INTERNATIONAL

**Designation: ~~E2445 – 05 (Reapproved 2010)~~ E2445/E2445M – 14**

# Standard Practice for ~~Qualification~~ Performance Evaluation and Long-Term Stability of Computed ~~Radiology~~Radiography Systems[1]

This standard is issued under the fixed designation ~~E2445;~~E2445/E2445M; 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 practice specifies the fundamental parameters of computed radiography systems to assure satisfactory and repeatable results for nondestructive testing.~~

1.1 This practice describes the evaluation of Computed Radiology (CR) systems for industrial ~~radiography.~~radiology. It is intended to ensure that the evaluation of image quality, as far as this is influenced by the ~~scanner/IP~~CR system, meets the needs of users ~~and enables the test of long-term stability.~~ of this standard, and their customers, and enables process control and long-term stability of the CR system.

1.2 This practice specifies the fundamental parameters of CR systems to be measured to determine baseline performance, and to track the long term stability of the system. These tests are for applications up to 320kV. When greater than 320kV or when a gamma source is used, these tests may still be used to characterize a system, but may need to be modified as agreed between the user and cognizant engineering organization (CEO).

1.3 The CR system performance tests specified in this practice shall be completed upon acceptance of the system from the manufacturer and at intervals specified in this practice to monitor long term stability of the system. The intent of these tests is to monitor the system performance degradation and to identify when an action needs to be taken when the system degrades by a certain level.

1.4 ~~Each of the tests described may be performed with individual gages specified. The user shall decide which tests shall be used for system control using individual test objects or the CR test phantom~~The use of gauges[2] ~~(~~(provided~~Appendix X1~~). ~~The computed radiological tests, specified as "user tests" in this practice, may be utilized at appropriate intervals determined by the user, based on the application of the examination operations. The~~ in this standard is mandatory for each test. In the event these tests or gauges are not sufficient, the user, in coordination with the CEO shall develop additional or modified tests, test objects, gauges, or image quality indicators to evaluate the CR system. Acceptance levels for these ALTERNATE tests shall be ~~appropriate for the materials and range of use of the system. Fading, uniformity, and erasure tests shall also be part of the control system. All other tests for qualification and capability are to be performed and certified by the CR equipment manufacturer.~~ determined by agreement between the user and CEO.

1.5 The values stated in either SI units or inch-pound units are to be regarded ~~as the standard. Values in inch-pound units are for information purposes.~~separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *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.*

[1] This practice 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] The sole source of supply of the apparatus shown in Appendix X2 known to the committee at this time is ~~Nuclear Associates, A Division of Cardinal Health, 120 Andrews Road, Hicksville, NY 11801, Phone: 1-888-466-8257, Catalog Number: 07-605-2435.~~ Rockwell Collins' ARINC, 1300 Thomas Drive, Panama City Beach, FL 32408, Phone: 405-605-7095, ARINC part number A0295224002 (USAF design) or A0295224003 (NAVAIR design). The NAVAIR design includes two additional test targets that are not used in this test standard. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.[1]

## 2. Referenced Documents

2.1 *ASTM Standards:*[3]

E746 Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems
E1316 Terminology for Nondestructive Examinations
E1647 Practice for Determining Contrast Sensitivity in Radiology
E2002 Practice for Determining Total Image Unsharpness in Radiology
E2007 Guide for Computed Radiography
E2033 Practice for Computed Radiology (Photostimulable Luminescence Method)
E2446 Practice for Classification of Computed Radiology Systems

## 3. Terminology

3.1 *Definitions*—The definition of terms relating to gamma- and X-radiology, which appear in Terminology E1316, Guide E2007, and Practice E2033 shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aliasing*—~~pre-sampled high spatial frequency signals beyond the Nyquist frequency (given by the pixel distance) reflected back into the image at lower spatial frequencies.~~artifacts that appear in an image when the spatial frequency of the input is higher than the output is capable of reproducing.

[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.

3.2.1.1 *Discussion*—

This will often appear as jagged or stepped sections in a line or as moiré patterns (see Fig. 1).

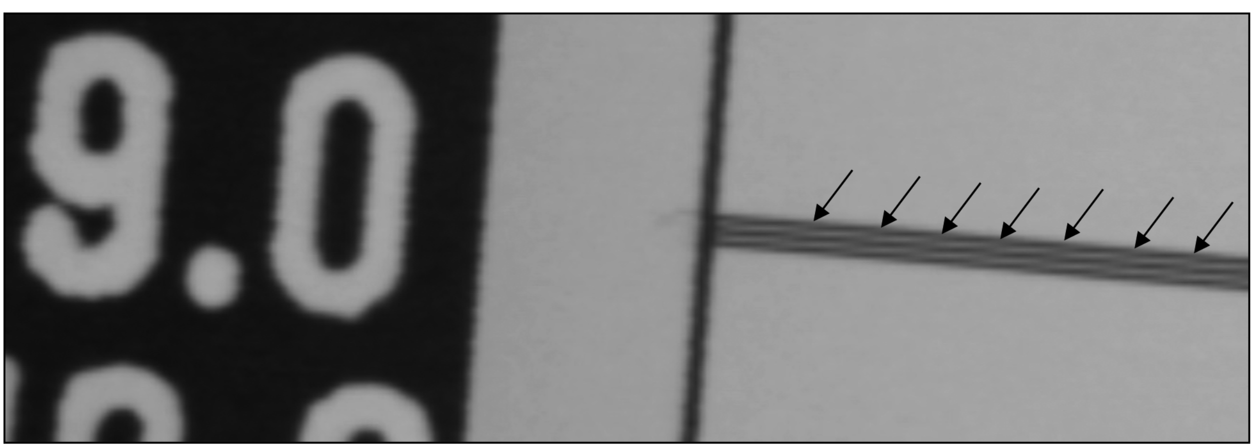
3.2.2 *banding*—linear striping aligned parallel to the IP transport direction, which may be caused by improper scanner normalization (see Fig. 2).

