Designation: E2446 – 16

Standard Practice for Manufacturing Characterization of Computed Radiography Systems[1]

1. Scope

1.1 This practice describes the manufacturing characterization of computed radiography (CR) systems, consisting of a particular phosphor imaging plate (IP), scanner, software, and an image display monitor, in combination with specified metal screens for industrial radiography.

1.2 The practice defines system tests to be used to characterize the systems of different suppliers and make them comparable for users.

1.3 This practice is intended for use by manufacturers of CR systems or certification agencies to provide quantitative results of CR system characteristics for nondestructive testing (NDT) user or purchaser consumption. Some of these tests require specialized test phantoms to ensure consistency of results among suppliers or manufacturers. These tests are not intended for users to complete, nor are they intended for long term stability tracking and lifetime measurements. However, they may be used for this purpose, if so desired.

1.4 The CR system performance is described by the basic spatial resolution, contrast, signal and noise parameters, and the equivalent penetrameter sensitivity (EPS). Some of these parameters are used to compare with DDA characterization and film characterization data (see Practice E2597 and Test Method E1815).

NOTE 1—For film system characterization, the signal is represented by the optical density of 2 (above fog and base) and the noise as granularity. The signal-to-noise ratio is normalized by the aperture (similar to the basic spatial resolution) of the system and is part of characterization. This normalization is given by the scanning circular aperture of 100 µm of the micro-photometer, which is defined in Test Method E1815 for film system characterization.

1.5 The measurement of CR systems in this practice is restricted to a selected radiation quality to simplify the procedure. The properties of CR systems will change with radiation energy but not the ranking of CR system performance. Users of this practice may carry out the tests at different or additional radiation qualities (X-ray or gamma ray) if required.

1.6 The values stated in SI are to be regarded as the standard.

1.7 *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 to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E746 Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems

E1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging

E1316 Terminology for Nondestructive Examinations

E1815 Test Method for Classification of Film Systems for Industrial Radiography

E2002 Practice for Determining Total Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy

E2007 Guide for Computed Radiography

E2033 Practice for Computed Radiology (Photostimulable Luminescence Method)

E2445 Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems

E2597 Practice for Manufacturing Characterization of Digital Detector Arrays

E2903 Test Method for Measurement of the Effective Focal Spot Size of Mini and Micro Focus X-ray Tubes

2.2 *ISO Standard:*[3]

ISO 17636-2 Non-Destructive Testing of Welds—Radiographic Testing—Part 2: X- and Gamma Ray Technologies with Digital Detectors

[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] 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] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

3. Terminology

3.1 *Definitions*—The definition of terms relating to gamma- and X-radiography, 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 *computed radiography system (CR system)*—A complete system of a storage phosphor imaging plate (IP), a corresponding read out unit (scanner or reader), software and an image display monitor, which converts the information of the IP into a digital image (see also Guide E2007).

3.2.2 *computed radiography system performance level*—A particular group of CR performance levels, which is characterized by a SNR_N (signal-to-noise ratio) range, an interpolated basic spatial resolution range $iSR_b^{detector}$ and equivalent penetrameter sensitivity (EPS) shown in Table 4 in a specified exposure range.

3.2.3 *gain/amplification*—Opto-electrical gain setting of the scanning system.

3.2.4 *ISO speed S_{IPx}*—Defines the speed of a CR system and is calculated from the reciprocal dose value, measured in Gray (Gy), which is necessary to obtain a specified minimum SNR_N of a CR system performance level.

3.2.5 *linearized signal intensity*—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.

4. Significance and Use

4.1 There are several factors affecting the quality of a CR image including the basic spatial resolution of the IP system, geometrical unsharpness, scatter and contrast sensitivity. There are several additional factors (for example, software and scanning parameters) that affect the accurate reading of images on exposed IPs using an optical scanner.

4.2 This practice is to be used to establish a characterization of CR system by performance levels on the basis of a normalized SNR, interpolated basic spatial detector resolution and EPS. The CR system performance levels in this practice do not refer to any particular manufacturers' imaging plates. A CR system performance level results from the use of a particular imaging plate together with the exposure conditions, standardized phantom, the scanner type, and software and the scanning parameters. This characterization system provides a means to compare differing CR technologies, as is common practice with film systems, which guides the user to the appropriate configuration, IP, and technique for the application at hand. The performance level selected may not match the imaging performance of a corresponding film class because of the difference in the spatial resolution and scatter sensitivity. Therefore, the user should always use IQIs for proof of contrast sensitivity and basic spatial resolution.

4.3 The measured performance parameters are presented in a characterization chart. This enables users to select specific CR systems by the different characterization data to find the best system for his specific application.

4.4 The quality factors can be determined most accurately by the tests described in this practice. Some of the system tests require special tools, which may not be available in user laboratories. Simpler tests are described for quality assurance and long term stability tests in Practice E2445.

4.5 Manufacturers of industrial CR systems or certification agencies will use this practice. Users of industrial CR systems may use Practice E2445 or perform some of the described tests and measurements outlined in this practice, provided that the required test equipment is used and the methodology is strictly followed. Any alternative methods or radiation qualities may be applied if equivalence to the methods of this practice is proven to the appropriate cognizant engineering organization.

4.6 The publication of CR system performance levels will enable specifying bodies and contracting parties to agree to particular system performance level, as a first step in arriving at the appropriate settings of a system, or the selection of a system. Confirmation of necessary image quality shall be achieved by using Practice E2033.

5. Apparatus

5.1 CR system evaluation depends on the combined properties of the phosphor imaging plate (IP) type, the scanner and software used, and the selected scan parameters and image display monitor. Therefore, documentation for each test shall include the IP type, scanner, software, scan parameters, and image display monitor, and the results shall be calculated and tabulated before arriving at a performance assignment. The applied test equipment for SNR measurement (Fig. 1) and algorithm 6.1.1 correspond to Test Method E1815. The recommended thickness for aperture test object (diaphragm) is 10.2 mm (0.4 in.) of Pb. The SDD shall be at least 1 m (39 in.). Do not use any material (for example, lead) behind the cassette and leave a free space of at least 1 m (39 in.) behind the cassette 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 contact with the cassette.

5.2 The step wedge method (Fig. 2) describes a simpler procedure for SNR measurement than described in Test Method E1815, which permits obtaining similar results with less expense, and less accuracy.

6. Procedure for Quantitative Measurement of Image Quality Parameters

6.1 *Measurement of the Normalized Signal-to-Noise Ratio (SNR_N)*

6.1.1 *Step Exposure Method*—For measurement of the SNR, the following steps are taken (see also Test Method E1815):

6.1.1.1 The IP shall be positioned in front of an X-ray tube with tungsten anode. Make the exposures with an 8 mm (0.32 in.) copper filter at the X-ray tube and the kilovoltage set such that the half value layer in copper is 3.5 mm (0.14 in.). The kilovoltage setting will be approximately 220 kV. Metal screens can be used in the cassette if the manufacturer recommends its application. The focal spot size is not relevant for SNR measurements.

