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Standard Practice for Qualification and Long-Term Stability of Computed Radiology Systems[1]

This standard is issued under the fixed designation E2445; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice specifies the fundamental parameters of computed radiography systems to assure satisfactory and repeatable results for nondestructive testing.

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

1.3 Each of the tests described may be performed with individual gages specified. The user shall decide which tests shall be used for system control using individual test objects or the CR test phantom[2] (Appendix X1). The computed radiological tests, specified as "user tests" in this practice, may be utilized at appropriate intervals determined by the user, based on the application of the examination operations. The tests shall be appropriate for the materials and range of use of the system. Fading, uniformity, and erasure tests shall also be part of the control system. All other tests for qualification and capability are to be performed and certified by the CR equipment manufacturer.

1.4 The values stated in SI units are to be regarded as the standard. Values in inch-pound units are for information purposes.

1.5 *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]

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

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aliasing*—pre-sampled high spatial frequency signals beyond the Nyquist frequency (given by the pixel distance) reflected back into the image at lower spatial frequencies.

3.2.2 *computed radiology system (CR system)*—a complete system of a storage phosphor imaging plate (IP) and corresponding read out unit (scanner or reader), which converts the information of the IP into a digital image (see also Guide E2007).

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

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

[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 known to the committee at this time is Nuclear Associates, A Division of Cardinal Health, 120 Andrews Road, Hicksville, NY 11801, Phone: 1-888-466-8257, Catalog Number: 07-605-2435. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[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.

3.2.5 *gain/amplification*—opto-electrical gain setting of the scanning system.

3.2.6 *ISO speed* S_{IPx}—defines the speed of a CR system and is calculated from the reciprocal dose value, measured in Gray, which is necessary to obtain a specified minimum SNR of a CR system.

3.2.7 *laser beam jitter*—a lack of smooth movement of the imaging plate/laser scanning device, which results in lines of the image, which consist of a series of steps.

3.2.8 *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.

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

3.2.10 *scanner slippage*—the slipping of an IP in a scanner transport system resulting in fluctuation of intensity of horizontal image lines.

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

4. Significance and Use

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

4.2 The quality factors can be determined most accurately by the CR equipment manufacturer tests as described in Practice E2446. Individual test targets, which are recommended for practical user tests, are described for quality assurance. These tests can be carried out either separately or by the use of the CR phantom (Appendix X1). This CR phantom incorporates many of the basic quality assessment methods and those associated with the correct functioning of a CR system, including the scanner, for reading exposed plates and incorrectly erasing IPs for future use of each plate.

4.3 This practice is for users of industrial CR systems. This practice defines the tests to be performed, by users of CR systems, periodically to evaluate the CR systems to prove proper performance over the life-cycle of the system.

4.4 *Application of Various Tests and Test Methods*

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

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

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

(1) Spatial resolution (by duplex-wire method, optional converging line pairs),
(2) Contrast (recognized contrast percentage of the material to examine),
(3) Slipping (yes/no),
(4) Jitter (yes/no),
(5) Shading (percentage at selected distance),
(6) Radiation parameters of the performed tests, and
(7) Date and operator name.

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

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

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

5. Apparatus—CR Quality Indicators

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

5.1.1 *Contrast Sensitivity Quality Indicator:*

5.1.1.1 The description of the contrast sensitivity target corresponds to Practice E1647. For use with this practice, three targets are made from aluminum (Material Group 02), copper (Material Group 4) and stainless steel (Material Group 1). The target thickness is 12.5 mm (0.50 in.) aluminum, 6.3 mm (0.25 in.) copper and stainless steel. Each target contains a contrast area for 1, 2, 3, and 4 % wall-thickness contrast sensitivity.

5.1.2 *Duplex Wire Quality Indicator:*

5.1.2.1 The description of the duplex wire quality indicator corresponds to Practice E2002. The gage shall be oriented at a 5° angle to the direction of the scanned lines (fast-scan direction) or the perpendicular direction (slow-scan-direction).

5.1.3 *Converging Line Pair Quality Indicator:*

5.1.3.1 The target consists of five converging strips of lead (0.03 mm (0.001 in.) thickness), which can be used for a spatial resolution test by reading the limit of recognizable line pairs. It shall cover a range from 1.5 to 20 line pairs per mm (lp/mm). Two quality indicators shall be used, one in parallel with the scanned lines and the other one oriented in the perpendicular direction.

