Designation: ~~E1411 – 16~~ E1411 – 23

Standard Practice for Qualification of Radioscopic Systems[1]

This standard is issued under the fixed designation E1411; 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 ~~provides~~covers test and measurement details for measuring the performance of X-ray and gamma ray radioscopic systems. ~~Radioscopic~~ Radioscopy is a radiographic technique that can be used in (*1*) dynamic mode radioscopy to track motion or optimize radiographic parameters in real-time (25 to 30 frames per second), or both, near real-time (a few frames per second), or high speed (hundreds to thousands of frames per second) or (*2*) static mode radioscopy where there is no motion of the object during exposure as a filmless recording medium. This practice[2] ~~examination applications are diverse. Therefore, system configurations are also diverse and constantly changing as the technology advances.~~ provides application details for radioscopic examination using penetrating radiation using an analog component such as an electro-optic device (for example, X-ray image intensifier (XRII) or analog camera, or both) or a Digital Detector Array (DDA) used in dynamic mode radioscopy. This practice is not to be used for static mode radioscopy using DDAs. If static radioscopy using a DDA (that is, DDA radiography) is being performed, use Practice E2698.

1.1.1 This practice also may be used for Linear Detector Array (LDA) applications where an LDA uses relative perpendicular motion between the detector and component to build an image line by line.

1.1.2 This practice may also be used for "flying spot" applications where a pencil beam of X-rays rasters over an object to build an image point by point.

1.2 ~~This practice is intended as a means of initially qualifying and re-qualifying a radioscopic system for a specified application by determining its performance level when operated in a static mode. System architecture including the means of radioscopic examination record archiving and the method for making the accept/reject decision are also unique system features and their effect upon system performance must be evaluated.~~*Basis of Application:*

1.2.1 The requirements of this practice and Practice E1255 shall be used together. The requirements of Practice E1255 provide the minimum requirements for radioscopic examination of materials. This practice is intended as a means of initially qualifying and re-qualifying a radioscopic system for a specified application by determining its performance when operated in a static or dynamic mode. Re-qualification may require agreement between the cognizant engineering organization and the supplier, or specific direction from the cognizant engineering organization and should be addressed in the purchase order or the contract.

1.2.2 System architecture including the means of radioscopic examination record archiving and the method for making the accept/reject decision are also unique system features and their effect upon system performance must be evaluated.

1.2.3 This qualification procedure is intended to benchmark radioscopic system performance under selected operating conditions

[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 ASME Boiler and Pressure Vessel Code applications see related Practice SE-1255 in Section II of that code.

to provide a measure of system performance. Qualification shall not restrict operation of the radioscopic system at other radioscopic examination parameter settings, which may provide improved performance on actual examination objects. This practice neither approves nor disapproves the use of the qualified radioscopic system for the specified application. It is intended only as a standardized means of evaluating system performance.

1.3 The general principles, as stated in this practice, apply broadly to transmitted-beam penetrating radiation radioscopy systems. Other radioscopic systems, such as those employing neutrons and Compton back-scattered X-ray imaging techniques, are not covered as they may involve equipment and application details unique to such systems.

1.4 The user of this practice shall note that energies higher than ~~320keV~~320 keV may require different methods than those described within this practice.

1.5 This practice requires that a System Qualification Report be issued before using the system for production use.

1.6 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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~~safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E746 Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems below 4 MeV
E747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology
E801 Practice for Controlling Quality of Radiographic Examination of Electronic Devices
E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiography
E1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging
E1255 Practice for Radioscopy
E1316 Terminology for Nondestructive Examinations
E1647 Practice for Determining Contrast Sensitivity in Radiology
E1735 Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems from 4 to 25 MeV
E1817 Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)
E2002 Practice for Determining Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy
E2698 Practice for Radiographic Examination Using Digital Detector Arrays
E2903 Test Method for Measurement of the Effective Focal Spot Size of Mini and Micro Focus X-ray Tubes

2.2 *ANSI Standard:*[4]

ANSI/HPS N43.3 For General Radiation Safety – Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies Up to 10 MeV

2.3 *ISO Standards:*[5]

ISO 19232–2 Step Hole Image Quality Indicator
ISO 19232–5 Duplex Wire Image Quality Indicator

[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.
[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

2.4 ~~*Other*~~*Federal Standards:*[6]

~~EN 462–2~~21 CFR 1020.40 ~~Step Hole IQI (withdrawn and replaced with ISO 19232–2)~~Safety Requirements of Cabinet X-Ray Systems