3.2.3 *computed radiology system (CR system)*—a complete system of a storage phosphor imaging plate (IP) ~~and~~type, corresponding read out unit (scanner or ~~reader), which converts the information of the IP into a digital image (see also Guide~~reader) including pertinent equipment settings (for example, sampling resolution, laser power, photomultiplier tube (PMT) gain, etc.), image acquisition and processing ~~E2007).~~ software, and image display monitor.

~~3.2.3 *computed radiology system class*—a particular group of storage phosphor imaging plate systems, which is characterized by a SNR (Signal-to-Noise Ratio) range shown in Table 1 and by a certain unsharpness range (for example, $MTF_{20}$-value) in a specified exposure range.~~

3.2.4 *CR phantom*—a device containing an arrangement of test targets used to evaluate the image quality of a CR system, as well as monitoring the image quality of the chosen system.

3.2.5 ~~*gain/amplification*—~~*customer*—~~opto-electrical gain setting of the scanning system.~~the company, government agency, or other authority responsible for the design, or end user, of the system or component for which radiographic examination is required, also known as the Cognizant Engineering Organization (CEO).




NOTE 1—Aliasing is more pronounced as lines pair spacing decreases.

**FIG. 1 Example of Aliasing on a Line Pair Gauge Image**

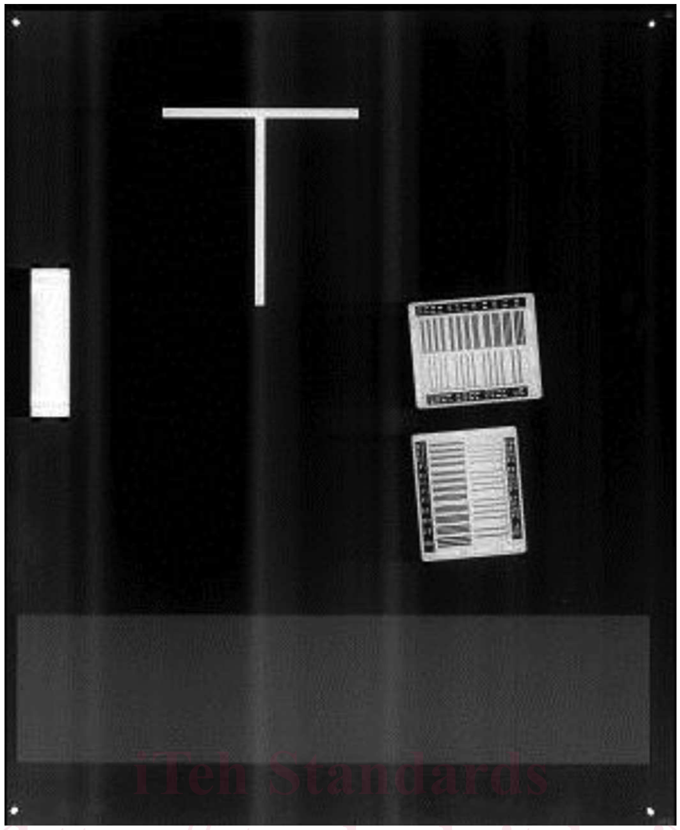


**FIG. 2 Example of Banding (Parallel to IP Transport Direction) in a Computed Radiograph of a Prototype Test Phantom**



3.2.6 ~~*ISO speed S*~~*fading*—~~$_{IPx}$—defines the speed of a CR system and is calculated from the reciprocal dose value, measured in Gray, which is necessary to obtain a specified minimum SNR of a CR system.~~reduction of intensity of the stored image in the imaging plate over time.

3.2.7 *gain*—overall signal amplification of the scanning system.

3.2.8 *laser beam jitter*—a lack of smooth movement of the ~~imaging plate/laser~~ laser scanning device, which results in jagged scan lines ~~of~~on the ~~image, which~~image (see Fig. 3~~consist of a series of steps.~~).

3.2.9 ~~*linearized signal intensity*—~~*linear pixel value*—a numerical ~~signal~~ value of a picture element (pixel) of the digital image, which is proportional to the radiation dose. ~~The linearized signal intensity is zero, if the radiation dose is zero.~~

3.2.9.1 *Discussion—*

Example: for conversion of 12 bit log to 16 bit linear:

$$PV_{16\,\text{bit linear}} = 65535 \times 10^{\left(\frac{PV_{12\,\text{bit log}}}{1024} - 4\right)} \quad (1)$$

The linear pixel value is zero if the radiation dose is zero.

3.2.10 *long-term stability*—performance measurements of a CR system over the life-cycle of the devices, used to evaluate relative system performance over time.

3.2.11 *manufacturer*—CR system manufacturer, supplier for the user of the CR system.

3.2.12 *PMT*—photomultiplier tube or other light capture device used by the specific scanner.

3.2.13 *PMT non-linearity*—deviation from a linear response of the PMT at high light input values or from step changes in light.

3.2.13.1 *Discussion—*

At high light input values the PMT may under-respond, also the PMT may over-shoot or undershoot in response to a step change in light (see Fig. 4).

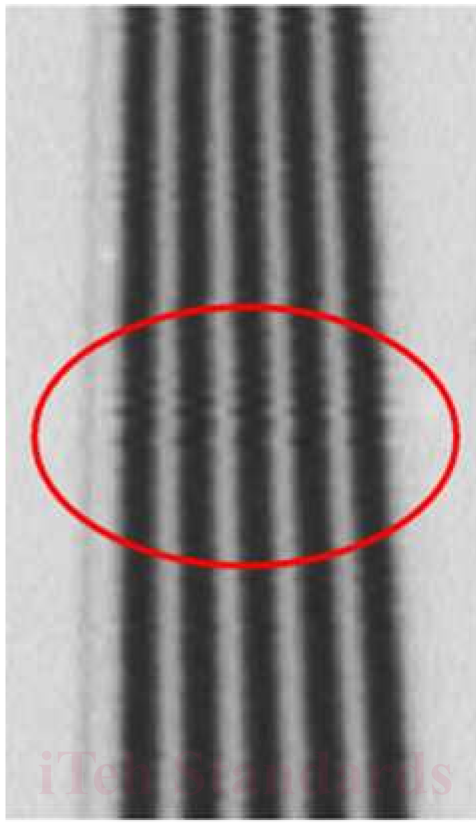


FIG. 3 Example of Laser Beam Jitter as Observed in a Computed Radiograph of a Converging Line Pair Gauge



