU OF FILM FOR RADIOGRAPHY OF WELDS."

#### 1.1.6 CR PERSONNEL CERTIFICATION.

CR inspection personnel certified as a Level I Operator, Level II Inspector, or Level III Examiner shall be examined and certified in accordance with their activity's written practice. Training hours and experience hours shall meet or exceed those in reference (b) unless otherwise approved. The activity's written

practice shall meet the requirements of reference (a) and shall meet the specific CR training and work time experience (WTE) stated below:

For personnel currently certified under a film RT program that meets the requirements of reference (a), certification in the same level for CR may be reduced to the following:

- Training may be reduced to 24 hours, at least 16 hours of which shall be equipment familiarization.
- WTE may be reduced up to 50% for CR specific experience.

Reference (b) requirements for currently certified Level III Examiner in film radiography can be modified to the following: Where reference (b) requires one or two additional years experience beyond the Level II Inspector requirements, only six months minimum experience beyond the Level II Inspector requirements is required. Where reference (b) requires four additional years experience beyond the Level II Inspector requirements, only one year minimum experience beyond the Level II Inspector requirements is required.

This reduction is intended to acknowledge the overlap in knowledge and experience between film RT and digital CR.

Each activity's written practice shall describe their CR Examiner certification process. A process similar to operator/inspector training, experience and examination, as required by reference (b), shall be supplemented with additional training, experience and examinations appropriate for the work performed. Relevant sections of ANSI/ASNT CP-105 (Topical Outlines for Qualification of Nondestructive Testing Personnel) may be used as a guide to develop training.

## 1.2 DEFINITIONS.

The standard terminology for CR nondestructive examination as described in ASTM E1316 shall apply to this section, except as noted below.

1.2.1 Computed Radiography (CR). A filmless radiography method that replaces conventional film with reusable imaging plates. A CR scanner device (also known as a CR reader) is used to digitize and erase latent images from exposed imaging plates and create digital images, in place of the photographic development process used to fix radiograph images on films.

1.2.2 CR System. A complete system consists of an imaging plate (manufacturer and type), individual scanner unit, scanner firmware, image acquisition and processing software.

1.2.3 Imaging Plate (IP). The reusable media used for exposing CR images.

1.2.4 Pixel Value. The numeric value of pixels in a digital image. Pixel value data shall be stored as linear pixel values, which are directly proportional to the radiation dose absorbed in a small region of the IP. When mapped to brightness or color for display by software on a monitor, linear or non-linear mappings may be used to create a visible display.

1.2.5 Pixel pitch (sampling pitch). The geometrical spacing between adjacent samples of the phosphor brightness on an exposed imaging plate.

## 1.3 GENERAL CR REQUIREMENTS.

### 1.3.1 Minimum Radiographic Procedure Requirements.

Written CR inspection procedures shall contain, as a minimum, the elements detailed in reference (a) as well as the following CR system information.

- a. Scanner manufacturer and model.
- b. Scanner normalization method and frequency.
- c. CR acquisition software identification and version (e.g., “Version 4”).
- d. All allowable CR acquisition software settings, pitch, gain, speed, etc.
- e. Image review software identification and version.
- f. Image display monitor manufacturer, model, and pixel spacing.
- g. Image display monitor calibration method and frequency.
- h. Image display monitor graphics adapter model and bit depth.
- i. IP manufacturer and type used.
- j. Viewing facilities, including background illumination requirements in viewing area.
- k. Pixel value requirements (including minimum and maximum values, and tolerances in areas of interest and image quality indicators).
- l. Digital image file format used and image storage, backup and retrieval methods.
- m. Length measuring calibration process, including details of reference to be used and location of any external reference (source side, film side).

1.3.2 CR Software. CR data acquisition systems shall be capable of a minimum bit depth of 12 bits (4096 intensity levels). CR review software shall be capable of saving all annotations, measurements, records, notes, etc. associated with the interpretation of the original production digital image file in electronic format.

1.3.2.1 Image Evaluation. Electronic measurement accuracy shall be evaluated as part of system qualifications per ASTM E2445. All dimensional requirements or measurements shall be calibrated to actual dimensions on the specimens, not to apparent dimensions on the display monitor. Digital magnification (zoom) of CR images is permissible provided all image quality requirements are met at the enlarged size. Any digital image processing, including magnification, shall comply with the displayed image quality requirements and be annotated on the radiographic record.

