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.

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# Standard Practice for Radioscopic Examination of Weldments[1]

This standard is issued under the fixed designation E1416; 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 covers a uniform procedure for radioscopic examination of weldments. Requirements expressed in this practice are intended to control the quality of the radioscopic images and are not intended for controlling acceptability or quality of welds.

1.2 This practice applies only to the use of equipment for radioscopic examination in which the image is finally presented on a display screen (monitor) for operator evaluation. The examination may be recorded for later review. It does not apply to fully automated systems where evaluation is automatically performed by computer.

1.3 The radioscopic extent, the quality level, and the acceptance criteria to be applied shall be specified in the contract, purchase order, product specification, or drawings.

1.4 This practice can be used for the detection of discontinuities. This practice also facilitates the examination of a weld from several directions, such as perpendicular to the weld surface and along both weld bevel angles. The radioscopic techniques described in this practice provide adequate assurance for defect detectability; however, it is recognized that, for special applications, specific techniques using more stringent requirements may be needed to provide additional detection capability. The use of specific radioscopic techniques shall be agreed upon between purchaser and supplier.

1.5 *Units*—The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 7.

1.7 *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:*[2]

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

E1032 Practice for Radiographic Examination of Weldments Using Industrial X-Ray Film

E1255 Practice for Radioscopy

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

E1647 Practice for Determining Contrast Sensitivity in Radiology

E1742 Practice for Radiographic Examination

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

E2033 Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)

E2698 Practice for Radiographic Examination Using Digital Detector Arrays

[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.

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2.2 *Other Standard:*[3]

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

## 3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of terms applicable to this practice may be found in Terminology E1316.

## 4. Apparatus

4.1 Success of the radioscopic process depends on the overall system configuration and the selection of appropriate subsystem components. Guidance on the selection of subsystem components and the overall system configuration is provided in Guide E1000 and Practice E1255. Guidance on the initial qualification and periodic re-qualification of the radioscopic system is provided in Practice E1411. The suitability of the radioscopic system shall be demonstrated by attainment of the required image quality and compliance with all other requirements stipulated herein; unless otherwise specified by the cognizant engineering organization, the default image quality level shall be 2-2T.

4.2 *Radiation Source (X-ray or Gamma-ray)*—Selection of the appropriate source is dependent upon variables regarding the weld being examined, such as material composition and thickness. The suitability of the source shall be demonstrated by attainment of the required image quality and compliance with all other requirements stipulated herein. Guidance on the selection of the radiation source may be found in Guide E1000 and Practice E1255.

4.3 *Manipulation System*—Selection of the appropriate manipulation system (where applicable) is dependent upon variables such as the size and orientation of the object being examined and the range of motions, speed of manipulation, and smoothness of motion. The suitability of the manipulation system shall be demonstrated by attainment of the required image quality and compliance with all other requirements stipulated herein. Guidance on the selection of the manipulation system may be found in Practice E1255.

4.4 *Imaging System*—Selection of the appropriate imaging system is dependent upon variables such as the size of the object being examined and the energy and intensity of the radiation used for the examination. The suitability of the imaging system shall be demonstrated by attainment of the required image quality and compliance with all other requirements stipulated herein. Guidance on the selection of an imaging system may be found in Guide E1000 and Practice E1255.

4.5 *Image Processing System*—Where agreed between purchaser and supplier, image processing systems may be used for noise reduction through image integration or averaging, contrast enhancement and other image processing operations.

4.6 *Collimation*—Selection of appropriate collimation is dependent upon the geometry of the object being examined. It is generally useful to select collimation to limit the primary radiation beam to the weld and the immediately adjacent base material in order to improve radioscopic image quality.

4.7 *Filters and Masking*—Filters and masking may be used to improve image quality from contrast reductions caused by low-energy scattered radiation. Guidance on the use of filters and masking can be found in Guide E94.