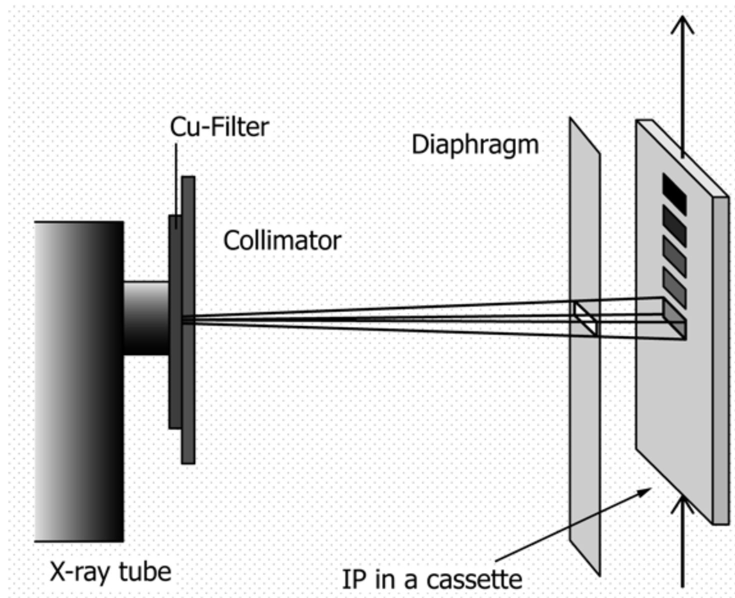


FIG. 1 Scheme of Experimental Arrangement for the Step Exposure Method

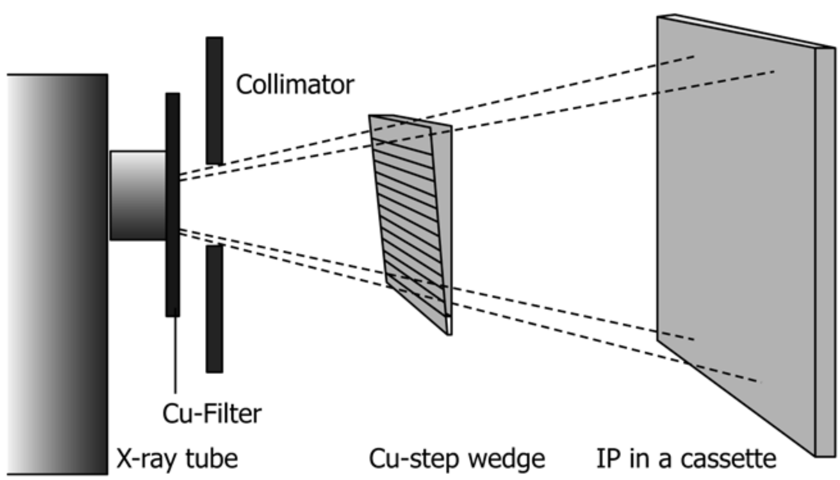


FIG. 2 Scheme for the Measurement of the SNR by the Step Wedge Method

6.1.1.2 Determine the required exact kilovoltage setting by making an exposure (or an exposure rate) measurement with the detector placed at a distance of at least 750 mm (29.5 in.) from the tube target and an 8 mm (0.32 in.) copper filter at the tube. Then make a second measurement with a total of 11.5 mm (0.45 in.) of copper at the tube. These filters should be made of 99.9 % pure copper.

6.1.1.3 Calculate the ratio of the first and second readings. If this ratio is not 2, adjust the kilovoltage up or down and repeat the measurements until a ratio of 2 (within 5 %) is obtained. Record the setting of kilovoltage for use with the further IP tests.

6.1.1.4 The scanner shall read with a dynamic range of ≥ 12 bit and operate at its highest spatial resolution or a basic spatial resolution for which the characterization shall be carried out. Background and anti-shading correction may be used before the analysis of data, if it relates to the standard measurement procedure for all measurements.

6.1.1.5 The procedure shall be carried out and documented for one or more agreed sets of scanner parameters per imaging plate type. It is recommended to use the standard parameters of the CR scanner as given by the manufacturer and the parameter set for the highest resolution.

6.1.1.6 IPs are exposed under the conditions described above: A signal (S) and noise (σ) or the quotient, the signal to noise ratio (SNR vs. dose and pixel value curve shall be measured—see Fig. 3 and Fig. 4). It is important that the exposure of the IP for the SNR measurements be spatially uniform. Any non-uniformities in X-ray transmission of the cassette front, or defects in a front metal screen or in the phosphor layer itself could influence the SNR measurement. No major scratches or dust shall be visible in the measurement area. Therefore, exercise considerable care in selection and placement of the aperture, selection, and maintenance of the cassette, the metal screens (if any), and the imaging plate. To achieve a uniform area of interest on to the IP, the following

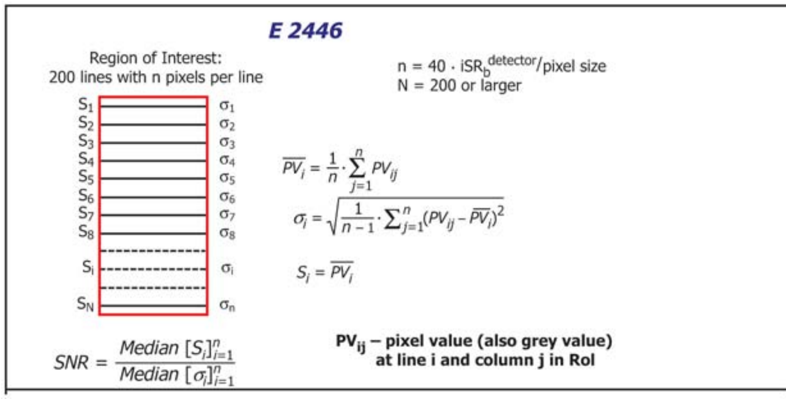
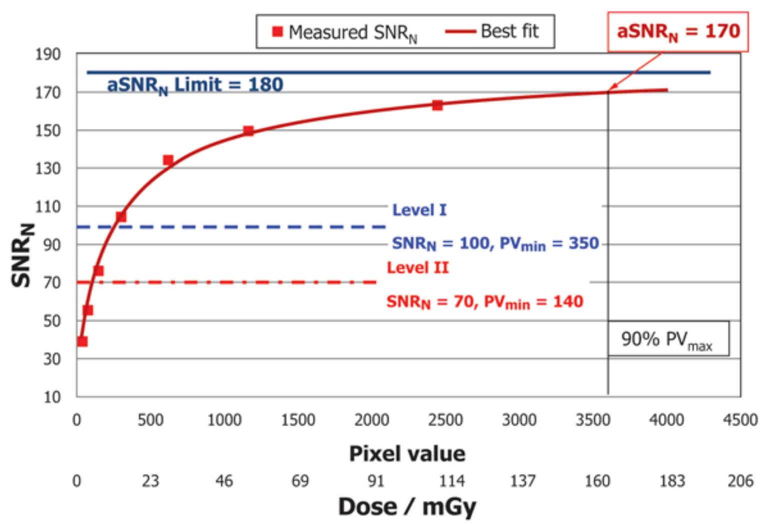


FIG. 3 Scheme for Measurement of SNR in the RoI with Pixel Values PV_{ij}



NOTE 1—The tested CR system qualifies for:
Level I performance from PV 350 – 4095 (see Table 4)
Level II performance from PV 140 – 4095 (see Table 4)
PV_{max} = 4095, as determined with procedure of 6.4

FIG. 4 Example Plot of Measured SNR_N Versus PV (12 bit system, iSR_b = 70 µm) for Determination of Level I and II Performance Range (see 6.4)

standard protocol is recommended. Other approaches may be used as long as a uniform exposure is created. At least twelve areas (test areas) of ≥400 mm^2 (0.62 in.^{2}) are evenly exposed on the same IP over the full working range of dose. Due to the different construction principles of scanners, the measurement shall be performed for different pixel sizes as recommended by the manufacturer. A waiting time of 15 minutes is recommended between exposure and scan of the IPs to avoid distortions by fading effects. Typically the characterization is performed for selected parameter sets only if agreed by the manufacturer and the certifying laboratory. The digital read-out pixel values shall be calibrated in such a way that they are linear in relation to the radiation dose, which corresponds to the photo stimulated luminescence (PSL) intensity of the exposed IPs. These calibrated pixel values shall be used for the calculation of the SNR to obtain a reliable result. Measurements shall be made on at least six different samples, and the results are to be averaged for each of the twelve or more dose levels measured.

6.1.1.7 The signal (*S*) and noise (standard deviation σ) of the measured pixel values shall be calculated from a region of interest (RoI) without shading or artifacts. Sample SNR values shall be taken in different regions of the image area under test to ensure that SNR values are within 10 %. The size of the RoI used to measure the mean signal and noise shall be at least 40 by 200 pixels.

6.1.1.8 An example technique for ensuring reliable signal-to-noise measurements is described in the following. This can be achieved using a commonly available image processing tool. The signal and noise shall be calculated from a data set of 8000 values or more per exposed area. The unfiltered data set is subdivided into 200 groups or more with 40 values per group

(200 or more profile lines with 40 pixels per profile). For each group with index *i*, the signal S_I and the noise value σ_i are calculated from the pixel values PV_{ij} in the region of interest (RoI). An increased number of groups per RoI yields a better (lower) uncertainty of the result. Fig. 3 describes the measurement procedure in detail and the equations to use. If $SR_b^{detector}$ > pixel size, it is recommended to use a profile line width (lw) of:

$$lw\ (\text{pixel}) = 40 \cdot iSR_b^{\text{detector}}/\text{pixel size} \quad (1)$$

6.1.1.9 The final value *S* is obtained by the median of all S_i values. The final σ value is obtained by the median of all σ_i values. SNR shall be calculated as reference value SNR_N, normalized to a resolution of 88.6 µm, which is related to a squared aperture (pixel size of 88.6 x 88.6 µm²). The final value SNR_N is calculated by considering the measured interpolated basic spatial resolution iSR_{bmax} (see 6.5):

$$\text{SNR}_N = SNR \cdot \frac{88.6\ \mu m}{iSR_{bmax}} \quad (2)$$

where:

iSR_{bmax} = interpolated maximum value of basic spatial resolution in µm as measured in 6.5.