5.1.4 *Linearity Quality Indicators:*

5.1.4.1 Rulers of high-absorbing materials are located on the perimeter of the scanned range. Two quality indicators shall be used, one parallel with the scanned lines and the other one oriented in the perpendicular direction. The scaling should be at least in mm or tenths of inches.

5.1.5 *T-target:*

5.1.5.1 This CR quality indicator consists of a thin plate of brass or copper (≤0.5 mm (≤0.02 in.) thick) with sharp edges. This plate is manufactured in a T-shape with 0.5 mm (0.2 in.) wide segments. The T should have a size of at least 50 by 70 mm (2 by 2¾ in.). It shall be aligned perpendicular and parallel to the direction of the scanned lines and is used to check for laser jitter and may be used to measure a modulation transfer function of the complete system (see Fig. X1.1).

5.1.6 *Scanner Slipping Quality Indicator:*

5.1.6.1 The quality indicator consists of a homogeneous strip of aluminum 0.5 mm (0.02 in.) in thickness. The quality indicator has the shape of a rectangle (see Fig. X1.1) and shall be aligned perpendicular and parallel to the direction of the scanned lines.

5.1.7 *Shading Quality Indicator:*

5.1.7.1 Different shading quality indicators may be used. One type is based on the homogeneous exposure of an imaging plate (IP) with a thin Al-plate 0.5 to 1.0 mm (0.06 to 0.04 in.) above the IP. The exposure shall be made with low-energy radiation (50 to 100 keV).

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

5.1.8 *Central Beam Alignment Quality Indicator (BAM-snail):*

5.1.8.1 The alignment quality indicator consists of a roll 1.5 to 2.0 mm high (0.06 to 0.08 in.) of thin lead foil separated by a spacer of 0.1 to 0.2 mm (0.004 to 0.008 in.) of low-absorbing material (see X1.2).

5.2 *Application Procedures for CR Quality Indicators*—The CR quality indicators provide an evaluation of the quality of a CR system as well as for a periodical quality control. Arrangement of the CR quality indicators shall be in accordance with this practice, or as specified by the cognizant engineering organization.

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

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

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

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

5.2.2 *Initial Assessment of CR Quality Indicators:*

5.2.2.1 For initial quality assessment, examine the radiographic image(s) of the CR phantom or the separated quality indicators on the monitor (or hard copy) for the features described in 5.1.1 to 5.1.8 and 6.2.1 to 6.2.8. The results can provide the basis of agreement between contracting parties.

5.3 *Periodical Control:*

5.3.1 The CR quality indicators of 5.1.1 through 5.1.7 (alignment by 5.1.8) or the CR phantom shall be exposed and the results examined at any interval agreed between the contracting parties. For periodical control, ensure that the agreed quality values of the tests 6.1.3 and 6.2.1 to 6.2.8 are achieved.

5.4 *Imaging Plate Fading:*

5.4.1 The intensity of the stored image in the imaging plate will decrease over time (called "fading"). The measurement of fading characteristic shall be done by performing the following steps:

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

5.4.1.2 Readout the imaging plate five minutes after exposure.

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

5.4.1.4 Always expose the imaging plate with the same X-ray parameters (kV, mAs, and distance).

5.4.1.5 Change the time between exposure and read-out. The time interval between exposure and readout will be doubled for every measurement; steps are 15 min, 30 min, 1 h, 2 h, 4 h, and so forth, up to 4 days or as needed to match application requirement for read-out.

5.4.1.6 Plot the linearized read-out intensity (gray value) versus time between exposure and read-out of the imaging plate.

5.4.2 The fading effect needs to be considered to ensure correct exposure conditions.

5.4.3 To enable reproducible test results, it is important to consider fading effects, which influence the required exposure time. The time between exposure and read-out for all tests shall correspond to the typical application of the CR system.

