



Standard Practice for Computed Radiology (Photostimulable Luminescence Method)¹

This standard is issued under the fixed designation E2033; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice² covers application details for computed radiology (CR) examination using a process in which photostimulable luminescence is emitted by the penetrating radiation detector, a storage phosphor imaging plate (SPIP). Because the techniques involved and the applications for CR examination are diverse, this practice is not intended to be limiting or restrictive, but rather to address the general applications of the technology and thereby facilitate its use. Refer to Guides E94 and E2007, Terminology E1316, and Practices E747 and E1025, and 21 CFR 1020.40 and 29 CFR 1910.96 for additional information and guidance.

1.2 The general principles discussed in this practice apply broadly to penetrating radiation CR systems. However, this document is written specifically for use with X-ray and gamma-ray systems. Other CR systems, such as those employing neutrons, will involve equipment and application details unique to such systems.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific safety statements, see Section 10 and 21 CFR 1020.40 and 29 CFR 1910.96.

2. Referenced Documents

2.1 ASTM Standards:³

E94 Guide for Radiographic Examination

E747 Practice for Design, Manufacture and Material Group-

¹ This test method is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) Method.

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² For ASME Boiler and Pressure Code applications, see related Practice SE-2033 in Section II of that code.

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

ing 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 (IQI) Used for Radiology

E1316 Terminology for Nondestructive Examinations

E1453 Guide for Storage of Magnetic Tape 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 Radiography

2.2 ASNT Standards:

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing⁴

ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel⁴

2.3 Federal Standards:

Title 21, CFR 1020.40 Safety Requirements of Cabinet X-Ray Systems⁵

Title 29, CFR 1910.96 Ionizing Radiation⁵

2.4 AIA Standard:

NAS-410 Certification and Qualification of Nondestructive Testing Personnel⁶

3. Summary of Practice

3.1 A CR examination system can be used for a wide variety of applications. 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 practice establishes the basic parameters for the application and control of the CR method.

⁴ Available from American Society for Nondestructive Testing, 1711 Arlington Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

⁵ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

⁶ Available from Aerospace Industries Association of America, Inc., 1250 Eye St. NW, Washington, D.C. 20005.

4. Significance and Use

4.1 The X-, gamma-ray detector discussed in this practice 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. This practice is written so that it can be specified on the engineering drawing, specification, or contract and must be supplemented by a detailed procedure (see Section 6 and Annex A1 and Annex A2).

5. Equipment

5.1 *System Configuration*—Different examination systems configurations are possible, and it is important to understand the advantages and limitations of each. It is important that the optimum system be selected for each examination requirement through a careful analysis of the benefits and limitations of the available system components and the chosen system configuration. The provider as well as the user of the examination services should be fully aware of the capabilities and limitations of the examination system that is proposed for examination of the part. The provider and the user of examination services shall agree upon the system configuration to be used for each application under consideration and how its performance is to be evaluated.

5.1.1 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 CRT display.

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

6. General Procedure Considerations

6.1 The purchaser and supplier shall mutually agree upon a written procedure using the applicable annex of supplemental requirements and also consider the following general requirements.

6.1.1 *Equipment Qualifications*—A listing of the system features that must be qualified to ensure that the system is capable of performing the desired examination.

6.1.2 *Source Parameter*—A listing 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 distances, range of object to image plane distances, and source to image plane distances.

6.1.3 *Image Processing Parameters*—A listing 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 filtering. Great care should be exercised in the selection of 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.

6.1.4 *Image Display Parameters*—A listing 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.

6.1.5 *Accept-Reject Criteria*—A listing of the expected kinds of part imperfections and the rejection level for each.

6.1.6 *Performance Evaluation*—A listing of the qualification tests and the intervals at which they are to be applied to ensure the system is suitable for its intended purpose.

6.1.7 *Image Archiving Requirements*—A listing of the requirements, if any, for preserving a historical record of the examination results. The listing may include examination images along with written or electronically recorded alphanumeric or audio narrative information, or both, sufficient to allow subsequent reevaluation or repetition of the examination.

6.1.8 *Qualifications*—Nondestructive testing (NDT) personnel shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or a standard such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, or a similar document.

