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Standard Practice for Qualification of Radioscopic Systems[1]

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1. Scope

1.1 This practice covers test and measurement details for measuring the performance of X-ray and gamma ray radioscopic systems. 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] 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 *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 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 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, 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.*

[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.

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

2.4 *Federal Standards:*[6]

21 CFR 1020.40 Safety Requirements of Cabinet X-Ray Systems

29 CFR 1910.96 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.

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 specifies the procedures to be used in determining the performance 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, as well as key system features, are to be recorded in a qualification document which shall qualify the performance 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 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.

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.

[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.

[6] Available from 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.

5.3 This practice addresses the performance of radioscopic systems in the static mode or dynamic mode, that can allow 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.

5.4 Radioscopic system performance measured pursuant to this practice does not guarantee the level of performance which may be realized in actual 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; 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 are covered in a separate written procedure required by Practice E1255.

6. Requirements

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

6.1.1 A 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,

6.1.6 *Image Quality*—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(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.

7. Hazards

7.1 The premises and equipment shall present no hazards to the safety of personnel or property. Radioscopic examination procedures shall be conducted under protective conditions so that personnel will not receive ionizing radiation dose levels exceeding that permitted by company, city, state, or national regulations. NCRP 49, NCRP 61, NCRP 116, NCRP 147, ANSI/HPS N43.3, 21 CFR 1020.40, and 29 CFR 1910.96 may be used as guides to ensure that radiographic facilities and procedures are performed so that personnel shall not receive a radiation dose exceeding the maximum permitted by city, state, or national codes.

8. Qualification Procedure

8.1 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.

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

8.3 The image display shall fulfill the requirements described in Practice E1255.

8.4 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.

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

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

8.7 DDAs and LDAs shall be corrected for gain and offset and bad pixels in accordance with Practice E2698.

8.8 Radioscopic system performance shall be evaluated as to (*1*) image unsharpness and contrast sensitivity or (*2*) Radioscopic Quality Level or Equivalent IQI Sensitivity for the

applicable material over the range of minimum and maximum section thicknesses for which the radioscopic system is to be qualified.

8.9 Each imager mode (field of view and pixel size, as applicable), frame rate, 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; however, for fixed focus tubes the focal spot size given by the manufacturer of the tube may be used for calculation of geometric unsharpness. Any radioscopic examination technique parameter which varies more than ±20 % from a tested technique shall be treated as a new imaging technique and must be evaluated. Parameters include source to detector distance, source to object distance, magnification, field of view and pixel size, X-ray energy and intensity, frame rate, and averaging/integration.

8.10 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.

8.11 If image recording or hard copy devices are incorporated, each shall be qualified as to image quality with reference to the original radioscopic image.

8.12 *Image Quality*—Evaluate (*1*) detector and image unsharpness ($U^{detector}$ and U^{image}) and (*2*) either contrast sensitivity or Radioscopic Quality Level or Equivalent IQI Sensitivity (EPS).

8.12.1 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. Unsharpness measurements shall be made both parallel to and at right angles to scan lines, as applicable.

8.12.1.1 *Detector Unsharpness*—Unprocessed detector unsharpness ($U^{detector}$) measurements shall be made using a Practice E2002 (or ISO 19232–5) duplex wire gauge at the image converter input surface with no additional absorber. Recorded data shall include source to detector and source to object distances, field of view and pixel size, unsharpness, radiation source energy and intensity for each imager mode and focal spot for which the radioscopic system is to be qualified. X-ray energy shall be as for the material at the minimum and maximum thicknesses for which the system is to be qualified. Detector unsharpness shall be measured in accordance with Practice E2002 and reported in the System Qualification Report. Alternately, unsharpness measurements may 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. Horizontal (along the TV scan lines, as applicable) and vertical (normal to TV scan lines, as applicable) resolution shall be recorded. Detector unsharpness shall be measured in line-pairs per mm at a specified contrast when using a line-pair gauge and reported in the System Qualification Report.