NOTE 2—Test Method E1815 requires the use of a micro-photo densitometer with circular aperture of 100 µm diameter for the measurement of granularity σ_D of films. Because the pixels in digital images are organized in squares, the corresponding pixel size is calculated by sqrt $((100\ \mu m)^2\ \pi / 4)$ = 88.6 µm (1 µm = 3.93701E-05 in.). This value of 88.6 µm for normalization was selected for comparison of noise in digital images with film granularity.

6.1.1.10 SNR_N shall be plotted versus pixel value (Fig. 4) and versus exposure dose.

6.1.2 *Step Wedge Method (Manufacturer Test and Enhanced User Test)*—The measurement of the SNR can be performed with less accuracy using a step wedge, as shown in Fig. 2. This method, if approved by the cognizant engineering organization (CEO), may be of interest for users to determine the SNR with less expensive equipment:

6.1.2.1 For that purpose, a step wedge of Cu, with at least twelve equally increasing steps, shall be used as in the arrangement shown in Fig. 2. The selection of the X-ray voltage shall be as described in 6.1.1.1. The maximum thickness of the step wedge shall absorb 90 % of the radiation of the central beam, which requires a thickness of 11.7 mm (0.46 in.). To cover a range of two or more orders of magnitude of the radiation dose, at least two suitable and different exposures with adequate exposure time or tube current (mA) shall be made. A waiting time of 10 minutes is recommended between exposure and scan of the IPs to avoid distortions by fading effects. The distance between step wedge and IP shall be ≥500 mm (19.69 in.) to reduce the influence of scattered radiation. A magnification of 2× is recommended. A beam collimator shall be used to restrict exposures to the step wedge only. X-ray voltage and filtering shall be selected in accordance with 6.1.1.1 through 6.1.1.3.

NOTE 3—X-ray penetration through Cu-steps of different thickness is distorted by beam hardening and suitable adjustment of exposure is required.

6.1.2.2 The projected area of each step shall be about 20 by 20 mm (≥400 mm²). SNR values should not be taken closer than four times the iSR_b^{image} to an edge.

6.1.2.3 All details for the measurement of the SNR shall correspond to 6.1.1.6 – 6.1.1.9. The graphical analysis shall be based on the plot of SNR = f(sqrt [Exposure·exp($-\mu_{Cu} \cdot w_{Cu}$)]), where μ_{Cu} is the absorption coefficient, w_{Cu} is the wall thickness of the corresponding step of the step wedge and the value "Exposure" is calculated from exposure time (seconds), multiplied by tube current (mA).

NOTE 4—For accurate plots, it is necessary to consider the wall thickness dependence of μ_{Cu} on the wall thickness (beam hardening). The influence of scattered radiation should be reduced by exact collimation. Different exposures with different exposure time or mA-settings are recommended for the required plot. The exposure value (mAs) of the different exposures of the step wedge target should be increased by about 5.

6.2 *Contrast Sensitivity by Equivalent Penetrameter Sensitivity (EPS)*

6.2.1 The characterization by performance levels being based on the EPS can be performed with less accuracy on basis of visual evaluation of radiographs than by the quantitative SNR_N step exposure method using the following procedure on basis of Practice E746, as illustrated in Fig. 5. The standard procedure is the EPS measurement at 90% of the maximum achievable pixel value, PV_{max} (see also 6.3 and Fig. 4) with a steel absorber as described in Practice E746 and the measurement of the effective attenuation coefficient. Optionally, the complete plot of EPS vs. dose curve may be measured (Fig. 5) and PV_{min} may be determined as shown in Fig. 6 for the different performance levels. Other fine grained materials than mild steel and different radiation qualities may be used if requested for other applications as, for example, testing of light materials in aerospace applications.

6.2.2 *Required Measurements and Evaluations*—These evaluations are adapted from Practices E746 and E2002. Image quality indicators from these standards and a 1-mm steel plate for measurement of the relative contrast are arranged in a standard phantom (Fig. 5) and exposed with a (Practice E746) 19 mm (¾ in.) absorber of mild steel to qualify. The tube voltage shall be 220 kV with 2 mm Cu in front of the tube port instead of 200 kV as recommended in Practice E746.

6.2.2.1 The EPS value shall be determined at least at 90 % of the PV_{max}. Alternatively, the EPS performance may be determined in the characterized linear or linearized PV range as illustrated in Fig. 5.

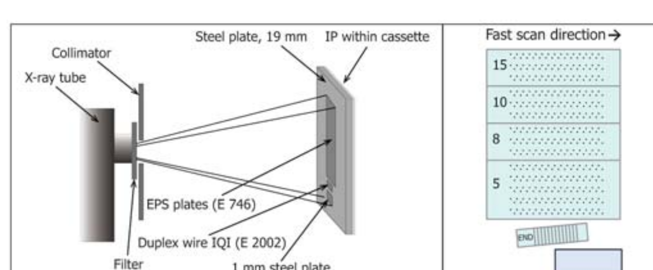
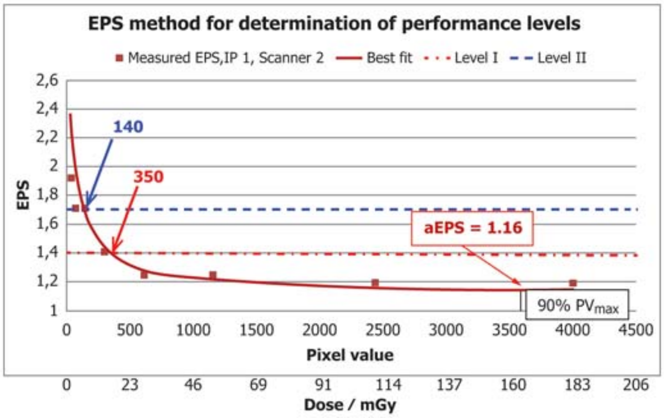


FIG. 5 Illustration of EPS Characterization Set Up (left) and Test Phantom (right). The Duplex Wire IQI is Tilted Approximately 5°.



NOTE 1—The tested CR system qualifies for:
—Level I performance from PV 350–4095 (see Table 4)
—Level II performance from PV 140–4095 (see Table 4)
—PV_{max} = 4095, as determined with procedure of 6.4
—aEPS = 1.16

FIG. 6 Example Plot for Measured of EPS Versus PV (12 bit system, iSR_b = 70 µm) for Determination of Level I and II Performance Range

6.2.2.2 *Determination of Relative Contrast C_{1mm}*—Fig. 5 illustrates a typical layout for a 19-mm (¾-in.) thick steel plate, at least 20 cm (≈ 8 in.) wide by 25 cm (≈ 10 in.) long, containing a series of Practice E746 EPS plaques of varying thicknesses and hole sizes, a 1-mm steel plate and a Practice E2002 unsharpness gauge with duplex wires oriented approximately 5° tilted to the plate edge direction for monitoring of the influence of the geometric unsharpness and all IQIs are situated on the source side. The 19-mm (¾-in.) steel plate should cover the complete IP and IP cassette. The X-ray source shall be collimated to the 19-mm (¾-in.) plate only. The surface finish of the absorber plate shall be no worse than RMS 250. If the EPS absorber plate does not cover the entire IP, the IP shall be masked with lead around the absorber plate.

6.2.3 EPS characterization by Practice E746. For each exposure (data point in Fig. 6) at different dose of the set of Fig. 5, determine the lowest (best) EPS performance of each exposure by determining the duplex row (Practice E746 illustrates step layout and corresponding EPS %), where a minimum of 15 holes out of 30 holes in each duplex row (50% rule) are clearly visible. Table 1 provides EPS values (see also Practice E746) for each visible duplex row on the specified standard of a 19-mm (¾-in.) absorber plate of steel. Plot the EPS (in %) taken with the set of Fig. 5 in a graph as presented in Fig. 6 that corresponds with the qualifying hole size row of Table 1, its corresponding exposure identification and pixel value.