7. CR Examination System Performance Considerations and Measurement

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.

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 the CR examination requirements and has the added safety feature of discontinued radiation production when switched off. A radioisotope source has the advantages of small physical size, portability, simplicity, and uniformity of output.

7.1.1.1 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.

7.1.1.2 Conventional focal spots of 1.0 mm and larger are useful at low geometric magnification values close to 1 \times . Fractional focal spots ranging from 0.4 mm up to 1.0 mm are useful at geometric magnifications up to approximately 2 \times . Minifocus spots in the range from 0.1 mm up to 0.4 mm are useful at geometric magnifications up to about 6 \times . 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 magnifications of more than 100 \times .

7.1.2 *SPIP*—The storage phosphor imaging plate is a key element. It has the function of 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 field of view.

7.1.3 *SPIP Reader*—The SPIP reader has the function of optically scanning the imaging plate, collecting the emitted light, converting the light to an electronic signal, then converting this signal to a digital format.

7.1.4 *Electronic Imaging Processing System:*

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

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

7.1.4.3 The digital image processing system warrants special attention because it is the means by which examination information will be interpreted. Great care must be exercised 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.

7.1.5 *Image Display:*

7.1.5.1 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.

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 7.1.6.1 through 7.1.6.5. Each archiving system has its own peculiarities as to image quality, archival storage properties, equipment, and media cost. The examination record archiving system should be chosen on the basis of these and other pertinent parameters, as agreed upon by the provider and user of services. The reproduction quality of the archival method should be sufficient to demonstrate the same image quality as was used to qualify the examination system.

7.1.6.1 Film or paper radiographs of the part made under the same conditions as the examination image.

7.1.6.2 Photograph of the actual image display.

7.1.6.3 CRT hard copy device used to create a paper copy image from the CRT signal.

7.1.6.4 Digital recording on magnetic disk or tape used to store the image of the part digitally.

7.1.6.5 Digital recording on optical disk used to store the image of the part digitally.

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 contemporaneously with the CR examination image. Examination record data should be in accordance

with Guide E1475 and may be in writing or a voice narrative, providing the following minimum data:

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

7.1.7.2 Specific examination data as to part number, batch, serial number, and so forth (as applicable);

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

7.1.7.4 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 examinations.

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 actual or simulated features that must be reliably 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. Performance measurement methods are a matter of agreement between the provider and user.

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, as agreed upon by the supplier and user, to minimize the possibility of time-dependent performance variations.

7.2.2 *Measurement with IQIs*—System performance measurement using IQIs shall be in accordance with accepted industry standards 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.

7.2.3 *Measurement with RQIs*—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

sections. RQI details are a matter of agreement between the user and supplier. RQIs are described in Practice [E1817](#).

7.2.3.1 Use of an RQI—The RQI should be placed into the system in the same position as the actual part.

7.2.3.2 Examination Techniques—Radiation beam energy, intensity, focal spot size, enlargement, digital image processing parameters, and other system variables utilized for examination of the RQI shall be identical to those used for the actual examination.

7.2.4 Use of Calibrated Line Pair Test Pattern and Step Wedge:

7.2.4.1 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.

7.2.4.2 The step wedge must be made of the same material as the part with steps representing 100, 99, 98, and 97 % of both the thickest and the thinnest material sections to be examined. The thinner steps shall be contiguous to their respective 100 % section thicknesses to facilitate discerning the minimum visible thickness step. Other thickness steps are permissible upon agreement between the user and the supplier.

7.2.4.3 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 [7.2.2](#) and [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 radioisotope 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.

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

7.2.4.5 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 [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 [7.2.2](#) or [7.2.3](#) and immediately thereafter determining the equivalent spatial resolution and contrast sensitivity values.

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.

8. Examination Interpretation and Acceptance Criteria

8.1 Interpretation—Interpretation is performed by an operator in a typical CR environment.

8.2 Personnel Qualification—The supplier and user should reach an agreement as to operator qualifications, including duty and rest periods.

8.3 Accept/Reject Criteria—Accept/reject criteria is a matter of contractual agreement between the user and the supplier.

