Designation: E746 – 23

Standard Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems below 4 MeV[1]

This standard is issued under the fixed designation E746; 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 standard covers a practice whereby industrial radiographic imaging systems or techniques may be comparatively assessed using the concept of relative image quality response (RIQR). Changes within a radiographic technique such as film/detector types, distances, or filtering/collimation can be comparatively assessed using this standard. The RIQR method presented within this practice is based upon the use of equivalent penetrameter sensitivity (EPS) described within Practice E1025 and subsection 5.4 of this practice. Fig. 1 illustrates a relative image quality indicator (RIQI) that has four different plaque thicknesses (0.38 mm, 0.25 mm, 0.20 mm, and 0.13 mm (0.015 in., 0.010 in., 0.008 in., and 0.005 in.)) sequentially positioned (from top to bottom) on an absorber plate of a specified material and thickness. The four plaques contain a total of 14 different arrays of penetrameter-type hole sizes designed to render varied conditions of threshold visibility when exposed to the appropriate radiation. Each "EPS" array consists of 30 identical holes; thus, providing the user with a quantity of threshold sensitivity levels suitable for relative image qualitative response comparisons. There are two standard materials (steel and plastic) specified herein for the RIQI and absorber. For special applications the user may design a non-standard RIQI-absorber configuration; however the RIQI configuration shall be controlled by a drawing similar to Fig. 1. Use of a non-standard RIQI-absorber configuration shall be described in the user's written technique and approved by the CEO.

1.2 This practice is not intended to qualify the performance of a specific radiographic technique nor for assurance that a radiographic technique will detect specific discontinuities in a specimen undergoing radiographic examination.

1.3 This practice is not intended to be used to classify or derive performance classification categories for radiographic imaging systems. For example, performance classifications of radiographic film systems may be found within Test Method E1815, and manufacturer characterization of computed radiography (CR) systems may be found in Practice E2446. However, the RIQI and absorber described in this practice are used by Practice E2446 for manufacturer characterization of computed radiography (CR) systems and by Practice E2445 to evaluate performance and to monitor long term stability of CR systems.

1.4 These tests are for applications below 4 MeV. When a gamma source or other high energy source is used, these tests may still be used to characterize the system, but may need a modification of the absorber thickness to adjust the available RIQR range as agreed between the user and cognizant engineering organization (CEO). For high-energy X-ray applications (4 MV to 25 MV), Test Method E1735 provides a similar RIQR standard practice.

1.5 The values stated in SI are to be regarded as the 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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]

B152/B152M Specification for Copper Sheet, Strip, Plate, and Rolled Bar

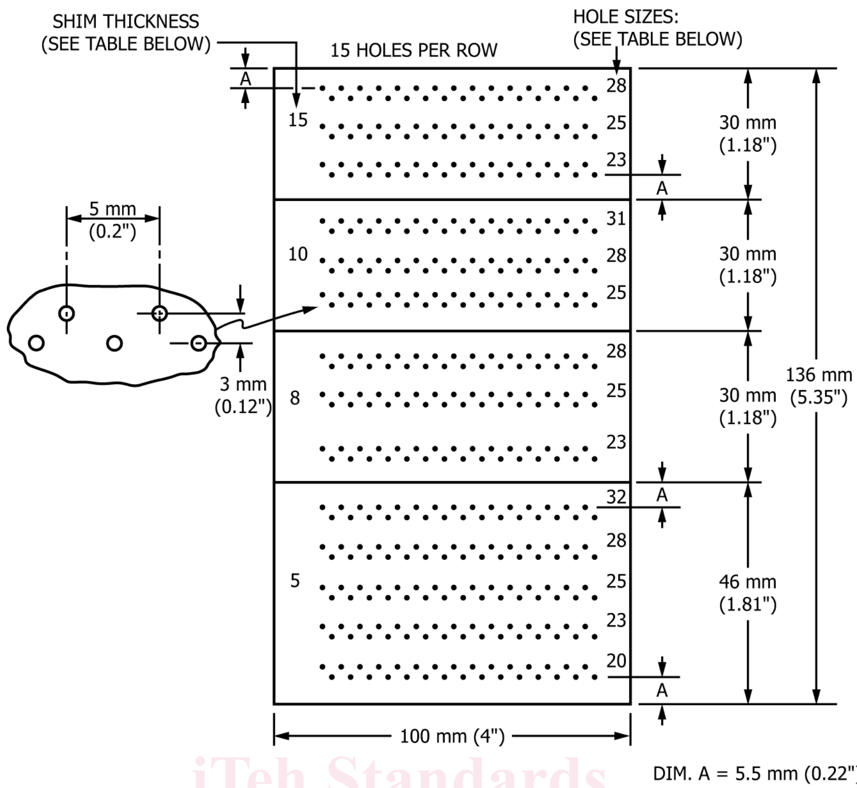
E999 Guide for Controlling the Quality of Industrial Radiographic Film Processing

E1025 Practice for Design, Manufacture, and Material

[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 Dec. 1, 2023. Published January 2024. Originally approved in 1980. Last previous edition approved in 2018 as E746 – 18. DOI: 10.1520/E0746-23.

