SECTION 11.4
Volume II

COMPUTED RADIOGRAPHY PROCEDURES (PHOTOSTIMULABLE LUMINESCENCE)

11.4.1 SCOPE

This guideline outlines application details for Computed Radiology (CR) examination using a process in which photostimulable luminescence is emitted by the penetrating radiation detector to a Storage Phosphor Imaging Plate (SPIP). Because the technique is complex and the applications for CR examination are diverse, this guideline is not intended to be limiting or restrictive, but rather to address the general applications of the technology and thereby facilitate its use.

The general principles discussed in this guideline apply broadly to penetrating radiation CR systems. However, this guideline is written specifically for use with X-ray and gamma-ray systems.

11.4.2 REFERENCES

American Society for Testing and Materials (ASTM) Standards

E94 – Guide for Radiographic Examination

E747 – Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology

E1025 – Practice for Design, Manufacture and Material Grouping Classification of Hole-Type Image Quality Indicators Used for Radiology

E1316 – Terminology for Nondestructive Examinations

E1453 - Guide for Storage of Media that Contains Analog or Digital Radioscopic Data

E1475 – Guide for Data Fields for Computerized Transfer of Digital Radiological Examination Data

E1817 - Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)

E2007 – Guide for Computed Radiology (Photostimulable Luminescence (PSL) Method)

American Society for Nondestructive Testing (ASNT) Standards

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

American National Standards Institute (ANSI) / ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

Code of Federal Regulations (CFR)

Title 21, CFR 1910.96 Ionizing Radiation

Aerospace Industries Association of America, Inc. (AIA) Standard

NAS-410 Certification and Qualification of Nondestructive Testing Personnel

11.4.3 SUMMARY OF PROCEDURE

A typical CR examination system consists of a radiation source, a storage phosphor imaging plate detector, a plate reader, an electronic imaging system, a digital image processor, a monitor display, a digital image archiving system, and if desired, equipment for producing hard copy analog images. This guideline establishes the basic parameters for the application and control of the CR method. For purposes of this guideline, the words radiology and radiography will be used interchangeably.

11.4.4 SIGNIFICANCE AND USE

The X-ray, gamma-ray detector discussed in this guideline is a storage phosphor imaging plate, hereafter referred to as SPIP. The SPIP, which is the key component in the CR process, differentiates CR from other radiologic methods.

11.4.5 EQUIPMENT

11.4.5.1 SYSTEM CONFIGURATION

Different examination system configurations are possible and it is important to understand the advantages and limitations of each. The

optimum system for each examination requirement should be selected through a careful analysis of the benefits and limitations of the available system components and the chosen system configuration. The fabricator and the Florida Department of Transportation (FDOT) State Materials Office should be fully aware of the capabilities and limitations of the examination system. The fabricator and the FDOT State Materials Office shall agree upon the system configuration to be used for each application under consideration and how its performance should be evaluated.

The minimum system configuration will include an appropriate source of penetrating radiation, a phosphor plate detector, a plate reader, and an electronic imaging system with a display.

A more complex system might include a microfocus X-ray system, a digital image processing evaluation system, and an image recording and printing system.

11.4.6 GENERAL PROCEDURE REQUIREMENTS

The fabricator shall prepare and submit a written procedure to the FDOT State Materials Office for review. The procedure shall be written by or authorized by a Non-destructive Testing (NDT) Level III, shall follow the applicable annex of supplemental requirements as referenced in ASTM E2033 and also consider the following general requirements.

(A) Equipment Qualifications – Provide a list of system features that must undergo performance measurement qualifications to ensure it is capable of performing the desired examination.

(B) Source Parameters – Provide a list of all the radiation source-related variables that can affect the examination results for the selected system configuration such as: source energy, intensity, focal spot size, range of source to object distance, range of object to image plane distances, and source to image plane distances.

(C) Image Processing Parameters – Provide a list of the image processing variables, if any, necessary to enhance fine detail detectability in the part and to achieve the required image quality. These would include, but are not limited to, techniques such as noise reduction, contrast enhancement, and spatial directional image processing parameters such as spatial filtering, which may emphasize features in certain orientations and suppress them in others. The listing should indicate the means for qualifying image processing parameters.