~~EN 462–5~~29 CFR 1910.96 ~~Duplex Wire IQI (withdrawn and replaced with ISO 19232–5)~~Ionizing Radiation

2.5 *National Council on Radiation Protection and Measurement (NCRP) Standards:*[7]

NCRP 49 Structural Shielding Design and Evaluation for Medical Use of X Rays and Gamma Rays of Energies Up to 10 MeV

NCRP 61 Radiation Safety Training Criteria for Industrial Radiography

NCRP 116 Limitation of Exposure to Ionizing Radiation

NCRP 147 Structural Shielding Design for Medical X-ray Imaging Facilities

2.6 *Other Standard:*

SMPTE RP-133 Specifications for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard-Copy Recording Cameras[8]

3. Terminology

~~3.1 *Definitions*—For definitions of terms used in this practice, see Terminology E1316.~~

3.1 *Definitions*—For definitions of terms used in this practice, see Terminology E1316.

~~3.2 *Definitions of Terms Specific to This Standard:*~~

~~3.2.1 *detector unsharpness*—the unsharpness of the detector with magnification 1 (IQI in contact to surface of the active area of the detector) measured as described in 7.12. The value is given in line-pairs/mm (LP/mm) or [µm]. A conversion table can be found in Practice E2002.~~

~~3.2.2 *system unsharpness*—the unsharpness of the system with given magnification measured as described in 7.13. The value is given in line-pairs/mm (LP/mm) or [µm].~~

4. Summary of Practice

4.1 This practice provides a standardized procedure for the initial qualification and subsequent periodic requalification of a radioscopic system to establish radioscopic examination capabilities for a specified range of applications. Practice E1255 also requires the user to perform a technique qualification suitable for its intended purpose and develop part specific inspection procedures before radioscopic examination of product.

~~4.2 This practice is intended for use in association with a standard practice governing the use of radioscopic examination, such as Practice E1255.~~

4.2 This practice specifies the procedures to be used in determining the performance ~~level~~ of the radioscopic system. Unique system features, including component selection, system architecture, programmability, and image archiving capabilities are important factors and are taken into account in this practice. The overall system ~~performance level,~~ performance, as well as key system features, are to be recorded in a qualification document which shall qualify the performance ~~level~~ of the total radioscopic system. An example of the Radioscopic System Qualification document form is included in the Appendix X1. This document may be tailored to suit the specific application and actual computer and storage technology.

5. Significance and Use

5.1 As with conventional radiography, radioscopic examination is broadly applicable to the many materials and object configurations which may be penetrated with X-rays or gamma rays. The high degree of variation in architecture and performance among radioscopic systems due to component selection, physical arrangement, and object variables makes it necessary to establish the ~~level of~~ performance that the selected radioscopic system is capable of achieving in specific applications. The manufacturer or integrator of the radioscopic system, as well as the user, require a common basis for determining the performance level of the radioscopic system.

[6] Available from ~~American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.~~U. S. Government Accountability Office (GAO), 441 G St., NW, Washington, DC 20548, http://www.gao.gov.

[7] Available from NCRP Publications, 7010 Woodmont Ave., Suite 1016, Bethesda, MD 20814.

[8] Available from the Society of Motion Picture and Television Engineers, White Plains Plaza, 445 Hamilton Ave, Ste 601, White Plains, NY 10601–1827, www.smpte.org.

5.2 This practice does not purport to provide a method to measure the performance of individual radioscopic system components that are manufactured according to a variety of industry standards. This practice covers measurement of the combined performance of the radioscopic system elements when operated together as a functional radioscopic system.

5.3 This practice addresses the performance of radioscopic systems in the static mode ~~only. Radioscopy can also be a dynamic, real-time or near real-time examination technique~~ or dynamic mode, that can allow ~~test-part motion as well as parameter changes during the radioscopic examination process. The use of this practice is not intended to be limiting concerning the use of the dynamic properties of radioscopy.~~ relative test-part motion between source, part, and detector, and may or may not have the ability to effect parameter changes during the radioscopic examination process. Users of radioscopy are cautioned that the dynamic aspects of radioscopy can have beneficial as well as detrimental effects upon system ~~performance and must be evaluated on a case-by-case basis.~~ performance.