4.8 *Image Quality Indicators (IQI)*—Unless otherwise specified by the applicable job order or contract, image quality indicators shall comply with the design and identification requirements specified in Practices E747, E1025, E1647, E1742, or E2002.

4.9 *Shims, Separate Blocks, or Like Sections*—Shims, separate blocks, or like sections made of the same or radioscopically similar materials (as defined in Practice E1025) may be used to facilitate image quality indicator positioning as described in 9.10.3. The like section should be geometrically similar to the object being examined.

4.10 *Location and Identification Markers*—Lead numbers and letters should be used to designate the part number and location number. The size and thickness of the markers shall depend on the ability of the radioscopic technique to discern the markers on the images. As a general rule, markers from 0.06 to 0.12 in. (1.5 to 3 mm) thick will suffice for most low energy (less than 1 MeV) X-ray and iridium$^{192}$ radioscopy. For higher energy (greater than 1 MeV and cobalt$^{60}$) radioscopy, it may be necessary to use markers that are thicker (0.12 in. (3 mm) thick or more). In cases where the system being used provides a display of object position within the image, this shall be acceptable as identification of object location. In case of digital storage of the images, digital markers and annotations in the image may be used if they are stored permanently with the image.

## 5. Materials

5.1 *Recording Media*—Recording media for storage of images shall be in a format agreed by the purchaser and supplier. This may include either analog or digital media.

## 6. Basis of Application

6.1 The following items are subject to contractual agreement between the parties using or referencing this practice.

6.2 *Personnel Qualification:*

6.2.1 If specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard 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.

6.3 *Qualification of Nondestructive Testing Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Specification E543. The

[3] Available from The Society of Motion Picture and Television Engineers (SMPTE), www.smpte.org.

applicable edition of Specification E543 shall be specified in the contractual agreement.

6.4 *Performance Measurement*—The radioscopic system shall be qualified according to Practice E1411.

6.4.1 Performance measurement intervals shall be according to Practice E1411 unless otherwise specified.

6.5 *Time of Examination*—The time of examination shall be in accordance with 9.1 unless otherwise specified.

6.6 *Procedures and Techniques*—The procedures and techniques to be utilized shall be as described in this practice unless otherwise specified. Specific techniques may be specified in the contractual agreement.

6.7 *Extent of Examination*—The extent of examination shall be in accordance with 8.3 unless otherwise specified.

6.8 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with Section 10 unless otherwise specified. Acceptance criteria shall be specified in the contractual agreement.

6.9 *Reexamination of Repaired/Reworked Items*—Reexamination of repaired/reworked items is not addressed in this practice and if required shall be specified in the contractual agreement.

## 7. Safety

7.1 Radioscopic procedures shall comply with applicable city, state, and federal safety regulations.

## 8. Requirements

8.1 *Procedure Requirement*—Unless otherwise specified by the applicable job order or contract, radioscopic examination shall be performed in accordance with a written procedure. Specific requirements regarding the preparation and approval of the written procedures shall be as agreed by purchaser and supplier. The production procedure shall address all applicable portions of this practice and shall be available for review during interpretation of the images. The written procedure shall include the following:

8.1.1 Material and thickness range to be examined,

8.1.2 Equipment to be used, including specifications of source parameters (such as tube voltage, current, focal spot size) and imaging equipment parameters (such as detector size, field of view, electronic magnification, camera black level, gain, look-up table (LUT), type of display monitor),

8.1.3 Examination geometry, including source-to-object distance, object-to-detector distance and orientation,

8.1.4 Image quality indicator designation and placement,

8.1.5 Test-object scan plan, indicating the range of motions and manipulation speeds through which the test object shall be manipulated in order to ensure satisfactory results (see description in 6.2.1.2 of Practice E1255),

8.1.6 Image-processing parameters,

8.1.7 Image-display parameters,

8.1.8 Image storage, and

8.1.9 Plan for system qualification and periodic requalification as described in Practice E1411.

8.2 *Radioscopic Coverage*—Unless otherwise specified by purchaser and supplier agreement, the extent of radioscopic coverage shall include 100 % of the volume of the weld and the adjacent base metal.