8.12.1.2 *Image Unsharpness (U^{image})*—Unprocessed image unsharpness measurements shall also be made at the object plane average position during manipulation. The Practice E2002 gauge shall be placed on the source side when on the object. Recorded data shall include SDD, average SOD, magnification, field of view, image unsharpness, source energy and intensity for each imager mode and focal spot which is to be qualified. X-ray energy shall be as for the material at the minimum and maximum thicknesses for which the system is to be qualified. Unsharpness measurements shall be made using a Practice E2002 (or ISO 19232–5) duplex wire gauge or line-pair gauge consisting of equal width lead foil lines and spaces on a radiation-transparent substrate, Horizontal (along TV or other scan lines) and vertical (normal to TV or other scan lines) resolution shall be recorded. Image unsharpness shall be measured in accordance with Practice E2002 when using the E2002 gauge or in line-pairs per mm at a specified contrast when using a line-pair gauge and reported in the System Qualification Report.

8.12.2 *Contrast Sensitivity*—Contrast Sensitivity measurements shall be by either a step wedge and shims or cutouts (such as the Practice E1647 gauge) in accordance with 8.12.2.1 or Radioscopic Quality Level or Equivalent IQI Sensitivity (EPS) in accordance with 8.12.2.2.

8.12.2.1 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. Contrast sensitivity measurements shall be made by shims or a step wedge made of the material for which the system is to be qualified such as the gauge in Practice E1647. Contrast Sensitivity shall be computed as described in 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. Measurement geometries shall be the same as for the unsharpness tests outlined in 8.12.1. Measured Contrast Sensitivity shall be reported in the System Qualification Report, or

8.12.2.2 *Radioscopic Quality Level or Equivalent IQI Sensitivity*—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. Measurement geometries shall be the same as for the unsharpness tests outlined in 8.12.1. Suitable devices are described in, but not limited to, Practices E746, E747, E801, E1025). IQIs manufactured in accordance with ISO 19232 and former EN462 may be used. The device(s) used shall be specified in the System Qualification Report. Measured Radioscopic Quality Level or Equivalent IQI Sensitivity shall be reported in the System Qualification Report.

8.12.2.3 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.

8.12.2.4 Measurements shall be recorded for each technique and image converter mode or field of view (and pixel size if applicable) that are used for the examination application.

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

8.14 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.

8.15 All qualification performance measurements shall be made in the mode (static or dynamic) to be used in production.

11. Periodic Re-qualification and Verification

11.1 Re-qualification is necessary whenever:

11.1.1 The detector, X-ray generator, X-ray tube, or other component(s) affecting image quality are repaired or replaced.

11.1.2 Changes are made to the image acquisition or processing software that affects image quality.

11.1.3 Image display monitors are repaired or replaced.

TABLE 1 System Performance Tests

System Performance Test / Parameter	Symbol	Unit	Requirement	Gauge
Detector Unsharpness[A]	$U^{detector}$ $1/U^{detector}$	µm lp/mm	X	E2002 Line pair
Image Unsharpness[A]	U^{image} $1/U^{image}$	µm lp/mm	X	E2002 Line pair
Contrast Sensitivity	CS	%	X	E1647
Quality Level[B]	QL	X-YT	Alternate 1 to CS	E1025 or E747
Equivalent IQI Sensitivity[C]	EPS	%	Alternate 2 to CS	E746

[A] Use of either gauge meets requirement.
[B] See Practice E1025 for "X-YT" definition.
[C] See Practice E1025 for EPS definition.

9. Qualification Statement

9.1 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/dynamic> mode, is capable of performing as reported in this qualification document. The user is cautioned that deviation from these conditions can significantly alter the radioscopic system's performance."

10. Records and Associated Documentation

10.1 The overall system performance level, as well as key system features, is to be recorded in a System Qualification Report which shall certify the performance level of the total radioscopic system. All information and measurements required in Sections 6 and 8 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 Report is included in Appendix X1. The sample in Appendix X1 may be adapted to newer storage technologies and computer hardware; for example, see X1.16.

11.1.4 The system is moved.

11.2 Periodic verification may also be necessary if technique verification methods are not adequate to assure the continued performance to which the system was initially qualified. The maximum deviation of the results shall be fixed in a written procedure or referred to the System Qualification Report; if no value is given, 20 % tolerance should be used. Periodicity of the verification is by agreement between the cognizant engineering organization and the supplier of radioscopic NDT services but should be no more than 10 days between verifications.

12. Keywords

12.1 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; image unsharpness; line-pair gauge; magnification; near real-time radioscopy; noise reduction; penetrating radiation; radioscopic; radioscopic examination geometry; raster scan; real-time radioscopy; static mode; step wedge; transmitted beam

APPENDIX

(Nonmandatory Information)

X1. SUGGESTED RADIOSCOPIC SYSTEM QUALIFICATION REPORT 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