~~5.4 This qualification procedure is intended to benchmark radioscopic system performance under selected operating conditions to provide a measure of system performance. Qualification shall not restrict operation of the radioscopic system at other radioscopic examination parameter settings, which may provide improved performance on actual examination objects.~~

5.4 Radioscopic system performance measured pursuant to this practice does not guarantee the level of performance which may be realized in actual ~~operation.~~ operation but does provide a baseline against which periodic performance evaluations can be compared to ensure the system is operating within established limits. The effects of object-geometry and orientation-generated scattered radiation cannot be reliably predicted by a standardized examination. All radioscopic systems age and degrade in performance as a function of time. Maintenance and operator adjustments, if not correctly made, can adversely affect the performance of radioscopic ~~systems.~~systems; therefore, the system shall be re-qualified at periodic intervals (see Section 10).

5.5 The performance of the radioscopic system operator in manual and semi-automatic radioscopic systems is not taken into account in this practice and can have a major effect upon radioscopic system performance. Operator qualifications and certification are an important aspect of system operation and ~~should be~~ are covered in a separate written ~~procedure.~~ procedure required by Practice E1255.

6. ~~Application and Equipment Information Statement~~ Requirements

6.1 The following minimum application and qualification standard information shall be reported in the qualification document:

6.1.1 A ~~brief~~ statement about the intended application,

6.1.2 Static or dynamic mode,

6.1.2.1 If static, the frame rate and number of frames averaged or integrated,

6.1.2.2 If dynamic, the frame rate and recursive frame averaging if used,

6.1.3 Material(s) and thickness range(s) for which the system is to be qualified,

6.1.4 Maximum test part size or radioscopic examination envelope,

6.1.5 A brief statement about the kind of object features which are to be detected,

~~6.1.5 The required system unsharpness to resolve, or detect the presence of, the smallest required feature dimension lying in a plane at right angles to the radiation beam. This value shall be expressed in LP/mm and is equal to the reciprocal of twice the required small feature size expressed in mm,~~

6.1.6 *Image Quality*—~~The required contrast sensitivity to resolve, or detect the presence of, the smallest feature dimension lying along the radiation beam expressed as a percentage of the total path length of the radiation beam in the material,~~Required image quality shall be designated:

6.1.6.1 The required image unsharpness (U^{image}) and

6.1.6.2 The required contrast sensitivity expressed as a percentage of the total path length of the radiation beam in the material, or

6.1.6.3 The required Radioscopic Quality Level (see Practice E1255), Equivalent IQI Sensitivity (also known as Equivalent Penetrameter Sensitivity (EPS), or both (see Practices E746 and E1025),

6.1.7 The desired throughput requirements expressed in linear and area dimensions per unit time, and

6.1.8 The standardized image quality ~~indicator~~ indicator(s), representative quality indicator(s) (RQIs), or both, to be used in qualifying the radioscopic system. (Each device shall be traceable to a Certificate of Conformance.)

6.2 The following minimum equipment information shall be included in the qualification document:

6.2.1 The system make, model number, serial number, date of manufacture and configuration, or components thereof,

6.2.2 Radioscopic scan plan details and whether manual or programmable,

6.2.3 Field(s) of View (and pixel size if applicable),

6.2.4 Accept/Reject decision as to whether manual, computer-aided or fully automated, and

6.2.5 Pertinent equipment details for each radioscopic system sub-system.

~~6.3 This practice neither approves nor disapproves the use of the qualified radioscopic system for the specified application. It is intended only as a standardized means of evaluating system performance.~~

~~**7. Qualification Procedure**~~

~~7.1 Before testing, the radioscopic system shall be determined to be in good operating condition. Each sub-system shall be checked to ascertain that it performs according to the manufacturer's specifications.~~

~~7.2 The radioscopic system and each component thereof shall be operated within its ratings at all times during qualification.~~

~~7.3 The radioscopic system shall be determined to be in compliance with applicable local, state, and federal radiation safety standards. Proper procedures must be taken to safeguard personnel during the performance of these tests.~~

~~7.4 The image display shall be placed in an area of subdued, controllable lighting that is free from glare and reflections that might affect image assessment. When using a computer monitor for display the images, the monitor shall fulfill the requirements described in Practice E2698.~~

~~7.5 The radioscopic system shall be at operating temperature and stabilized. All operator accessible operating controls may be adjusted as necessary to obtain the optimal image quality.~~

~~7.6 Maintenance adjustments shall not be made during the examination process. If maintenance examinations are necessary, all affected examinations shall be repeated.~~

~~7.7 Where provided, beam collimators and diaphragms shall be used to minimize scatter radiation thereby promoting the highest quality radioscopic image.~~

~~7.8 Radioscopic system performance shall be evaluated as to unsharpness and contrast sensitivity for the applicable material over the range of minimum and maximum section thicknesses for which the radioscopic system is to be qualified.~~

~~7.9 Each imager mode (field of view), radiation source focal spot size and imaging geometry that is to be used shall be evaluated. The focal spot size shall be measured by Test Methods E1165 or E2903 for microfocus tubes; for fixed focus tubes the focal spot~~

size given by the manufacturer of the tube may be used for calculation of system unsharpness. Any radioscopic examination geometry parameter which varies more than ±20 % from a tested geometry shall be treated as a new imaging geometry and must be evaluated. Imaging geometry parameters include FDD (focal detector distance), FOD (focal object distance), and magnification.