6.2.3.1 The source-to-detector distance (SDD) shall be at least 1 m (39 in.). The geometric unsharpness, u_g, shall not exceed 50 µm and u_g shall not exceed 20 % of $iSR_b^{detector}$. The kilovoltage setting shall be selected corresponding to 6.1.1.1 – 6.1.1.3 and is approximately 220 kV for the steel absorber. No material (for example, lead) shall be used behind the cassette, free space of at least 1 m (39 in.) shall be left behind the cassette or a steel screen of about 0.5 mm (0.02 in.), and a lead plate of > 2 mm (0.08 in.) shall be used just behind the cassette

TABLE 1 EPS Values on Standard 19-mm (¾-in.) Absorber Plate as a Function of Step and Hole Size

Plaque Number	Step Size mm (in.)	Hole Size mm (in.)	EPS %
		0.71 (0.028)	1.92
15	0.38 (0.015)	0.64 (0.025)	1.82
		0.58 (0.023)	1.71
		0.79 (0.031)	1.66
10	0.25 (0.010)	0.71 (0.028)	1.57
		0.64 (0.025)	1.49
		0.71 (0.028)	1.41
8	0.20 (0.008)	0.64 (0.025)	1.33
		0.58 (0.023)	1.25
		0.81 (0.032)	1.19
		0.71 (0.028)	1.12
5	0.13 (0.005)	0.64 (0.025)	1.05
		0.58 (0.023)	1.00
		0.50 (0.020)	0.94

(steel screen is positioned between cassette and lead) and in contact with the cassette. The EPS method may be applied for materials other than steel by agreement of the CEO or the contracting parties.

6.2.3.2 The interpolated basic spatial resolution as determined from the exposure through the absorber plate shall be no more than 10 % worse than the interpolated basic spatial resolution as determined without the absorber plate at 220 kV (8 mm Cu). If this is not achieved, the focal spot size (as measured by Test Methods E1165 or E2903) shall be reduced or the SDD shall be increased.

6.3 *Linearity Test of Pixel Value Response for Linearized Values*

6.3.1 Measured signal values (mean pixel values) of 6.1 or 6.2 are plotted versus exposure dose along a linear exposure scale for linear systems (see Fig. 7). Nonlinear systems shall be tested with a numeric linearization corresponding to the manufacturer's conversion equation for linearization. The pixel value range characterization is valid only for the specific scanner operational parameters used, including photomultiplier tube gain, laser power, sampling resolution setting, and all other operator adjustable scanner control parameters. Exposures should be approximately equally distributed within the qualified PV range. The linearity test shall be performed in the range from 10 to 90 % of the full PV range. At least eight data points should be taken.

6.3.2 The measured pixel values shall not deviate from the linear fit more than 5 %. If the linearity does not cover the full range, a PV_{max} value shall be specified that shall not be exceeded in NDT practice.

6.3.3 No PV_{max} characterization is required if the system is linear over the full scanner PV range to exposure dose.

NOTE 5—PV_{max} specification is typically not required. Related to the observation that sometimes nonlinearities may appear, if readers scan IP areas that have been exposed with extraordinary high exposure dose values, the linearity test should cover the full PV range. Fading may also influence the linearity with increased exposure time.

6.4 *Determination of Minimum Pixel Value, PV_{min}*

6.4.1 *Determination of PV_{min} with the SNR Method—*

TABLE 2 Required Tests of Practice E2445 and Required Result

Required Test	Required Result
Geometric Distortion (by spatial linearity image quality indicators in Type I Test Phantom)	Fail if distortion > 2%
Laser Jitter (by T-target in Type I CR Test Phantom)	Not permitted Straight and continuous edges required
Laser Beam Scan Line Integrity (no test object required)	Not permitted
Scan column dropout (no test object required)	Not permitted
Scanner Slippage (by homogeneous strip slippage target in Type I CR Test Phantom)	Not permitted
Imaging plate Artifacts (no test object required)	Not permitted
Erasure (high absorption object required)	Fail if > 2%
Shading or banding (by homogeneous plate, three shading image quality targets in Type I)	Fail if more than ±10%
Test Results Shall be Reported, also in Case of Exceeding the Limits	**Result to Report**
PMT Non-linearity (by T-target in Type I CR Test Phantom)	Report if > 2%
Burn-In (high absorption object required)	Report if > 2%
Spatial Linearity (by spatial linearity image quality indicators in Type I CR Test Phantom)	Report if > 2%
Imaging plate response variation (no test object required)	Report if > ±10%
Optional Test on Request	**Result to Report**
Imaging Plate Fading (no test object required), optional test	Report fading in %, calculated from values measured at 5 min and 2 h.

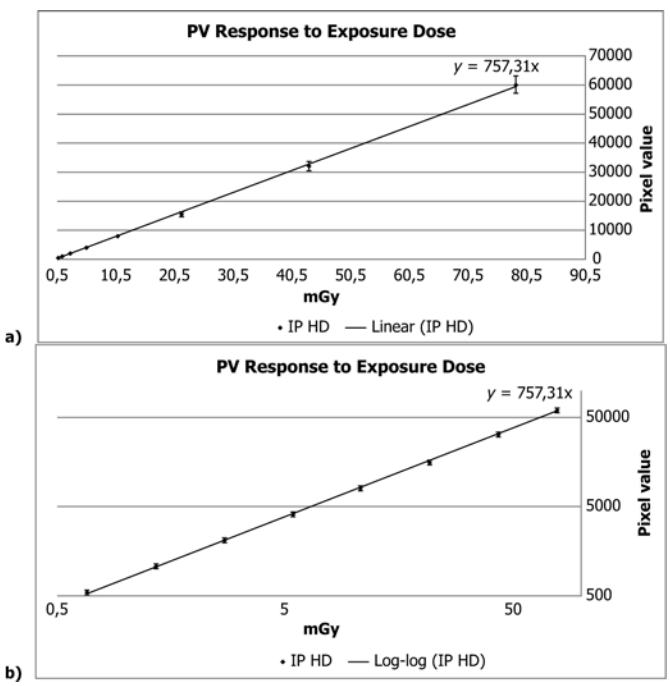


FIG. 7 PV Linearity Characterization for CR Systems with 5% Bars
(a) The system is qualified successfully in the PV range from 0 to 65535 (16 bit system).
(b) The error bars in the low intensity range can be evaluated better in the double logarithmic graph.

6.4.1.1 Plot a graph of SNR_N versus mean pixel value PV_{mean} as a function as illustrated in Fig. 4.

6.4.1.2 Use SNR_N versus PV correlation data as presented in Fig. 4 for the specific qualifying CR system to determine the minimum pixel value that provides the desired minimum SNR_N for the performance level as specified in Table 4.

6.4.1.3 Pixel values and SNR_N values shall be determined without the use of any digital filtering. Some scanner systems may provide degraded SNR or SNR_N values at very high pixel values and low gain. In the event that this occurs, a maximum pixel value (PV_{max}) shall be specified as the upper linear PV without degradation of the plotted line.

TABLE 4 CR System Performance by Performance Levels

CR System Performance	Required Minimum SNR_N (Normalized to SR_b=88.6 µm)	Permitted Maximum $iSR_b^{detector}$ Value (µm)	Permitted Maximum Achieved EPS by E746 (%)[A]
CR Special	200	50	1.00
CR Level I	100	100	1.41
CR Level II	70	160	1.66
CR Level III	50	200	1.92

[A] E746 specifies the test for steel at 200-220 kV. If the measurement is performed with other materials or kV values, or both, user dependent values may be specified.

6.4.1.4 When establishing minimum pixel values using this method, the specific scanner and its parameters used as well as the specific imaging plate type used shall be recorded for this characterization.

6.4.1.5 The minimum SNR_N values for specification of PV_{min} and PV_{max} (if required) for performance Special to Level III are provided in Table 4.

6.4.2 *Determination of PV_{min} with the EPS Method—*

6.4.2.1 Plot a graph of EPS versus mean pixel value PV_{mean} as a function as illustrated in Fig. 6.

6.4.2.2 Use the EPS versus PV graph as presented in Fig. 6 for the specific characterization of the CR system to determine the minimum pixel value that provides the desired EPS for the performance level as specified in Table 4.

6.4.2.3 Pixel values and EPS values shall be determined without the use of any digital filtering. Some scanner systems may provide degraded EPS values at very high pixel values and low gain. In the event that this occurs, a maximum pixel value (PV_{max}) shall be specified.

6.4.2.4 When establishing minimum pixel values using this method, the specific scanner and its parameters used as well as the specific imaging plate type used shall be recorded for this characterization.

6.4.2.5 The maximum EPS values for specification of PV_{min} and PV_{max} (if required) for performance Special to Level III are provided in Table 4.

NOTE 6—Minimum SNR_N performance levels are one of the three basic preconditions for satisfying image quality. The IQI sensitivity improves (smaller EPS) with *(1)* higher SNR or SNR_N (higher radiation intensity and exposure time), *(2)* higher attenuation coefficients (reduced radiation energy), and *(3)* better (lower values) basic spatial resolution. All these three parameters are relevant for sufficient image quality.

