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

This standard is issued under the fixed designation 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 describes the evaluation of Computed Radiology (CR) systems for industrial radiology. It is intended to ensure that the evaluation of image quality, as far as this is influenced by the CR system, meets the needs of users 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 The use of gauges[2] provided 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 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 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.*

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*—artifacts that appear in an image when the spatial frequency of the input is higher than the output is capable of reproducing.

[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 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, which you may attend.[1]

[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) type, corresponding read out unit (scanner or reader) including pertinent equipment settings (for example, sampling resolution, laser power, photomultiplier tube (PMT) gain, etc.), image acquisition and processing software, and image display monitor.

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 *customer*—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).

3.2.6 *fading*—the 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 laser scanning device, which results in jagged scan lines on the image (see Fig. 3).

3.2.9 *linear pixel value*—a numerical value of a picture element (pixel) of the digital image, which is proportional to the radiation dose.

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 under-shoot in response to a step change in light (see Fig. 4).

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).

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 fluctuations of PV or distortion of geometric linearity or both, appearing perpendicular to the IP transport direction (see Fig. 6).

3.2.18 *shading*—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.

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

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

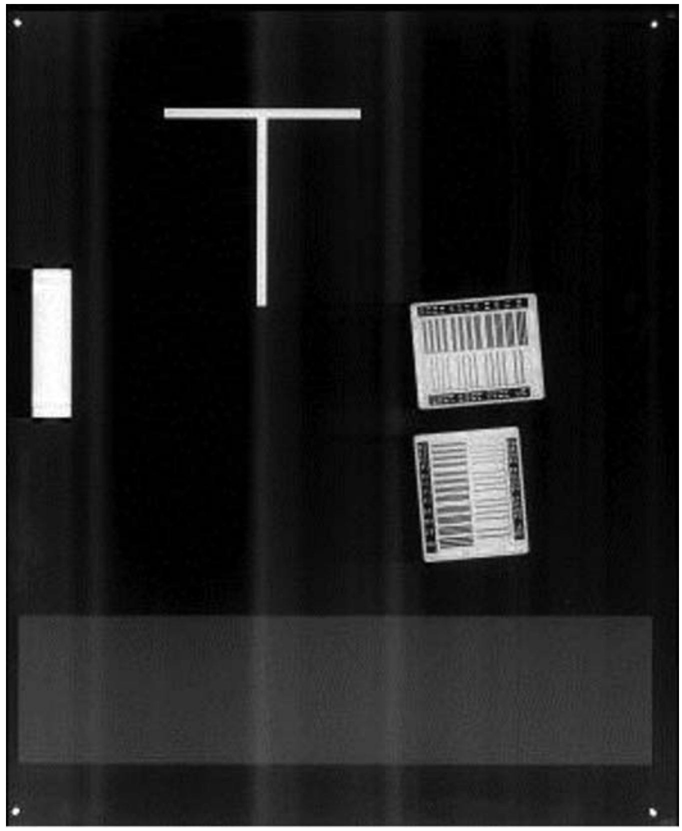


FIG. 2 Example of Banding (Parallel to IP Transport Direction) in a Computed Radiograph of a Prototype Test Phantom

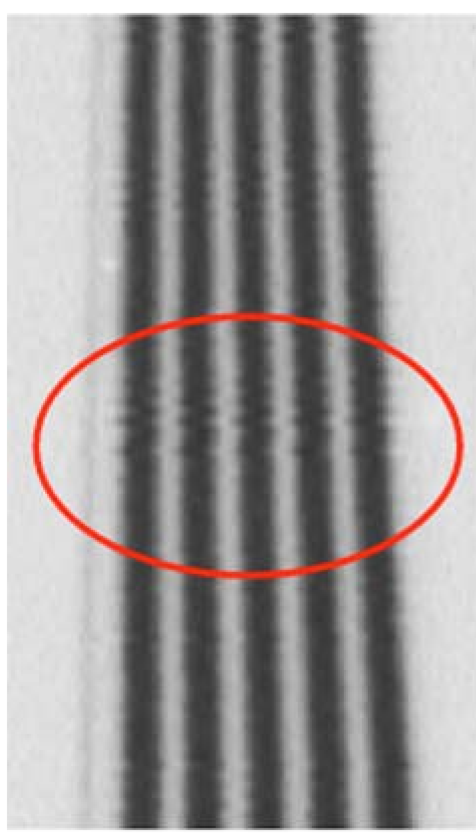


FIG. 3 Example of Laser Beam Jitter as Observed in a Computed Radiograph of a Converging Line Pair Gauge

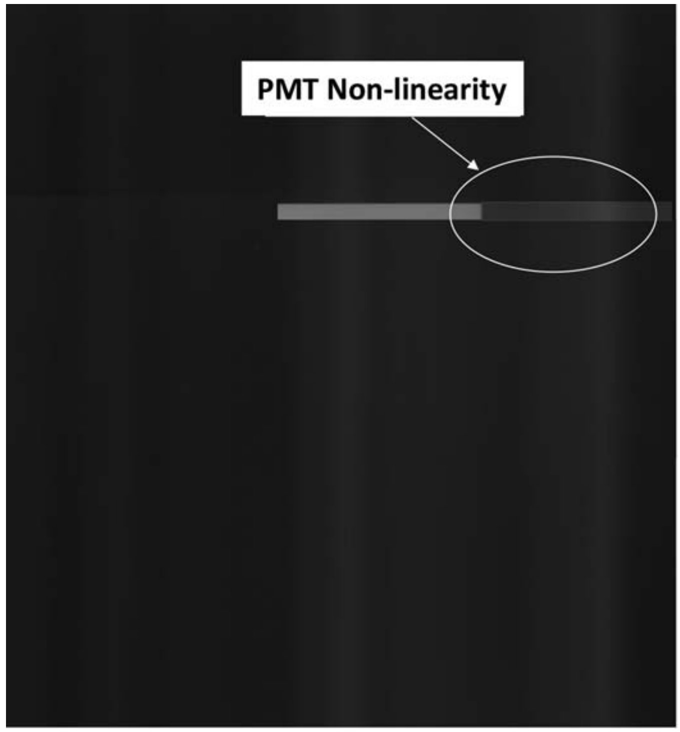


FIG. 4 Example of PMT Non-Linearity as Observed in a Computed Radiograph of a USAF Process Control Standard

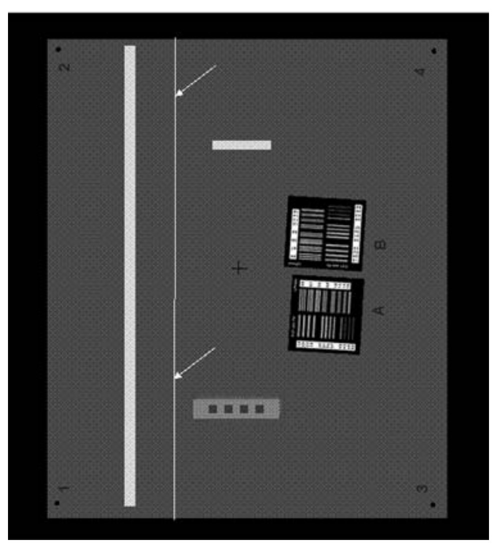


FIG. 5 White Arrows Highlight a Simulated Example of Scan Column Dropout

4. Significance and Use

4.1 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 It 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 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 system, but rather to establish a performance baseline that will enable tracking while in-service.