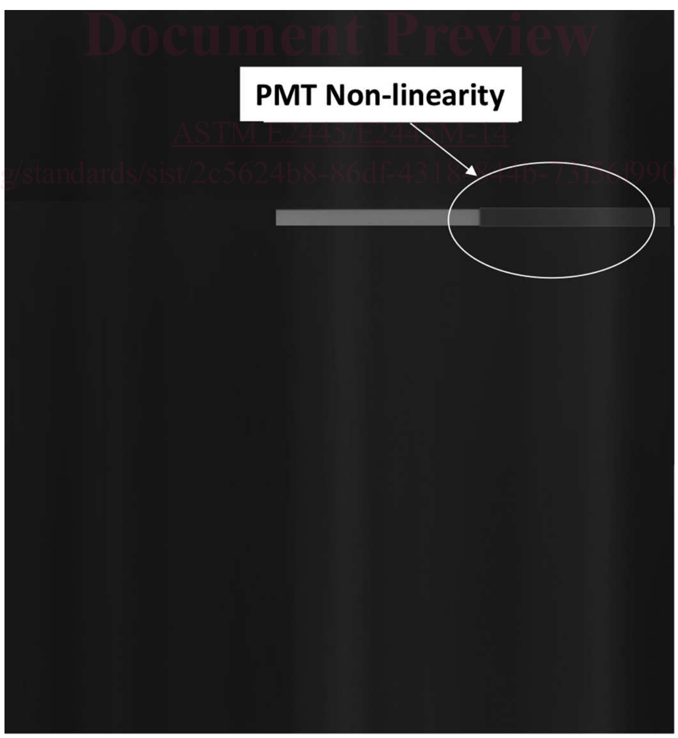





FIG. 4 Example of PMT Non-Linearity as Observed in a Computed Radiograph of a USAF Process Control Standard

3.2.14 *scan column dropout*—a zero PV linear image artifact created parallel to the transport direction when the path of the scanner's laser beam is prevented from reaching the imaging plate, often due to an internal obstruction (contaminates, for example) (see Fig. 5).

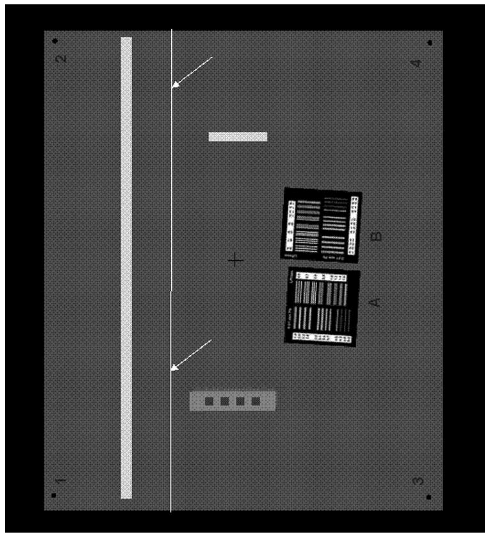


FIG. 5 White Arrows Highlight a Simulated Example of Scan Column Dropout

3.2.15 *scan line integrity (or line ripple)*—fluctuation of line intensity appearing perpendicular to the IP transport direction.

3.2.16 *scanner normalization*—as used in this document, scanner normalization refers to a process performed to ensure a flat field image is produced when an imaging plate is exposed without an absorber.

3.2.16.1 *Discussion*—

Scanner normalization procedures are dependent on the scanner model, and may or may not be able to be performed by the user.

3.2.17 *scanner slippage*—the slipping of an IP in a scanner transport system resulting in fluctuation of intensity of horizontal image lines.fluctuations of PV or distortion of geometric linearity or both, appearing perpendicular to the IP transport direction (see Fig. 6).

3.2.18 *signal-to-noise ratio (SNR)—shading—*quotient of mean value of the linearized signal intensity and standard deviation of the noise (intensity distribution) at this signal intensity. The SNR depends on the radiation dose and the CR system