[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.



Step Identification	Shim Thickness, mm (in.)	Hole Identification	Hole Size, mm (in.)
15	0.38 ± 0.012 (0.015 ± 0.0005)	32	0.81 ± 0.025 (0.032 ± 0.001)
10	0.25 ± 0.012 (0.010 ± 0.0005)	31	0.79 ± 0.025 (0.031 ± 0.001)
8	0.20 ± 0.012 (0.008 ± 0.0005)	28	0.71 ± 0.025 (0.028 ± 0.001)
5	0.13 ± 0.012 (0.005 ± 0.0005)	25	0.64 ± 0.025 (0.025 ± 0.001)
		23	0.58 ± 0.025 (0.023 ± 0.001)
		20	0.50 ± 0.025 (0.020 ± 0.001)

Hole Spacing (horizontal): 5 mm ± 0.1 mm (0.2 in. ± 0.004 in.) Nonaccumulative
Row Spacing: 3 mm ± 0.1 mm (0.12 in. ± 0.004 in.)
Spacing between hole sets: 5 mm ± 0.1 mm (0.2 in. ± 0.004 in.)
All other dimensions shall be in accordance with standard engineering practice.

FIG. 1 Relative Image Quality Indicator

Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiography
E1079 Practice for Calibration of Transmission Densitometers
E1316 Terminology for Nondestructive Examinations
E1735 Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems from 4 to 25 MeV
E1815 Test Method for Classification of Film Systems for Industrial Radiography
E2002 Practice for Determining Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy
E2445 Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems
E2446 Practice for Manufacturing Characterization of Computed Radiography Systems

2.2 *ISO Standards*[3]:
ISO 5-2 Photography Density Measurements-Part 2: Geometric Conditions for Transmission Density
ISO 7004 Photography- Industrial Radiographic Film, Determination of ISO Speed, ISO average gradient, and ISO gradients G2 and G4 when exposed to X- and gamma-radiation

3. Terminology

3.1 *Definitions*—The definitions of terms relating to gamma and X-radiology in Terminology E1316 shall apply to terms used in this practice.

[3] Available from International Organization for Standardization (ISO), 1, ch. De la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *detector, n*—an imaging device used to store a radiographic latent image or directly convert ionizing radiation into electrical signals in proportion to the quantity of radiation absorbed.

3.2.2 *Relative Image Quality Indicator (RIQI), n*—an image quality measuring device that is capable of determining meaningful differences between two or more radiographic imaging systems or changes of individual components of radiographic imaging systems.

4. Significance and Use

4.1 This standard provides a practice for RIQR evaluations of film and non-film imaging systems when exposed through an absorber material. Three alternate data evaluation methods are provided in Section 9. Determining RIQR requires the comparison of at least two radiographs or radiographic processes whereby the relative degree of image quality difference may be determined using the EPS plaque arrangement of Fig. 1 as a relative image quality indicator (RIQI). In conjunction with the RIQI, a specified radiographic technique or method must be established and carefully controlled for each radiographic process. This practice is designed to allow the determination of subtle changes in EPS that may arise to radiographic imaging system performance levels resultant from process improvements/changes or change of equipment attributes. This practice does not address relative unsharpness of a radiographic imaging system as provided in Practice E2002. The common element with any relative comparison is the use of the same RIQI arrangement for both processes under evaluation.

4.2 In addition to the standard evaluation method described in Section 9, there may be other techniques/methods in which the basic RIQR arrangement of Fig. 1 might be utilized to perform specialized assessments of relative image quality performance. For example, other radiographic variables can be altered to facilitate evaluations provided these differences are known and documented for both processes. Where multiple radiographic process variables are evaluated, it is incumbent upon the user of this practice to control those normal process attributes to the degree suitable for the application. Specialized RIQR techniques may also be useful with micro focus X-ray, isotope sources of radiation or with the use of non-film radiographic imaging systems. RIQR may also be useful in evaluating imaging systems with alternate materials (RIQI and base plate) such as plastic, copper-nickel, or aluminum. When using any of these specialized applications, the specific method or techniques used shall be as specified and approved by the cognizant engineering organization.

