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Standard Guide for Radiographic Examination Using Industrial Radiographic Film[1]

This standard is issued under the fixed designation E94/E94M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This guide[2] covers satisfactory X-ray and gamma-ray radiographic examination as applied to industrial radiographic film recording. It includes statements about preferred practice without discussing the technical background which justifies the preference. A bibliography of several textbooks and standard documents of other societies is included for additional information on the subject.

1.2 This guide covers types of materials to be examined; radiographic examination techniques and production methods; radiographic film selection, processing, viewing, and storage; maintenance of inspection records; and a list of available reference radiograph documents.

NOTE 1—Further information is contained in Guide E999, Practice E1025, Practice E1030/E1030M, and Practice E1032.

1.3 The use of digital radiography has expanded and follows many of the same general principles of film based radiography but with many important differences. The user is referred to standards for digital radiography [E2597, E2698, E2736, and E2737 for digital detector array (DDA) radiography and E2007, E2033, E2445/E2445M, and E2446 for computed radiography(CR)] if considering the use of digital radiography.

1.4 *Interpretation and Acceptance Standards*—Interpretation and acceptance standards are not covered by this guide, beyond listing the available reference radiograph documents for castings and welds. Designation of accept - reject standards is recognized to be within the cognizance of product specifications and generally a matter of contractual agreement between producer and purchaser.

1.5 *Safety Practices*—Problems of personnel protection against X-rays and gamma-rays are not covered by this guide. For information on this important aspect of radiography, reference should be made to the current document of the National Committee on Radiation Protection and Measurement, Federal Register, U.S. Energy Research and Development Administration, National Bureau of Standards, and to state and local regulations, if such exist. For specific radiation safety information, refer to NIST Handbook ANSI 43.3, 21 CFR 1020.40, and 29 CFR 1910.1096 or state regulations for agreement states.

1.6 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system should be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.7 If an NDT agency is used, the agency should be qualified in accordance with Specification E543.

1.8 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations to this guide should 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.

1.9 *This standard does not purport to address all of the safety problems, 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.* (See 1.5.)

1.10 *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 guide 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 Guide SE-94 in Section V of that Code.

***A Summary of Changes section appears at the end of this standard**

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E543 Specification for Agencies Performing Nondestructive Testing

E746 Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems

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

E999 Guide for Controlling the Quality of Industrial Radiographic Film Processing

E1000 Guide for Radioscopy

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

E1030/E1030M Practice for Radiographic Examination of Metallic Castings

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

E1079 Practice for Calibration of Transmission Densitometers

E1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging

E1254 Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films

E1316 Terminology for Nondestructive Examinations

E1390 Specification for Illuminators Used for Viewing Industrial Radiographs

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

E1735 Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems from 4 to 25 MeV

E1742/E1742M Practice for Radiographic Examination

E1815 Test Method for Classification of Film Systems for Industrial Radiography

E1817 Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)

E1936 Reference Radiograph for Evaluating the Performance of Radiographic Digitization Systems

E2007 Guide for Computed Radiography

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

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

E2445/E2445M Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems

E2446 Practice for Manufacturing Characterization of Computed Radiography Systems

E2597 Practice for Manufacturing Characterization of Digital Detector Arrays

E2698 Practice for Radiographic Examination Using Digital Detector Arrays

E2736 Guide for Digital Detector Array Radiography

E2737 Practice for Digital Detector Array Performance Evaluation and Long-Term Stability

E2903 Test Method for Measurement of the Effective Focal Spot Size of Mini and Micro Focus X-ray Tubes

E3169 Guide for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)

2.2 *ANSI Standard:*[4]

ANSI/I3A/PIMA IT 2.26 Determination of Safelight Conditions

2.3 *Federal Standards:*[5]

Title 21, Code of Federal Regulations (CFR) 1020.40, Safety Requirements of Cabinet X-Ray Systems

Title 29, Code of Federal Regulations (CFR) 1910.96, Ionizing Radiation (X-Rays, RF, etc.)

2.4 *ISO Standards:*[6]

ISO 14096-2 Non-destructive Testing — Qualification of Radiographic Film Digitization Systems — Part 2: Minimum Requirements

ISO 18901 Imaging Materials — Processed Silver-Gelatin-type Black-and-white Films — Specifications for Stability

ISO 18902 Imaging Materials — Processed Imaging Materials — Albums, Framing and Storage Materials

ISO 18917 Photography—Determination of Residual Thiosulphate and Other Related Chemicals in Processed Photographic Materials—Methods Using Iodine-amylose, Methylene Blue and Silver Sulfide

2.5 *Other Document:*[7]

NBS Handbook ANSI N43.3 General Radiation Safety Installations Using NonMedical X-Ray and Sealed Gamma-Ray Sources up to 10 MeV

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, refer to Terminology E1316.

4. Significance and Use

4.1 Within the present state of the radiographic art, this guide is generally applicable to available materials, processes, and techniques where industrial radiographic films are used as the recording media.

4.2 *Limitations*—This guide does not take into consideration the benefits and limitations of nonfilm radiography such as

[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.

[5] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

[6] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

[7] Available from National Technical Information Service (NTIS), U.S. Department of Commerce, 5301 Shawnee Rd, Alexandria, VA 22312.

radioscopy, digital detector arrays, or computed radiography. Refer to Guides E1000, E2736, and E2007.