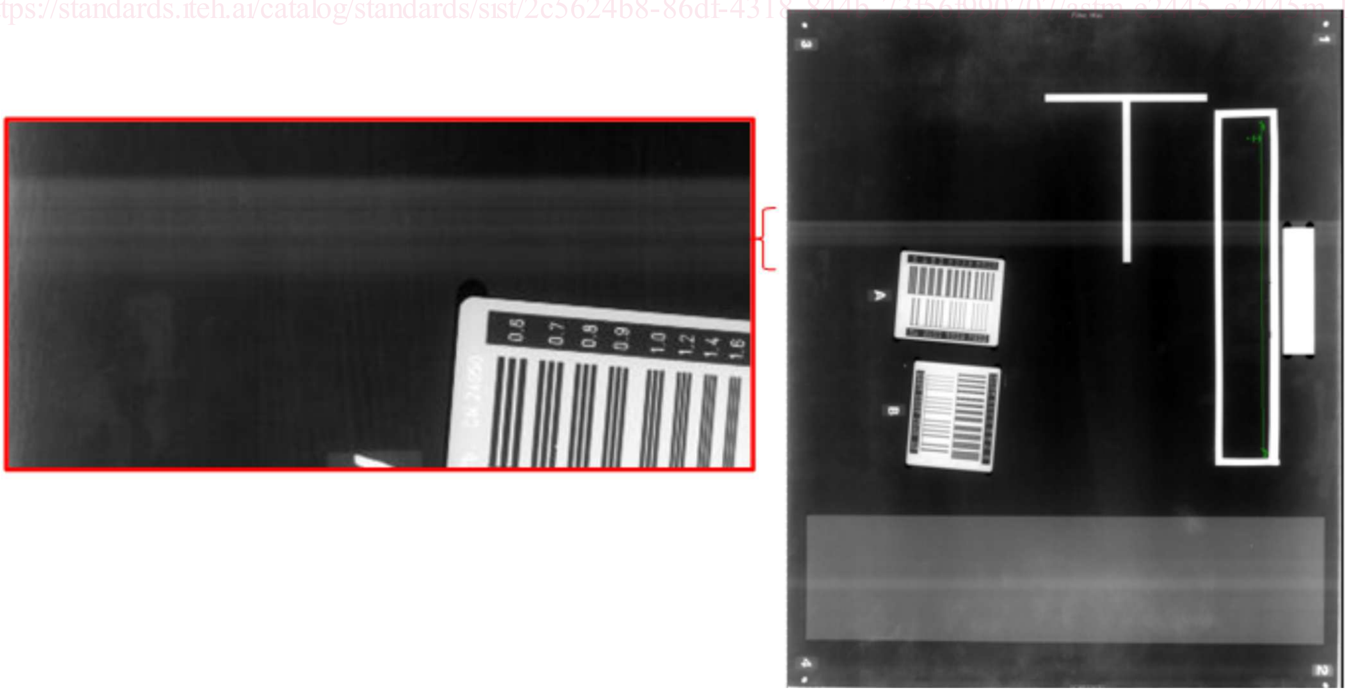


FIG. 6 Example of Scanner Slippage (Parallel to Laser Scan Direction) in a Computed Radiograph of a Prototype Process Control Standard

properties.non-uniform pixel values perpendicular to the IP transport direction, which may also be caused by improper alignment of the light guide or photomultiplier tube assembly or improper scanner normalization.

3.2.19 *wait time*—time between end of exposure and beginning the scan of the imaging plate.

3.2.20 *user*—the user and operating organization of the CR system.

## 4. Significance and Use

4.1 There are several factors affecting the quality of a CR image including the spatial resolution of the IP system, geometrical unsharpness, scatter and contrast sensitivity (signal/noise ratio). There are several additional factors (for example, scanning parameters), which affect the accurate reading of images on exposed IPs using an optical scanner.This practice is intended to be used by the NDT using organization to measure baseline performance of the CR system and to monitor its performance throughout its service as an NDT imaging system. For purposes of this document, the CR System is defined as:

4.1.1 Storage phosphor imaging plate (IP) type and manufacturer,

4.1.2 Read out unit (scanner or reader) manufacturer and model, including applicable scanner settings (e.g., sampling resolution, PMT gain, pixel value (PV) look up table, etc.),

4.1.3 Image acquisition and processing software, and

4.1.4 Image display monitor.

4.2 The quality factors can be determined most accurately by the CR equipment manufacturer tests as described inIt is to be understood that the CR system has already been selected and purchased by the user from a manufacturer based on the inspection needs at hand. The user shall accept the CR scanner based on manufacturer's results of Practice E2446. Individual test targets, which are recommended for practical user tests, are described for quality assurance. These tests can be carried out either separately or by the use on the specific CR scanner as provided in a data sheet for that serialized CR scanner or other acceptance test agreed to between the user and manufacturer (not covered in this practice). This practice is not intended to be used as an "acceptance test" of the CR phantom (Appendix X1). This CR phantom incorporates many of the basic quality assessment methods and those associated with the correct functioning of a CR system, including the scanner, for reading exposed plates and incorrectly erasing IPs for future use of each plate.system, but rather to establish a performance baseline that will enable tracking while in-service.

4.3 Although many of the properties listed in this standard have similar metrics to those found in E2446, data collection methods are not identical, and comparisons among values acquired with each standard should not be made.

4.4 This practice is for users of industrial CR systems. This practice defines the tests to be performed, by users of CR systems, periodically performed and required intervals. Also defined are the methods of tabulating results that CR users will complete following the baseline of the CR system. These tests will also be performed periodically at the stated required intervals to evaluate the CR systems to prove proper performance over the life-cycle of the system.system to determine if the system remains within acceptable operational limits as established in this practice.

4.5 *Application of Various Tests and Test Methods* There are several factors that affect the image quality of a CR image. Factors which are dependent on the CR system performance include basic spatial resolution, relative contrast, and signal-to-noise ratio (SNR) which yield the contrast sensitivity (CS), and Equivalent Penetrameter Sensitivity (EPS). There are several additional factors that are dependent on how well the CR system is functioning (i.e., resulting from normal wear and tear, inadequate maintenance, improper setup/calibration, etc.), such as slippage, laser jitter, geometric distortion, etc. Other factors which are related to the specific applications (e.g., geometric unsharpness, scatter, etc.) are not evaluated in these tests.

4.4.1 *Tests after Repair, Upgrade or the Use of Another IP Type:* Since modifications, such as repair or upgrade of the CR scanner and improved IP may improve the functionality of the system, specialized tests are required to prove the proper performance of the CR system.

4.4.1.1 *User Tests for Long-term Stability*—Quality assurance in test laboratories requires periodical tests of the CR system to prove the proper performance of the system. The time interval depends on the degree of usage of the system and shall be defined by the user and consideration of the CR equipment manufacturer's information.

4.4.1.2 The tests described in 6.2.1 through 6.2.6 require usage of quality indicators of 5.1 or the CR test phantom shall be used regularly at user-defined intervals to test the basic performance. The documentation shall contain:

*(1)* Spatial resolution (by duplex-wire method, optional converging line pairs),

*(2)* Contrast (recognized contrast percentage of the material to examine),

*(3)* Slipping (yes/no),

*(4)* Jitter (yes/no),

*(5)* Shading (percentage at selected distance),

*(6)* Radiation parameters of the performed tests, and

*(7)* Date and operator name.

4.4.1.3 Fading tests should be performed only if the scanner or IP-brand is changed without data from the CR equipment manufacturer, or the system is used under extreme (beyond manufacturer's recommendation) temperature conditions. The fading should be less than 50 % in the expected period between exposure and scan.