9. Records, Reports, and Identification of Accepted Material

9.1 Records and reports are a matter of agreement between the user and the supplier. If an examination record archiving requirement exists, refer to [7.1.7](#), which outlines the necessary information that should be a part of an archival examination record.

9.2 Example records and reports in digital format can be found in Guide [E1475](#).

10. Safety Conditions

10.1 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 (NCRP) Standard should be the guide to radiation safety.

11. Keywords

11.1 analog; computed radiology; detector; digital; display; examination; image; processor; source; storage phosphor imaging plate

ANNEXES

(Mandatory Information)

A1. DEPARTMENT OF DEFENSE CONTRACTS, SUPPLEMENTAL REQUIREMENTS

A1.1. Scope

A1.1.1 *Purpose*—This annex is to be used in conjunction with Practice E2033. It permits the use of, and gives guidance on, the implementation of CR examination for materials, components, and assemblies, when specified in the contract documents. The requirements described herein allow the use of CR for new applications as well as to replace radiology when inspection coverage, greater throughput, or improved inspection economics can be obtained, provided a satisfactory level of image quality can be demonstrated.

A1.1.2 *Application*—This annex provides guidelines for a written procedure as required in 6.1 of Practice E2033. Should the requirements in this annex conflict with any other requirements of Practice E2033, then this annex takes precedence. The requirements of this annex are intended to control the quality of the examination and not to specify the accept/reject criteria. Accept/reject criteria are provided in other contract documents.

A1.2 Referenced Documents

A1.2.1 In addition to those documents referenced in Practice E2033, the following standards are applicable to the extent specified herein.

A1.2.1.1 *ASTM Standards:*
E1742 Practice for Radiographic Examination³

A1.2.1.2 *Government Standards*—Unless otherwise stated, the issues of these documents are those listed in the Defense Index of Specifications and Standards (DODISS), and supplement thereto, cited in the contract document.

A1.2.2 *Order of Precedence*—In the event of conflict between the text of this annex and the references listed in A1.2.1, this annex shall take precedence. However, nothing in this annex shall supersede applicable laws and regulations unless a specific exemption has been obtained from the cognizant authorities.

A1.3. Terminology

A1.3.1 *representative quality indicator (RQI)*—an actual or simulated part containing actual or simulated features that must be reliably detected.

A1.3.2 *component*—the part or parts described, assembled, or processed to the extent specified by the drawing.

A1.3.3 *contracting agency*—a prime contractor, subcontractor, or government agency that procures CR examination services.

A1.3.4 *contract documents*—the procuring contract and all drawings, specifications, standards, and other information included with or referred to by the procuring contract.

A1.3.5 *mandatory examination requirements*—those CR examinations that are a part of the required radiologic examinations specified in the contract documents.

A1.3.6 *NDT facility*—the organization that is responsible for the providing of nondestructive examination services.

A1.3.7 *optional examination*—those examinations that are conducted for process verification or information only and are not a part of the required radiologic examination specified in the contract documents.

A1.3.8 *part*—the material, component, or assembly that is the subject of the examination.

A1.3.9 *prime contractor*—a contractor having responsibility for the design control and delivery to the Department of Defense for system/equipment, such as aircraft, engines, ships, tanks, vehicles, guns and missiles, ground communications and electronic systems, ground support, and test equipment.

A1.3.10 *written procedure*—a series of steps that are to be followed in a regular definite order. The system operator shall follow the written procedure to consistently obtain the desired results and image quality level when performing the examination. The development of a technique should usually precede the preparation of a written procedure.

A1.3.11 Other definitions not given herein shall be as specified in Terminology E1316.

A1.4 General Requirements

A1.4.1 *Personnel Qualification*—Personnel shall be qualified and certified in accordance with the general requirements of SNT-TC-1A, until specific requirements are included. System qualification, the development of examination techniques, scan plans, and the overall implementation of the examination in accordance with this annex shall be under the control and supervision of a qualified SNT-TC-1A Level III, or equivalent, with additional CR training and experience or in conjunction with an individual having the necessary training and experience in CR examination.

