



Designation: E1255 – 16

Standard Practice for Radioscopy¹

This standard is issued under the fixed designation E1255; 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 practice² provides application details for radiosopic examination using penetrating radiation. This includes dynamic radioscopy and for the purposes of this practice, radioscopy where there is no motion of the object during exposure (referred to as static radiosopic imaging) both using an analog component such as an electro-optic device or analog camera. Since the techniques involved and the applications for radiosopic examination are diverse, this practice is not intended to be limiting or restrictive, but rather to address the general applications of the technology and thereby facilitate its use. Refer to Guides E94 and E1000, Terminology E1316, Practice E747, Practice E1025, Practice E2698, and Fed. Std. Nos. 21 CFR 1020.40 and 29 CFR 1910.96 for a list of documents that provide additional information and guidance.

1.2 The general principles discussed in this practice apply broadly to penetrating radiation radiosopic systems. However, this document is written specifically for use with X-ray and gamma-ray systems. Other radiosopic systems, such as those employing neutrons, will involve equipment and application details unique to such systems.

1.3 The former mandatory Annex “A1. DEPARTMENT OF DEFENSE CONTRACTS, SUPPLEMENTAL REQUIREMENTS” was deleted and the detailed requirements are appended now in the non-mandatory Appendix X1. Appendix X1 may be used to fulfill existing contracts.

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

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.* For specific safety

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.

Current edition approved June 1, 2016. Published July 2016. Originally approved in 1988. Last previous edition approved in 2009 as E1255 - 09. DOI: 10.1520/E1255-16.

² For ASME Boiler and Pressure Vessel Code applications see related Practice SE-1255 in Section II of that code.

statements, see Section 9 and Fed. Std. Nos. 21 CFR 1020.40 and 29 CFR 1910.96.

2. Referenced Documents

2.1 ASTM Standards:³

E94 Guide for Radiographic Examination Using Industrial Radiographic Film

E543 Specification for Agencies Performing Nondestructive Testing

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

E1000 Guide for Radioscopy

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

E1316 Terminology for Nondestructive Examinations

E1411 Practice for Qualification of Radioscopic Systems

E1453 Guide for Storage of Magnetic Tape Media that Contains Analog or Digital Radioscopic Data

E1475 Guide for Data Fields for Computerized Transfer of Digital Radiological Examination Data

E1742 Practice for Radiographic Examination

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

E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)

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 ASNT Standard:⁴

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

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 Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

2.3 Federal Standards:⁵

21 CFR 1020.40 Safety Requirements of Cabinet X-Ray Systems

29 CFR 1910.96 Ionizing Radiation

2.4 *National Council on Radiation Protection and Measurement (NCRP) Standard:*

NCRP 49 Structural Shielding Design and Evaluation for Medical Use of X Rays and Gamma Rays of Energies Up to 10 MeV⁶

2.5 *National Aerospace Standard:*

NAS-410 NAS Certification and Qualification of Nondestructive Test Personnel⁷

2.6 *Other Standards:*

ISO 9712 Nondestructive Testing—Qualification and Certification of NDT Personnel⁸

SMPTE RP 133 Specifications for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard-Copy Recording Cameras⁹

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 *basic detector spatial resolution*—half the value of unsharpness measured as described in **7.2.5.3** with magnification 1 (IQI in contact to surface of the active area of the detector). The value is given in [μm] or Line/mm (L/mm).

3.2.2 *basic system spatial resolution*—half the value of system unsharpness measured as described in **7.2.5.3**. The value is given in μm or lines/mm (L/mm).

3.2.3 *camera spatial resolution*—an expression for the resolution of the camera inside the image intensifier.

3.2.4 *system unsharpness*—the unsharpness of the system with given magnification measured as described in **7.2.5.3**. The value is given in μm or line pairs/mm (LP/mm). Practice **E2002** shows a conversion between both values in Table 1.