4.4.1.4 The IPs shall be checked for artifacts (6.2.7) and proper erasure (6.2.6).

~~4.4.1.5 Degradation of IPs or photo multipliers in the scanner may reduce the system sensitivity after extensive usage. For this reason, the SNR should be measured at longer intervals (for example, annual period) by the user or service personnel. The SNR shall not be less than 90 % of the original value. The increase of the SNR can be accepted without limits, if the system unsharpness is not increased.~~

## 5. General Testing Procedures

5.1 The tests performed herein can be completed either by the use of the Type I CR Phantom (Appendix X1) for applications up to 320kV, Type II CR Phantom (Appendix X2) for applications up to 160kV, or individual test targets described in Section 7. When greater than 320kV or when a gamma source is used, these tests may still be used to characterize a system, but may need to be modified as agreed by the user and CEO. The CR phantoms incorporate many of the basic image quality assessment test targets into a single test device, but some tests cannot be performed with both phantoms. See Table 1 to see which tests can be performed by each phantom.

5.2 To ensure consistent PVs for calculation of test results, the wait time between end of exposure and scanning of the imaging plate should be a consistent time of at least 5 minutes.

5.3 Tests are divided into two categories: *(1)* Core Image Quality Tests, and *(2)* Supplemental (optional) Tests.

5.3.1 Core Image Quality Tests shall be performed on each CR scanner. If more than one combination of CR system components and scanner settings are used in production, the user shall select one combination to be used for the Core Image Quality Tests.

5.3.2 Supplemental (optional) Tests may be performed at the discretion of the user and may provide useful information for some applications.

5.4 The technique shall be established for each test and documented. The technique information shall include, at a minimum where applicable:

5.4.1 Drawing sketch or photograph of the setups, showing the location and orientation of the phantom or test target with respect to the x-ray source, and imaging plate (IP),

5.4.2 Kilovoltage (kV),

5.4.3 Tube current (mA or microA),

5.4.4 Exposure time,

5.4.5 Wait time,

5.4.6 X-ray tube manufacturer, model, and focal spot size used (includes variable focal spot size settings),

5.4.7 Focal Spot to Detector Distance (FDD),



TABLE 1 System Performance Tests and Process Checks of the CR System

| Sysytem Performance Test | | Unit | Test Type | | Test Target | | | | Acceptance Criteria |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Baseline | Long-term Stability | Type I Phantom | Type II Phantom | Alternate Test Target Required | No Test Target Required | |
| Core Image Quality Tests | | | | | | | | | |
| Contrast Sensitivity | CS | % | x | x | x | x | | | 2% contrast step |
| Basic Spatial Resolution | $SR_b$ | µm | x | x | x | x | | | ± one wire/line pair from baseline |
| Geometric Distortion | | | x | x | x | x | | | < 2% distortion |
| Laser Jitter | | | x | x | x | x | | | straight and continued edges |
| PMT Non-linearity | | | x | x | x | x | | | not be visible at typical window width settings |
| Laser Beam Scan Line Integrity | | | x | x | x | x | | | none visible |
| Scan Column Dropout | | | x | x | x | x | | | none visible |
| Scanner Slippage | | | x | x | x | x | | | < noise (Type I) < 2% distortion (Type II) |
| Shading | | | x | x | x | | | x (Type II) | ± 15% or none visible[B] |
| Banding | | | x | x | | | | x | ± 15% or none visible[B] |
| Erasure | | | x | x | | | see 8.3.1 | x | ≤ 2% PV or none visible[B] |
| Equivalent Penetrameter Sensitivity[A] | EPS | % | x | x | | | see Appendix X3 | | ± one hole set from baseline[C] |
| Signal-to-Noise Ratio[A] | SNR | | x | x | | | | x | SPC[D] |
| Supplemental Tests (optional) | | | | | | | | | |
| Burn-In | | | x | x | | | see 8.3.2 | | ≤ 2% PV or none visible[B] |
| Spatial Linearity | | | x | x | x | | | | ≤ 2% distortion |
| Central Beam Alignment | | | x | x | x | | | | regularly spaced spiral |
| Image Plate Artifacts | | | x | x | | | | x | n/a |
| Image Plate Response Variation | | | x | | | | | x | < 10% PV variation |
| Image Plate Fading | | | x | | | | | x | n/a |

[A] Only EPS or SNR is required (not both).
[B] Acceptance criteria depends on evaluation method selected in Section 9.
[C] For the E746 configuration, ± one hole set on a plaque IQI equates to approximately 15% total variation.
[D] Statistical Process Control (SPC) is required to establish acceptance criteria limits and tolerances.

5.4.8 Focal Spot to Object Distance (FOD),
5.4.9 Geometric unsharpness (Ug),
5.4.10 Detector screens and filters and usage,
5.4.11 Imaging plate manufacturer and type/size,
5.4.12 Cassette type,
5.4.13 CR scanner settings (for example, gain setting, resolution setting, and other parameters if available), and
5.4.14 X-ray beam filtration (at tube), collimator, diaphragm and part masking.

## 6. Application of Baseline Performance Tests and Test Methods

6.1 *CR System Baseline Performance Tests:*

6.1.1 The user shall baseline the CR scanner along with the complete CR system (as defined in 4.1) by performing the Core Image Quality Tests listed in Table 1. Supplemental Tests may be used to baseline the system if desired. Additional tests beyond those defined in this practice are to be defined by the using organization in terms of specific tests to perform, how the data are presented, and the frequency of the testing. This approach does the following:

6.1.1.1 Provides a quantitative baseline of performance.

6.1.1.2 Provides results in a defined form that can be viewed by the CEO.

6.1.1.3 Offers a means to perform process checking of performance on a continuing basis.

6.1.2 Acceptance values, and tolerances thereof, obtained from these tests shall be established by this practice.

6.1.3 When the test produces a result below the requirements, the CR scanner is not to be placed in service unless it is repaired, replaced, or some other change is instituted that will assure the image quality of the inspection as stated in the agreement between contracting parties. This assumes that the other elements of the CR system are within their tolerances including the x-ray source/generator, the imaging plates, the image acquisition and processing software, the image display monitor, and the inspection itself (for example, severe x-ray scatter in the inspection is controlled).

6.1.4 The results of the baseline performance test of the new CR system shall be documented as delineated in Table 2 and taken as reference values "Results (baseline)" for further use.