1.3.3 CR Equipment Performance Characterization. Each CR scanner shall be fully characterized and evaluated as specified in ASTM E2445 in conjunction with each imaging plate type used to perform inspections for baseline performance prior to use. ASTM E2445 provides the option to use one of two methods for performing sensitivity tests considering image noise; however, the method for determining the signal-to-noise ratio shall be conducted. Repairs or replacements performed on CR scanners that may affect the image quality (e.g., software/firmware revision levels) shall necessitate re-evaluation of the CR system to the requirements of ASTM E2445. Replacements or upgrades of CR system components (e.g., scanner/readers with different resolutions, change of pixel value bit depth or use of different manufacturer’s equipment) shall necessitate a re-evaluation to all requirements of ASTM E2445.

1.3.3.1 System performance shall also be re-evaluated at least quarterly for continued performance (long-term stability) to the requirements of ASTM E2445.

1.3.4 Core Image Quality Tests. If more than one combination of CR system components or more than one technique is used in production, the activity shall select one technique to be used for the quality tests. Before capturing images for baseline evaluations, the scanner shall be normalized such that a flat field is

produced when an IP is exposed without an absorber. The use of alternate gauges or phantoms is permitted as approved by the CR Level III Examiner, provided all the Core Image Quality Test parameters can be measured. ASTM E2445 CR Type II Phantoms shall be approved only for applications up to 160kV. CR Type I Phantoms may be used for applications up to 320kV. Applications for greater than 320kV or gamma source must be approved per paragraph 1.1.4.

1.3.4.1 Records of system baseline performance and long-term stability tests shall be maintained by the activity and made available to NAVSEA or its authorized representative upon request.

#### 1.4 RADIOGRAPHY REQUIREMENTS.

1.4.1 Screens and Filters. Where imaging plates are used, filter screens of materials such as steel or copper may be used alone or in conjunction with lead screens to suppress the effects of fluorescence or scattered radiation. The specific combination of screens and filters used must be listed in the CR inspection procedure and technique.

1.4.2 Image Plates. Radiographs shall be made with a combination of imaging plate type, radiation dose, scanner unit, and image acquisition and processing software settings that perform at System Performance Level "CR Level I" or better as defined in ASTM E2446.

1.4.2.1 Imaging Plates (IPs) shall be inspected on a routine basis for surface wear and any signs of discoloration that could affect image quality. IPs exhibiting visual evidence of degradation shall be erased and evaluated for unacceptable performance. IPs exhibiting substantial residual images shall be evaluated for unacceptable sensitivity. IPs exhibiting unacceptable performance or sensitivity shall not be used for production inspections. Unexposed IPs shall be stored in a dark and dry environment and in a manner such that they are protected from sources of ionizing background exposure. IPs shall be stored flat (not bent or curled) and in a manner that will not induce pressure marks (e.g. vertical storage or storage in non-crushable containers if stacked) when not in use. Exposed production CR IPs shall be handled in conditions of subdued lighting. Protective plastic on lead screens should not be removed so as to help prevent IP contamination or scratching from the lead. IPs should be handled with soft lint free gloves and kept free from any source of contamination that could result in artifacts or reduce the IP life.

1.4.3 Image Quality. Images shall be free from artifacts or image imperfection which might mask or be confused with defects in the material being examined. If doubt exists concerning the true nature of an indication, the image shall be rejected. Typical digital artifact types and potential causes include:

- a. Blooming, saturation, or flare artifacts caused by exceeding the useful dynamic range of the system.
- b. Artifacts caused by foreign materials on imaging plates, or by imaging plates exhibiting scratches, abrasions, or damage from rough handling.
- c. Gray scale streaking or other CR scanner artifacts caused by mechanical transport mechanism irregularities.
- d. Loss of image detail or poor sensitivity caused by worn or degraded IPs.
- e. Residual images caused by incomplete erasure or burn-in left over from a prior exposure of an IP.
- f. Partial imaging plate erasure caused by exposure of IPs to excessive ambient light following exposure or during scanning or by insufficient or excessive delay between exposure and scanning.
- g. Gray scale banding that can result from inadequate exposure or excessive gain settings.
- h. Afterglow artifacts caused by direct luminescence from the IP.
- i. Non-uniform background caused by insufficient delay between exposure and readout of an IP.