A1.4.2 *Safety*—The performance of the examination shall present no hazards to the safety of personnel or property. Applicable federal, state, and local radiation safety codes shall be adhered to. All procedures shall be performed so that personnel shall receive the minimum dosage and shall in no case exceed federal, state, and local limits.

A1.4.3 *Archival Recording of Mandatory Examination*—When required by contractual agreement, the CR examination record shall contain the results of mandatory examinations. The examination record shall be suitably archived for a period of time not less than five years from the examination date or as may otherwise be required in the contract documents. Efficient examination record recall shall be available at any time over the record retention period. The examination record shall be traceable to the part (by serial number or other means) or to the batch or lot number, if tested in groups. Mandatory examinations shall be specified in the contract documents.

A1.4.3.1 *Examination Record*—The recorded examination record for mandatory examinations shall include the written results of the examination and the CR image, if an image is utilized in the accept/reject decision-making process. The recorded image shall be provided with such additional information as may be required to allow the subsequent off-line review of the examination results and, if necessary, the repeating of the examination.

A1.4.3.2 *Image Recording Media*—The CR image shall be recorded on a medium that is appropriate to the examination requirement. The recorded image shall reference the examination zones in such a way that the reviewer can confirm that all zones have been covered. The recorded image shall provide an image quality at least equal to that for which the system is qualified. The recording media shall be capable of maintaining the required image quality for the required record storage period or not less than five years from the recording date. The image record shall be maintained in an operable condition for the duration of the record storage period, measured from the date when the last image was recorded.

A1.4.3.3 *Recording Media Storage Conditions*—Media storage and handling shall be in accordance with Guides E1453 and E1475.

A1.4.4 *Image Quality Indicators*—Image quality indicators must be chosen with care to demonstrate the CR system's ability to detect discontinuities or other features that are of interest. Practices E1025 plaque-type, E747 wire-type IQIs, and E1817 RQIs with real or simulated defects, to match the application, are all acceptable unless a particular IQI or RQI is specified in the contract documents. The selected IQI or RQI shall be detailed in the written procedure. An IQI or RQI may not be required for the following CR examinations:

A1.4.4.1 When performing CR to identify adequate defect removal or grind-out, the final acceptance examination shall include an IQI or RQI,

A1.4.4.2 Examinations to show material details or contrast between two or more dissimilar materials, in component parts, or in assemblies, including honeycomb areas for the detection of fabrication irregularities or the presence or absence of material,

A1.4.4.3 Examinations of electronic components for contamination, loose or missing elements, solder balls, broken or misplaced wires or connectors, and potted assemblies for broken internal components or missing potting compound,

A1.4.4.4 Other CR examinations, and

A1.4.4.5 Where the use of an IQI is impractical or ineffective, an alternate method such as an RQI may be used, subject to the approval of the contracting agency.

A1.4.5 *Classification of Part Zones for CR*—The classification of parts into zones for various accept/reject criteria shall be determined from the contract documents.

A1.5 Detailed Requirements

A1.5.1 *Application Qualification:*

A1.5.1.1 *New Applications*—CR may be used when appropriate for new examination requirements, provided the required performance, including image quality, can be met.

A1.5.1.2 *Replacement of Existing Radiologic Applications*—When agreed to by the contracting officer, CR may be used to replace or augment existing radiologic applications, provided that the part features of interest are shown.

A1.5.2 *Written Procedure*—It shall be the responsibility of the NDT facility to develop a written examination procedure to ensure the effective and repeatable examination of the part. Those portions of the contract document that specify and detail the examination shall become an appendix to the written procedure. The written procedure must be approved by the Level III of the NDT facility. Where required, the written procedure shall be approved by the contracting agency prior to use. The written procedure shall include as a minimum the following information:

A1.5.2.1 A drawing, sketch, or photograph of the component that shows the radiation beam axis, position(s) of the detector, and applicable IQI or RQI for each and all variations of the part orientation and beam energy,

A1.5.2.2 A physical description of the part, including size, thickness, weight, and composition,

A1.5.2.3 Classification of the part into zones,

A1.5.2.4 Part masking, if used, for each required view,

A1.5.2.5 Added radiation source collimation, expressed in terms of the radiation field dimensions on the source side of the part, for each required view,