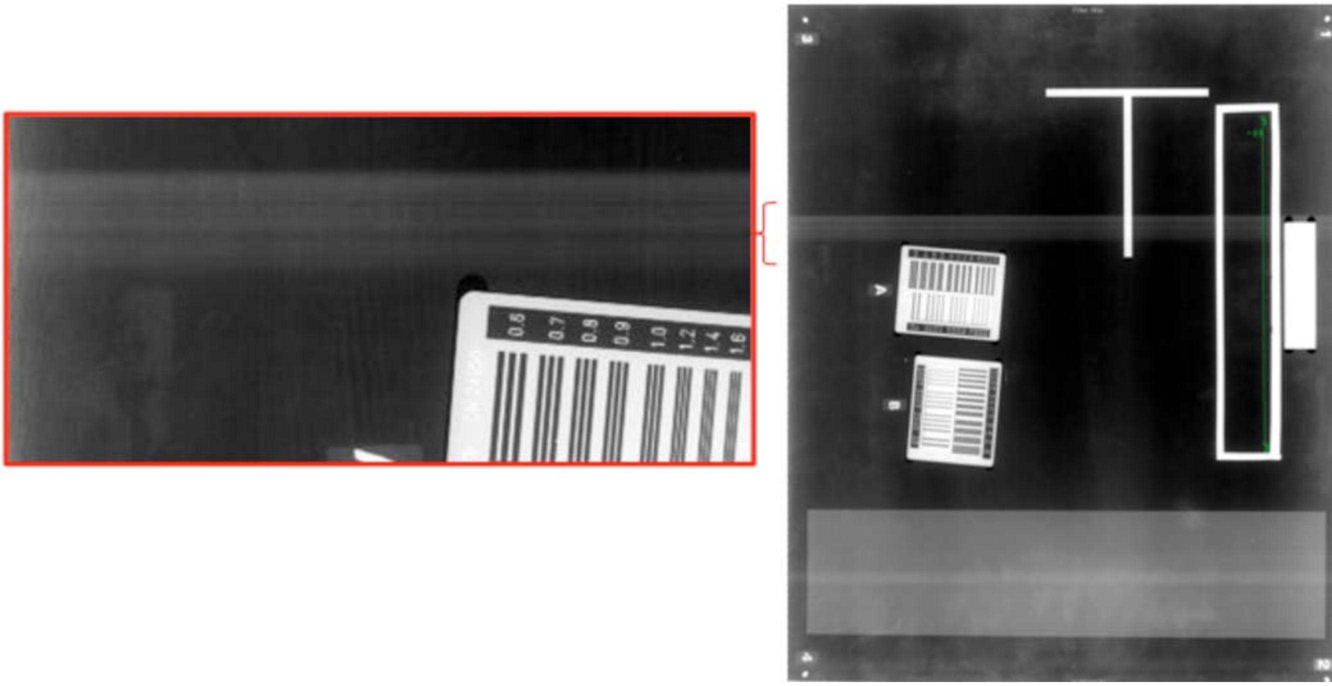


FIG. 6 Example of Scanner Slippage (Parallel to Laser Scan Direction) in a Computed Radiograph of a Prototype Process Control Standard

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 defines the tests to be 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 system to determine if the system remains within acceptable operational limits as established in this practice.

4.5 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.

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.

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			Result (baseline)	Limit	Result	Remarks
			Type I Phantom	Type II Phantom	Other				
Core Image Quality Tests									
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		

TABLE 2 *Continued*

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									

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

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*—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*—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).

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 *Parallel Line Pair Image Quality Indicators*—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*—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*—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 *Homogeneous Strip Target*—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 *Equivalent Penetrameter Sensitivity (EPS) Test Standard*—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.

7.2.12 *Central Beam Alignment Image Quality Indicator (BAM-snail)*—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 periodic quality control. Selection and arrangement of the CR image quality indicators shall be in accordance with this practice, or as specified by the CEO.

8. Test Procedures

8.1 The tests listed in this section shall be performed with the listed phantom and corresponding IQIs at specified intervals as established in this practice.

8.1.1 *Core Image Quality Tests:*

8.1.1.1 Contrast Sensitivity (by contrast sensitivity gauges in either Type I or Type II CR Test Phantom).

8.1.1.2 Basic Spatial Resolution (by duplex wire gauge in Type I CR Test Phantom or parallel line pair gauges in Type II CR Test Phantom).

8.1.1.3 Geometric Distortion (by spatial linearity image quality indicators in Type I CR Test Phantom or point measurement targets in Type II CR Test Phantom).

8.1.1.4 Laser Jitter (by T-target in Type I CR Test Phantom or long strip target in Type II CR Test Phantom).

8.1.1.5 PMT Non-linearity (by T-target in Type I CR Test Phantom or short strip target in Type II CR Test Phantom).

8.1.1.6 Laser Beam Scan Line Integrity (no test object required).

8.1.1.7 Scan Column Dropout (no test object required).

8.1.1.8 Scanner Slippage (by homogeneous strip slippage target in Type I CR Test Phantom or point measurement targets and visual evaluation in Type II CR Test Phantom).

8.1.1.9 Shading (by three shading image quality targets in Type I CR Test Phantom or three measurements in background of Type II CR Test Phantom).

8.1.1.10 Banding (no test object required).

8.1.1.11 Erasure (high absorption object per 8.3.1).

8.1.1.12 *Sensitivity Tests considering image noise:*

(1) EPS (EPS Test Standard per 7.2.11), or

(2) SNR (no test object required).

8.1.2 *Optional Tests:*

8.1.2.1 Burn-In (high absorption object per 8.3.1).

8.1.2.2 Spatial Linearity (by spatial linearity image quality indicators in Type I CR Test Phantom).

8.1.2.3 Central Beam Alignment (by BAM-snail target in Type I CR Test Phantom).

8.1.2.4 Imaging Plate Artifacts (no test object required).

8.1.2.5 Imaging Plate Response Variation (no test object required).

8.1.2.6 Imaging Plate Fading (no test object required).

8.2 *Procedure for Core Image Quality Tests (except EPS and SNR)*—For the tests involving the phantoms of this practice, either the Type I or Type II CR Test Phantom shall be placed on the cassette, which contains an imaging plate. The radiation source shall be set at a distance of 1 m [39 in.] or greater and the beam aligned with the center of the plate. Testing of the Type I CR phantom shall be performed at 220kV for applications >160kV, or 90kV for applications ≤160kV; Testing of Type II CR phantom shall be performed at 50kV. Above radiation energy of 100kV, use of a front screen is recommended (such as lead ≥0.1 mm [0.005 in.] or steel ≥0.5 mm [0.02 in.]) to reduce scattered radiation. Background pixel value shall not be saturated, to avoid "burning" edges of the test targets and producing erroneous data. The final image for evaluation shall have the PV of all targets of interest within the EPS or SQRT(1/SNR) plateau as defined in 9.4.2 and 9.5.2.2.

8.2.1 Note that for tracking performance of the CR system, the same technique, CR scanner settings, and CR system components shall be used during long term stability or process checking.

8.2.2 Before the capture of images for evaluation begins, the CR system shall have the scanner normalization performed in accordance with the manufacturer's recommendations.

8.3 *Procedure for Erasure and Burn-In Test:*

8.3.1 *Erasure:*

8.3.1.1 Using an IP that has been erased, an exposure shall be taken at 220 kV or a typical kV for the application range. This shall be accomplished using an absorber plate that covers approximately one half of the imaging plate and results in 5-10% maximum achievable mean linear PV in the region covered by the absorber plate. In the free beam area, the exposure shall result in 80-90% of the maximum achievable mean linear PV.

8.3.1.2 Erase the IP. Scan the IP after erasure.

8.3.1.3 Document the orientation of the IP during exposure and processing on the technique. Ensure the same orientation is maintained for subsequent tests.

8.3.2 *Burn-In (optional):*

8.3.2.1 The burn-in test shall only be performed on an IP that has successfully met the acceptance criteria for the erasure test (9.2.10). Prior to exposure, wait approximately 20 minutes from completion of the erasure test (8.3.1). Expose the IP without an absorber plate in such a way as to achieve a PV within the plateau as defined in 9.4.2 or 9.5.2.2 with the same kV as used in the erasure test.

8.3.2.2 The burn-in test may be repeated after a longer wait time to determine if the burn-in fades.

8.4 *Procedure for Sensitivity Tests considering Image Noise (only one of the following methods is required: EPS or SNR):*

8.4.1 *Procedure for EPS Test:*

8.4.1.1 For CR system baseline performance testing, place the EPS Test Standard (Appendix X3) on the IP and align an X-radiation source in the approximate center of the EPS Test Standard between the #8 and #10 EPS plaques (plaques may be slightly separated for this purpose). If the EPS Test Standard does not cover the entire IP, the IP should be masked with lead around the absorber plate. The Source-to-Detector Distance (SDD) shall be at least 1 m [39 in.]. The geometric unsharpness, Ug, shall not exceed 50 µm and Ug should not exceed 50% of SR_b detector. A collimator should be used which provides a beam projection that approximately matches the area of the EPS Test Standard. The kilovoltage setting shall be 220 kV if using steel, or 65kV if using aluminum. Backing materials of 1 mm [0.04 in] steel and a minimum of 4 mm [0.1 in.] lead should be placed beneath the IP with the steel being placed nearest the IP. Radiograph the EPS Test Standard with a minimum of eight exposures with similar technique parameters (i.e., the only technique variable is exposure, mA × time) for a range of dose sufficient to produce approximately 10-90% of the maximum pixel value (PV) of the system in approximately equal increments (i.e., for a 16 bit system, 100% max PV=65535; 10-90% max PV 6554-58982, PV increments ~6500-8000). The %EPS shall be determined per 9.4.

8.4.1.2 For long-term stability tests, %EPS only needs to be verified at a selected dose in the "plateau" region (i.e. only one exposure required).