1.4.4 Pixel Value Requirements. Where IP techniques are used, only linear pixel values (where a pixel value is directly proportional to the absorbed X-ray dose) shall be used to verify satisfactory exposure of radiographs. The pixel values in the area being examined shall meet or exceed the minimum pixel value requirement specified in the technique and be bounded by the maximum and minimum pixel value limits specified in the procedure. The minimum pixel value specified in the technique shall not be less than 50 percent of the pixel value corresponding to the exposure required to achieve the SNR at the plateau onset as defined in the SNR Performance section of ASTM E2445. Pixel value measurements on penetrameters shall be measured as the average pixel value in an analysis region located directly over the penetrometer hole. To perform verification of this requirement, the analysis region shall be no larger than 2mm (as measured in the radiograph) in any dimension (e.g., a 2mm diameter circular region or a 1.4mm × 1.4mm square region). The pixel value measured over the applicable “T” hole shall be no greater than 15 percent more than the minimum pixel value in the area of interest. It may be less than the pixel value in the area of interest.

1.4.5 Radiograph Identification. A system of positive identification of the radiographs shall be used. The following information shall appear on each radiograph, be included in the image metadata or in the records accompanying each radiograph:

- a. Identification of the organization making the radiograph.
- b. Date of exposure.
- c. Identification of the part, component, or system and, where applicable, the weld joint in the part, component, or system.
- d. Whether the radiograph is of the original area or a repair area.
- e. Each IP shall have a unique serialization mark or number that produces a visible and readable identification in inspection images.

1.4.6 Image Viewing Facilities. CR images on a monitor shall be viewed in a facility with subdued ambient lighting. The monitor screen shall be free from objectionable glare or secondary light reflections.

1.4.6.1 Equipment used to display digital images for interpretation shall conform to the following requirements:

- a. The monitor shall be monochrome with a flat-panel type display.
- b. The physical pixel pitch of the monitor used for final image interpretation shall be not greater than 165 microns.
- c. The monitor shall be capable of producing a minimum brightness, as measured at the monitor screen, at the maximum Digital Driving Level (DDL) of at least 500cd/m<sup>2</sup>. The monitor may be calibrated to a lower maximum brightness for use during interpretation if specified in the CR inspection procedure or technique.
- d. The monitor contrast ratio (monitor screen brightness at maximum DDL divided by brightness at minimum DDL) shall be not less than 800:1.
- e. The brightness at the maximum DDL and the contrast ratio of the monitor shall be verified using a light meter or calibration sensor at least quarterly. The monitor brightness shall be photometrically calibrated at least once per quarter.

1.4.6.2 The monitor used to evaluate digital images shall be verified by displaying the Society of Motion Picture and Television Engineers (SMPTE) test pattern image RP-133, AAPM TG18-QC, or equivalent. Screen brightness and contrast may be adjusted in conjunction with ambient lighting as necessary. All contrast and resolution test targets can be successfully resolved as described within SMPTE RP-133 when

displayed at 1:1 (100%) zoom setting. The following is a list of all required display performance parameters:

- a. The primary display system shall be capable of rendering faithful reconstruction of all SMPTE RP-133 image targets with no distortion of the square grid lines or flickering of the screen.
- b. Spatial Resolution: All five of the low contrast and all five of the high contrast resolution bar sets shall be resolved in the middle and all four corners of the SMPTE pattern without aliasing. If the display pattern does not fill the monitor screen at the 1:1 (100%) zoom setting, resolution shall be verified at the monitor center and at each corner of the monitor.
- c. Gray Scale Performance: All eleven of the 10% contrast change squares shall be simultaneously resolved from adjacent contrast squares and the 5% and 95% square contrast patches shall be simultaneously resolved against their backgrounds.

1.4.6.2.1 At a minimum, verification of the display performance parameters shall be performed at the beginning of each shift, following all repairs of the display system, and anytime an inspector may have reason to question the performance of the electronic display system. A monitor that does not meet the above requirements shall not be used for production inspections.

1.4.6.3 The results of each monitor calibration and performance verification check shall be documented and retained for the current and previous quarter.