A1.5.2.6 Detector field of view for each required view,

A1.5.2.7 Detector diaphragm settings, expressed in terms of field of view at the detector, for each required view,

A1.5.2.8 The allowable range of radiation energy and beam current or source isotopic identification and intensity and the focal spot or source size for each required view,

A1.5.2.9 Added beam filtration, if used, for each required view,

A1.5.2.10 The inspection geometry and coverage for each required view,

A1.5.2.11 Type of IQI or RQI used and the required quality level,

A1.5.2.12 All hardware and software settings that can be changed by the operator to affect the outcome of the examination. Such settings include, but are not limited to, image processor variables, and

A1.5.2.13 The recording media and storage image format for mandatory image storage.

A1.5.3 *Part Examination*—The number of parts to be examined and the coverage required for each part shall be specified in the contract documents. If not specified, all parts shall receive 100 % coverage as detailed in the written procedure.

A1.5.4 *Image Quality*, is as specified in the contract documents. Image quality assessment shall be performed using the same system parameters as in the inspection and as documented in the written procedure.

A1.5.4.1 The IQI may be placed on the part or on a mounting block, at or near the part location, following the requirements of Practice E1742. In the case of small fields of view or other situations where it is not practical to place the IQI

in the field of view with the part and maintain it normal to the X-ray beam, the IQI may be imaged immediately before and after the part examination. Batch quantities of similar parts need not have IQI images made between each part, at the discretion of the Level III. The examination results shall be invalid if the before and after IQI images fail to demonstrate the required sensitivity. The before and after IQI images shall be considered a part of interpretation and archiving purposes.

A1.5.4.2 With written permission from the contracting agency, other IQIs or an RQI with natural or artificial flaws may be used instead of the specified IQI.

A1.5.5 *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.

A1.5.6 *Repair of System*—Repair or replacement of key system components, including, but not limited to, the radiation source, image forming, 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 year. The qualification statement shall be posted on the system. The results of the qualification tests shall be maintained in the system equipment file until the completion of the next qualification procedure or the expiration of the archival image retention period, whichever is longer.

A1.5.7 *Image Interpretation*—System qualification in accordance with Section 7 of Practice E2033 applies.

A1.5.8 *Feature Size Determination*—Where feature measurement from the image is required, the written procedure shall include methodology for determining and maintaining the accuracy of the selected measurement method.

A1.5.8.1 *Feature Measurement by Comparison*—This method involves comparing the part feature with a known, observable dimension, which 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.

A1.5.9 *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.

A1.5.10 *Timing of Examination*—The examination shall be performed at the time of manufacturing, assembly, or rework as required by the contract documents.

A1.5.11 *Identification*—A means shall be provided for the positive identification of the part to the archival inspection record. Archived images shall be annotated to agree with the part identification.

A1.5.12 *Locating the Examination Areas*—Whenever more than one image is required for a weldment or other part, location markers shall be placed on the part so that the orientation of the part and the location of part features relative to the field of view may be established. This requirement does not apply to the examination of simple or small shapes where the part orientation and coverage is not in question.

A1.5.13 *Surface Preparation*—Parts may be inspected without surface preparation, except when required to remove surface conditions that may interfere with proper interpretation of the image.

A1.5.14 *Detailed Data*—The supplier of examination services shall keep the written procedure, qualification documentation, and the signed inspection reports or tabulated results, or both, for five years from the examination date, unless otherwise specified in the contract documents.

A1.5.15 *Reexamination of Repairs*—When a repair has been performed, the repaired areas shall be reexamined using the same technique to evaluate the effectiveness of the repair. Each repaired area shall be identified with R1, R2, R3, and so forth, to indicate the number of times repair was performed.

A1.5.16 *Retention of Examination Records*—Mandatory examination records and associated images shall be stored in a proper repository at the contractor's plant for five years from the date from which they were made. Special instructions, such as storage for other periods of time, making backup copies, copying the records to other media, or having the records destroyed, shall be specified in the contract documents.

A1.5.17 *Rejection of Parts*—Parts containing defects specified in the contract documents shall be separated from acceptable material, appropriately identified as discrepant, and submitted for material review when required by the contract documents.