NOTE 7—The classical quality assurance procedure in film radiography is based on the measurement of the film density. Exposed films are accepted only if they have a minimum optical density. A similar procedure can be applied in CR. Each CR system (or any digital imaging system) provides pixel values of each picture element (pixel). The pixels in the region of interest (RoI) that are to be evaluated, should exceed a minimum pixel value, in a similar way as minimum optical density in film radiography. Single outliers as e.g. indications of dust indications may not be evaluated. This minimum pixel value is the reference minimum pixel value PV_{minx} as determined in 6.4. This procedure permits basic quality assurance in CR in relation to contrast sensitivity.

6.5 *Determination of Interpolated Basic Spatial Detector Resolution of CR Systems*

6.5.1 *Duplex-Wire Method*

6.5.1.1 The test object to measure the $iSR_b^{detector}$ is the duplex-wire gage corresponding to Practice E2002. The exposure shall be performed in a distance of 1 m (39 in.) or greater using an X-ray tube with a focal spot size ≤ 1 mm. Focal spot size and focus detector distance shall be selected for a geometric unsharpness of less than 5 % of the total measured unsharpness. The duplex-wire gage shall be positioned directly on the cassette with the IP and lead screen. The measurement shall be performed perpendicular and parallel to the scanning direction of the laser beam. This requires two exposures with one gauge or one exposure with two gauges. The duplex-wire gage shall be used in an angle of about 5° to the scanning direction of the laser beam and about 5° to the perpendicular direction.

6.5.1.2 The measurement of unsharpness may depend on the radiation quality. For characterization and applications above 160 kV the test shall be performed with 220 kV (X-ray tube with beryllium window, tungsten target, and no pre-filtering). For low energy applications the radiation quality shall be 90 kV (X-ray tube with beryllium window, tungsten target, and no pre-filtering). A pre filter up to 0.5 mm (0.02 in.) copper in front of the tube port can be used by specification of the manufacturer. The CR image shall be exposed between 60 % and 90 % of full saturation value. The full saturation value is the maximum achievable pixel value, PV_{max}, of the system (e.g., PV_{max} = 65 535 for a linear 16 bit system. See also 6.3 for determination of PV_{max}.). A SNR of ≥ 100 shall be obtained.

6.5.1.3 The measurement shall be done across the middle area of the IQI image integrating along the width of about 30 to 60 % of the wire length of the duplex wires to avoid variability along the length of the wires (Fig. 8a).

6.5.1.4 For sufficient accuracy in the measurement of the $iSR_b^{detector}$ value the 20% modulation depth (dip) value shall be approximated from the modulation depth (dip) values of the neighbor duplex wire modulations. Fig. 8 and Fig. 9 illustrate the procedure for determination of $iSR_b^{detector}$.

6.5.1.5 The $iSR_b^{detector}$ is calculated as the polynomial approximation of the modulation depth (dip) vs. the wire pair spacing of neighbored wire pairs with at least two wire pairs with more than 20 % dip between the wires in the profile and at least two wire pairs with less than 20 % dip between the wires in the profile (Fig. 8 and Fig. 9), if their values are larger than zero. If no values are available with dip < 20 %, the largest wire pair value with the dip of zero shall be used. If the measured $iSR_b^{detector}$ is smaller than the pixel size, for example, a result of aliasing effects, $iSR_b^{detector}$ shall be characterized as $iSR_b^{detector}$ = pixel size.

6.5.1.6 The calculation of the modulation depth (dip) shall be performed as shown in Fig. 8c and Fig. 8d. The resulting approximated or interpolated basic spatial resolution value (see Fig. 9) shall be documented as "interpolated $SR_b^{detector}$-value" or $iSR_b^{detector}$.

NOTE 8—The dependence of modulation depth (dip) from wire pair spacing should be fitted with a polynomial function of second order for calculation of the intersection with the 20 % line as indicated in Fig. 8 and Fig. 9.

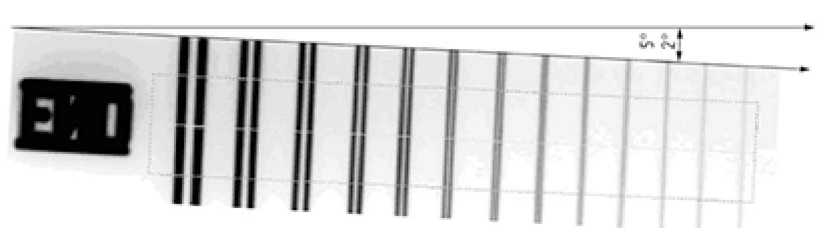
6.5.1.7 The interpolated basic spatial resolution shall be measured both perpendicular and parallel to the scanning direction of the laser. The larger value of both $iSR_b^{detector}$-values ($SR_{bmax}^{detector}$) shall be used as maximum interpolated basic spatial resolution for characterization. It should be rounded to the nearest 5 µm step in the characterization statement.

NOTE 9—If a system has an interpolated basic spatial resolution of 200 µm in fast scan direction of the laser, and 100 µm perpendicular to the fast scan direction, then the final maximum interpolated basic spatial system resolution is $iSR_{bmax}^{detector}$ = 200 µm

6.6 *Test Procedures of Practice E2445*

6.6.1 When making radiographs for CR system performance characterization, the manufacturer's guidelines shall be used for handling and scanning. The following tests, described in Practice E2445 under "Test Procedures," shall be performed additionally. The tests shall be passed with no findings or the results shall be under the threshold of Table 2, otherwise the test result shall be documented in the characterization report.

6.6.1.1 This means there will be minimum geometric distortion and nonlinearity. The characteristics of the laser beam



NOTE 1—X– distance
Y– amplitude

FIG. 8 Example for Measurement of the Modulation's Depth of Radiographs with Duplex Wire IQI
(a) Image of Duplex Wire as Shown in a Radiograph

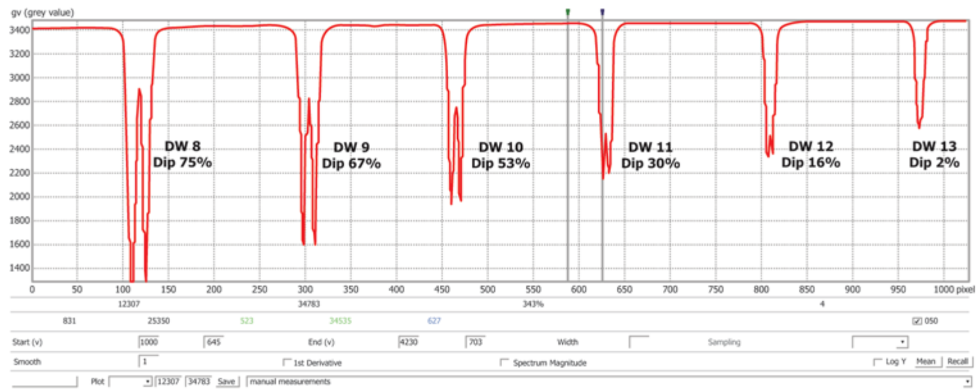


FIG. 8 (b) Measured Duplex Wire Profile with Determined Modulation Depths (Dips) *(continued)*

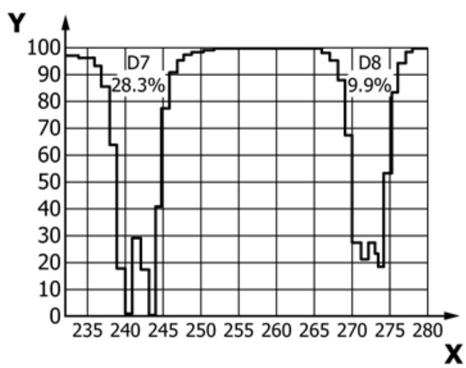


FIG. 8 (c) Enlarged Duplex Wire Profile. *(continued)*

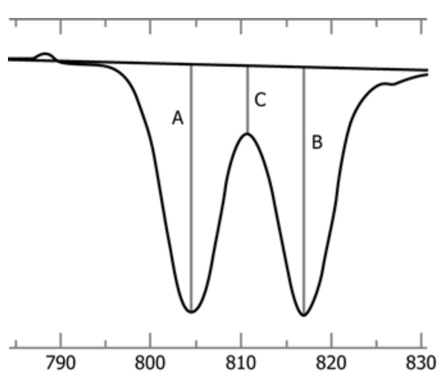


FIG. 8 (d) Scheme of the Calculation of the Dip Value in % with Dip = 100 x (A+B-2C)/(A+B). *(continued)*

in the scanner will be optimized with no beam jitter, no signal dropout, and best laser focus. The CR plates will be transported without slipping. The image shading will be within limits of ±10 %. The plates used will be correctly erased and will be free from artifacts.