4.3 Although reference is made to documents that may be used in the identification and grading, where applicable, of representative discontinuities in common metal castings and welds, no attempt has been made to set standards of acceptance for any material or production process.

4.4 Radiography will be consistent in image quality (contrast sensitivity and definition) only if all details of techniques, such as geometry, film, filtration, viewing, etc., are obtained and maintained.

5. Equipment and Configuration

5.1 To obtain quality radiographs, it is necessary to consider as a minimum the following list of items. Detailed information on each item is further described in this guide.

5.1.1 Radiation source (X-ray or gamma),

5.1.2 Energy selection,

5.1.3 Source size (X-ray focal spot dimension or gamma source size),

5.1.4 Ways and means to eliminate scattered radiation,

5.1.5 Film system class,

5.1.6 Source-to-film and object-to-film distance,

5.1.7 Image quality indicators (IQIs),

5.1.8 Screens and filters,

5.1.9 Geometry of part or component configuration,

5.1.10 Identification and location markers, and

5.1.11 Radiographic quality level.

6. Radiographic Quality Level

6.1 Image Quality Indicators (IQIs) are devices placed within a radiographic set-up to indicate that a certain contrast sensitivity and definition has been achieved. IQIs demonstrating the required sensitivity level do not guarantee that a similar size flaw in a part will be detected but indicate that the radiographic quality has been met. Information on the design and manufacture of image quality indicators (IQIs) can be found in Practices E747, E801, E1025, and E1742/E1742M.

6.2 Radiographic quality level is usually expressed in percent of part thickness and diameter of feature to be detected. If a single percent number is given, the feature diameter is assumed to be twice the given percent thickness of the part. For example, if 2% is given for one inch [25.4 mm] thick part, the feature diameter is 2 × 0.02 × 1 in. [25.4 mm] or 0.04 in. [1.016 mm]. Image quality levels using hole-type IQIs (see Practice E1025) are designated by a two part expression *X-YT*. The first part of the expression *X* refers to the IQI thickness expressed as a percentage of the specimen thickness. The second part of the expression *YT* refers to the diameter of the hole and is expressed as a multiple of the IQI thickness, *T*. The image quality level 2-2*T* means that the IQI thickness *T* is 2% of the specimen thickness and that the diameter of the IQI imaged hole is 2 times the IQI thickness. If using wire IQIs, the wire set and wire number are designated. Correspondence between hole-type and wire-type IQIs is given in Practice E747. Hole- and wire-type IQIs are the major types used for industrial radiography. Other types may also be used (for example, see Practice E1817). The quality level usually required for radiography is 2 % (2-2*T* when using hole type IQI) unless a higher or lower quality is agreed upon between the purchaser and the supplier. The level of inspection specified should be based on the service requirements of the product. Great care should be taken in specifying quality levels 2-1*T*, 1-1*T*, and 1-2*T* by first determining that these quality levels can be maintained in production radiography.

6.3 If IQIs of material radiographically similar to that being examined are not available, IQIs of the required dimensions but of a lower-absorption material may be used.

6.4 The quality level required using wire IQIs should be equivalent to the 2-2T level of Practice E1025 unless a higher or lower quality level is agreed upon between purchaser and supplier. Table 4 of Practice E747 provides a list of various hole-type IQIs and the corresponding diameter of the wires to achieve the Equivalent Penetrameter Sensitivity (EPS) with the applicable 1T, 2T, and 4T holes in the plaque IQI. Appendix X1 of Practice E747 gives the equation for calculating other equivalencies, if needed.

7. Energy Selection

7.1 X-ray energy affects image quality. In general, the lower the energy of the source utilized the higher the achievable radiographic contrast, however, other variables such as excessive dose geometry and scatter conditions may override the potential advantage of higher contrast. For a particular energy, a range of thicknesses which are a multiple of the half value layer, may be radiographed to an acceptable quality level utilizing a particular X-ray machine or gamma ray source. In all cases, the specified IQI (penetrameter) quality level must be shown on the radiograph. In general, satisfactory results can normally be obtained for X-ray energies between 100 kV to 500 kV in a range between 2.5 to 10 half value layers (HVL) of material thickness (see Table 1). This range may be extended by as much as a factor of 2 in some situations for X-ray energies in the 1 to 25 MV range primarily because of reduced scatter.

8. Radiographic Equivalence Factors

8.1 The radiographic equivalence factor of a material is that factor by which the thickness of the material must be multiplied to give the thickness of a “standard” material (often steel) which has the same absorption. Radiographic equivalence

TABLE 1 Typical Steel HVL Thickness in Inches [mm] for Common Energies

kV/MV	Thickness, Inches [mm]
120 kV	0.10 [2.5]
150 kV	0.14 [3.6]
200 kV	0.20 [5.1]
250 kV	0.25 [6.4]
400 kV (Se 75)	0.35 [8.9]
750 kV (Ir 192)	0.51 [12.5]
1 MV	0.57 [14.5]
2 MV (Co 60)	0.80 [20.3]
4 MV	1.00 [25.4]
6 MV	1.15 [29.2]
10 MV	1.25 [31.8]
16 MV and higher	1.30 [33.0]