8.4.2 *Procedure for SNR Tests:*

8.4.2.1 For CR system baseline performance testing, a system consisting of a cassette and IP shall be uniformly exposed. The IP shall be positioned with an SDD of 1 m [39 in.]. Leave free space of at least 1 m [39 in.] behind the cassettes or use a steel screen of about 0.5 mm [0.02 in.] and a lead plate of > 2 mm [0.08 in.] just behind the cassette (steel screen is positioned between cassette and lead) and in eight exposures using similar technique parameters (i.e., the only technique variable is exposure, mA × time) for a range of dose sufficient to produce approximately 10-90% of the maximum linear pixel value (PV) of the system in approximately equal increments (i.e., for a 16 bit system, 100% max PV=65535; 10-90% max PV=6554-58982, PV increments ~6500-8000). The SNR shall be measured per 9.5.

8.4.2.2 For high-energy applications, the kilovoltage setting shall be 220kV and the filter shall be of copper 8 mm [0.32 in.] in thickness. A front lead screen of 0.1 mm [0.005 in.] thickness may be used in the exposure cassette.

8.4.2.3 For low-energy applications, the kilovoltage setting shall be 90 kV and the filter shall be of aluminum 2 mm [0.08 in.] in thickness. No front and back screens of lead are required.

8.4.2.4 For long-term stability tests, SNR or SQRT(1/SNR) only needs to be verified at a selected dose in the plateau region (i.e., only one exposure is required).

8.5 *Procedures for Supplemental (optional) Tests:*

8.5.1 *Burn-In*—See 8.3.2.

8.5.2 *Spatial Linearity (optional)*—Same as 8.2 using Type I CR Test Phantom.

8.5.3 *Central Beam Alignment (optional)*—The radiation beam shall be aligned perpendicular to the center of the alignment image quality indicator (BAM-snail) within the Type I CR Test Phantom (Appendix X1).

8.5.4 *Imaging Plate Artifacts (optional):*

8.5.4.1 All IPs in inventory should be serialized.

8.5.4.2 Prior to testing for artifacts, each IP should be cleaned in accordance with manufacturer instructions, recommended cleaner and lint-free cloth.

8.5.4.3 Expose each IP to the lowest kV used in examination. Use sufficient exposure conditions to achieve a PV within the plateau as defined in 9.4.2 or 9.5.2.2. Scan the IP and store the corresponding image file.

8.5.5 *Imaging Plate Response Variation (optional)*—In some instances, performance of the same type imaging plate may vary by lot, resulting in differing image intensities when exposed to the same exposure parameters. The following evaluation may be performed as an initial acceptance test of imaging plate lots.

8.5.5.1 Expose each IP to the lowest kV used in examination. Use sufficient exposure conditions to achieve a PV within the plateau as defined in 9.4.2 or 9.5.2.2. Scan the IP and store the corresponding image file.

8.5.5.2 Set the linear pixel value of this measurement as reference for the specific imaging plate type.

8.5.5.3 Using the same X-ray parameters (kV, mAs, and distance), evaluate same imaging plate types from other lots.

8.5.6 *Imaging Plate Fading (optional)*—The fading effect needs to be considered to ensure correct exposure conditions. To enable reproducible test results, it is important to consider fading effects, which influence the required exposure time. The time between IP exposure and IP scanning for all tests shall correspond to the application of the CR system. The measurement of fading characteristic shall be done by performing the following steps:

8.5.6.1 Expose an imaging plate homogeneously using typical exposure conditions. For documentation, the following parameters shall be recorded: kV, mAs, SDD, pre-filter material and thickness, and imaging plate type. The exposed image shall have a mean linear pixel value between 70 and 90 % of the maximum possible PV of the CR reader at lowest gain and under linearized conditions.

8.5.6.2 Scan the IP as soon as practical after exposure (i.e., using a short wait time) and establish a baseline mean linear PV using an ROI that covers a majority of the IP image. Subsequent tests should use a similar short wait time to achieve consistent results.

8.5.6.3 Set the linearized read-out intensity of this measurement as reference (=100 %).

8.5.6.4 Subsequent exposures shall have increasing time intervals between IP exposure and IP scanning. Suggested steps are 5 min and 1 h, or as needed to match application requirement.

9. Calculation of the Results, Acceptance Criteria and Report

9.1 All test results shall be documented using the data sheet format as shown in Table 2.

9.2 The results using the Type I CR Test Phantom shall be calculated as follows:

9.2.1 *Determination of Contrast Sensitivity:*

9.2.1.1 A line profile (with line profile width to cover half of the width of the contrast step) shall be taken through the steps on at least one of the three Practice E1647 contrast sensitivity gauges (7.2.1) as selected by the user.

9.2.1.2 The average noise of the profile shall be less than the difference in the intensity between the full and reduced wall thickness at the 2% step (see Fig. 7). The same gauge material(s) shall be used for subsequent periodic tests and shall be recorded with the result.

9.2.2 *Determination of Basic Spatial Resolution:*

9.2.2.1 The first unresolved wire pair shall be taken for determination of the unsharpness value corresponding to Practice E2002. This is the first wire pair, which is projected with a dip between the wires of less than 20 % (see Fig. 8), as measured with a line profile. The line profile width should be approximately 30-60% of the length of the wires (see Fig. 9) in order to obtain a robust repeatable value, but shall use a minimum of 11 pixel width line profile (or average of 11 single pixel width line profiles). The basic spatial resolution (SR_b) corresponds to one half of the measured unsharpness as defined in E2002.

9.2.2.2 The SR_b measurement shall be determined from the largest of the readings of both the laser scan and IP transport directions. (A second exposure must be acquired with the phantom rotated 90 degrees to obtain both measurements using this phantom.)

9.2.2.3 For long-term stability tests, SR_b readings shall be no more than ± one wire pair of the baseline reading.

9.2.3 *Geometric Distortions:*

9.2.3.1 The overall geometric distortion of the CR image shall be checked by exposing a spatial linearity image quality indicator (mm-scale or finer, 7.2.5), in *x*- and *y*-directions.

9.2.3.2 Calibrate the resident software distance measurement tool on either the *x*- or *y*-scale, and then check the accuracy of the overall length of the scale not used for calibration. Measured geometric distortion shall be less than or equal to 2%.

9.2.4 *Laser Jitter:*

9.2.4.1 Using a T-target (7.2.7), evaluate for laser beam jitter by examining the edges of the "T" on the image. View the "T" edges with 100% (1:1 pixel mapping) up to a maximum of the monitor display megapixels (MP) × 50% (i.e., max magnification of 100% (2MP), 150% (3MP), 250% (5MP), 400%

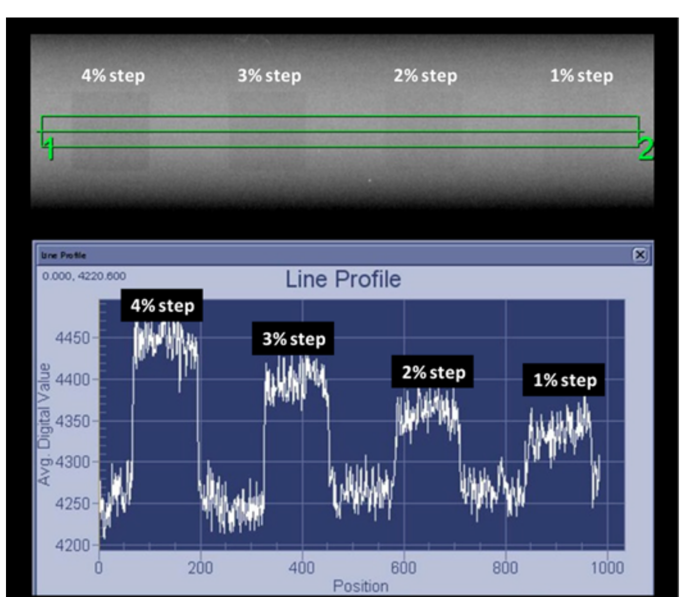
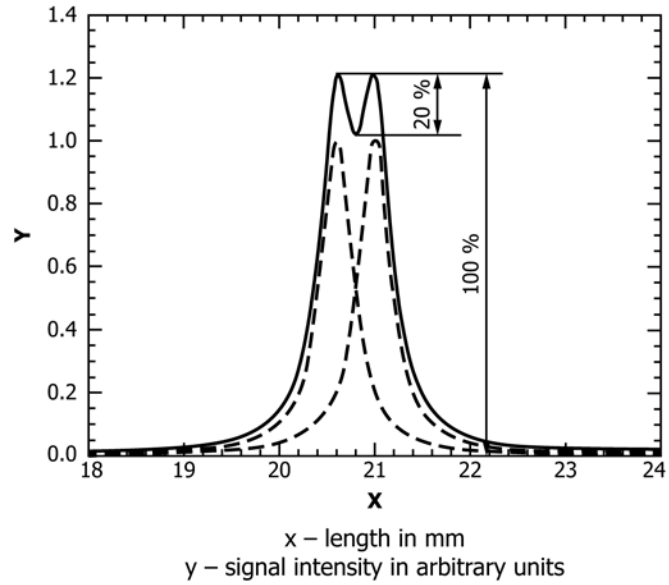


FIG. 7 Radiographic Image of Contrast Sensitivity Gauge With Line Profile Data Illustrating <1% Contrast Sensitivity



x – length in mm
y – signal intensity in arbitrary units

NOTE 1—The two wires of a wire pair are resolved if the dip between the line maxima is 20 % or greater of the maximum intensity.