7.10 If the radioscopic system incorporates image processing, processed as well as unprocessed images shall be evaluated. All image processor enhancement functions used to produce the processed radioscopic image must be recorded and are a part of the qualification record.

7.11 If image recording devices are incorporated, each must be qualified as to playback quality with reference to the original radioscopic image.

7.12 Unprocessed detector unsharpness measurements shall be made at the image converter with no additional absorber. Recorded data shall include FDD, FOV, unsharpness, radiation source energy and intensity for each imager mode and focal spot for which the radioscopic system is to be qualified. Unsharpness measurements shall be made using a line-pair gauge consisting of equal width lead foil lines and spaces on an appropriate low density substrate, such as plastic, or the duplex wire gauge (suitable devices are described in 7.15). Horizontal (along the TV scan lines) and vertical (normal to TV scan lines) resolution shall be recorded.

7.13 Unprocessed system unsharpness measurements shall also be made at the object region of interest average position during manipulation with no additional absorber. Recorded data shall include FDD, average FOD, magnification, field of view, system unsharpness, source energy and intensity for each imager mode and focal spot which is to be qualified. Resolution measurements shall be made using a line-pair gauge consisting of equal width lead foil lines and spaces on a radiation-transparent substrate, or the duplex wire gauge (suitable devices are described in 7.15). Horizontal (along TV or other scan lines) and vertical (normal to TV or other scan lines) resolution shall be recorded.

7.14 Unprocessed contrast sensitivity measurements shall be made at the object position for the material over the range of the minimum and maximum thicknesses for which the system is to be qualified. Recorded data shall include field of view, contrast sensitivity, source energy and intensity for each imager mode and source tube focal spot for which the radioscopic system is to be qualified. Contrast sensitivity measurements shall be made by shims or a step wedge made of the material for which the system is to be qualified (see Practice E1647). The thickness increments shall represent at least 100 %, 99 %, 98 % and 97 % of the minimum and maximum thicknesses for which the system is to be qualified. All steps shall be adjacent to the 100 % step for comparison purposes. The minimum detectable differential thickness expressed as a percentage of the 100 % thickness shall be recorded. Measurement geometry shall be the same as for the unsharpness tests outlined in 7.13.

7.15 Qualification measurements for the performance of the radioscopic system shall be made using at least one type of standardized image quality indicator. The device(s) selected shall be appropriate for the materials and thicknesses to which they are applied. Such device(s) shall be capable of performing radioscopic unsharpness (duplex wire IQI), contrast measurement (Practice E1647), or a combination of both (wire and hole type IQI standards) on the material and thickness for which the system is to be qualified. Suitable devices are described in, but not limited to, Practices E747, E1025, E2002, ISO 19232–5 (Duplex Wire IQI standards), ISO 19232–2 (Step Hole IQI standard). IQIs manufactured in accordance with ISO 19232 and former EN462 may be used. The device(s) used shall be specified in the qualification report.

7.15.1 Measurements shall be made for unprocessed and processed radioscopic images for the material at the minimum and maximum thicknesses for which the system is to be qualified.

7.15.2 Measurements shall be recorded for each image converter mode or field of view.

7.15.3 Measurements shall be recorded for each radioscopic image display and each image recording device.

7.15.4 Unsharpness measurements shall be at right angles to each other if the image quality measurement device has directional characteristics as in the case of single or duplex wires. If the radioscopic system involves a raster scan in the image formation process, resolution measurements shall be made both parallel to and at right angles to the scan lines.

7.15.5 Sufficient radioscopic system parameter settings shall be recorded to allow the qualification measurements to be repeated. Required parameters include FDD, average FOD, average magnification, field of view at the part, kV, mA and focal spot size. Where image processing is utilized, all applied image enhancement processes, including noise reduction, edge sharpening, contrast manipulation and any other functions which may affect image quality must be fully documented.