4. Summary of Practice

4.1 Visual evaluation as well as computer-aided automated radioscopic examination systems are used in a wide variety of penetrating radiation examination applications. A simple visual evaluation radioscopic examination system might consist of a radiation source, a fluorescent screen viewed with an analog camera, suitably enclosed in a radiation protective enclosure and a video display. At the other extreme, a complex automated

radioscopic examination system might consist of an X-ray source, a robotic examination part manipulator, a radiation protective enclosure, an electronic image detection system with a camera, a frame grabber, a digital image processor, an image display, and a digital image archiving system. All system components are supervised by the host computer, which incorporates the software necessary to not only operate the system components, but to make accept/reject decisions as well. Systems having a wide range of capabilities between these extremes can be assembled using available components. Guide **E1000** lists many different system configurations.

4.2 This practice provides details for applying radioscopic examination with camera techniques; however, supplemental requirements are necessary to address areas that are application and performance specific.

5. Significance and Use

5.1 As with conventional radiography, radioscopic examination is broadly applicable to any material or examination object through which a beam of penetrating radiation may be passed and detected including metals, plastics, ceramics, composites, and other nonmetallic materials. In addition to the benefits normally associated with radiography, radioscopic examination may be either a dynamic, filmless technique allowing the examination part to be manipulated and imaging parameters optimized while the object is undergoing examination, or a static, filmless technique wherein the examination part is stationary with respect to the X-ray beam. The differentiation to systems with digital detector arrays (DDAs) is the use of an analog component such as an electro-optic device or an analog camera. Recent technology advances in the area of projection imaging, camera techniques, and digital image processing provide acceptable sensitivity for a wide range of applications. If normal video rates are not adequate to detect features of interest then averaging techniques with no movement of the test object shall be used.

6. Equipment and Procedure

6.1 *System Configuration*—Many different radioscopic examination systems configurations are possible, and it is important to understand the advantages and limitations of each. It is important that the optimum radioscopic examination system be selected for each examination requirement through a careful analysis of the benefits and limitations of the available system components and the chosen system configuration. The provider as well as the user of the radioscopic examination services should be fully aware of the capabilities and limitations of the radioscopic examination system that is proposed for examination of the object. The provider and the user of radioscopic examination services shall agree upon the system configuration to be used for each radioscopic examination application under consideration, and how its performance is to be evaluated.

6.1.1 The minimum radioscopic examination system configuration will include an appropriate source of penetrating radiation, a means for positioning the examination object within the radiation beam, in the case of dynamic radioscopy, and a detection system. The detection system may be as simple

⁵ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://www.dodssp.daps.mil>.

⁶ Available from NCRP Publications, 7010 Woodmont Ave., Suite 1016, Bethesda, MD 20814.

⁷ Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, <http://www.aia-aerospace.org>.

⁸ 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>.

⁹ Available from the Society of Motion Picture & Television Engineers. (SMPTE), 3 Barker Ave., 5th Floor, White Plains, NY 10601, <https://www.smpete.org>.

as a camera-viewed fluorescent screen with suitable radiation shielding for personnel protection that meets applicable radiation safety codes.

6.1.2 A more complex system might include the following components:

6.1.2.1 An Image Intensifier to intensify the photon detection from the fluorescent screen,

6.1.2.2 A micro- or mini-focus X-ray tube to be used with high magnification to facilitate higher-resolution projection imaging,

6.1.2.3 A multiple axis examination part manipulation system to provide dynamic, full volumetric examination part manipulation under operator manual control or automated program control, for dynamic radioscapy,

6.1.2.4 An electronic imaging system to display a bright, two-dimensional gray-scale image of the examination part at the operator's control console,

6.1.2.5 A digital image processing system to perform image enhancement and image evaluation functions,

6.1.2.6 An archival quality image recording or storage system, and

6.1.2.7 A radiation protective enclosure with appropriate safety interlocks and a radiation warning system.

6.1.3 Whether a simple or a complex system is used, the system components and configuration utilized to achieve the prescribed examination results shall be carefully selected.

6.2 Practice:

6.2.1 The purchaser and supplier for radioscopic examination services shall mutually agree upon a written procedure and also consider the following general requirements.