FIG. 8 Resolution Criterion for the Evaluation of Duplex-Wire Profiles

(8MP)) magnification on the image display monitor in various areas across the image to ensure the edges are straight and continuous. Under- or over-shoot of the scan lines in light-to-dark transitions along the "T" edge indicates a timing error, or laser beam modulation problem. The "stair step" characteristics of the straight edge are normal due to digitization effects.

9.2.5 *PMT Non-linearity:*

9.2.5.1 Examine the computed radiographs of the T-target for the evidence of PMT non-linearity (Fig. 4). PMT non-linearity is evident as intensity streaking in the laser scan direction typically in transitions across high contrast areas. PMT non-linearity shall not be visible at typical window width settings.

9.2.6 *Laser Beam Scan Line Integrity:*

9.2.6.1 Evaluate the image scan lines with 4× (or greater) magnification on the computer screen in various areas along the image to ensure spaces are not visible between scan lines oriented perpendicular to the transport direction.

9.2.7 *Scan Column Dropout:*

9.2.7.1 Evaluate the image to ensure lucent (bright white) straight lines (Fig. 5) are not visible in the open field oriented parallel to the transport direction.

9.2.8 *Scanner Slippage:*

9.2.8.1 Using the homogeneous strip slippage target (7.2.9), inspect for deviations in the intensity of the scanned lines. The deviation between the line intensities shall be less than (or equal to) the noise, measured along one of these lines using a line profile of 11 pixel width or larger.

9.2.9 *Shading (use one of the two following methods):*

9.2.9.1 *Three Point Method:*

(1) Using three identical image quality indicators (7.2.10), measure the mean linear pixel value at each target using an ROI that closely fits within the target area. Target "EC" is used for the central measurement. Measurements at targets ER and EL should be within ± 15% of target EC.

9.2.9.2 *Visual Method:*

(1) Visually evaluate the unsaturated background of the phantom image in regions free of targets to ensure there is no visible gradient in either the horizontal or vertical directions. Window and level settings shall be selected to represent typical production evaluation criteria.

9.2.10 *Banding (use one of the two following methods):*

9.2.10.1 *ROI Method:*

(1) Determine the existence of banding in the image by maximizing the contrast until a brightness variation is visible in the background (i.e., regions without targets) of the image. If banding is visible (see Fig. 6), measure the mean linear PV at the maximum and minimum (i.e., darkest and lightest) bands using an ROI approximately the same width as the band being evaluated. A nominal background measurement shall be measured in a region free of visible banding. All measurement areas shall be free of targets. The difference between each band and the nominal background measurement shall be within ± 15%.

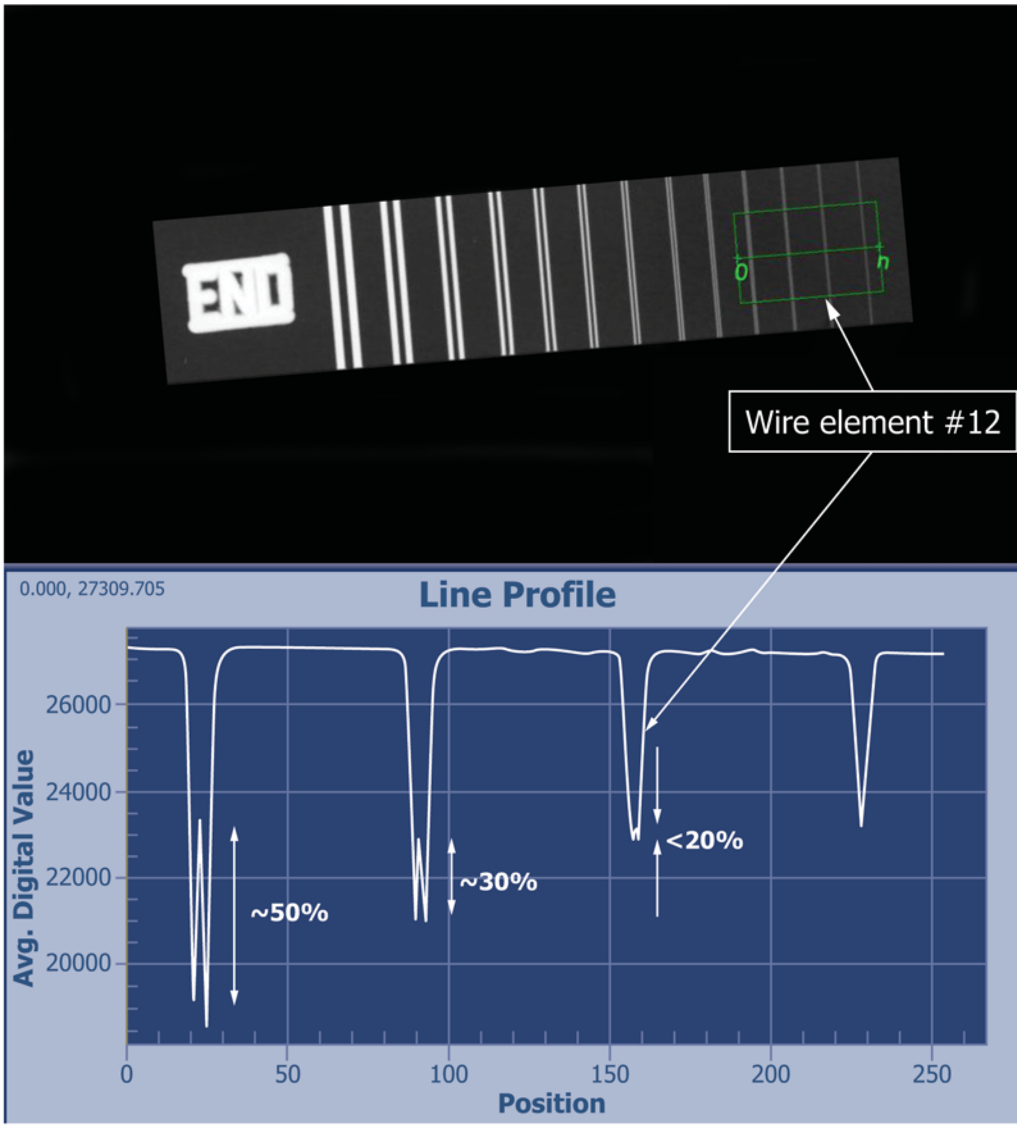
9.2.10.2 *Visual Determination Method:*

(1) Visually evaluate the unsaturated background of the phantom image in regions free of targets to ensure banding oriented parallel to the transport direction (Fig. 6) is not visible. Window and level settings shall be selected to represent typical production evaluation criteria.

9.2.11 *Erasure (use one of the two following methods):*

9.2.11.1 *PV Difference Method:*

(1) Erasure shall be calculated from the image taken in 8.3.1.2. Determine the PV difference between the mean linear PV of the free exposed area and the mean linear PV of the area covered by the absorber. Unless otherwise agreed to between



#12 wire element <20% dip; SR_b = 63 µm

FIG. 9 Wire-Pair Image Analysis for Calculation of Basic Spatial Resolution

the user and CEO, the ROI for each area should cover as large a region as possible within each area. The PV difference divided by the maximum achievable PV shall be ≤ 2%.

9.2.11.2 *Visual Method:*

(1) Visually evaluate the image taken in 8.3.1.2 to ensure there is no residual image visible in the area covered by the absorber. Window and level settings shall be selected to represent typical production evaluation criteria.

9.2.12 *Burn-In (optional—use one of the two following methods):*

9.2.12.1 Burn-in should be calculated from the image taken in 8.3.2.1. Determine the PV difference between the mean linear PV of the free exposed area of the burn-in test and the mean linear PV of the area covered by the absorber in the erasure test (see 8.3.1.1). The ROI for each area should cover as large a region as possible within each area. The relative value of the PV difference divided by the mean linear PV of the free exposed area should be ≤ 2%. The time between completion of the erasure test (8.3.1) and the exposure of the burn-in test (8.3.2.1) should be documented.

