Designation: E1411 – 16

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 test and measurement details for measuring the performance of X-ray and gamma ray radioscopic systems. Radioscopic examination applications are diverse. Therefore, system configurations are also diverse and constantly changing as the technology advances.

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.

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 may require different methods than those described within this practice.

1.5 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology

E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology

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

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

E2698 Practice for Radiological 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 *ISO Standards:*[3]

ISO 19232–2 Step Hole Image Quality Indicator

ISO 19232–5 Duplex Wire Image Quality Indicator

2.3 *Other Standards:*[4]

EN 462–2 Step Hole IQI (withdrawn and replaced with ISO 19232–2)

EN 462–5 Duplex Wire IQI (withdrawn and replaced with ISO 19232–5)

[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), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3. Terminology

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 requalification of a radioscopic system to establish radioscopic examination capabilities for a specified range of applications.

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

4.3 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, 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 of the radioscopic system, as well as the user, require a common basis for determining the performance level of the radioscopic system.

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 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. 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.

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.

5.5 Radioscopic system performance measured pursuant to this practice does not guarantee the level of performance which may be realized in actual operation. 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.

5.6 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 are an important aspect of system operation and should be covered in a separate written procedure.

6. Application and Equipment Information Statement

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

6.1.3 Maximum test part size or radioscopic examination envelope,

6.1.4 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 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,

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 to be used in qualifying the radioscopic system.

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,

6.2.2 Radioscopic scan plan details and whether manual or programmable,

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

6.2.4 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.

7.16 All qualification performance measurements shall be made in the static mode.

8. Qualification Statement

8.1 The following qualification statement shall apply to radioscopic systems qualified pursuant to this practice: "Using the qualification device(s) selected, the qualified radioscopic system, when in identical operating condition, properly adjusted, operated and viewed by a qualified and certified operator in the static mode, is capable of performing to the level reported in this qualification document. The user is cautioned that deviation from these conditions can significantly alter the radioscopic system's performance."

9. Records and Associated Documentation

9.1 The overall system performance level, as well as key system features, are to be recorded in a qualification document which shall certify the performance level of the total radioscopic system. All information and measurements required in Sections 6 and 7 are to be recorded and retained until the radioscopic system is re-qualified. As an aid to standardization of the qualification document, a sample format of the Radioscopic System Qualification document is included in the Appendix X1. The sample in Appendix X1 may be adapted to newer storage technologies and computer hardware, for example, see X1.16. Not all parts of Sections 8 and 9 are applicable to all radioscopic systems. These sections should be tailored to the radioscopic system being qualified.

10. Periodic Re-qualification and Verification

10.1 Re-qualification is necessary whenever the radioscopic system undergoes significant maintenance or alterations which could affect performance or the application changes beyond the material and thickness ranges for which the system was qualified.

10.2 Periodic verification may also be necessary if performance monitoring methods are not adequate to assure the continued level of performance to which the system was initially qualified. The maximum deviation of the results shall be fixed in a written procedure; if no value is given 20 % tolerance should be used.

11. Keywords

11.1 contrast sensitivity; detector unsharpness; duplex wire gauge; edge sharpening; field of view (FOV); focal detector distance (FDD); focal object distance (FOD); focal spot size; image processor; image quality indicator; imager; line-pair gauge; magnification; near real-time radioscopy; noise reduction; penetrating radiation; radioscopic; radioscopic examination geometry; raster scan; real-time radioscopy; system unsharpness; static mode; step wedge; transmitted beam

APPENDIX

(Nonmandatory Information)

X1. SUGGESTED RADIOSCOPIC SYSTEM QUALIFICATION DOCUMENT FORMAT

X1.1 The format given in this Appendix is intended to be representative of the kind of radioscopic system qualification information which is required, and may be changed to suit the particular circumstances.

X1.2 Application

_____

_____

_____

_____

_____

_____

X1.3 Material(s) and Thickness Range(s) for Which System is to be Qualified

_____

_____

_____

_____

_____

X1.4 Maximum Test Part Size

_____ cm × _____ cm × _____ cm (required radioscopic examination envelope)

X1.5 Required Spatial Resolution
(based upon the smallest feature which must be resolved lying in a plane at right angles to the radiation beam)

Horizontal = _____ mm; Vertical = _____ mm

X1.6 Required Contrast Sensitivity

Required Contrast Sensitivity = _____%

X1.7 Desired Radioscopic Examination Throughput

_____

_____

_____

_____

_____

X1.8 Equipment Details

X1.8.1 The following is a suggested listing of pertinent radioscopic system equipment details. The listing may be changed to suit the particular system configuration as may be necessary.