6.2.1.1 *Equipment Qualifications*—A listing of the system features that shall be qualified to ensure that the system is capable of performing the desired radioscopic examination task. System features are described in Guide E1000. The qualification shall be done as described in Practice E1411 or—for existing contracts from the former Annex A1—in Appendix X1.

6.2.1.2 *Examination Object Scan Plan for Dynamic Radioscapy*—A listing of object orientations, ranges of motions, and manipulation speeds through which the object shall be manipulated to ensure satisfactory examination.

6.2.1.3 *Radioscopic Parameters*—A listing of all the radiation source-related variables that can affect the examination outcome for the selected system configuration, such as: source energy, intensity, focal spot size, filter in the X-ray beam, collimators, range of source-to-object distances, range of object-to-image plane distances, and source-to-image plane distances.

6.2.1.4 *Image Processing Parameters*—A listing of all the image processing variables necessary to enhance flaw detectability in the object and to achieve the required sensitivity level. These would include, but are not limited to, techniques such as noise reduction, contrast enhancement, and spatial filtering. Great care should be exercised in the selection of directional image processing parameters such as spatial filtering, which may emphasize features in certain orientations and suppress them in others. The listing should indicate the means for qualifying image processing parameters.

6.2.1.5 *Image Display Parameters*—A listing of the techniques and the intervals at which they are to be applied for standardizing the image display as to brightness, contrast, focus, and linearity.

6.2.1.6 *Accept-Reject Criteria*—A listing of the expected kinds of object imperfections and the rejection level for each.

6.2.1.7 *Performance Evaluation*—A listing of the qualification tests and the intervals at which they are to be applied to ensure that the radioscopic examination system is suitable for its intended purpose. The evaluation shall be done as described in Practice E1411 or—for existing contracts from the former Annex A1—in Appendix X1.

6.2.1.8 *Image Archiving Requirements*—A listing of the requirements, if any, for preserving a historical record of the examination results. The listing may include examination images along with written or electronically recorded alphanumeric or audio narrative information, or both, sufficient to allow subsequent reevaluation or repetition of the radioscopic examination.

6.2.1.9 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT CP-189, SNT-TC-1A, NAS-410, ISO 9712, or similar document, and certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.2.1.10 *Agency Evaluation*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated in accordance with Practice E543. The applicable revision of Practice E543 shall be specified in the contractual agreement.

7. Radioscopic Examination System Performance Considerations and Measurement

7.1 *Factors Affecting System Performance*—Total radioscopic examination system performance is determined by the combined performance of the system components, which includes the radiation source, manipulation system (for dynamic radioscapy), detection system, information processing system, image display, automatic evaluation system, and examination record archiving system.

7.1.1 *Radiation Sources*—While the radioscopic examination systems may utilize either radioisotope or X-ray sources, X-radiation is used for most radioscopic examination applications. This is due to the energy spectrum of the X-radiation that contains a blend of contrast-enhancing longer wavelengths, as well as the more penetrating, shorter wavelengths. X-radiation is adjustable in energy and intensity to meet the radioscopic examination test requirements, and has the added safety feature of discontinued radiation production when switched off. A radioisotope source has the advantages of small physical size, portability, simplicity, and uniformity of output.

7.1.1.1 X-ray machines produce a more intense X-ray beam emanating from a smaller focal spot than do radioisotope sources. X-ray focal spot sizes range from a few millimetres down to less than one micrometre. Reducing the source size reduces geometric unsharpness, thereby enhancing detail sensitivity. X-ray sources may offer multiple or variable focal spot

sizes. Smaller focal spots produce higher resolution when using geometrical magnification and provide reduced X-ray beam intensity, while larger focal spots provide higher X-ray intensity and produce lower resolution. Microfocus X-ray tubes are available with focal spots that may be adjusted to less than 1 micrometre in diameter, while still producing an X-ray beam of sufficient intensity so as to be useful for the radioscopic examination of finely detailed objects.