## 1.5 INTERPRETATION OF RADIOGRAPHS AND DIGITAL IMAGE RECORDS.

1.5.1 Activities shall provide a data management plan for CR data management and record retention. Records comprised of digital images shall be retained using an archive method approved per paragraph 1.1.4 in a form suitable for backup, searching, and disposition. All digital images shall be transferred to the disposition archive using DICONDE network transfer protocols or media volume formats as specified by ASTM E2738 and ASTM E2339. Digital image records shall not be deleted from the archive of the performing organization until receipt of transfer to the disposition archive is received and confirmed. In addition to the information specified in reference (a), computed radiographic records shall contain the following as a minimum:

- a. Identification of the governing radiographic procedure.
- b. Identifications and versions of CR acquisition firmware and software and digital image review software.
- c. CR Scanner manufacturer, model, and serial number.
- d. CR acquisition software settings, including (at minimum) pixel pitch, gain, pixel value mapping (e.g., linear, log, or square root).
- e. CR image processing or filtering employed for image display during final interpretation.
- f. CR image display gray mapping type (e.g., linear) and limits (e.g., center and width values or minimum and maximum values, inverted or non-inverted).
- g. Allowable inspector adjustments to CR display mapping during interpretation.
- h. The original unmodified, un-enhanced inspection image data for each inspection view. When display filters or enhancements are applied to digital images, they should be saved in a way as to delineate them from the original images.
- i. Screen materials, thickness ranges, and relative locations within or outside the IP cassette.
- j. Image processing methods and techniques employed.

1.5.2 Hardcopy images or films produced by digital printers shall not be used for archiving of digital inspection radiographs. Equipment used to acquire, process, and store digital radiographs shall conform to the following requirements:

- a. CR radiographs shall be stored in a DICOM format compliant with ASTM E2738 and ASTM E2339.
- b. The storage hardware shall store images without lossy compression in a format with sufficient bit depth to store either as-acquired or normalized image data without truncation.
- c. Stored image data and associated metadata shall be organized in a searchable database to facilitate the location and retrieval of imagery.
- d. Original image data shall be retained, along with all information needed to redisplay images in the as-interpreted state. Any digital annotations or image markings applied to images shall not overwrite the underlying image data.
- e. The image storage equipment shall include a high-reliability hardware design and shall be utilized in conjunction with a system for image data integrity, backup, geography redundancy, and security approved per paragraph 1.1.4.
- f. Any magnetic or optical media used for image data storage shall be housed in accordance with the guidelines of ASTM E1453 and shall be permanently labeled with a unique identifier that is tracked and searchable in the image database.

1.5.3 Printed or lossy digital reproductions of computed radiographic digital images shall be limited to in-process evaluations or to facilitate repairs and shall not be permitted for final acceptance inspection or archival image storage unless approved per paragraph 1.1.4.

1.6 RADIOGRAPHIC QUALITY LEVEL. For digital radiographs, the required penetrameter holes for each region of interest shall be visible using the same settings for display mapping, zoom, and image processing as used to display the corresponding region in the radiograph for interpretation. Any inspection image exhibiting signs of IP degradation that could mask or be confused with any defect shall be cause for re-evaluation. Any IP exhibiting unacceptable base sensitivity or objectionable conditions as prescribed under this standard shall not be used for production inspections.

## APPENDIX A: CHECKLIST FOR SUBMISSIONS REQUESTING AUTHORIZATION TO USE COMPUTED RADIOGRAPHY IN LIEU OF FILM FOR RADIOGRAPHY OF WELDS

### REFERENCES

- a. NAVSEA Requirements for Computed Radiography of Welds in T9074-AS-GIB-010/271 Applications
- b. NAVSEA T9074-AS-GIB-010/271
- c. ASTM 2033 Standard Practice for Radiographic Examination using Computed Radiography

### BACKGROUND

Reference (a) allows organizations to request authorization to use computed radiography (CR) in lieu of film for certain types of radiography. While CR is similar to the conventional film radiography process up through creation of an exposure, it requires additional controls for the new elements it presents for the remainder of the process. These checklists have been developed to help simplify and standardize the adjudication of submissions, by providing a consolidated listing of key additional elements requiring consideration and control.

Reference (a) CR submissions include three parts (CR Procedure, CR Techniques(s), and CR Data Management Plan), each of which addresses certain aspects of the additional elements in the CR process. A separate checklist has been developed for each type of submission, since they may not be submitted or reviewed simultaneously.