A1.5.18 *Reexamination*—When there is a reasonable doubt as to the ability to interpret the results because of improper execution or equipment malfunction, the part shall be reexamined using the correct procedure. If the problem is not resolved by reexamination, the procedure shall be reviewed by the Level III of the NDT facility and adjusted, if necessary. Reference exposures may be made using conventional film radiography, if possible. If the reexamination was caused by equipment malfunction, the equipment may not be returned to service until the malfunction is repaired and the equipment is requalified to the current qualification requirements in accordance with Section 7 of Practice E2033.

A1.5.19 *Part Marking*—The marking of parts shall be as specified in Practice E1742.

A1.6 Notes

A1.6.1 This section contains information of a general or explanatory nature and is not mandatory. (**Warning**—Active electronic components and some materials, such as

tetrafluoroethylene, are subject to radiation damage if exposed to large doses of radiation. While normal examinations should cause no problem, extended periods of radiation exposure should be avoided.)

A1.6.1.1 Human Factors—The success of examinations that involve human image interpretation are, like other radiological techniques, subject to human factors. Careful attention should be given to the human environment where image interpretation takes place, to make it as conducive to correct, consistent image interpretation as possible. Measures should also be implemented to ensure that fatigue does not interfere with correct and consistent image interpretation.

A1.6.1.2 Use of IQI(s)—As with conventional film radiography, the achievement of the required IQI sensitivity does not guarantee the ability to find all discontinuities down to the minimum defect size. Many discontinuities, especially those of a planar nature, are very orientation sensitive. For this

reason, the use of RQIs with real or simulated discontinuities may more accurately characterize the ability of the system to detect orientation-sensitive discontinuities.

A1.6.1.3 Use of Image-Processing Techniques—Care should be exercised in applying digital image-processing techniques to evaluate the overall effect upon image quality. For example, contrast enhancement techniques may emphasize contrast in one brightness range while decreasing contrast in other brightness ranges. Some spatial filters have directional aspects whereby features in one direction are emphasized while those in the orthogonal direction are de-emphasized. Such cautions are intended to cause the careful evaluation of digital image-processing techniques and not to discourage their use.

A1.6.1.4 Feature Size Determination—As with conventional film radiography, great care must be exercised in trying to assess part feature dimensions from a two-dimensional projected view.

A2. NONGOVERNMENT CONTRACT SUPPLEMENTAL REQUIREMENTS

A2.1. Scope

A2.1.1 Purpose—This annex is to be used in conjunction with Practice E2033. This annex includes application-specific details as may be agreed upon by the purchaser and the supplier of CR examination services.

A2.1.2 Application—This annex satisfies the requirements of 6.1 of Practice E2033. Should this annex conflict with any other requirements of Practice E2033, this annex shall prevail. The requirements of this annex are intended to control the quality of the examination and not to specify the accept/reject criteria for the part. Accept/reject criteria are provided in other contract documents.

A2.2. Terminology

A2.2.1 representative quality indicator (RQI)—an actual or simulated part containing actual or simulated features that must be reliably detected.

A2.2.2 component—the part or parts described, assembled, or processed to the extent specified by the drawing.

A2.2.3 contract documents—the procuring contract and all drawings, specifications, standards, and other information included with or referred to by the procuring contract.

A2.2.4 contractor—a contractor having first-level responsibility for the design, manufacture, and delivery of an end item. When an examination is required, the contractor is the user of examination services.

A2.2.5 mandatory examination—those examinations that are a part of the required examinations specified in the contract documents.

A2.2.6 nondestructive testing (NDT) facility—the organization that is responsible for providing nondestructive examination services.

A2.2.7 optional examination—those examinations that are conducted for process verification or information only and are not a part of the required radiologic examinations specified in the contract documents.

A2.2.8 provider of CR services—a contractor, subcontractor, or other entity that provides computed radiology (CR) examination services.

A2.2.9 part—the material, component, or assembly that is the subject of the examination.

A2.2.10 user of CR services—a contractor, subcontractor, or other entity that procures CR examination services. The provider and user of CR examination services may be a part of the same organization or different organizations.