7.1.1.2 Focal spot sizes in this standard 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. Conventional focal spots of 1.0 mm and larger are useful at low geometric magnification values close to 1 \times . Fractional focal spots ranging from 0.4 mm up to 1.0 mm are useful at geometric magnifications of up to approximately 2 \times . Minifocus spots in the range from 0.1 mm up to 0.4 mm are useful at geometric magnifications up to about 6 \times . Greater magnifications suggest the use of a microfocus spot size of less than 0.1 mm in order to minimize the effects of geometric unsharpness. Microfocus X-ray tubes are capable of focal spot sizes of less than 1 micrometre (10^{-6} metre) and are useful for geometric magnifications of more than 100 \times .

7.1.2 *Manipulation System for Dynamic Radioscopy*—The examination part manipulation system has the function of holding the examination object and providing the necessary degrees of freedom, ranges of motion, and speeds of travel to position the object areas of interest in the radiation beam in such a way so as to maximize the radioscopic examination system's response. In some applications it may be desirable to manipulate the radiation source and detection system instead of, or in addition to, the object. The manipulation system shall be capable of smooth, well-controlled motion, especially so for high-magnification microfocus techniques, to take full advantage of the dynamic aspects of the radioscopic examination.

7.1.3 *Detection System*—The detection system is a key element. It has the function of converting the radiation input signal containing part information into a corresponding electronic output signal while preserving the maximum amount of object information. The detector may be a two-dimensional area detector providing an area field of view.

7.1.3.1 A simple detection system may consist of a fluorescent screen viewed directly by an analog camera. Advantages include a selectable resolution and low component costs. The disadvantages include noisy imagery due to inefficient light capture from the fluorescent screen and pin cushion distortion.

7.1.3.2 Most radioscopic systems use image intensifiers that increase the capture efficiency from a fluorescent screen, intensify and reduce the image to an output phosphor that is then captured by a standard analog or digital TV/CCD camera, or equivalent. The image intensifier enables increased frame rates, or higher examination throughputs in relation to the use of a fluorescent screen alone. This enables the use of a standard low cost camera resulting in much higher SNR than if the image intensifier were not used. Disadvantages of the image

intensifier include image blooming, pin cushion distortion and a limited basic detector spatial resolution of about 100 to 400 μm .¹⁰

7.1.3.3 Cameras in combination with image intensifiers may use analog or digital readout circuitry. Analog cameras may produce video signals and may be used with TV displays; digital cameras need computing devices for displaying the images. Digital cameras and lenses may be selected out of a wide range of options in camera spatial resolution, image size, sensitivity and frame rate.

7.1.4 *Information Processing System:*

7.1.4.1 The function of the information processing system is to take the output of the detection system and present a useful image for display and operator interpretation, or for automatic evaluation. The information processing system may take many different forms, and may process analog or digital information, or a combination of the two.

7.1.4.2 The information processing system includes all of the electronics and interfaces after the detection system including the image display and automatic evaluation system. Information system components include such devices as frame grabbers, image processors, and in general any device that processes radioscopic examination information after the detection system.

7.1.4.3 The digital image processing system warrants special attention, since it is the means by which radioscopic examination information may be enhanced. Great care shall be exercised in determining which image processing techniques are most beneficial for the particular application. Directional spatial filtering operations, for example, must be given special attention as certain feature orientations are emphasized while others are suppressed. While many digital image processing operations occur sufficiently fast to follow time-dependent radioscopic system variables, others do not. Some image processing operations require significant image acquisition and processing time, so as to limit the dynamic response of the radioscopic examination, in dynamic radioscopic systems.

7.1.5 *Automatic Evaluation System*—Some radioscopic examination applications can be fully automated including the accept/reject decision through computer techniques. The automatic evaluation system's response to various examination object conditions shall be carefully determined under actual operating conditions. The potential for rejecting good objects and accepting defective objects shall be considered. Automatic evaluation system performance criteria should be mutually determined by the provider and user of radioscopic examination services.

7.1.6 *Image Display:*

7.1.6.1 The function of the image display is to convey radioscopic information about the examination object to the system operator. For visual evaluation systems, the displayed

¹⁰ Note that some scientific CCD cameras, and amorphous silicon detectors that always provide digital imagery are now capable of reading fluorescent screens at fast frame rates without the need of an image intensifier. These devices are not covered by this standard.