8.3 *Examination Speed*—For dynamic examination, the speed of object motion relative to the radiation source and detector shall be controlled to ensure that the required radioscopic quality level is achieved.

8.4 *Radioscopic Image Quality*—All images shall be free of artifacts that could mask or be confused with the image of any discontinuity in the area of interest. It may be possible to prevent blemishes from masking discontinuities or being confused with discontinuities by moving the object being examined relative to the imaging device. If any doubt exists as to the true nature of an indication exhibited in the image, the image shall be rejected and a new image of the area shall be made.

8.5 *Radioscopic Quality Level*—Radioscopic quality level shall be determined upon agreement between the purchaser and supplier and shall be specified in the applicable job order or contract. If no quality level is defined, 2-2T shall be the standard. Radioscopic quality shall be specified in terms of equivalent penetrameter (IQI) sensitivity and shall be measured using image quality indicators conforming to Practices E747, E1025, or E1742. Additionally, for system unsharpness measurement, the Practice E2002 duplex wire gauge shall be used.

8.6 *Acceptance Level*—Accept and reject levels shall be stipulated by the applicable contract, job order, drawing, or other purchaser and supplier agreement.

8.7 *Image-Viewing Facilities*—Viewing facilities shall provide subdued background lighting of an intensity that will not cause troublesome reflection, shadows, or glare on the image. The image display performance, size, and placement are important radioscopic system considerations. A test pattern similar to SMPTE RP133 shall be used to qualify the display.

8.8 *Storage of Images*—When storage is required by the applicable job order or contract, the images should be stored in a format stipulated by the applicable contract, job order, drawing, or other purchaser and supplier agreement. The image-storage duration and location shall be as agreed between purchaser and supplier (see Guides E1453 and E1475).

## 9. Procedure

9.1 *Time of Examination*—Unless otherwise specified by the applicable job order or contract, perform radioscopy prior to heat treatment.

9.2 *Surface Preparation*—Unless otherwise agreed upon, remove the weld bead ripple or weld-surface irregularities on both the inside and outside (where accessible) by any suitable process so that the image of the irregularities cannot mask, or be confused with, the image of any discontinuity. Interpretation can be optimized if surface irregularities are removed such that the image of the irregularities is not discernible.

9.3 *System Unsharpness*—System unsharpness shall be measured using Practice E2002 duplex wire IQI (see also

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Guide E1000). System Unsharpness ($U_{im}$) is defined as total unsharpness ($U_{total}$) divided by magnification ($v$) (see Guide E1000):

$$U_{im} = U_{total} / v \quad (1)$$

Unless otherwise specified in the applicable job order or contract, $U_{im}$ shall not exceed the following:

**TABLE Unsharpness ($U_{im}$) (Maximum)**

| Material Thickness | $U_{im}$, max, in. (mm) |
|---|---|
| under 2 in. (50 mm) | 0.020 (0.50) |
| 2 through 3 in. (50 through 75 mm) | 0.030 (0.75) |
| over 3 through 4 in. (75 through 100 mm) | 0.040 (1.00) |
| greater than 4 in. (100 mm) | 0.070 (1.75) |

Discussion: In standards with DDA (E2698), CR (E2033), or film (E1032) the following unsharpness requirement for materials under 1 in. (25.4 mm) thickness is used: Maximum 0.010 in. (0.254 mm).

9.4 *Examination Speed*—For dynamic examination, determine the speed of object motion relative to the radiation source and detector upon agreement between the purchaser and supplier. Base this determination upon the achievement of the required radioscopic quality level at that examination speed.

9.5 *Direction of the Radiation*—Direct the central beam of radiation perpendicularly toward the center of the effective area of the detector or to a plane tangent to the center of the image, to the maximum extent possible, except for double-wall exposure-double-wall viewing elliptical projection techniques, as described in 9.14.2.