(D) Image Display Parameters – Provide a list of the techniques and the intervals at which they are to be applied for standardizing the video image display as to brightness, contrast, focus and linearity.

(E) Accept-Reject Criteria – Be in compliance with the applicable American Welding Society (AWS) code and contract documents.

(F) Performance Evaluation – Provide a list of the qualification tests and the intervals at which they are to be applied to ensure the system is suitable for its intended purpose.

(G) Image Archiving Requirements – Provide a list of the requirements, if any, for preserving a historical record of the examination results. The listing shall include examination images along with written or electronically recorded alphanumeric description(s) of techniques and results.

(H) Qualifications – Nondestructive testing personnel shall be qualified in accordance with the following: ANSI / ASNT-CP-189, SNT-TC-1A, or NAS-410. System qualification, the development of examination techniques, scan plans, and the overall implementation of an examination in accordance with this annex shall be under the control and supervision of a qualified Level III with additional training and experience or in conjunction with an individual having the necessary training and experience in CR examination.

(I) Examination Image Control – The system shall be checked for performance before each day's production usage, using the method and devices that were initially used to qualify the written procedure. A log shall be maintained to document any changes in system performance requiring changes in operating parameters and listing all equipment maintenance. System requalification shall be required whenever image quality requirements can no longer be met.

(J) Repair of System - Repair or replacement of key system components, including, but not limited to, the radiation source, image formatting, image transmission, image processing, and image display subsystems, shall be cause for system requalification. In no case shall the interval between qualification tests exceed one (1) year. The qualification statement shall be posted on the CR system. The results of the qualification tests shall be maintained in the system equipment file at least until completion of the next qualification procedure or the expiration of the archival image retention period, whichever is longer.

(K) Image Interpretation – System qualification in accordance with Section 7 of Practice E2033 applies.

(L) Feature Size Determination – When feature measurement from the image is required, the written procedure shall include methodology for determining and maintaining the accuracy of the selected measurement method.

(M) Feature Measurement by Comparison – This second method involves comparing the part feature with a known, observable dimension that must be wholly within the field of view. Many digital image processors facilitate this type of measurement by counting pixels over the feature length. The pixel number is often converted to engineering units by comparison with a known length. However, the orientation and position along the X-ray beam (magnification) of both the feature and the calibrating reference length affect the accuracy of such measurements.

(N) Gray Scale Range – The gray-scale range required to meet initial qualification contrast sensitivity requirements for image quality shall be recorded and monitored. For systems using human image assessment, it is particularly important that the gray-scale range and the number of gray-scale steps be closely matched to the response of the human eye. The written procedure shall include a means for monitoring the required gray-scale range using a contrast sensitivity gage, step wedge, or similar device made of the part or IQI material.

11.4.7 CR EXAMINATION SYSTEM PERFORMANCE CONSIDERATION AND MEASUREMENT

11.4.7.1 FACTORS AFFECTING SYSTEM PERFORMANCE

Total examination system performance is determined by the combined performance of the system components that includes the radiation source, storage phosphor plate detector, plate reader, electronic image processing system, image display, and examination record archiving system.

11.4.7.1.1 Radiation Sources

Examination systems may utilize either radioisotope or X-ray sources. The energy spectrum of the X-radiation contains a blend of contrast enhancing longer wavelengths as well as the more penetrating, shorter wavelengths. X-radiation is adjustable in energy and intensity to meet CR examination requirements and has the added safety feature of discontinued radiation production when switched off. A radioisotope source has the advantage of small physical size, portability, simplicity, and uniformity of output.

A) X-ray machines produce a more intense X-ray beam emanating from a smaller focal spot than do radioisotope sources. X-ray focal spot sizes range from a few millimeters down to a few micrometers. Reducing the source size reduces geometric unsharpness, thereby enhancing detail sensitivity. X-ray sources may offer multiple or variable focal spot sizes. Smaller focal spots produce higher resolution with reduced X-ray beam intensity, while larger focal spots can provide higher X-ray intensity with lower resolution. Microfocus X-ray tubes are available with focal spots that may be adjusted to as small as a few micrometers in diameter while still producing an X-ray beam of sufficient intensity so as to be useful for the CR examination of finely detailed parts.