9.2.12.2 *Visual Method:*

(1) Visually evaluate the image taken in 8.3.2.1 to ensure there is no residual image visible in the area covered by the absorber. Window and level settings shall be selected to represent typical production evaluation criteria.

9.2.13 *Spatial Linearity (optional):*

9.2.13.1 The spatial linearity of the CR system should be checked by exposing a spatial linearity image quality indicator (mm-scale or finer, 7.2.5), in laser scan and IP transport directions.

9.2.13.2 Calibrate the resident software distance measurement tool, and check the accuracy of the major units of the scales by measuring the distances between four equally spaced locations (i.e., measure from point 1 to 2, 2 to 3, and 3 to 4) in both the laser scan and IP transport directions. The measurements should cover the entire width and length of the image. The three measurements in each direction should vary by 2% or less.

9.2.14 *Central Beam Alignment (optional):*

9.2.14.1 The radiation beam should be aligned perpendicular to the center of the alignment image quality indicator (BAM-snail) within the CR phantom (Appendix X1). The resulting computed radiographic image, consisting of a regularly spaced spiral, indicates that alignment is correct.

9.3 The results using the Type II CR Test Phantom shall be calculated as follows:

9.3.1 *Determination of Contrast Sensitivity*—Same as 9.2.1.

9.3.2 *Determination of Basic Spatial Resolution:*

9.3.2.1 Using the parallel line pair image quality indicator (7.2.4), the first unresolved line pair shall be used for determination of the basic spatial resolution. This is the first line pair, which is projected with a dip within the line pairs of less than 20 % as measured with a line profile. The line profile should be approximately 30-60% length of the line pairs (Fig. 10) in order to obtain a robust repeatable value, but shall use a minimum of an 11 pixel width line profile (or the average of 11 single width line profiles). If agreed upon by the CEO, the reading may also be performed by visual interpretation by selecting the first line pair in which the space between the lines is not visible when the radiographic image is presented at 100% (1:1 pixel mapping) magnification or greater.

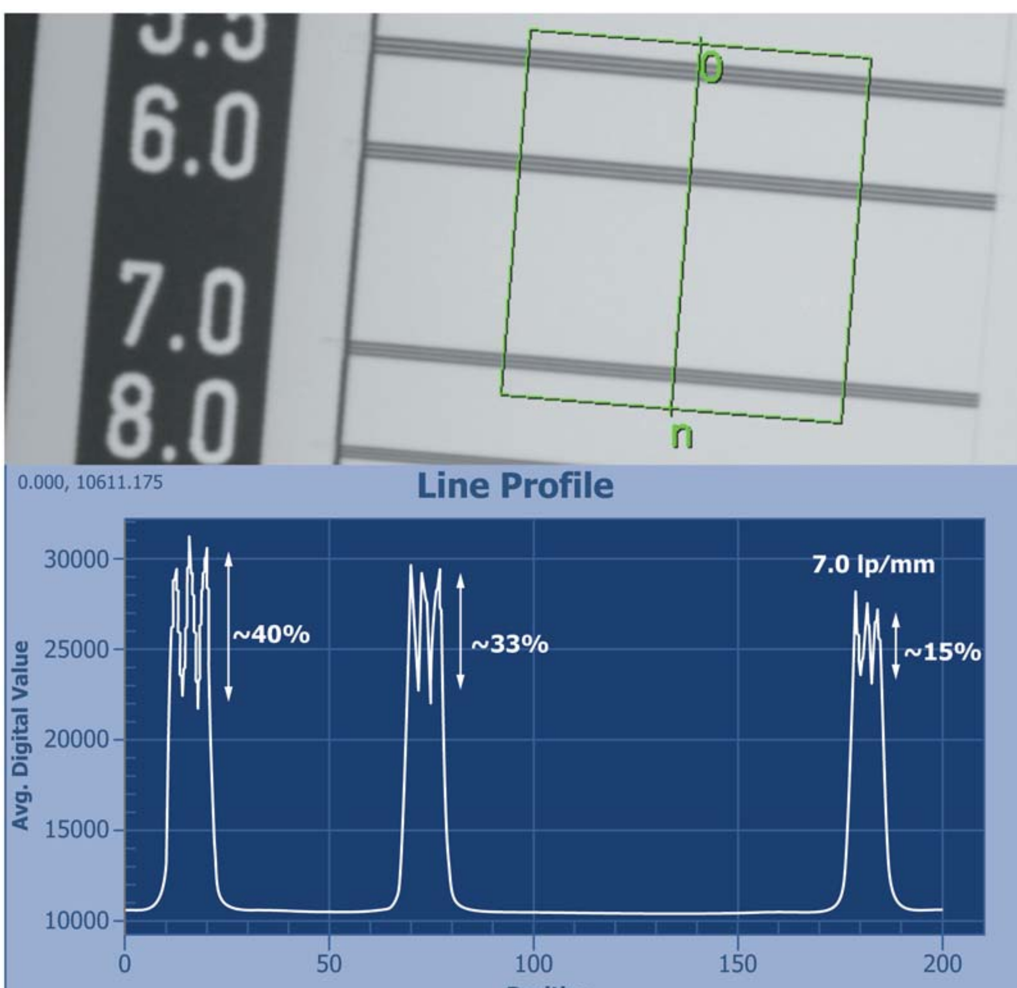
9.3.2.2 The SR_b measurement shall be determined from the largest of the readings of both the laser scan and IP transport directions.

9.3.2.3 The basic spatial resolution (SR_b in µm) is calculated by (1 / [2·read-out (in lp/mm)] × 1000).

9.3.2.4 For long-term stability tests, SR_b readings shall be no more than ± one line pair of the baseline reading.

9.3.3 *Geometric Distortions:*

9.3.3.1 The overall geometric distortion of the CR image shall be checked by exposing point measurement targets (7.2.6), located at known locations near the four corners of a phantom representing the maximum size imaging plate to be scanned. Distance measurement calibration using the resident software tool shall be performed on the two point targets oriented in either the *x* or *y* direction, and overall geometric distortion shall be checked in the other (*x* or *y*) direction as well



7.0 lp/mm < 20% dip; SR_b = 71 µm

FIG. 10 Lead Foil Line Pair Image Analysis for Calculation of Basic Spatial Resolution

as in the diagonal direction. See Fig. X2.1 for point measurement target spacing. Measured geometric distortion shall be less than 2%.

9.3.4 *Laser Jitter:*

9.3.4.1 Using strip targets (7.2.8), evaluate for laser beam jitter by examining the edges of the long strip target (oriented parallel to the transport direction) on the image. View the strip edges with 100% (1:1 pixel mapping) up to a maximum of the monitor display megapixels (MP) × 50% (i.e., max magnification of 100% (2MP), 150% (3MP), 250% (5MP), 400% (8MP)) on the image display monitor in various areas along the image to ensure the edges are straight and continuous. Under- or over-shoot of the scan lines in light to dark transitions along the edge of the strip targets indicates a timing error, or laser beam modulation problem. The "stair step" characteristics of the straight edge are normal due to digitization effects.

9.3.5 *PMT Non-linearity:*

9.3.5.1 Examine the computed radiographs of the short strip target (oriented perpendicular to the transport direction) for the evidence of PMT non-linearity. PMT non-linearity is evident as intensity streaking in the laser scan direction typically in transition across high contrast areas. PMT non-linearity shall not be visible at typical window width settings.

9.3.6 *Laser Beam Scan Line Integrity*—Same as 9.2.6.

9.3.7 *Scan Column Dropout*—Same as 9.2.7.

9.3.8 *Scanner Slippage:*

9.3.8.1 Scanner slippage is also evident as a decreased length of the acquired image parallel to the transport direction. As a result, using the point measurement targets (7.2.6) and the procedure in 9.3.2.2 will satisfy this test.

9.3.9 *Shading (use one of the two following methods):*

9.3.9.1 *ROI Method:*

(1) Measure the mean linear pixel value using a 10 mm [0.4 in.] square ROI placed at three evenly spaced locations across the laser scan direction of the image. The measurement areas shall be free of targets. Measurements at the outside locations shall be within ± 15% of center location.

9.3.9.2 *Visual Method*—Same as 9.2.9.2.

9.3.10 *Banding*—Same as 9.2.10.

9.3.11 *Erasure*—Same as 9.2.11.

9.3.12 *Burn-In (optional)*—Same as 9.2.12.

9.4 *EPS:*

9.4.1 The EPS performance shall be established by visual evaluation of computed radiographs of the EPS Test Standard (Appendix X3) placed on a 19 mm [0.75 in.] absorber.