6.6.1.2 Fading effects will be measured optionally. The standard measurement shall be taken at 5 min and 2 h. The fading *Fd* (in %) is calculated from the pixel value taken after 5-min waiting time after exposure (PV5) and 120-min waiting time after exposure (PV120). FA is calculated by:

$$Fd = 100 \cdot (1 - (PV120 / PV5)) \tag{3}$$

6.6.1.3 If specified by the manufacturer, the graph of fading versus time shall be included in the characterization report.

6.6.2 The measurement of the PMT nonlinearity is based on the measurement of an image taken with the T-target in the Type I CR test phantom. The Type I CR test phantom shall be positioned in a distance of 1 m (about 39 in.) from the X-ray source and the IP shall be positioned directly behind the phantom. The exposure shall be taken at 90 kV without any filter in front of the tube port. Lead filters in front of the IP shall be used in agreement with the manufacturer requirements. The CR image shall be exposed between 60 % and 90 % of full saturation value. A SNR of ≥ 100 shall be obtained. A profile function shall be used to determine the PMT nonlinearity. The profile is taken as shown in Fig. 10 about 12 mm (½ in.) from the T-end, perpendicular to the fast scan direction. The nonlinearity PMT_{Nl} is calculated by:

$$PMT_{Nl} = 200\% \cdot \frac{P1 - P2}{P1 + P2} \tag{4}$$

If the left and right profile steps are different, the average value of both steps shall be taken.

7. Determination of Characterization Data

7.1 *Determination of ISO Speed*

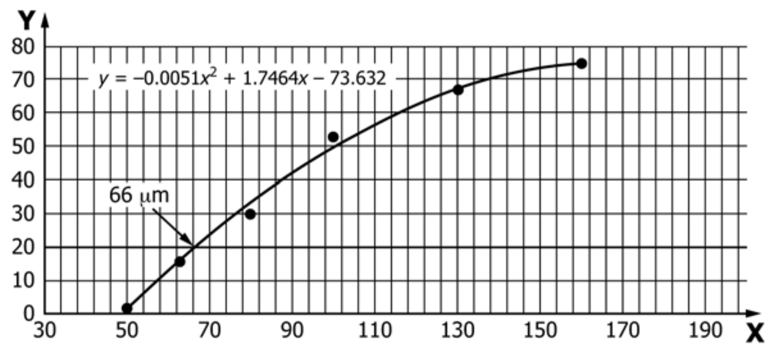
7.1.1 The ISO speed S_{ISO} is calculated by the dose K_S, which is needed for exposure of an IP with the pixel value PV_{min} by $S_{ISO} = K_S^{-1}$ (K_S in Gray). The ISO speed shall be given corresponding to each system class, which can be achieved with a system.

NOTE 10—For the same CR system, different ISO speeds are given for different performance levels.

7.1.2 The CR system manufacturer will provide the ISO speeds and the PV_{min}-values depending on the imaging plate type, the scanner and software used and its parameter setting. The ISO speed may be determined in steps corresponding to the values of Table 3.

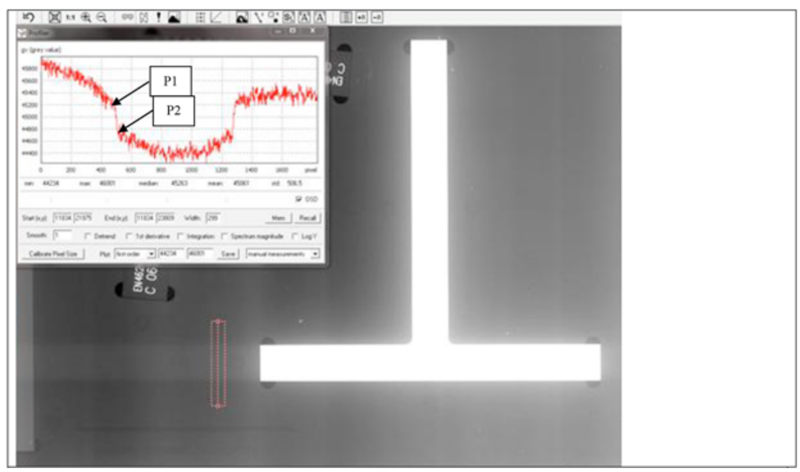
7.2 *Efficiency*—The efficiency shall be determined from the plot SNR_N versus exposure dose (see Fig. 4). The efficiency at 220 kV is defined as the SNR_N value at an exposure of 1 mGy (SNR_N at 1mGy). If the measured efficiency (SNR_N at 1mGy) is smaller than 50, then the efficiency shall be determined as the SNR_N value at an exposure of 5 mGy divided by 2.24 (SNR_N at 5mGy/square root of 5). This value shall be given as parameter in the spider net graph in Fig. 12.

7.3 *Achievable aSNR$_N$—aSNR$_N$* is measured at 90% ±5% PV at the selected scanner parameter set to characterize the



NOTE 1—X- wire pair spacing in µm
Y- modulation depth (dip) in %
Example for determination of the interpolated basic spatial resolution ($iSR_b^{detector}$) by interpolation from the measured modulation depths (dips) of neighbored duplex wire elements and interpolation of the 20 % value resulting here in $iSR_b^{detector}$ = 66 µm.

FIG. 9 Modulation Depth vs. Duplex Wire Pair Spacing ($SR_b^{detector}$)



NOTE 1—The measurement is performed perpendicular to the fast scan direction at the profile position as shown, at the end of the T-target, in a distance of 12 mm (½ in.). The measured value is 0.9 %.

FIG. 10 Test of PMT-nonlinearity at the T-Target

system (see Fig. 4). The value can be approximated from the graph SNR_N versus PV.

7.4 *$aSNR_N$ Limit*

7.4.1 The measured SNR_N shall be plotted versus exposure dose. The curve shall be fitted with the following equation to determine *a*, *b*, and *c*:

$$SNR_N = \frac{K}{\sqrt{a + bK + cK^2}} \quad (5)$$

where:

K = Exposure dose in mGy,
a = Noise offset, for example, opt. read out noise,
b = Factor for photon noise, and
c = Factor for detector structure noise (fixed pattern noise).

7.4.2 Typically, twelve measurements at twelve dose values over three dose decades are required for the exposure.

7.4.3 The $aSNR_{N-}$ limit for high-dose exposure of the IP-scanner system and the selected scan parameter set is calculated by:

$$aSNR_N^{limit} = \frac{1}{\sqrt{c}} \quad (6)$$

7.5 *Achievable Contrast Sensitivity (CSa)*

7.5.1 The achievable contrast sensitivity is calculated from the $aSNR_N$ (Fig. 4) and the measured contrast C_{1mm} of the EPS exposure setup (Fig. 5).

7.5.2 The relative contrast is calculated from the profile function across the edge of the 1-mm Fe plate at the 19-mm Fe plate at 220 kV (see 6.1.1.1 – 6.1.1.3 for correct kV selection) and highest used exposure dose (see Fig. 5). Fig. 11 gives an example for this measurement and the setting of the profile function. The profile function shall be used with line averaging to achieve a CNR > 10. The relative contrast for the 1 mm step (in mm^{-1}) is approximated as follows:

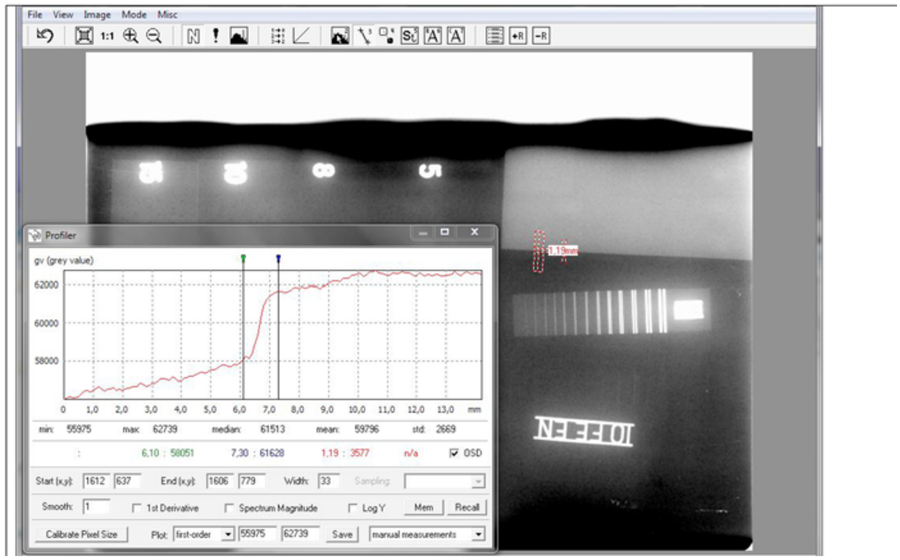
$$C_{1mm} = \ln\left(\frac{I_{max}}{I_{min}}\right) \approx \frac{2 \cdot \Delta I}{I_{min} + I_{max}} \cdot 1mm^{-1} \quad (7)$$

The expected value at 220 kV and sufficient collimation to the absorber plate is $C_{1mm} \approx 0.05\ mm^{-1}$ for mild steel.