A2.2.11 written procedure—a written series of steps, describing the examination, that are to be followed in a regular definite order. The system operator shall follow the written procedure to consistently obtain the desired results and image quality level when performing the examination. The development of a technique usually precedes the preparation of a written procedure.

A2.2.12 Other definitions not given herein shall be as specified in Terminology E1316.

A2.3 General Requirements

A2.3.1 Personnel Qualification—NDT personnel shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard, such as SNT-TC-1A, ANSI/ASNT CP-189, 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. Operation of the system,

including interpretation of the image, shall be made by qualified Level II personnel.

A2.3.2 Safety—Performance of the examination shall present no hazards to the safety of personnel or property. Applicable federal, state, and local radiation safety codes shall be adhered to. All procedures shall be performed so that personnel shall receive the minimum dosage and in no case exceed federal, state, and local limits.

A2.3.3 Archival Recording of Mandatory CR Examinations—The examination record shall contain the results for mandatory examinations. The examination record shall be suitably archived for a period of one year after the date of examination or for a longer time if specified in the contract documents. Efficient examination record recall shall be available at any time over the record retention period. The examination record shall be traceable to the part by serial number or other means. This requirement will not apply to optional examinations that are not specified in the contract documents.

A2.3.3.1 Examination Record—The recorded examination record for mandatory examinations shall include the written results of the examination and the image, if an image is utilized in the accept/reject decision-making process. The recorded image shall be provided with such additional information as may be required to allow the subsequent off-line review of the examination results and, if necessary, repeating the examination.

A2.3.3.2 Image Recording Media—The image shall be recorded on a media that is appropriate to the examination requirement. The recorded image shall reference the examination zones in such a way that the reviewer can confirm that all zones have been covered. The recorded image shall provide an image quality at least equal to that for which the system is qualified. The recording media shall be capable of maintaining the required image quality for the required record storage period or not less than five years from the recording date. The recorded image playback shall be maintained in an operable condition for the duration of the record storage period measured from the date when the last image was recorded.

A2.3.3.3 Recording Media Storage Conditions—Media storage and handling shall be in accordance with Guide **E1453**.

A2.3.3.4 Other Recording—When the recording of the examination record is not in fulfillment of mandatory archival recording requirements, other recording methods and media may be used.

A2.3.4 Image Quality Indicators (IQI)—An IQI must be chosen with care to demonstrate the CR system's ability to detect discontinuities or other features of interest. Practices **E1025** plaque-type, **E747** wire-type IQIs, and **E1817** RQIs with real or simulated discontinuities that match the application are all acceptable unless a specific IQI is specified in the contract documents. The selected IQI or RQI shall be detailed in the written procedure but may not be required for the following examinations:

A2.3.4.1 Examining assemblies for debris or foreign objects.

A2.3.4.2 For adequate defect removal or grind-out. However, the final acceptance examination shall include an IQI or RQI.

A2.3.4.3 Optional examinations.

A2.3.4.4 Where the use of a specified IQI is impractical or ineffective, an alternate method such as an RQI may be used, subject to the approval of the contracting agency.

A2.3.5 Classification of Part Zones—The classification of parts into zones for various accept/reject criteria shall be determined from the contract documents. In cases in which no accept/reject criteria is specified, the Level III of the NDT facility shall document those anomalies considered critical and indicate in writing that no formal accept/reject criteria was provided.

A2.4 Detailed Requirements

A2.4.1 Application Qualification—CR may be used when appropriate for new as well as existing radiologic examination requirements, provided that the required performance, including image quality, can be met. When CR is used to replace or augment existing radiologic applications, the part features of interest will be shown.

A2.4.2 Written Procedure—It shall be the responsibility of the NDT facility to develop a written examination procedure to ensure the effective and repeatable examination of the part. Those portions of the contract document that specify and detail CR examination shall become an appendix to the written procedure. The written procedure must be written or approved by the Level III of the NDT facility. When required, the written procedure shall be approved by the contracting agency prior to use. The written procedure shall include as a minimum the following information:

A2.4.2.1 A drawing, sketch, or photograph of the component that shows the radiation beam axis, position(s) of the detector and applicable IQI for each and all variations of the part orientation, and beam energy. This requirement may be expressed in coordinates for automated systems having calibrated manipulation systems.