### PURPOSE

The checklists are provided here as guidance to organizations preparing submissions to request the use of CR in lieu of film for Welder Qualification Testing or Radiographic Inspections to the requirements of Reference (b). In the event of significant changes to the checklists, updated versions will be made available via official memorandum.

### CR PROCEDURE SUBMISSION CHECKLIST

*Note: All procedure requirements common to film and CR must be met. Numbers in parentheses refer to paragraphs (§+ #) or items (#) from Reference (a) or (b).*

Source information (reference (b) ¶ 3.3.2.1)  
to include either: X-Ray Machine  
Information

- Model and Type. *Note: In case techniques or procedures are shared among organizations, the x-ray tube model must be specified as well as the controller model; the generator(s) model is optional. To ensure a consistent spectrum is applied, there must be sufficient information provided to determine the tube window material and thickness, and whether the tube is operated with constant potential, full-wave rectified AC, or half-*

*wave rectified AC voltage.*

- Manufacturer
- Focal Spot Size. *Note: If more than one focal spot is available, each Technique must specify the spot size to be used.*
- Voltage Rating

Isotope Source Information

- Type of Isotope
- Maximum Source Strength

CR equipment description (reference (a) ¶ 1.2.2 and 1.3) including:

- Scanner manufacturer and model
- Scanner normalization method and frequency  
*Note: The “method” should specify whether normalization is performed by organization personnel or by a qualified service vendor. The “frequency” should specify flat-field corrections be performed both at a maximum interval (e.g., at least every 24 months) or whenever vertical streaking/banding artifacts are observed that are judged by the cognizant Examiner to be severe enough to interfere with interpretation.*
- CR acquisition software identification and version (e.g., “Waygate Technologies Rhythm RT, Version 6”).
- All allowable CR acquisition software settings (pitch, gain, speed, laser power, etc.) as applicable  
*Note: Settings must be specified to ensure that linear pixel values (i.e., directly proportional to radiation dose) are produced. If multiple combinations of settings are allowed, the combination to be used must be specified in each Technique.*
- Image review software identification and version (e.g., “Carestream INDUSTREX, Version 5”).
- Scanner preventative maintenance plan (including service frequency and performer)

Monitor/Adapter specifications (reference (a) ¶ 1.3.1 and 1.4.6)

- Image display monitor manufacturer, model, and pixel spacing  
*Note: This is typically a medical-grade 21” 5 megapixel grey-only device with photometric calibration capability, e.g., EIZO GX550 or similar DOME, BARCO, etc.*
- Image display monitor graphics adapter model and bit depth
- Monitor must be a flat-panel type (not CRT)
- Monitor pixel spacing must not be greater than 165 microns
- Monitor must be capable of producing a brightness greater than or equal to 500 cd/m<sup>2</sup> as specified by the manufacturer. *NOTE: no specific testing is required, since it is periodically verified using a light sensor during photometric calibration.*
- Monitor must be capable of producing contrast ratio greater than or equal to 800:1, as specified by the manufacturer. *NOTE: no specific testing is required, since it is periodically verified using a light sensor during photometric calibration.*

Image display/review monitor calibration method and frequency (reference (a) ¶ 1.3.1)

and 1.4.6)

- The maximum calibrated brightness (in  $\text{cd}/\text{m}^2$ ) must be specified.  
*Note: the monitor may be set to less than  $500 \text{ cd}/\text{m}^2$  maximum brightness to facilitate image viewing in darkened environments if specified in the procedure or technique.*
- The calibration method must utilize a light sensor and software to adjust and confirm brightness response as a function of monitor digital driving level. *Note: periodic calibration of the brightness sensor used for photometric calibration is not required, so use of a sensor built into the monitor is acceptable.*
- The calibration interval is quarterly or more often.
- The method of documenting each monitor “photometric calibration” must be specified. *Note: if software is used to record these events, a process for backing up this information away from the review computer must be specified in the data management plan.*

Image display/review monitor performance verification method and frequency (reference (a) ¶ 1.4.6)