5. Relative Image Quality Indicator

5.1 The materials for the RIQI and absorber should be the same. For metals, use the same alloy and heat treat family; for non-metallic materials, use the same polymer system. When situations arise which preclude the use of same or "like" materials (that is, excessive material grain variation affecting test results), alternate absorber base plate materials may be used, provided the alternate material and thickness produce the same optical density (film) or PV (for CR/DDA) as the like material of the thickness used to calculate the EPS.

5.2 All absorber base plates shall be at least 200 mm by 250 mm (8 in. by 10 in.) wide and long (for CR applications it may be beneficial to use an absorber base plate that covers the entire CR imaging plate to prevent creation of a ghost image). The absorber base plate shall be made of mild steel for the 200 kV method and polymethylmethacrylate (PMMA) plastic for the 30 kV method. The surface finish of absorber base plates shall be a maximum of 6.3 µm (250 µin.) Ra, ground finish (both faces). The steel plate shall be 19 mm ± 0.12 mm (0.750 in. ± 0.005 in.) thick and the plastic plate shall be 35 mm ± 0.12 mm (1.375 in. ± 0.005 in.) thick. If the EPS performance of the chosen detector is outside of the ranges provided here, use Eq 1 to determine the appropriate thickness of the absorber plate. Absorber base plate thickness X and EPS value scale inversely.

5.3 The RIQI steps may be fabricated as a single multi-step unit or separately and taped together to form the penetrameter type hole arrays shown in Fig. 1. If tape is used, the tape shall not cover or interfere with any of the holes in the RIQI. All dimensions of the RIQI shall conform to Fig. 1.

5.4 The RIQI shown in Fig. 1 consists of 14 arrays of 30 holes where all hole diameters are the same for each array. Hole diameters are based upon a "multiple" of each respective step thickness; therefore, each array of 30 holes has a unique "equivalent" penetrameter sensitivity (EPS) as defined by the following relationship (Practice E1025):

$$EPS,\ \% = \frac{100}{X} \times \sqrt{\frac{Th}{2}} \qquad (1)$$

where:

h = hole diameter, mm
T = step thickness of IQI, mm
X = absorber plate thickness, mm

Hole diameters within each EPS array are progressively smaller from the top to the bottom of Fig. 1; thus, providing descending EPS values ranging from 1.92 % to 0.94 % for the 19 mm (0.75 in.) thick absorber and 1.05 % to 0.51 % for the 35 mm (1.375 in.) thick absorber. The surface finish of the RIQIs shall be a maximum of 6.3 µm (250 µin.) Ra, ground finish (both faces).

5.5 The RIQI shown in Fig. 1 shall be placed on the radiation source side and within the approximate center of the appropriate absorber base plate as illustrated in Fig. 2(B).

6. Calibration of X-Ray Source

6.1 Use a source to detector distance at least 750 mm (29.5 in.) for all exposures.

6.2 The voltage calibration of the X-ray source for 200 kV (commonly used with steel absorber) is modified from ISO 7004. This standard recommends testing at 200 kV, which deviates from ISO 7004 which recommends 220 kV. As the overall kV value may be altered, 200 kV was chosen as an initial value; see ISO 7004 for additional information on determining the correct kV values. With an 8 mm (0.32 in.)