System Manufacturer _____ System Model Number _____
Serial Number _____ Date of Manufacture __/__/__
System Configuration: Cabinet _____ or Walk-in Room _____
Scan Plan: Manual Control Y/N Program Control Y/N
Accept/Reject Decision: Manual Y/N Computer Aided Y/N Automatic Y/N

X1.9 X-Ray Generating System

Manufacturer _____ Model _____ Under System Control Y/N
Conventional _____ ; Minifocus _____ ; Microfocus _____ ; kV Range _____ to _____
Minimum mA _____ ; Maximum mA _____
kV measurement: Primary _____ or Voltage Divider _____ ; Large Focal
Spot _____ mm diameter, _____ watts; Small Focal Spot _____ mm diameter,
_____ watts; Inherent filtration _____ ;
Additional filtration _____ ;

or

X1.9.1 Radioisotope Source

Camera Manufacturer _____ Model _____ Isotope _____
Initial Source Strength _____ Curies on __/__/__ ; Curies at the time of system qualification _____ ;
Source physical size _____ mm diameter × _____ mm long.

X1.10 Primary Beam Source Collimator

Manufacturer _____ Model _____ Under System Control Y/N
Variable Opening from _____ mm × _____ mm to _____ mm ×_____ mm;
Fixed Opening _____ mm × _____ mm

X1.11 Primary Beam Image Converter Diaphragm

Manufacturer _____ Model _____ Under System Control Y/N
Variable Opening from _____ mm × _____ mm to _____ mm ×_____ mm;
Fixed Opening _____ mm × _____ mm

X1.12 Image Conversion System

Manufacturer _____ Model _____ Under System Control Y/N
Type of device _____
Conversion screen _____ Normal Mode Image _____ cm × _____ cm;
Other fields of view: Mag. 1 _____ cm × _____ cm; Mag. 2 _____ cm ×_____ cm
Size of output image: _____ cm × _____ cm

X1.13 Video Image Transmission System

Manufacturer _____ Model _____ Under System Control Y/N
Image Pickup Device: CCD Pixel Format _____ × _____ ;
Tube Type _____ ; Camera Lens _____ mm/f _____ ;
Gamma _____ Video Bandwidth _____ MHz Signal-to-Noise Ratio _____ dB;
Horizontal Resolution _____ lines; Vertical Resolution _____ lines
Scan lines per frame _____ Frames per Second _____ Interlace ___:___
Output Video Format Specification _____ Automatic Camera Controls: Gain Y/N; Black Level Y/N;
Electronic Focus Y/N;
Positive/Negative Image Select Y/N;
Sweep Reversal—Horizontal Y/N; Vertical Y/N;

X1.14 Image Processor

Manufacturer _____ Model _____ Under System Control Y/N
Pixel Format_____ H × _____ V; Digitized to ____ bits; Pixel Dimensions at Image Converter Input ____ mm × ____ mm;
Functions: Integration to _____ Frames; Fixed Average to ____ Frames;
Recursive Average to _____ Frames; Positive/Negative Image
Select Y/N; Fixed Contrast Manipulation Lookup Tables Y/N; Number _____: Programmable Contrast Manipulation
Lookup Tables Y/N; Histogram Equalization Within a Window Y/N; Edge Sharpening Filters Y/N; Types _____ ,
_____ , _____ , _____ , _____ , _____ , and
_____ ;
Pseudo Color Y/N; RGB Y/N; Composite Y/N; No. of Colors _____
Analytical Functions: X-Y Measurement Y/N; Point-to-Point Y/N;
Pixel Brightness at Cursor Y/N; Pixel Address at Cursor Y/N;
Graphics: X-Axis Brightness Y/N; Y Axis Brightness Y/N;
Pixel Brightness Histogram within a Window Y/N;
Video Standards—Input _____ ; Output _____ :
☐ Image Processing with a PC (specify details in a separeate sheet)

X1.15 Video Display Monitor

Manufacturer _____ Model _____ Display Size _____ cm
Under System Control Y/N; Monochrome _____ ; Color _____ ; NTSC _____ ;
RGE _____ ; Scan Lines _____ ; Fields/Second _____ ; Frames/Second _____ ;
Interlace __:__ ; Bandwidth _____ MHz at _____ dB Down;
Horizontal Resolution _____ Lines; Vertical resolution _____ Lines;
Horizontal Linearity _____ %; Vertical Linearity _____ %; DC Restoration Y/N;
Positive/Negative Image Select Y/N;
☐ usage of Computer Monitor ☐ fulfills requirements in ASTM E2698 chapter 7.5