6.1.5 Maximum deviations from "Results (baseline)" as tolerances and limits are established in this document, documented in Table 2 and taken as reference values "Limit" for further use.

6.1.6 When any CR system component is changed, by definition the "CR system" has changed (see 4.1); therefore the Core Image Quality Tests shall be performed to establish the baseline for this new CR system.

6.2 *User Tests for Long Term Stability*—Image quality assurance requires periodic tests of the CR system to ensure the proper performance of the system.

6.2.1 *Test Intervals*—The frequency shall be at least quarterly unless otherwise approved by the CEO.

6.2.2 *Acceptance Criteria and Tolerances*—Table 1 lists the minimum acceptance criteria for all long-term stability tests. For SNR, limits and tolerances shall be established using statistical process control (SPC) per 9.5.

6.3 *Supplemental (optional) Tests*—Supplemental (optional) tests may be performed at the user's discretion in addition to the tests in 6.1 and 6.2. Where applicable, recommended acceptance criteria are provided in Table 1 and Section 9.

6.4 *Retesting Requirements:*

6.4.1 New CR System Baseline Performance Tests should be performed when any system hardware or software component is repaired, replaced, or upgraded.

6.4.2 Long Term Stability Tests should be performed after routine maintenance.

## 7. ~~Apparatus—CR Quality Indicators~~ Apparatus

7.1 The tests described in Table 1 and in Section 6 require the usage of either the Type I CR Phantom (see Appendix X1) or the Type II CR Phantom (see Appendix X2). However, this document does not preclude the use of other gauges or phantoms which can measure the same parameters listed in Table 1. The use of alternate gauges must be approved by the CEO.

7.2 *Description of CR Image Quality Indicators for User Tests*—The following is a description of CR image quality indicators, which will be identified by reference to this practice.

7.2.1 *Contrast Sensitivity Image Quality ~~Indicator:~~ Indicator—*

~~5.1.1.1 The description of the contrast sensitivity target corresponds to Practice E1647. For use with this practice, three targets are made from aluminum (Material Group 02), copper (Material Group 4) and stainless steel (Material Group 1). The target thickness is 12.5 mm (0.50 in.) aluminum, 6.3 mm (0.25 in.) copper and stainless steel. Each target contains a contrast area for 1, 2, 3, and 4 % wall-thickness contrast sensitivity.~~The description of the contrast sensitivity test target corresponds to Practice E1647. For use with this practice, three test targets are made from aluminum (Material Group 2), copper (Material Group 4) and stainless steel (Material Group 1). The test target thickness is 12.5 mm [0.50 in.] aluminum, 6.3 mm [0.25 in.] copper and stainless steel. Each test target contains a contrast area for 1, 2, 3, and 4 % wall-thickness contrast sensitivity and is implemented in both the Type I (aluminum, copper, and stainless) and Type II (aluminum only) CR Phantoms (Fig. X1.1 and Fig. X2.1).

7.2.2 *Duplex Wire Image Quality ~~Indicator:~~ Indicator—*

TABLE ~~1~~ Test Report of CR ~~Systems~~

| | | | | |
|---|---|---|---|---|
| ~~CR System~~ | | | | |
| ~~Construction Year~~ | | | | |
| ~~Last Service~~ | | | | |
| ~~Used IPs~~ | | | | |
| ~~Date of Tests~~ | | | | |
| ~~Tests~~ | | | ~~Result~~ | ~~Remark~~ |
| | ~~Basic Spatial Resolution~~ | ~~Duplex Wire E2002~~ | | |
| | | ~~Converging Line Pairs~~ | | |
| | ~~$SNR_N$~~ | | | |
| | ~~Geometric Distortions~~ | | | |
| | ~~Laser Beam Function~~ | | | |
| | ~~Blooming or Flare~~ | | | |
| | ~~Scanner Slipping~~ | | | |
| | ~~Shading~~ | | | |
| | ~~Erasure~~ | | | |
| | ~~IP Artifacts~~ | | | |
| ~~Conclusion~~ | | | | |
| ~~Operator~~ | | | | |

TABLE 2 Test Report of CR System

| System Information | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Test Component | | | Manufacturer/Model/Serial Number | | | | | |
| CR System | IP Type | | | | | | | |
| | Software | | | | | | | |
| | Viewing Monitor | | | | | | | |
| | Scanner | | | | | | | |
| | Scanner Settings | | Sampling Resolution (µm) | | | | | |
| | | | PMT Gain (if applicable) | | | | | |
| | | | Other (specify): | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Radiation Source | | | Manufacturer/Model | | | | | |
| | | | Focal Point (mm) | | | | | |
| Exposure Conditions | | | | | | | | |
| Exposure Conditions | | | Core Image Quality Tests (8.2) | Erasure Test (8.3.1) | Burn-In Test (8.3.2) | IP Artifacts (8.5.4) | IP Response (8.5.5) | IP Fading (8.5.6) |
| Date | | | | | | | | |
| Tube Filter Material | | | | | | | | |
| Tube Filter Thickness | | | | | | | | |
| kV | | | | | | | | |
| mA | | | | | | | | |
| Time (sec) | | | | | | | | |
| SDD (specify units) | | | | | | | | |
| Test | | | EPS (8.4.1) | SNR (8.4.2) | | | | |
| Date | | | | | | | | |
| Tube Filter Material | | | | | | | | |
| Tube Filter Thickness | | | | | | | | |
| kV | | | | | | | | |
| mA | | | | | | | | |
| SDD (specify units) | | | | | | | | |
| Exposure # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Time (sec) | | | | | | | | |
| EPS | | | | | | | | |
| SQRT (1/SNR) | | | | | | | | |

| Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test | | Baseline Test | | | | | | | |
| | | Test after Repair or New Software | | | | | | | |
| | | Long Term Stability | | | | | | | |
| Test Phantom Type | | | | | | | | | |
| Test Procedure Section | Test Metric | Test Target (Method) | Evaluation Procedure Section: Type I Phantom | Type II Phantom | Other | Result (baseline) | Limit | Result | Remarks |
| Core Image Quality Tests | | | | | | | | | |



~~5.1.2.1 The description of the duplex wire quality indicator corresponds to Practice E2002. The gage shall be oriented at a 5° angle to the direction of the scanned lines (fast-scan direction) or the perpendicular direction (slow-scan-direction).~~ The description of the duplex wire image quality indicator corresponds to Practice E2002. The gauge shall be oriented at a 2°–5° angle to the laser scan direction and at a 2°–5° angle to the IP transport direction. This test target may be evaluated visually or with software tools to measure basic spatial resolution and is implemented in one orientation in the Type I CR Phantom (Fig. X1.1).