9.4.2 The EPS data typically produce a distinguishable increase in EPS at low dose and a relatively flat plateau as dose increases (see Fig. 11). Identify the plateau as the exposure range that exhibits a relatively low and consistent EPS value (≤15% variation of EPS value). All CR system processing parameters, energy level, and exposure data for each exposure shall be recorded and maintained.

9.4.3 For each exposure, record the EPS performance by determining the hole set where a minimum of 15 holes (out of 30 holes in each hole set) are clearly visible. (A larger minimum number of holes may be used provided it is used for all exposures). No major scratches or dust and no shading shall be visible in the measurement area. Table 3 provides EPS

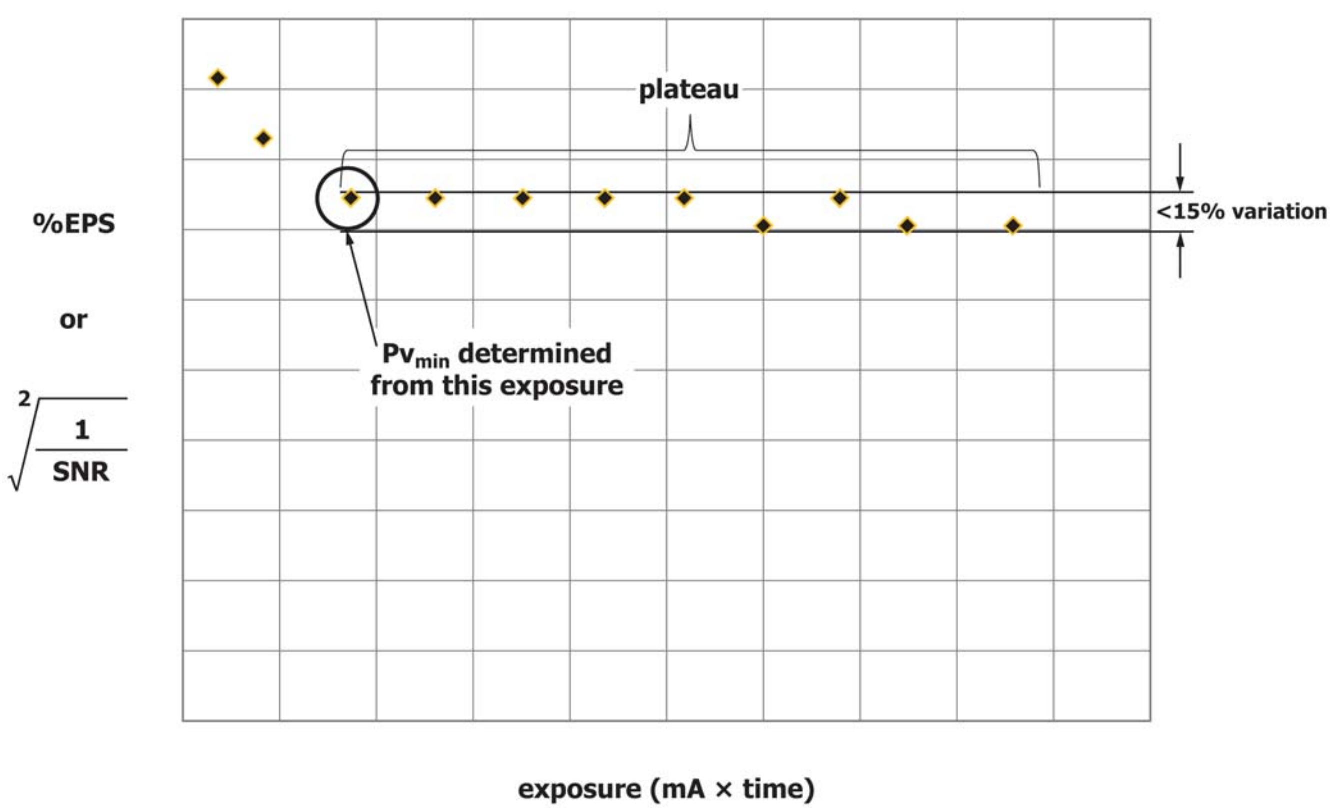


FIG. 11 %EPS or SQRT(1/SNR) vs. Exposure

TABLE 3 EPS Values for Practice E746 RIQI on 19 mm [0.75 in.] Absorber

Step Thickness	Hole Diameter	EPS%
0.38 mm [0.015 in.]	0.71 mm [0.028 in.]	1.93
0.38 mm [0.015 in.]	0.64 mm [0.025 in.]	1.83
0.38 mm [0.015 in.]	0.58 mm [0.023 in.]	1.75
0.25 mm [0.010 in.]	0.79 mm [0.031 in.]	1.66
0.25 mm [0.010 in.]	0.71 mm [0.028 in.]	1.58
0.25 mm [0.010 in.]	0.64 mm [0.025 in.]	1.49
0.20 mm [0.008 in.]	0.71 mm [0.028 in.]	1.41
0.20 mm [0.008 in.]	0.64 mm [0.025 in.]	1.33
0.20 mm [0.008 in.]	0.58 mm [0.023 in.]	1.28
0.13 mm [0.005 in.]	0.81 mm [0.032 in.]	1.19
0.13 mm [0.005 in.]	0.71 mm [0.028 in.]	1.12
0.13 mm [0.005 in.]	0.64 mm [0.025 in.]	1.05
0.13 mm [0.005 in.]	0.58 mm [0.023 in.]	1.01
0.13 mm [0.005 in.]	0.50 mm [0.020 in.]	0.94

values per Practice E746 for each hole set on the standard shown in Appendix X3.

9.4.4 Record the EPS value versus exposure. An example plot is shown in Fig. 11.

9.4.5 Record the EPS performance as the maximum EPS (i.e., largest) value in the plateau.

9.4.6 *(Optional)*—Record the minimum pixel value as the pixel value at the start of the plateau. Determine the mean pixel value (PV) in the approximate center of the computed radiograph on the base plate between the #8 and #10 EPS plaques in an area free of any holes, or, alternatively, within a central area of the base plate alongside the EPS plaques.

9.4.7 For long-term stability tests, EPS only needs to be verified at a selected dose in the plateau region (for example, only one exposure required), and shall be within one hole set of the baseline measurement.

9.5 *SNR:*

9.5.1 The SNR performance shall be established by measurement of SNR of computed radiographs of a homogeneously exposed IP.

9.5.1.1 To minimize the influence of fading effects, the measurement shall be done about 15 minutes after exposure.

9.5.1.2 The linear pixel value (PV) mean and standard deviation (σ) shall be calculated from a data set of at least 4000 values or more of the central IP area in a homogeneous exposed data field. No major scratches or dust and no shading shall be visible in the measurement area.

9.5.1.3 The SNR is calculated as the quotient of linearized PV^{mean} by standard deviation (σ) or by using the resident SNR software tool. For improved accuracy, the E2446 procedure may be applied.

9.5.1.4 The measured SNR shall be documented.

9.5.1.5 Periodic tests shall be performed with the same radiation image quality (tube voltage and pre-filter), the same distances and collimation and mA. All parameters and results shall be documented.

9.5.1.6 SNR measurements with rectangular measurement windows (see note) shall be done in both directions (laser scan and IP transport directions).

9.5.2 SNR data shall be collected over a range of exposures for system baseline performance testing and to establish the SNR plateau.

9.5.2.1 Record the SQRT(1/SNR) value versus exposure. An example plot is shown in Fig. 11.

9.5.2.2 The SQRT(1/SNR) data typically show a high value at low dose and a lower, relatively flat plateau as dose increases. Identify the plateau as the exposure working range that exhibits a relatively low and consistent SQRT(1/SNR) value (plateau at <15% variation).

9.5.2.3 Record the SNR performance as the SNR at the maximum SQRT (1/SNR) (i.e., largest) value in the plateau.

9.5.2.4 *(Optional)*—Record the minimum PV as the PV at the start of the plateau.

9.5.2.5 For long-term stability tests, SNR or SQRT(1/SNR) only needs to be verified at a selected dose in the plateau region (i.e., only one exposure required), and shall be within limits established in 9.5.2.6.

9.5.2.6 Upper and lower control limits for SNR shall be established using SPC on a minimum of 10 tests. If results are within ± 10% of a mean value, the limits shall be considered valid. Results beyond these limits shall require an investigation into the cause of the variability.

9.6 *Optional Tests:*

9.6.1 *Burn-In (optional)*—See 9.2.12.

9.6.2 *Spatial Linearity (optional)*—See 9.2.13.

9.6.3 *Central Beam Alignment (optional)*—See 9.2.14.