B) Conventional focal spots of 1.0 mm and larger are useful at low geometric magnification values close to 1X. Fractional focal spots ranging from 0.4 mm to 1.0 mm are useful at geometric magnifications up to approximately 2X. Minifocus spots in the range of 0.1 mm up to 0.4 mm are useful at geometric magnifications up to 6X. Greater magnifications suggest the use of a microfocus spot size of less than 0.1 mm to minimize the effects of geometric unsharpness. Microfocus X-ray tubes are capable of focal spot sizes of less than 10 µm (10^{-8} m) and are useful for geometric magnification of more than 100X.

11.4.7.1.2 Storage Phosphor Imaging Plate

The SPIP functions by converting the radiation input signal containing part information into a corresponding optical signal while preserving the maximum amount of part information. The SPIP is a two-dimensional area detector providing an area of view.

11.4.7.1.3 Storage Phosphor Imaging Plate Reader

The SPIP Reader functions by optically scanning the imaging plate, collecting the emitted light, converting the light to an electronic signal, then converting this signal to a digital format.

11.4.7.1.4 Electronic Imaging Processing Systems

The function of the electronic imaging processing system is to take the output of the SPIP Reader and create a digital file for image display and operator interpretation.

The electronic imaging processing system includes all of the electronics and interfaces after the SPIP Reader, image enhancement, and image display.

The electronic imaging processing system is the means by which examination information will be interpreted. Exercise care in determining which image processing techniques are most beneficial for the particular application. Directional spatial filtering operations, for example, must be given special attention as certain feature orientations are emphasized while others are suppressed.

11.4.7.1.5 Image Display

The function of the image display is to convey information about the part to the system operator. The image display size, spatial resolution, magnification, and ambient lighting are important system considerations.

11.4.7.1.6 Examination Record Archiving System

Many applications require an archival quality examination record of the examination. The archiving system may take many forms, a few of which are listed in A through E below. Each archiving systems has its own peculiarities as to image quality, archival storage properties, equipment and media cost. The reproduction quality of the archival method should be sufficient to demonstrate the same image quality as was used to qualify the examination system.

A) Film or paper radiographic image.

B) Photograph of the actual image display.

C) Hard copy device used to create a paper copy image from the electronic signal.

D) Digital recording on magnetic disk or tape used to store the image

E) Digital recording on optical disk used to store the image

11.4.7.1.7 Examination Record Data

The examination record should contain sufficient information to allow the examination to be reevaluated or duplicated. Examination record data should be recorded during the CR examination. Examination record data should be in accordance with Guide E1475 providing the following minimum data:

Examination system designation, examination date, operator identification, operating turn or shift, and other pertinent and customer data:

Specific examination data as to part number, batch serial number, and other applicable information.

A) Part orientation and examination site information by reference to unique part features within the field of view; and

B) System performance monitoring by recording the results of the prescribed examination system performance monitoring tests, as set forth in Section 5, at the beginning and end of a series of examination.

11.4.7.2 Performance Measurement

System performance parameters must be determined initially and monitored regularly to ensure consistent results. The best measure of total CR examination system performance can be made with the system in operation, utilizing a Representative Quality Indicator (RQI) similar to the part under actual operating conditions. This indicates the use of an actual or simulated part containing features that must be readily and accurately detected. Such an RQI will provide a reliable indication of the system's capabilities. Conventional wire or plaque-type Image Quality Indicators (IQIs) may be used in place of, or in addition to, the RQI.

11.4.7.2.1 Performance Measurement Intervals

System performance measurement techniques should be standardized so that performance measurement tests may be readily duplicated at specified intervals. System performance should be evaluated at sufficiently frequent intervals to minimize the possibility of time-dependent performance variations.

11.4.7.2.2 Measurement with Image Quality Indicators

System performance measurement using IQIs shall be in accordance with the ***American Association of State Highway and Transportation Officials (AASHTO)/AWS D1.5 Bridge Welding Code*** describing the use of IQIs. The IQIs should be placed on the part as close as possible to the area of interest. The use of wire-type IQIs should also take into account that the system may exhibit asymmetrical sensitivity, in which case the wire diameter axis shall be oriented along the system's axis of least sensitivity. Selection of IQI

thickness should be consistent with the thickness of the part along the radiation path length. IQIs are described in Practices E747 and E1025.