7.5.3 The CSa value in % of material thickness for the 1 mm step at the 19 mm absorber plate is calculated by:

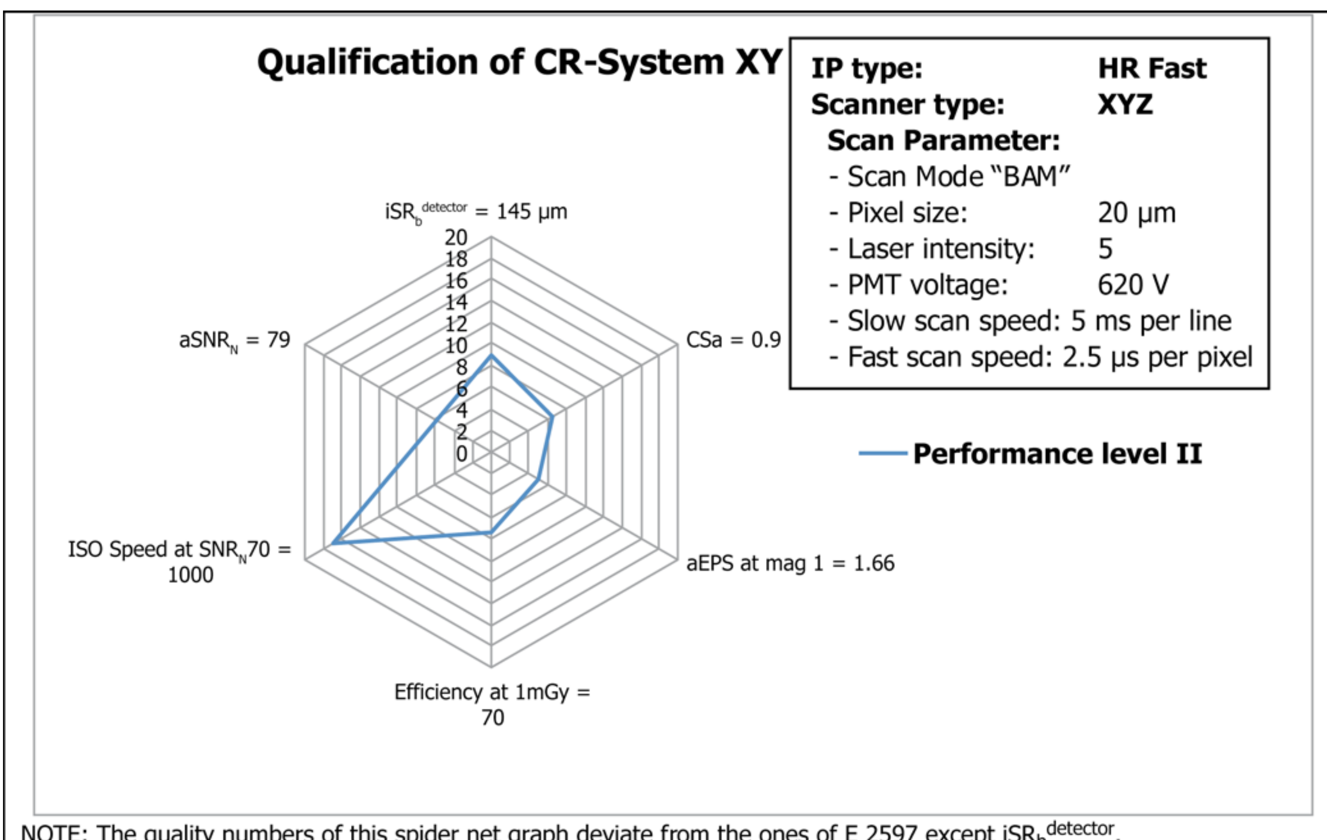
$$CS_a = 100\% \cdot \frac{I_{max} + I_{min}}{19.5 \cdot 2\Delta I \cdot aSNR} \quad (8)$$

with $SR_{bmax}^{detector}$ in mm.



NOTE 1—The PV difference between the cursors is divided by the average PV of both cursor positions for calculation of C_{1mm} (see Eq 7).

FIG. 11 Determination of Relative Contrast C_{1mm} from the Edge Profile of the Indication of a 1 mm Fe Plate on 19 mm (¾ in.) Fe (Unprocessed Image)



NOTE 1—XY – Name of CR System and Settings with Fast IP

FIG. 12 Example of the Result of a CR System Characterization

NOTE 11—CS_a may also be calculated from SNR_N if Eq 8 will be extended by Eq 2, with $SR_{bmax}^{detector}$ in mm.

$$CS_a = 100\% \cdot \frac{0.0886 \cdot (I_{max} + I_{min})}{19.5 \cdot 2\Delta I \cdot iSR_{bmax}^{detector} \cdot aSNR_N} \quad (9)$$

7.6 *Achievable EPS (aEPS)*

7.6.1 The achievable EPS provides the information about the best (minimal) EPS value that can be obtained at high dose applications, measured at 90% ± 5% PV at the selected

TABLE 3 Determination of ISO Speed (S_{ISO}) from Dose K_S (in Gray) for an IP Read-Out Intensity of PV_{min} at the Characterized Performance Level as Determined from SNR_N and EPS Method

LogYK$_S$ From	LogYK$_S$ To	ISO Speed (S_{ISO})
-4.66	< -4.55	40 000
-4.55	< -4.45	32 000
-4.45	< -4.35	25 000
-4.35	< -4.25	20 000
-4.25	< -4.15	16 000
-4.15	< -4.05	12 500
-4.05	< -3.95	10 000
-3.95	< -3.85	8000
-3.85	< -3.75	6300
-3.75	< -3.65	5000
-3.65	< -3.55	4000
-3.55	< -3.45	3200
-3.45	< -3.35	2500
-3.35	< -3.25	2000
-3.25	< -3.15	1600
-3.15	< -3.05	1250
-3.05	< -2.95	1000
-2.95	< -2.85	800
-2.85	< -2.75	640
-2.75	< -2.65	500
-2.65	< -2.55	400
-2.55	< -2.45	320
-2.45	< -2.35	250
-2.35	< -2.25	200
-2.25	< -2.15	160
-2.15	< -2.05	125
-2.05	< -1.95	100
-1.95	< -1.85	80
-1.85	< -1.75	64
-1.75	< -1.65	50
-1.65	< -1.55	40
-1.55	< -1.45	32
-1.45	< -1.35	25
-1.35	< -1.25	20

scanner parameter set to characterize. The EPS setup as shown in Fig. 5 is used without magnification. The value can be determined from the EPS measurement versus PV (see Fig. 6) at 90% ± 5 % PV_{max}.

NOTE 12—The aEPS value can be approximated from the $aSNR_N$ measurement for validation of the measurement of 7.6.1 as follows:[4]

$$aEPS = 100\% \cdot \frac{2}{19\ mm} \cdot \sqrt{\frac{0.0886}{C_{1mm} \cdot aSNR_N}} \quad (10)$$

Typical values are: $C_{1mm} \approx \mu_{eff} \approx 0.05\ mm^{-1}$ for 220 kV and 19 mm (¾ in.) Fe absorber plate.

7.6.2 The aEPS value shall be documented in the characterization statement as determined from the graph EPS versus PV (Fig. 6) and posted in the spider graph as shown in Fig. 12.

8. Interpretation of Results and Classification

8.1 *System Evaluation*

8.1.1 The system evaluation for characterization corresponding to Table 4 depends on the combined properties of the imaging plate (IP) type, the scanner and software used, the selected scan parameters and the image display monitor for the EPS evaluation. Therefore, all measurements must be performed with the same IP type, scanner, software with same parameter setting and image display monitor with same parameter setting.