9.6.4 *IP Artifacts (optional):*

9.6.4.1 A CR image file of each IP may be saved at regular intervals to identify possible artifacts and be allocated with the serial number of the IP.

NOTE 1—Image evaluation during production CR imaging should include access to the CR IP artifact image (registration) files for artifact assessment and any impact on accurate evaluation.

9.6.5 *Imaging Plate Response Variation (optional):*

9.6.5.1 Measure the mean linearized PV of the image using an ROI which covers the majority of the image. PV variations should be less than 10% between IPs or IP lots unless otherwise determined by the responsible level 3. Use of IPs with large variations may require technique adjustments or changes to image acceptance criteria, or both, to allow use. Alternately, the user may consider restricted use of anomalous IPs.

9.6.6 *Imaging Plate Fading (optional):*

9.6.6.1 Plot the mean linearized PV versus wait time of the imaging plate. This information may be employed by the user to adjust techniques to meet image PV requirements where applicable.

10. Display of the Results

10.1 The user shall document all tests, conditions, and results. The period of testing shall meet the requirements in 6.3. It shall be documented in the user's written procedure and agreed upon between the contracting parties.

10.2 The results shall be summarized in Table 2.

11. Actions After Mismatch of the Limits in the Test Results

11.1 If an out of specification (as agreed between CEO and user) result of a test occurs, an action has to be taken to bring the system into limits again (for example, the CR scanner has to be repaired or replaced) or an agreement with the CEO has to be achieved about the deviation to the specification.

12. Precision and Bias

12.1 No statement is made about the precision or bias of this practice. The results merely state whether there is conformance to the criteria for success specified in the procedure.

13. Keywords

13.1 basic spatial resolution; burn-in; central beam alignment; contrast sensitivity; CR phantom; EPS; erasure; geometric distortion; imaging plate artifacts; imaging plate fading; laser beam scan line integrity; laser jitter; PMT non-linearity; scan column dropout; scanner slippage; spatial linearity

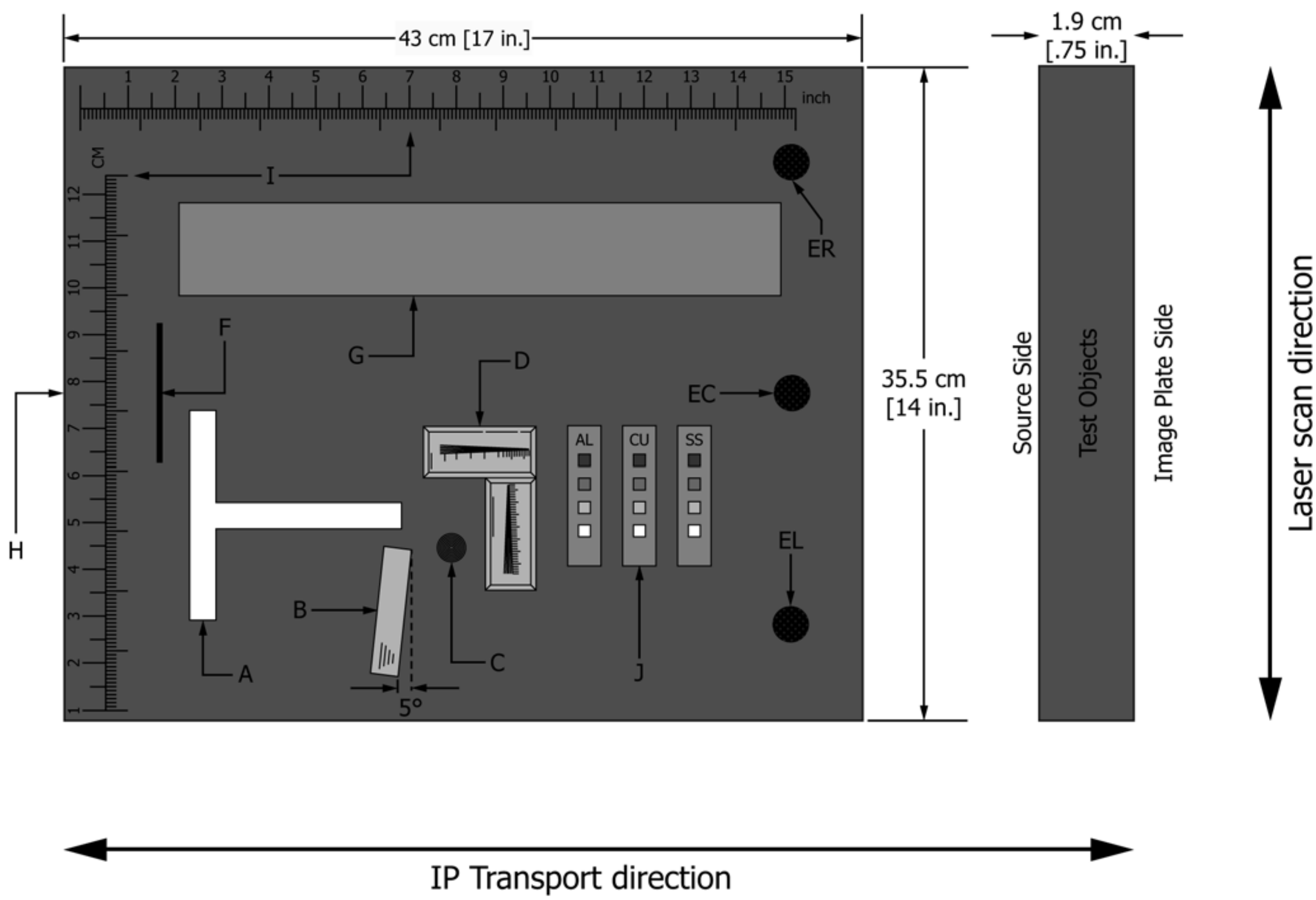
APPENDIXES

(Nonmandatory Information)

X1. CR TEST PHANTOM—TYPE I

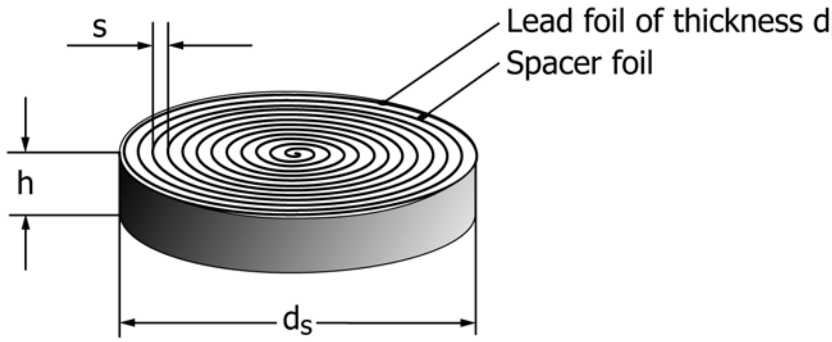
X1.1 *Location and Alignment of CR Image Quality Indicators in a CR Phantom*:

X1.1.1 Several CR image quality indicators (see Section 5) are located in a convenient test object, called a Type I CR phantom. This is the original CR Phantom as designed to meet Practice E2445 requirements. It consists of a carrier plate of low-absorbing material (for example, Lucite). Fig. X1.1 shows the arrangement. The CR image quality indicators shall be located on the IP side. If desired, individual test gauges may be utilized to determine specific results.



A: T-target for Laser Jitter Test: 114 × 12 × 2 mm [4.5 × 0.5 × 0.08 in.], Brass
B: Duplex-Wire Image Quality Indicator; in accordance with Practice E2002
C: Central Beam Alignment (BAM-snail)
D: Converging Line Pair Image Quality Indicators
E: EL, EC, ER: Measuring Points for Shading Correction 19 mm [0.75 in.] Diameter, 0.3 mm [0.1 in.] Acrylic Removed
F: Cassette Positioning Locator (does not appear on radiographic image)
G: Homogeneous Strip: Al, 0.5 mm [0.02 in.]
H: Lucite Plate
I: Inch/cm Ruler for Linearity Check
J: Contrast Sensitivity Image Quality Indicators
Aluminum: 12.7 mm [0.50 in.]
Copper: 6.35 mm [0.25 in.]
Stainless Steel: 6.35 mm [0.25 in.]

FIG. X1.1 CR Phantom Containing CR Image Quality Indicators for Qualification of Computed Radiography Systems



NOTE 1—Its radiographic image indicates deviations from the perpendicular position of the radiation source above the BAM-snail.