- Must include verifying simultaneous discrimination of all 10% contrast change squares and the 0%/5% and 95%/100% brightness square patches using a SMPTE-133 (or TG18 or equivalent) test pattern prior to interpreting images in any shift.
- Must include verifying visibility without aliasing of all low-contrast and high-contrast patterns at monitor center and corners using a SMPTE-133 (or TG18 or equivalent) test pattern prior to interpreting images in any shift.  
*Note: The procedure for performing this test must specify that no magnification zoom can be applied to the image (i.e., 1:1 or 100% setting), so that the light and dark regions of the test patterns are displayed on alternating rows or columns of the monitor display.*
- Must include the method of documenting each per-shift monitor verification  
*Note: if software is used to record these events, a process for backing up this information away from the review computer must be specified in the data management plan.*

Personnel Qualifications (reference (a) ¶ 1.1.6 and reference (b) ¶ 1.6)

*Note: This must be specific to CR and include both:*

- NDT Examiner qualification processes (including TEQP certification)
- Description of all requirements (testing, training, OJT experience, monitoring, requalification intervals) for Operators and Inspectors certified by the Organization.

Imaging Plates (reference (a) ¶ 1.3.1 and 1.4.2)

- Allowed Imaging Plate Type(s) (e.g., Carestream HR, Waygate Technologies IPS, etc.)  
*Note: If more than one plate type is allowed, a description of the allowed usages for each must be provided.*

Viewing Facilities (reference (a) ¶ 1.4.6)

- How objectionable reflections on the monitor are prevented
- Allowable background illumination level (in lux or foot-candles)  
*Note: ASTM E2033 recommends a maximum of 30 lux.*
- Make and model of the light meters used to measure background illumination
- The illumination monitoring process (e.g., measurement locations and directions)
- Illumination monitoring frequency requirements  
*Note: ASTM E2033 recommends a 6-month frequency.*
- Light meter calibration process and frequency  
*Note: ASTM E2033 recommends a 6-month frequency.*

Pixel Value Requirements including Minimum, Maximum, and Tolerances in areas of interest and image quality indicators (reference (a) ¶ 1.4.4)

*Note: Minimum pixel value is the metric used to ensure a sufficient dose for acceptable image quality and must be enforced by the exposure technique.*

- The pixel statistic to be utilized (average, minimum, median, etc.) as the “value”
- The size and location of analysis boxes used to characterize PVs on penetrameters and ROIs must be specified.

If a single numeric value for minimum Pixel Value in the ROI is not specified in the procedure:

- The process to determine the minimum allowable numeric PV for each Technique  
*Note: this process must be based on SNR vs. Pixel Value data. Optionally, a RQI/IQI demonstration may also be required.*
- A requirement to specify the numeric value for Minimum Pixel Value for each Technique
- Maximum pixel value  
*Note: Maximum PVs do not need to be numeric but may simply state that no saturation is allowed in the ROI.*
- Any PV tolerance requirements must include numerical limits (e.g., +/- 15%).

Method of Providing Radiograph Identification (reference (a) ¶ 1.5 and reference (b) ¶ 3.4.15) *Note: The procedure shall specify whether the information is recorded in the image itself, or in the metadata, or both, and shall include:*

- The exact text of the organization identification
- The format for the date of exposure (e.g., 20180910, 10092020, 10 SEPT 2018, 09/10/2018, 10/09/2018, etc.)
- The system for identifying the object under test, including specific, precise, and unambiguous determination of the text and format stored in each of the key metadata fields (Component Name, Component ID, Study Name, Study Date, Series Name, Series Date)
- The system for denoting original vice repaired welds
- The unique IP serialization text format, size, and location where applied to IPs that are not serialized on the active surface by the manufacturer. The serialization data may be optionally repeated in the metadata.

Penetrameters and Screens (reference (b) ¶ 3.4.2, 3.5; reference (a) ¶ 1.4.1, 1.6)

- Penetrometer or IQI type

*Note: Must include specifying the governing standard for penetrameters used*

- Limits or requirements on allowable materials, thicknesses, or locations (both at the source and within or outside cassettes) for filters and screens

*Note: The filter and screen combinations may vary for different inspection techniques, so a description of allowed and/or restricted usages (if any) for each allowed combination must be provided.*

- If any variation is allowed, a requirement that filters and screens be fully specified in each technique must be included.
- Allowances for increased scatter control (vice film techniques) must be specified.