8.1.2 The determination of the characterization parameters is based on the step exposures as described in 6.1.1.1 or on the step wedge exposures as described in 6.1.1.2, the EPS method as described in 6.2, and the measurement of the interpolated basic spatial resolution $iSR_b^{detector}$, as described in 6.5. The characterization results shall be documented as required by Table 6.

8.1.3 Depending on the results of the previous tests, the CR system shall be characterized in accordance with Table 4 as CR Special or CR Level I-III system.

8.1.4 A CR system is characterized to a performance level (Special, Level I-III) if the measurement results fulfill all three parameters of Table 4. If it is characterized to a certain level, it is also characterized to all levels with less performance, if exposed with less dose.

8.1.5 The manufacturer shall provide reference scanner parameters for characterization to the user of this practice.

8.2 *Range of CR System Characterization*

[4] See U. Ewert, U. Zscherpel, K. Heyne, M. Jechow, K. Bavendiek, *Materials Evaluation*, Vol. 70, no. 8, pp: 995-964, 2012.

TABLE 5 Quality Numbers for the CR System Characterization[A]

Parameter	FE Condition	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
$iSR_b^{detector}$ [µm]	90 kV and 220 kV	1000	800	630	500	400	320	250	200	160	130	100	80	63	50	40	32	25	20	16	13	10
CSa [%] at 90% PV	C at step 19-20 mm, 220 kV	5	4	3.2	2	1.6	1.3	1	0.8	0.63	0.5	0.4	0.32	0.25	0.2	0.16	0.13	0.1	0.08	0.063	0.05	0.04
aEPS [%] at 90%PV	E746, Fe, 220 kV	2.4	2.2	1.99	1.82	1.71	1.66	1.57	1.49	1.41	1.33	1.25	1.19	1.12	1.05	1.00	0.94	0.88	0.83	0.78	0.7	0.62
Efficiency at 1 mGy	SNR_N at 1 mGy, 220 kV	16	20	25	32	40	50	63	80	100	130	160	200	250	320	400	500	630	800	1000	1500	2000
ISO Speed at best level	220 kV	20	25	32	40	50	64	80	100	130	160	200	250	320	400	500	630	800	1000	1300	1600	2000
$aSNR_N$ at 90% PV	220 kV	20	25	32	40	50	63	80	100	130	160	200	250	320	400	500	630	800	1000	1300	1600	2000

[A] The quality numbers of Table 5 deviate partly from the quality levels as defined in Practice E2597. Only $iSR_b^{detector}$ is equivalent to the quality levels in Practice E2597.

TABLE 6 Example for the CR System Performance Statement of a CR Level II System

Performance Requirements				Result of Performance Characterization				
CR System Performance	Required Minimum SNR_N (Normalized to SR_b=88.6 μm)	Permitted Maximum $iSR_b^{detector}$ Value (μm)	Permitted Maximum Achieved EPS by E746 (%) Steel, 220 kV	$aSNR_N$ (Normalized to SR_b=88.6 μm)	Achieved $iSR_b^{detector}$ Value (μm)	aEPS by E746 (%)	PV_{min}	PV_{max}
CR Special	200	50	1.00	...	...	...	...	...
CR Level I	100	100	1.41	...	...	...	...	...
CR Level II	70	160	1.66	79	145	1.66	850	4095
CR Level III	50	200	1.92	65	145	1.92	350	4095

8.2.1 For computed radiographic characterization, the CR system performance will be determined by the following procedures.

8.2.2 The CR system characterization is performed by determination of an achievable $aSNR_N$-value, an achievable aEPS value at 90% ± 5 % of the linearized PV_{max} of the selected scanner parameter set to characterize and the interpolated basic spatial system resolution $iSR_{bmax}^{detector}$ in μm as shown in Table 4.

8.2.3 The characterization statement consists of three values as follows:

8.2.3.1 The measured normalized SNR_N shall be greater or equal to the assigned value of the required minimum normalized SNR_N in Table 4.

8.2.3.2 The measured maximum interpolated basic spatial resolution shall be rounded to the nearest 5 μm for documentation. The value shall be smaller or equal to the assigned value of Table 4.

8.2.3.3 The achieved EPS value shall be taken at 90% ± 5% PV at lowest gain and lowest laser intensity of the scanner. The value shall be smaller or equal to the permitted maximum value of Table 4.

8.2.3.4 The values PV_{min} and PV_{max} for the PV range of valid characterization as described in 6.3 and 6.4 shall be reported in the resulting table (see Table 7 as an example).

8.2.4 In addition to the characterization statement, a spider net graph shall be added with the following further characterization parameters (see Fig. 12):

TABLE 7 Example of Characterization Report

Product and Test Information	
Company name	Manufacturer 1
IP type	Standard, XY1
Scanner Type	Scanner XY2 Standard
Scanner and processing software names and versions	Soft XY3, V. 123
Scan parameter set	Standard 50μ - XY4
Image display monitor type, brand, and maximum brightness in cd/m^2	XYZ, 320 cd/m^2
Date of characterization	Friday, Dec. 13th, 2013
Test agency	ABCD
Operator in charge	Smith, A. F.
Report Data	
Tests of Practice E2446	**Results**
$iSR_b^{detector}$	145 μm
CSa at 220 kV on EPS absorber of Fe	0.9
aEPS at 220 kV on EPS absorber of Fe	1.66%
Efficiency at SNR_N at 1 mGy	70
ISO speed at SNR_N = 70 (for CR Level II)	1000
ISO speed at SNR_N = 50 (for CR Level III)	4000
$aSNR_N$	79
$aSNR_N^{limit}$	105
C_{1mm} (≈μ_{eff}) at 220kV on EPS absorber of Fe	0.05 mm^{-1}
PV_{min} for CR Level II	850
PV_{min} for CR Level III	350
PV_{max}	4095
Performance level	CR Level II
Applied Tests of Practice E2445	**Results**
Geometric distortion (by spatial linearity image quality indicators in Type I CR Test Phantom)	o.k. (<2 %)
Laser jitter (by T-target in Type I CR Test Phantom)	o.k.
PMT non-linearity (by T-target in Type I CR Test Phantom)	o.k. (<2 %)
Laser beam scan line integrity (no test object required)	o.k.
Scan column dropout (no test object required)	o.k.
Scanner slippage (by homogeneous strip slippage target in Type I CR Test Phantom)	o.k.
Shading or banding (by homogeneous plate, three shading image quality targets in Type I)	o.k.
Erasure (high-absorption object required)	o.k. (<2 %)
Burn-In (high-absorption object required)	3 % measured
Spatial linearity (by spatial linearity image quality indicators in Type I CR Test Phantom)	o.k. (<2 %)
Imaging plate artifacts (no test object required)	o.k.
Imaging plate response variation (no test object required)	o.k.
Imaging plate fading (no test object required), optional test	35 %, tested after 5 min and 2 h

8.2.4.1 $iSR_b^{detector}$ as maximum value of the measurements in fast and slow scan speeds as described in 6.5,

8.2.4.2 $aSNR_N$ as minimum value of the measurements in fast and slow scan speeds as described in 7.3,

8.2.4.3 *CSa* as minimum value of the measurements in fast and slow scan speeds as described in 7.5,

8.2.4.4 *aEPS* as described in 7.4,

8.2.4.5 Efficiency measured from the plot "SNR_N versus dose" taken at 1 mGy as described in 7.2 or at 5 mGy (if SNR_N < 50 at 1 mGy) and divided by 2.24, and

8.2.4.6 ISO speed as described in 7.1.

8.2.5 All test procedures under Practice E2445, as required in Table 2, shall be conform with the requirements of Table 2 for a valid systems characterization. The results shall fulfill the requirements and shall show deviations, if any, from the required properties.

9. Presentation of Results

9.1 The characterization results shall be presented in a spider net graph as shown in Fig. 12.

9.1.1 The quality numbers for the graph are listed in Table 5.

9.2 The result of the characterization shall be printed in the spider net graph and a table shall be given with the measured characterization data as shown in Table 6.

9.3 List applied test procedures as performed corresponding to Practices E2445 and E2446 and report results as required by Table 2. See the example in Table 7.

10. Precision and Bias

10.1 No statement is made about either the precision or bias of this practice for measuring characterization of CR systems. The results merely state whether there is conformance to the criteria for success specified in the procedure.

11. Keywords

11.1 basic spatial resolution; characterization; computed radiography; CR; EPS; equivalent penetrameter sensitivity; film system classification; manufacturer; minimum pixel value; normalized signal-to-noise ratio; photo-stimulated luminescence; PSL; SNR; SR_b; system performance levels