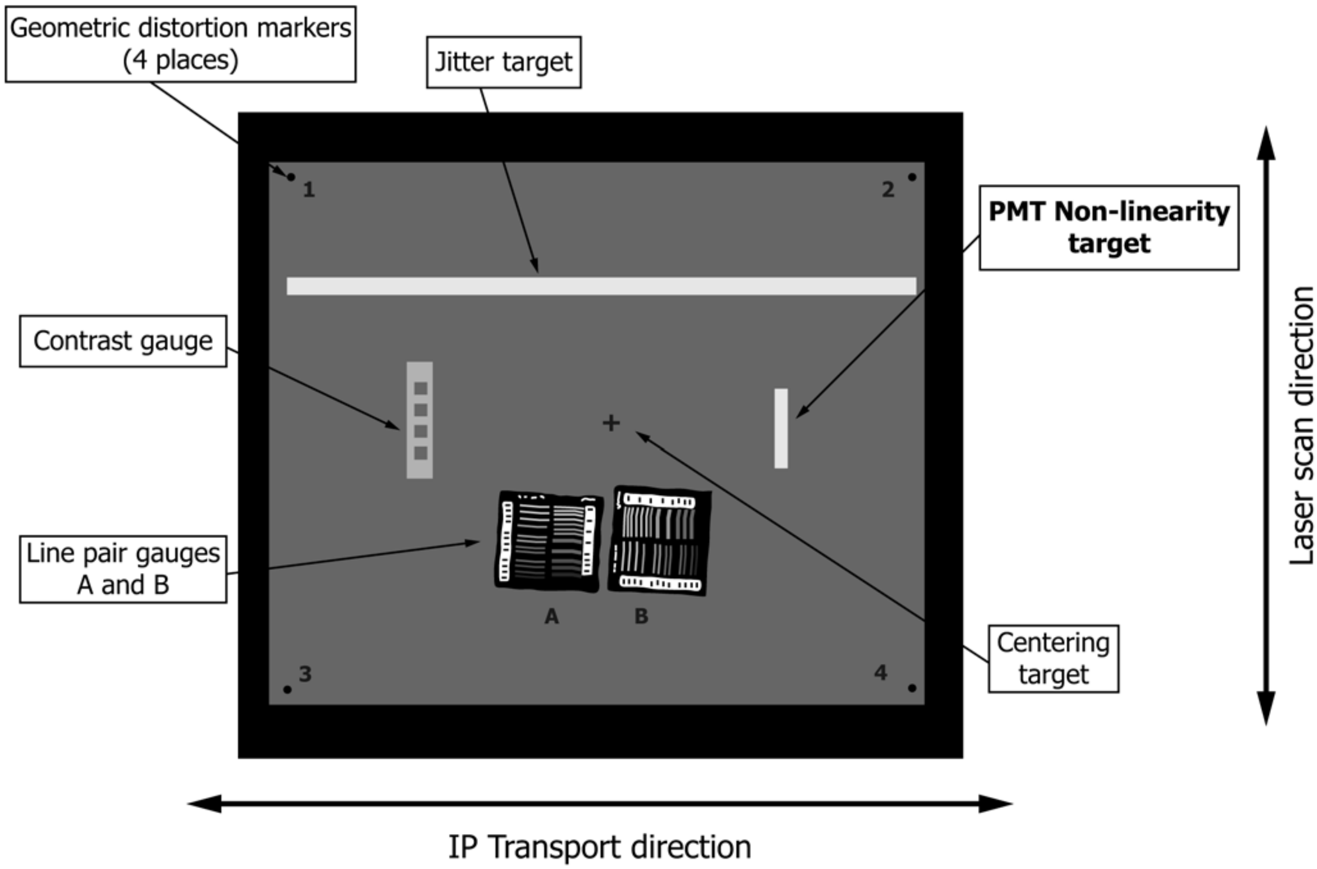
NOTE 2—The following dimensions are recommended: h = 1.5 to 2 mm [0.06 to 0.08 in.], s = h/11.5 mm [0.45 in.]) (structure disappears at deviations >5°), d_s > 8 mm [0.31 in.], d_i = 0.02 to 0.1 mm [0.0008 to 0.0004 in.].

FIG. X1.2 Alignment Quality Indicator and Source Position Indicator "BAM-snail"

X2. CR TEST PHANTOM—TYPE II FOR LOW ENERGY APPLICATIONS

X2.1 *Location and Alignment of CR Image Quality Indicators in a CR Phantom*:

X2.1.1 Several CR image quality indicators (see Section 5) are located in a convenient test object, called a Type II CR phantom. This was a variation of the Type I CR Phantom designed by the USAF for low energy applications (<160kV) in particular. It consists of a carrier plate of low-absorbing material (for example, Lucite). Fig. X2.1 shows the arrangement. The CR image quality indicators shall be located on the IP side. If desired, individual test gauges may be utilized to determine specific results.



The Type II CR Test Phantom includes:
Two parallel line pair gauges
One shot-centering target (steel fastener)
One 12.7 mm [0.5 in.] thick aluminum contrast gauge per Practice E1647
Four 1.5 mm [0.06 in.] diameter brass ball bearings (distances between targets: 1-3 and 2-4 are 318 mm [12.5 in.]; 1-2 and 3-4 are 394 mm [15.5 in]; 1-4 and 2-3 are 505 mm [19.9 in.]
Brass jitter target, 406 × 5 × 0.5 mm [16.0 × 0.200 × 0.020 in.]
Brass PMT non-linearity target, 76 × 5.5 × 0.5 mm [3.0 × 0.215 × 0.020 in.]
Lead numbers and letters to identify specific targets to aid procedure interpretation

FIG. X2.1 Type II CR Phantom Containing CR Image Quality Indicators for Qualification of Computed Radiology Systems

X3. DESCRIPTION AND LAYOUT OF EPS PLAQUES AND ABSORBER PLATE

X3.1 *Test Standard*—The test standard consists of four EPS plaques and an absorber plate. The plaques contain several rows of duplex holes. Based on the thickness of the plaques and diameter of the holes, each hole set represents an Equivalent Penetrameter Sensitivity (EPS) when placed on the absorber plate.

X3.1.1 EPS plaques consist of four plaques, built to the dimensional specifications of Practice E746.

X3.1.2 Absorber plate is built to the dimensional specifications of Practice E746 (i.e., 19 mm [0.75 in.] thick with surface finish requirements).

X3.1.3 Materials other than mild steel, as called out in Practice E746, may be used, but the RIQI and absorber shall be made of the same materials and the energy selection shall be appropriate for the chosen material and thickness. The surface finish of the absorber shall be a maximum of 6.3 µm [250 µin.] radium ground finish, both surfaces.

X3.2 *Assembly*:

X3.2.1 The EPS plaques shall be placed on the source side of the absorber plate, arranged in order of thickness, with the thickest plaque at the top of the absorber (see Fig. X3.1). The edges of the plaques shall be at least 38 mm [1.5 in.] from any edge of the absorber plate.

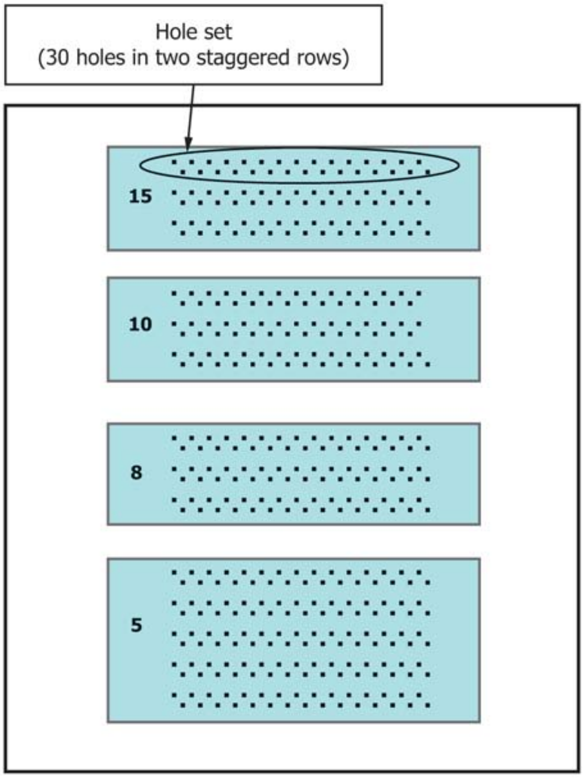


FIG. X3.1 General Arrangement of the EPS Test Standard

X3.2.2 The EPS plaques shall be affixed with tape to the absorber plate so that the plaques are flat. The tape shall not cover any holes.

NOTE X3.1—If a plaque is warped, it may yield unreliable results, and should be replaced.

X3.2.3 For convenience, the %EPS may be labeled on the absorber using permanent marker or lead letters. If lead letters are used, care must be taken to ensure placement of the letters does not obscure reading of the EPS holes.