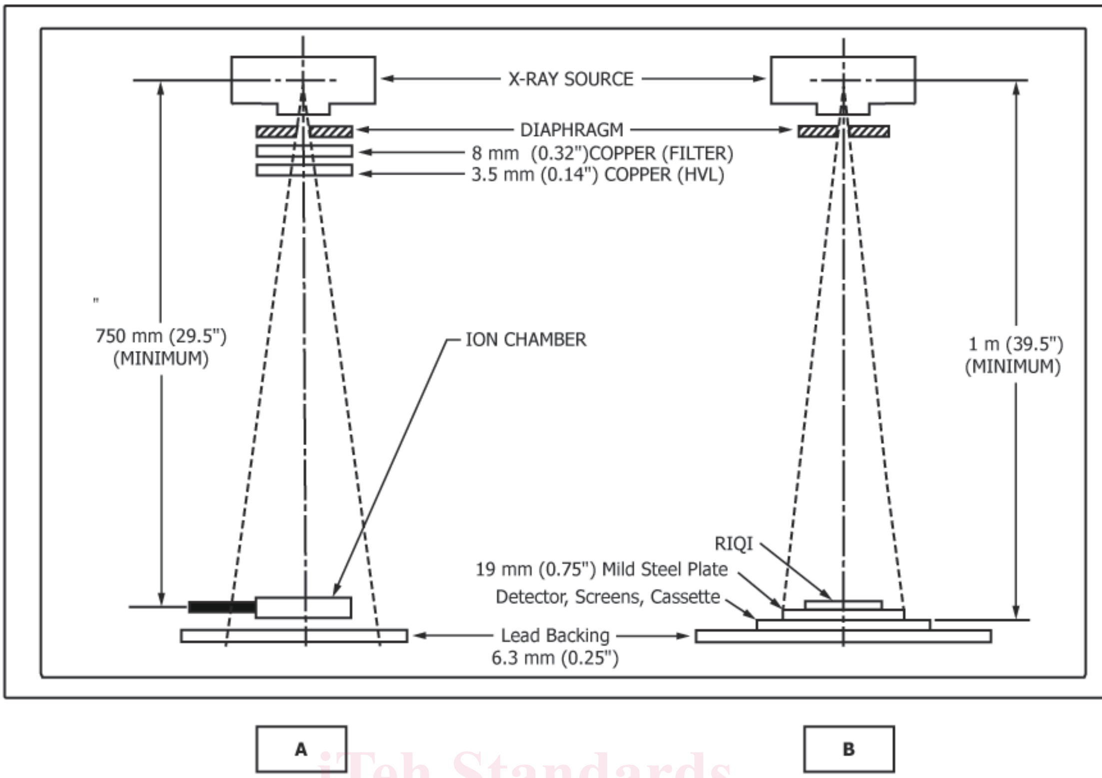


FIG. 2 (A) Setup for Energy Calibration (B) Setup for RIQR Exposures

copper filter at the X-ray tube, adjust the kilovoltage until the half value layer (HVL) in copper is 3.5 mm (0.14 in.) (see Specification B152/B152M). Using a calibrated ionization chamber or similar radiation measurement device, make a reading of the detector with 8 mm (0.32 in.) of copper at the tube, and then, make a second reading with a total of 11.5 mm (0.45 in.) of copper at the tube as shown in Fig. 2(A).

6.3 The voltage calibration of the X-ray source for 30 kV (commonly used with plastic absorber) is based on ISO 7004 method for 100 kV calibration, modified for 30 kV. With a 7.62 mm (0.30 in.) aluminum filter at the X-ray tube port, adjust the kilovoltage until the half value layer (HVL) in aluminum is 1.52 mm (0.06 in.). That is, the intensity of the X-ray beam with 9.14 mm (0.36 in.) aluminum at the tube port shall be one-half that with 7.62 mm (0.30 in.) aluminum at the tube port.

6.4 For both 200 kV and 30 kV X-ray beam calibration methods, calculate the ratio of the two readings. If this ratio is not 2, adjust the kilovoltage up or down and repeat the measurement until a ratio of 2 (within 5 %) is obtained. Record the X-ray machine voltage settings and use these same values for the RIQR evaluations. Prior to RIQR performance evaluations for both 200 kV and 30 kV methods, remove all HVL and filter materials at the X-ray tube port.

6.5 Use of other X-ray voltages or gamma spectra other than defined above shall employ a similar calibration method which shall be documented in the user's written technique and approved by the CEO.

7. Procedure

7.1 *Basic*—Use the physical set up as shown in Fig. 2(B). Position the X-ray tube directly over the approximate center of the RIQI and detector. The plane of the detector and RIQI must be normal to the central ray of the X-ray beam. Use a diaphragm at the tube to limit the field of radiation to the detector area.

7.2 Source-to-detector distance (SDD) is based upon achieving a geometrical unsharpness (Ug) of 0.05 mm (0.002 in.) or less on a 35 mm (1.375 in.) thick plastic absorber plate for 30 kV and a 19 mm (0.750 in.) thick steel absorber plate for 200 kV. Calculate the minimum SDD, in millimeters, as follows:

$$\text{For plastic, t=35 mm (1.375 in.), } SDD = 698\varphi + t \quad (2)$$

$$\text{For steel, t=19 mm (0.75 in.), } SDD = 381\varphi + t \quad (3)$$

where:

SDD = source-to-detector distance, mm, and
φ = focal spot size, mm.

The SDD shall be the larger of this calculated value and 1 m (39.4 in.).

7.3 *Detector Cassettes and Screens (film and CR)*—Low absorption cassettes shall be used to maximize the effectiveness of the RIQI and only a single detector shall be used within the cassette. For the 200 kV method, place the detector between lead-foil screens, the front screen being 0.130 mm ± 0.013 mm (0.005 in. ± 0.0005 in.) thick and the back screen