**TABLE 2** *Continued*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 8.2 | Contrast Sensitivity | E1647 gauge (line profile) | 9.2.1 | 9.3.1 | | | 2% contrast step | | |
| | Basic Spatial Resolution | Duplex Wire E2002 (line profile) | 9.2.2 | | | | ± one wire/line pair from baseline | | |
| | | Parallel Line Pairs (line profile) | | 9.3.2 | | | | | |
| | Geometric Distortion | Linear Quality Indicator (linear measurement) | 9.2.3 | | | | ≤ 2% distortion | | |
| | | Point Measurement Target (linear measurement) | | 9.3.3 | | | | | |
| | Laser Jitter | T-target (visual) | 9.2.4 | | | | straight and continuous edges | | |
| | | Long Strip Target (visual) | | 9.3.4 | | | | | |
| | PMT Non-Linearity | T-target (visual) | 9.2.5 | | | | not visible at typical window width settings | | |
| | | Short Strip Target (visual) | | 9.3.5 | | | | | |
| | Scan Line Integrity | Image Background (visual) | 9.2.6 | 9.3.6 | | | none visible | | |
| | Scan Column Dropout | Image Background (visual) | 9.2.7 | 9.3.7 | | | | | |
| | Scanner Slippage | Homogeneous Strip (line profile) | 9.2.8 | | | | ≤ noise | | |
| | | Point Measurement Target (linear measurement) | | 9.3.8 | | | ≤ 2% distortion | | |
| | Shading | Shading Image Quality Targets (PV measurement) | 9.2.9.1 | | | | ± 15% of target EC | | |
| | | Image Background (visual) | 9.2.9.2 | | | | none visible | | |
| | | Image Background (PV measurement) | | 9.3.9.1 | | | ± 15% of center measurement | | |
| | | Image Background (visual) | | 9.3.9.2 | | | none visible | | |
| | Banding | Image Background (PV measurement) | 9.2.10.1 | 9.3.10 | | | ± 15% of background | | |
| | | Image Background (visual) | 9.2.10.2 | 9.3.10 | | | none visible | | |
| 8.3.1 | Erasure | Image Background (PV measurement) | 9.2.11.1 | 9.3.11 | | | ≤ 2% PV | | |
| | | Image Background (visual) | 9.2.11.2 | 9.3.11 | | | no residual image visual | | |
| 8.4.1 | EPS | EPS Test Standard – Appendix X3 (visual) | | | 9.4 | | ± one hole set from baseline | | |
| 8.4.2 | SNR | Image Background (SNR calculation) | | | 9.5 | | (by SPC) | | |
| Supplemental Tests (optional) | | | | | | | | | |
| 8.3.2 | Burn-In | Image Background (PV measurement) | 9.2.12.1 | 9.3.12 | | | ≤ 2% PV | | |
| | | Image Background (visual) | 9.2.12.2 | 9.3.12 | | | no residual image visual | | |
| 8.5.2 | Spatial Linearity | Linear Quality Indicator (linear measurement) | 9.2.12 | | | | ≤ 2% distortion | | |
| 8.5.3 | Central Beam Alignment | BAM snail (visual) | 9.2.13 | | | | regularly spaced spiral | | |
| 8.5.4 | IP Artifacts | n/a | | | 9.6.4 | | n/a | | |
| 8.5.5 | IP Response | Image Background (PV measurement) | | | 9.6.5 | | < 10% PV variation | | |
| 8.5.6 | IP Fading | Image Background (PV measurement) | | | 9.6.6 | | n/a | | |
| | | | | | | | | | |
| Date of Tests | | | | | | | | | |
| Conclusion | | | | | | | | | |
| Operator | | | | | | | | | |



7.2.3 *Converging Line Pair Image Quality Indicator*—This test target is contained in the Type I CR Phantom (Fig. X1.1), but is not used in this standard.

7.2.4 ~~*Converging*~~*Parallel Line Pair Image Quality* ~~*Indicator:*~~ *Indicators—*

~~5.1.3.1 The target consists of five converging strips of lead (0.03 mm (0.001 in.) thickness), which can be used for a spatial resolution test by reading the limit of recognizable line pairs. It shall cover a range from 1.5 to 20 line pairs per mm (lp/mm). Two quality indicators shall be used, one in parallel with the scanned lines and the other one oriented in the perpendicular direction.~~The test target consists of multiple pairs of parallel slits cut into lead foil (0.05 mm [0.002 in.] thickness), which can be used for a basic spatial resolution test by reading the limit of recognizable line pairs. It shall cover a range from 1.5 to 10 line pairs per mm (lp/mm) as a minimum. The gauge shall be oriented at a 2°–5° angle to the laser scan direction and at a 2°–5° angle to the IP transport direction. Two of these test targets are arranged in each scan direction and implemented in the Type II CR Phantom (Fig. X2.1).

7.2.5 *Linearity Image Quality* ~~*Indicators:*~~ *Indicators—*

~~5.1.4.1 Rulers of high-absorbing materials are located on the perimeter of the scanned range. Two quality indicators shall be used, one parallel with the scanned lines and the other one oriented in the perpendicular direction. The scaling should be at least in mm or tenths of inches.~~Rulers of high-absorbing materials are located on the perimeter of the scanned range and may be used to measure spatial linearity, geometric distortion, and scanner slippage. Two image quality indicators shall be used, one parallel with the scanned lines and the other one oriented in the perpendicular direction. The scaling should be at least in mm or tenths of inches. This test target is implemented in the Type I CR Phantom (Fig. X1.1).