11.4.7.2.3 Measurement with Representative Quality Indicators

The RQI may be an actual part with known features that are representative of the range of features to be detected or may be fabricated to simulate the part with a suitable range of representative features. Alternatively, the RQI may contain known imperfections that have been verified independently. RQIs containing known, natural defects are useful on a single-task basis. Where standardization among two or more CR systems is required, a duplicate RQI should be used. The RQIs should approximate the part as closely as is practical, being made of the same material with similar dimensions and features in the area of interest. Manufactured RQIs should include features at least as small as those that must be reliably detected in the actual parts in locations where they are expected to occur in the actual part. Where features are internal to the part, it is permissible to produce the RQI in section. RQI details are a matter of agreement between the user and supplier. RQIs are described in ***Practice E1817***.

A) Use of an Representative Quality Indicator – The RQI should be placed into the system in the same position as the actual part.

11.4.7.2.4 Use of Calibrated Line Pair Test Pattern and Step Wedge

A calibrated line pair test pattern and step wedge may be used, if so desired, to determine and track performance in terms of spatial resolution and contrast sensitivity. The line pair test pattern is used without an additional absorber to evaluate system spatial resolution. The step wedge is used to evaluate system contrast sensitivity.

The step wedge must be made of the same material as the part with steps representing 100, 99, 98, and 97 percent of the thickest and the thinnest material sections to be examined. The thinner steps shall be contiguous to their respective 100 percent section thicknesses to facilitate discerning the minimum visible thickness step.

The line pair test pattern and the step wedge tests shall be conducted in a manner similar to the performance measurements for the IQI or RQI set forth in 11.4.7.2.2 and 11.4.7.2.3. It is permissible to adjust the X-ray energy and intensity to obtain a usable line pair test pattern image brightness. In the case of a radioscopic or X-ray generating system where the energy or intensity may not be adjusted, additional

filtration may be added at the radiation source to reduce the contrast to a useful level. Contrast sensitivity shall be evaluated at the same energy and intensity levels as are used for the CR technique.

A system that exhibits a spatial resolution of 3 line pairs/mm, a thin-section contrast sensitivity of 3 percent and a thick-section contrast sensitivity of 2 percent is considered to have an equivalent performance level of 3 – 2 percent - 3 1p/mm.

The line pair test pattern and the step wedge may be used to make more frequent periodic system performance checks than required in accordance with ***Section 11.4.7.2.1***. Resolution and contrast sensitivity checks must be correlated with IQI or RQI performance measurements. This may be done by first evaluating system measurement in accordance with ***Sections 11.4.7.2.2*** and ***11.4.7.2.3*** and immediately thereafter determining the equivalent spatial resolution and contrast sensitivity values.

11.4.7.2.5 Importance of Proper Environmental Conditions

Environmental conditions conducive to human comfort and concentration will promote examination efficiency and reliability. A proper examination environment will take into account temperature, humidity, dust, lighting, access, and noise level factors. Proper reduced lighting intensity is extremely important to provide for high-contrast glare-free viewing of images.

11.4.8 EXAMINATION INTERPRETATION AND ACCEPTANCE CRITERIA

11.4.8.1 Interpretation

Interpretation shall be performed by an operator in a typical CR environment.

11.4.8.2 Personnel Qualification

Personnel shall be qualified in accordance to the ***AASHTO/AWS D1.5 Bridge Welding Code***.

11.4.8.3 Accept/Reject Criteria

Accept/reject criteria shall be in accordance to the ***AASHTO/AWS D1.5 Bridge Welding Code*** or other applicable AWS welding code.

11.4.9 RECORDS, REPORTS, AND IDENTIFICATION OF ACCEPTED MATERIAL

If an examination record archiving requirement exists, refer to ***Section 11.4.7.1.7*** which outlines the information that should be a part of an archival examination record.

Example records and reports in digital format can be found in *Guide E1475*.

11.4.10 SAFETY CONDITIONS

Examination procedures shall be carried out under protective conditions so that personnel will not receive radiation dose levels exceeding that permitted by company, city, state, or national regulations. The recommendations of the National Council on Radiation Protection and Measurement Standard should be the guide to radiation safety.