A2.4.2.2 A physical description of the part, including size, weight, and composition.

A2.4.2.3 Classification of part into zones.

A2.4.2.4 Part masking, if used, for each required view.

A2.4.2.5 Added radiation source collimation, expressed in terms of the radiation field dimensions on the source side of the part for each required view.

A2.4.2.6 Detector field of view for each required view.

A2.4.2.7 Detector diaphragm settings, expressed in terms of field of view at the detector for each required view.

A2.4.2.8 The allowable range of radiation energy and beam current or source isotopic identification and intensity and the focal spot or source size for each required view.

A2.4.2.9 Added beam filtration, if used, for each required view.

A2.4.2.10 The inspection geometry and coverage for each required view.

A2.4.2.11 Type of IQI or RQI used and the required quality level.

A2.4.2.12 All hardware and software settings that can be changed by the operator to affect the outcome of the examination. Such settings include, but are not limited to, image processor variables.

A2.4.2.13 The recording media and stored image format for mandatory image storage.

A2.4.3 *Part Examination*—The number of parts to be examined and the coverage required for each part shall be specified in the contract documents. If not specified, all parts shall receive 100 % coverage as detailed in the written procedure.

A2.4.4 *Image Quality*—As specified in the contract documents. Image quality assessment shall be made in the same mode as that used for the inspection.

A2.4.4.1 The IQI may be placed on the part or on a mounting block at or near the part location. In the case of small fields of view or other situations where it is not practical to place the IQI in the field of view with the part and maintain it normal to the X-ray beam, the IQI may be imaged immediately before and after the part examination or batch of parts if they are similar. The CR examination results shall be invalid if the before and after IQI images fail to demonstrate the required image quality. Both before and after IQI images constitute the part image for CR image interpretation and archiving purposes.

A2.4.5 *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.

A2.4.6 *Repair of System*—Repair or replacement of key system components, including, but not limited to, the radiation source, image forming, 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 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.

A2.4.7 *Image Interpretation*—System qualification in accordance with Section 7 of Practice E2033 applies.

A2.4.8 *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.

A2.4.8.1 *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.

A2.4.9 *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.

A2.4.10 *Timing of Examination*—The examination shall be performed at the time of manufacturing, assembly, or rework as required by the contract documents.

A2.4.11 *Identification*—A means shall be provided for the positive identification of the part to the archival inspection record. Archived images shall be annotated to agree with the part identification.

A2.4.12 *Locating the Examination Areas*—Whenever more than one image is required for a weldment or other part, location markers shall be placed on the part so that the orientation of the part and the location of part features relative to the field of view may be established. Also, this requirement does not apply to the examination of simple or small shapes where the part orientation is obvious and coverage is not in question.

A2.4.13 *Surface Preparation*—Parts may be examined without surface preparation except as may be required to remove surface conditions that may interfere with proper interpretation of the image.

A2.4.14 *Detailed Data*—The provider of CR examination services shall keep the written procedure, the qualification documentation, and the signed examination reports or tabulated results for five years from the examination date unless otherwise specified in the contract documents.

A2.4.15 *Reexamination of Repairs*—When repair has been performed, the repaired areas shall be reexamined using the same CR technique to evaluate the effectiveness of the repair. Each repaired area shall be identified with R1, R2, R3, and so forth, to indicate the number of times repair was performed.

A2.4.16 *Retention of Examination Record*—Mandatory examination records and associated CR images shall be stored in a proper repository at the contractor's plant for one year from the date on which they were made. Special instructions, such as storage for other periods of time, making backup copies, copying the records to other media, or having the records destroyed shall be specified in the contract documents.

A2.4.17 *Rejection of Parts*—Parts containing defects specified in the contract documents shall be separated from acceptable material, appropriately identified as discrepant, and submitted for material review when required by the contract documents.

A2.4.18 *Part Disposition*—Parts that have undergone examination shall be marked or physically separated in such a manner so as to minimize the possibility of rejected or questionable parts being confused with acceptable ones.

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