7.2.6 *Point Measurement Test Targets*—Small spherical test targets made of high density material (e.g., 1.5 mm [0.06 in.] steel or lead balls), placed at known locations at the four corners of the scanned image. These test targets may be used for evaluation of overall image geometric distortion or scanner slippage, or both, and are implemented in the Type II CR Phantom (Fig. X2.1).

7.2.7 ~~*T-target:*~~ *T-target—*

~~5.1.5.1 This CR quality indicator consists of a thin plate of brass or copper (≤0.5 mm (≤0.02 in. ) thick) with sharp edges. This plate is manufactured in a T-shape with 0.5 mm (0.2 in.) wide segments. The T should have a size of at least 50 by 70 mm (2 by 2¾ in.). It shall be aligned perpendicular and parallel to the direction of the scanned lines and is used to check for laser jitter and may be used to measure a modulation transfer function of the complete system (see Fig. X1.1).~~This CR image quality indicator consists of a thin plate of brass or copper ≥2 mm [≥0.08 in.] thick with sharp edges. This plate is manufactured in a T-shape. The T should have a size of at least 114 by 5 mm [4.5 by 0.2 in.] for each leg. It shall be aligned perpendicular and parallel to the IP transport direction and is used to check for laser jitter and may be used to measure a Modulation Transfer Function (MTF) of the complete system. This test target is implemented in the Type I CR Phantom (Fig. X1.1).

7.2.8 *Strip Targets*—These CR image quality indicators consists of two thin plates of brass or copper (≥0.5 mm [≥0.02 in.] thick) with sharp edges. Each plate is manufactured in 5 mm [0.2 in.] wide segments, one plate being at least 50 mm [2 in.], and one being nearly the full length of the image to be scanned [16 in.]. The short plate shall be aligned perpendicular to the transport direction and is used to check for PMT non-linearity, while the long plate is aligned parallel to the transport direction and is used to check laser jitter. These test targets are implemented in the Type II CR Phantom (Fig. X2.1).

7.2.9 ~~*Scanner Slipping Quality Indicator:*~~ *Homogeneous Strip Target—*

~~5.1.6.1 The quality indicator consists of a homogeneous strip of aluminum 0.5 mm (0.02 in.) in thickness. The quality indicator has the shape of a rectangle (see Fig. X1.1) and shall be aligned perpendicular and parallel to the direction of the scanned lines.~~The image quality indicator consists of a homogeneous strip of aluminum 0.5 mm [0.02 in.] in thickness. The image quality indicator has the shape of a rectangle and shall be aligned parallel to the transport direction and is implemented in the Type I CR Phantom (Fig. X1.1).



7.2.10 *Shading Image Quality Indicator*—A series of three holes, measuring 19 mm [0.75 in.] in diameter and 0.3 mm [0.01 in.] deep. These test targets are implemented (labeled EL, ER, and EC) in the Type I CR Phantom (Fig. X1.1).

7.2.11 ~~*Shading Quality Indicator:*~~ *Equivalent Penetrameter Sensitivity (EPS) Test Standard—*

~~5.1.7.1 Different shading quality indicators may be used. One type is based on the homogeneous exposure of an imaging plate (IP) with a thin Al-plate 0.5 to 1.0 mm (0.06 to 0.04 in.) above the IP. The exposure shall be made with low-energy radiation (50 to 100 keV).~~The EPS test standard is built to the dimensional specifications of the Practice E746 Relative Image Quality Indicator (RIQI), but may be made of steel, aluminum, or other materials. See Appendix X3 for details of the EPS test standard.



~~5.1.7.2 Another type is the shading quality indicator of the CR test phantom (see X1.1).~~



7.2.12 *Central Beam Alignment Image Quality Indicator* ~~*(BAM-snail):*~~ *(BAM-snail)—*

~~5.1.8.1 The alignment quality indicator consists of a roll 1.5 to 2.0 mm high (0.06 to 0.08 in.) of thin lead foil separated by a spacer of 0.1 to 0.2 mm (0.004 to 0.008 in.) of low-absorbing material (see X1.2).~~ The alignment image quality indicator consists of a roll 1.5 to 2.0 mm high [0.06 to 0.08 in.] of thin lead foil separated by a spacer of 0.1 to 0.2 mm [0.004 to 0.008 in.] of low-absorbing material. This test target is implemented in the Type I CR Phantom (Figs. X1.1 and X1.2).

7.3 *Application Procedures for CR Image Quality Indicators*—The CR system image quality indicators provide an evaluation of the image quality of a CR system as well as for a ~~periodical~~periodic quality control. ~~Arrangement~~ Selection and arrangement of the CR image quality indicators shall be in accordance with this practice, or as specified by the ~~cognizant engineering organization.~~ CEO.

~~5.2.1 *Exposure of CR Quality Indicators (User Test):*~~

~~5.2.1.1 The CR quality indicators can be applied separately or all together in the CR phantom. The selected set of CR quality indicators or the CR phantom is placed on the cassette, which contains an imaging plate. The radiation source is set at a distance of 1 m (39 in.) or greater and the beam is aligned with the center of the plate. Above radiation energy of 100 keV, a lead screen of 0.1 mm (0.004 in.) shall be applied between CR quality indicators or CR phantom and the IP to reduce scattered radiation. Test exposures are made and the radiation and CR system functions are optimized. The final image for evaluation is to be agreed among contracting parties.~~

~~5.2.1.2 The exposure time and the parameter setting of the CR scanning unit determine the image quality as well as the type of imaging plate to use. These values, the X-ray settings, and the type of IP have to be documented and agreed, as well as the radiation energy (keV, gamma-source type), dose (for example, in mAs) and quality (prefilters, tube type and tube window).~~

~~NOTE 1—High exposure time and low gain settings yield high contrast resolution and SNR. Furthermore, the contrast sensitivity is higher for large pixel size settings (high unsharpness) than for small pixel size setting (low unsharpness).~~

~~5.2.2 *Initial Assessment of CR Quality Indicators:*~~