Baseline and periodic performance evaluations (reference (a) ¶ 1.3.3 and 1.3.4.1)

*Note: Must specify:*

- Maximum interval between E2445 periodic re-evaluations
  - Which items must be retested after preventative maintenance or after scanner repairs
  - Technique details for performing baseline characterization and periodic re-evaluation exposures, including IP size, IP type, source and filters, source-to-film distance, PV requirements, and phantom orientation. *Note: Acquisition settings may change for various inspection techniques, but only one specified technique need be utilized for baseline characterization and periodic performance monitoring; this one technique should be representative of the IP type, filters, and dose required to obtain satisfactory image quality in typical inspections.*
  - Which tests are performed, and details of image analysis process (box size/location, etc.)
  - Pass/fail criteria for each test
  - Records plan for images, test results, and associated documentation. *Note: Scanner performance test records must remain accessible for any inspection images acquired with that scanner.*
- (Reference (a) ¶ 1.5 Reference to the detailed description of the approved digital archive to be used for retention of digital radiographs)
  - (Reference (a) ¶ 1.5 Instructions for transfer of digital radiographs to a disposition archive *Note: This optionally may refer to a separate data management submission. The procedure governing any transfer process must include:*
    - Process for confirmation of receipt by the disposition archive prior to image deletion *Note: although use of Storage Commitment Protocol (SCP) for receipt acknowledgement of network transfers is acceptable and even preferred, a clear hand-off process is always required to ensure that both the receiver and sender know not to accidentally/prematurely delete a transferred record.*
    - For network transfers, the AE titles and TCP ports of sending and receiving databases must be specified.
    - For media transfers, transferred images must be packaged in complete volumes (including a DICOMDIR) that can be viewed using a standard DICONDE viewer before the volume is actually imported.

Specific requirements to ensure all of the Technique requirements of reference (b) Section 3 are

met

*Note: This should specify all CR-specific radiography quality requirements, including: (reference (a) ¶ 1.3.4, 1.4.3 and 1.6)*

CR image artifact examination requirements and image rejection criteria (reference (a) ¶ 1.4.3)

- IP handling and storage requirements (e.g., white gloves, environmental conditions, etc.) and detailed IP cleaning procedure that specifies all supplies, methods, and cleaning intervals (reference (a) ¶ 1.4.2)
- Allowable total background illumination to the IP between exposure and readout
- Limits on the minimum and maximum time between exposure and readout
- Detailed method for verifying minimum PV, including analysis region size and placement, statistics to be calculated
- Recording of all CR-specific technique parameters

Supporting data (reference (a) ¶ 1.4.4)

- If the procedure specifies a numerical minimum pixel value, the performance evaluation data used to characterize the SNR plateau and the minimum pixel value must be provided. However, these data are not required if the procedure only provides a method for determining a numerical value and leaves specification of the numerical value to individual techniques. *Note: The SNR plateau is obtained by analyzing a plot of SNR vs. pixel value; this data will vary depending on IP type, scanner gain setting (which, depending on scanner model and manufacturer, is determined by a combination of PMT voltage and/or pixel pitch and/or ADC gain setting), so all relevant technique parameters used must be specified.*
- Equipment baseline performance data.

## CR TECHNIQUE SUBMISSION CHECKLIST

*Note: All technique requirements common to film and CR must be met. Numbers in parentheses refer to paragraphs (¶+#) or items (#) from Reference (a) or (b).*

Supporting data for CR Technique Submissions: [reference (a)]

- Associated approved digital archive
- Performance evaluation data to characterize the SNR plateau and minimum pixel value for this technique. However, this is not required if the procedure specified a numerical value for all techniques. *Note: The SNR plateau is obtained by analyzing a plot of SNR vs. pixel value; these data will vary depending on IP type, scanner gain setting (which, depending on scanner model and manufacturer, is determined by a combination of PMT voltage and/or pixel pitch and/or ADC gain setting), so relevant technique parameters used must match those used to obtain these data.*
- The range of materials, thicknesses, and configurations covered by the technique
- CR images and corresponding films with representative indications for comparison
- Description and format of any information to be stored in metadata fields CR-specific technique information [reference (a) ¶ 1.5]