9.6 *Scattered Radiation*—Scattered radiation (radiation scattered from the test object and from surrounding structures) reduces radioscopic contrast and may produce undesirable effects on radioscopic quality. Use precautions such as collimation of the source, collimation of the detector, and additional shielding as appropriate to minimize the detrimental effects of this scattered radiation.

9.7 *Image Quality Indicator Selection*—For selection of the image quality indicator, the thickness on which the image quality indicator is based is the single-wall thickness plus the lesser of the actual or allowable reinforcement. Backing strips or rings are not considered as part of the weld or reinforcement thickness for image quality indicator selection. For any thickness, an image quality indicator acceptable for thinner materials may be used, provided all other requirements for radioscopy are met.

9.8 *Number of Image Quality Indicators:*

9.8.1 Place at least one image quality indicator of Practices E747, E1025, or E1742, and one image quality indicator of Practice E2002 in the area of interest representing an area in which the brightness is relatively uniform. The degree of brightness uniformity shall be agreed upon between purchaser and supplier. If the image brightness in an area of interest differs by more than the agreed amount, use two image quality indicators. Use one image quality indicator to demonstrate acceptable image quality in the darkest portion of the image and use one image quality indicator to demonstrate acceptable image quality in the lightest portion of the image.

9.8.2 When a series of images are made under identical conditions, it is permissible for the image quality indicators to be used only on the first and last images in the series, provided this is agreed upon between the purchaser and supplier. In this case, it is not necessary for the image quality indicators to appear in each image.

9.8.3 Always retain qualifying images, on which one or more image quality indicators were imaged during exposure, as part of the record to validate the required image quality indicator sensitivity and placement.

9.9 *Image Quality Indicator Placement:*

9.9.1 Place the image quality indicator on the source side adjacent to the weld being examined. Where the weld metal is not radioscopically similar to the base material or where geometry precludes placement adjacent to the weld, place the image quality indicator over the weld or on a separate block, as described in 9.10.

9.9.2 *Detector-Side Image Quality Indicators*—In those cases where the physical placement of the image quality indicators on the source side is not possible, place the image quality indicators on the detector side. The applicable job order or contract shall specify the applicable detector-side quality level. The accompanying documents shall clearly indicate that the image quality indicators were located on the detector side.

9.10 *Separate Block*—When configuration or size prevents placing the image quality indicators on the object being examined, use a shim, separate block or like section conforming to the requirements of 4.9 provided the following conditions are met:

9.10.1 The image quality indicator is no closer to the detector than the source side of the object being examined (unless otherwise specified).

9.10.2 The brightness or signal level in the area of the image quality indicator including the shim, separate block, or like section and IQI where applicable are similar to the brightness or signal level in the area of interest.

9.10.3 The shim, separate block, or like section is placed as close as possible to the object being examined.

9.10.4 When hole-type image quality indicators are used, the shim, separate block, or like section dimensions shall exceed the image quality indicator dimensions such that the outline of at least three sides of the image quality indicator image is visible on the image.

9.11 *Shim Utilization*—When a weld reinforcement or backing ring and strip is not removed, place a shim of material that is radioscopically similar to the backing ring and strip under the image quality indicators to provide approximately the same thickness of material under the image quality indicator as the average thickness of the weld reinforcement plus the wall thickness, backing ring and strip.

9.11.1 *Shim Dimensions and Location*—When hole-type image quality indicators are used, the shim dimensions and location shall exceed the image quality indicator dimensions by at least 0.12 in. (3 mm) on at least three sides. At least three sides of the image quality indicator shall be discernible in accordance with 9.10.4 except that only the two ends of the image quality indicator need to be discernible when located on piping less than 1 in. (25 mm) nominal pipe size. Place the shim so as not to overlap the weld image including the backing strip or ring.

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