6. Qualification and Long-Term Stability Test of CR Systems

6.1 *Determination of Contrast, Unsharpness, and Basic Spatial Resolution*

6.1.1 *Contrast Sensitivity Measurement:*

6.1.1.1 Practice E1647 contrast sensitivity gages are useful for visual and computer aided determination of contrast sensitivity for a selected wall thickness. Four levels of contrast sensitivity can be measured: 1 %, 2 %, 3 % and 4 %, independent of the imaging spatial resolution limitations. For interpretation, see Practice E1647. If image processing is available, a profile (width = 1 pixel) shall be taken through the target. The average noise of the profile shall be less than or equal to the difference in the intensity between the full and reduced wall thickness at the read-out percentage. The exposure conditions (kV, mAs, filters, distance, exposure time, date) and CR system settings and type shall be documented.

6.1.2 *Determination of Unsharpness and Basic Spatial Resolution by the Duplex-Wire Method:*

6.1.2.1 For testing of the basic spatial resolution, the duplex-wire gage corresponding to Practice E2002 can be applied. The exposure shall be performed in a distance of 1 m (39 in.) or greater with a focal spot size ≤1 mm. Focal spot size and focus detector distance shall be selected for a geometric unsharpness of less than 10 % 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 gage or one exposure with two gages. The duplex-wire gage shall be used in an angle of about 5° to the scanning direction of the laser beam and 5° to the perpendicular direction.

6.1.2.2 The measurement of unsharpness may depend on the radiation quality. For 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).

6.1.2.3 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. 1). The basic spatial resolution SR corresponds to one half of the measured unsharpness.

6.1.2.4 The duplex-wire read-out shall be documented and used for long-term stability test of the system.

6.1.2.5 The duplex-wire method allows the read-out of stepped unsharpness values only (see table in Practice E2002).

6.1.3 *Use of Converging Line Pair Quality Indicators:*

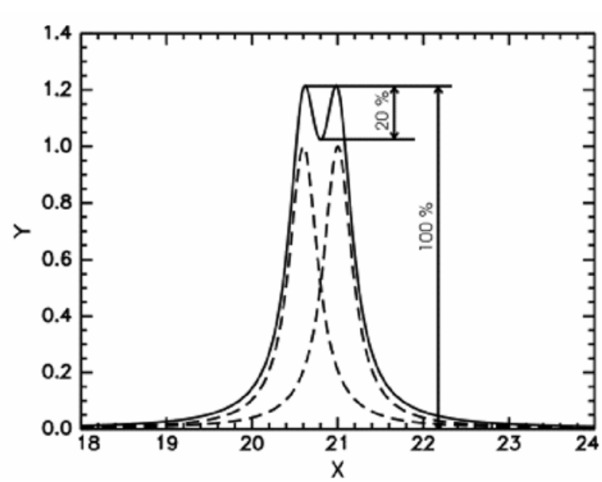
6.1.3.1 Converging line pair quality indicators shall be read both parallel and perpendicular to the scanned lines. If a converging line pair target is located 45° to the scanning direction, the read-out value must be divided by 1.414.

6.1.3.2 These quality indicators consist of converging line pairs and a scale in lp/mm. The read-out value in lp/mm is either taken (case "a") at the location between separated and unseparated line pairs or (case "b") at the location, where the number of lines is reduced by one or more.

6.1.3.3 In case "a," the basic spatial resolution (SR) is calculated by 1 / [2·read-out (in lp/mm)]. In case "b," the gages determine at what resolution aliasing (pre-sampled high-frequency signals beyond the Nyquist frequency reflected back into the image at lower spatial frequencies) occurs. Usually this corresponds to the pixel size of the scanner. It is also calculated by 1 / [2·read-out (in lp/mm)].

6.1.3.4 The recommended quality assurance schedule shall be agreed between the contacting parties. However, the resolution test should also be assessed after any servicing of the optics of the CR reader and usage of new IP types.

6.1.3.5 The accuracy of the converging line pair method depends on the SNR of the exposure, the radiation quality and the geometrical conditions as well as scatter effects in the cassette/IP/screen system. For high SNR (>100) and negligible geometrical unsharpness the standard deviation of this method between 1 and 10 lp/m is about ±0.2 lp/mm. If there are differences between the method in accordance with 6.1.2 and 6.1.3 the value of 6.1.2 shall be taken (in agreement with Practice E2002).



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 greater than 20 % of the maximum intensity.

FIG. 1 Resolution Criterion for the Evaluation of Duplex-Wire Profiles