- Specific imaging Plate Type and Brand (e.g., Carestream HR, Waygate Technologies IPS, etc.)
- Cassette loading, including Imaging Plate(s) location or position  
*Note: unless fully specified in the governing procedure per, the following must be provided in the technique to document cassette loading order and placement:*
  - (9) materials, thicknesses, or locations (both at source and within or outside of cassettes) for filters and screens
- Identification of the governing CR procedure
- CR acquisition firmware and software identification and version (e.g., “Waygate Technologies Rhythm RT, Version 6; scanner firmware version 230.12.a3”) and digital image review software (e.g., Waygate Technologies Rhythm Review, Version 5)
- Scanner manufacturer, model, and serial number
- All applicable CR acquisition software settings (including pixel pitch, gain, pixel value mapping, and all other relevant settings such as speed, laser power, etc.).
  - Settings must be specified to ensure that linear pixel values directly proportional to radiation dose are stored in the image.
  - Exposure and settings used in conjunction with specified IP must perform at “CR Level I” or better per ASTM E2446 (i.e.,  $SNR_N \geq 100$  and  $iSRb^{detector} \leq 100 \mu m$ ). *Note: (reference (a) ¶ 1.4.2) this may be demonstrated by reference to existing PV vs. SNR and equipment qualification data or by reference to manufacturer- provided data but must apply for the dose corresponding to the minimum allowed pixel value.*
- CR image processing or filtering employed for image display
- CR image display gray mapping type (e.g., linear) and limits (e.g., center and width values or minimum and maximum values, inverted or non-inverted)
- Allowable inspector adjustments to CR display mapping during interpretation *Note: this includes removal or application of image processing filters, zoom changes, and adjustment of gray mapping levels.*
- Minimum Pixel Value Requirements (including Minimum Values, Maximum Values, and Tolerances in areas of interest and image quality indicators).  
*Note: Minimum pixel value is the metric used to ensure that a sufficient dose for acceptable image quality is enforced for the exposure technique.*
  - A numeric value for Minimum Pixel Value (if not specified globally in the Procedure)
  - The specified Minimum Pixel value must not be less than 50% of the PV at SNR plateau onset for the acquisition settings used

## CR DATA MANAGEMENT PLAN SUBMISSION CHECKLIST

*Note: Numbers in parentheses refer to paragraphs (¶+#) or items (#) from Reference (a) or (b).*

Archive method (reference (a) ¶ 1.5) suitable for backup, searching, and disposition

- This must utilize either a commercial DICONDE database software product, or a detailed specification of a professionally-developed custom archive solution. *Note: this is not required to be a separate “archive” product – a “review station” based*

on a built-in database could serve as an acceptable platform. It must provide:

- Query capability on the primary DICONDE tags
- Control plan for data functions by user role (e.g., query, write, tag modify, send)
- Security and User Authentication plans for hardware and database access
- A plan for maintaining the database hardware and recovering from hardware failures
- A plan for backup of the database contents which includes:
  - Organization responsible for maintaining backups
  - Media or method to create backups
  - Frequency of backup
  - Storage of backup devices/media separate from the primary repository under appropriate temperature/humidity controls

Proof of DICONDE database transfer [reference (a) ¶ 1.5]

- Successful demonstration of a study/volume transfer to a DICONDE database without requiring any manual editing of the data

Description of how Technique and Film Identification information is stored

- List of what is stored in metadata vs. in ancillary forms
  - List of which software or role enters each mandatory DICONDE tag
  - List of which software or role enters each optional DICONDE tags that will be used
  - The method of associating ancillary information (e.g., PDF scans of associated paper forms) to the studies containing RT examination digital images
- Short-term and long-term records plan [reference (a) 1.5 and reference (b) ¶ 1.8] for images, test results, and associated documentation
- Note: Scanner performance test records must remain accessible for any inspection images acquired with that scanner.*

Disposition instructions for transfer of digital radiographs to a disposition archive

*Note: The procedure governing any transfer process must include:*

- Process for confirmation of receipt by the disposition archive prior to deletion  
*Note: although use of Storage Commitment Protocol (SCP) for receipt acknowledgement of network transfers is acceptable and even preferred, a clear hand-off process is always required to ensure that both the receiver and sender know not to accidentally or prematurely delete a transferred record.*
- For network transfers, the AE titles and TCP ports of sending and receiving databases must be specified.
- For media transfers, transferred images must be packaged in complete volumes (including a DICOMDIR) that can be viewed using a standard DICONDE viewer before the volume is actually imported.

Documentation of monitor photometric calibration (reference (a) ¶ 1.3.1 and 1.4.6)

- The method of documenting each monitor photometric calibration and per-shift verification must be specified.
- If software is used to record these events, a method for backing up this

information away from the review computer must be specified.