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Standard Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems[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 provides a practice whereby industrial radiographic imaging systems may be comparatively assessed using the concept of relative image quality response (RIQR). The RIQR method presented within this practice is based upon the use of equivalent penetrameter sensitivity (EPS) described within Practice E1025 and subsection 5.2 of this practice. Figure 1 illustrates a relative image quality indicator (RIQI) that has four different steel plaque thicknesses (.015, .010, .008, and .005 in.) sequentially positioned (from top to bottom) on a ¾-in. thick steel plate. The four plaques contain a total of 14 different arrays of penetrameter-type hole sizes designed to render varied conditions of threshold visibility ranging from 1.92 % EPS (at the top) to .94 % EPS (at the bottom) when exposed to nominal 200 keV X-ray 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.

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. 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.

1.3 This practice contains an alternate provision whereby industrial radiographic imaging systems may be comparatively assessed using Lucite plastic material exposed to nominal 30 keV X-ray radiation. The RIQI for this alternate evaluation is also illustrated in Fig. 1, except the plaque and base plate materials are constructed of Lucite plastic in lieu of steel. EPS values for Lucite plastic are provided in Section 5 based upon the use of a 1⅜-in. thick Lucite base plate. For high-energy X-ray applications (4 to 25 MeV), Test Method E1735 provides a similar RIQR standard practice.

1.4 The values stated in SI are to be regarded as the standard.

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.*

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 Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology
E1079 Practice for Calibration of Transmission Densitometers
E1316 Terminology for Nondestructive Examinations
E1735 Test Method for Determining Relative Image Quality of Industrial Radiographic Film Exposed to X-Radiation from 4 to 25 MeV
E1815 Test Method for Classification of Film Systems for Industrial Radiography
E2002 Practice for Determining Total Image Unsharpness in Radiology

[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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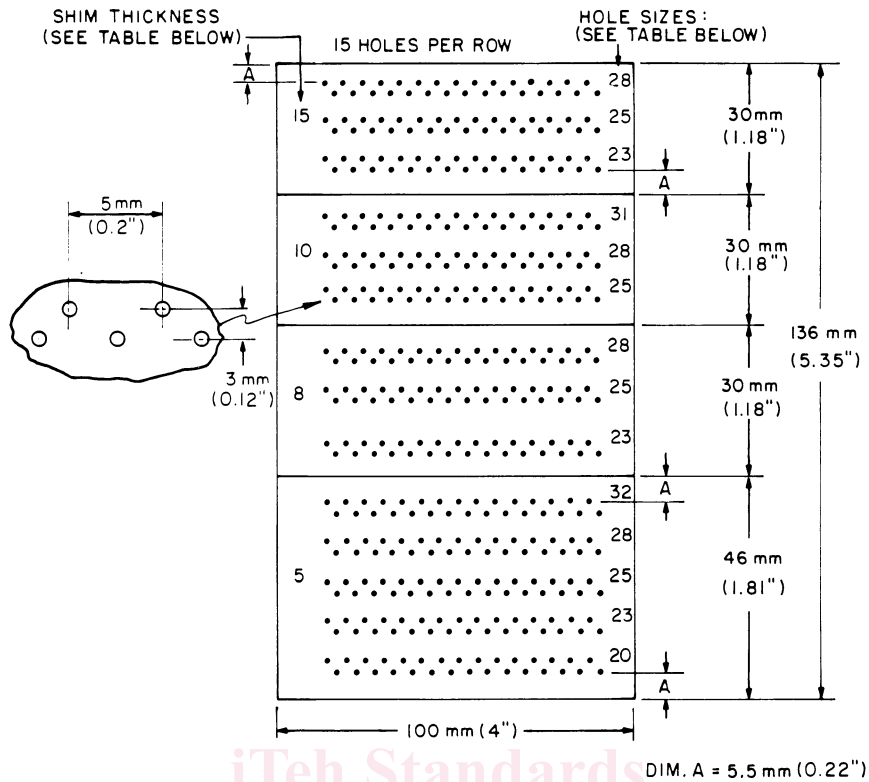
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



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

FIG. 1 Relative Image Quality Indicator

2.2 *ANSI Standard*[3]:
ANSI PH2.19 Photography Density Measurements-Part 2: Geometric Conditions for Transmission Density
2.3 *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.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *detector*—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 *cassette*—a device that is either flexible or rigid used to hold or protect a detector

3.2.3 *Relative Image Quality Indicator (RIQI)*— 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.2.4 *pixel intensity value (PV)*—a positive integer numerical value of gray scale level of a picture data element (pixel) directly proportional with originating digital image data values.

3.2.4.1 *Discussion—*

PV is directly related to radiation dose received by a digital detector, that is, PV is "0" if radiation dose was "0". The number of available PV integers is associated with gray scale bit depth of the digital image. For example: a 12-bit gray scale image will have a range from "0" to "4095" levels (shades) of gray (4096 total pixel value integers) and will become saturated when PV reaches "4095".

4. Significance and Use

4.1 This standard provides a practice for RIQR evaluations of film and non-film imaging systems when exposed through steel or plastic materials. 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 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 authority.

5. Relative Image Quality Indicator

5.1 The relative image quality indicator (RIQI) illustrated in Fig. 1 shall be fabricated from mild steel plate for the 200 keV evaluation method and Lucite plastic for the 30 keV evaluation method. 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.

5.2 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 (E1025):

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

where:

h = hole diameter, mm
T = step thickness of IQI, mm
X = thickness of test object, 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 steel method and 1.05 % to .51 % for the plastic method (Fig. 1 illustrates EPS values for the steel method). Descending EPS values for Lucite plastic are: 1.05 %, 1.00 %, .96 %, .91 %, .86 %, .81 %, .77 %, .73 %, .70 %, .65 %, .61 %, .58 %, .55 % and .51 % for the plaque steps of Fig. 1.

5.3 The absorber base plate shall be made of mild steel for the 200 keV method and Lucite plastic for the 30 keV method. Both base plates shall be at least 200 by 250 mm (8 by 10 in.) wide and long. The steel plate shall be 19 ± 0.12 mm (0.750 ± 0.005 in.) thick and the plastic plate shall be 36 ± 0.12 mm (1.375 ± 0.005 in.) thick. The surface finish of both absorber base plates shall be a maximum of 6.3 µm (250 µin.) Ra, ground finish (both faces).

5.4 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).

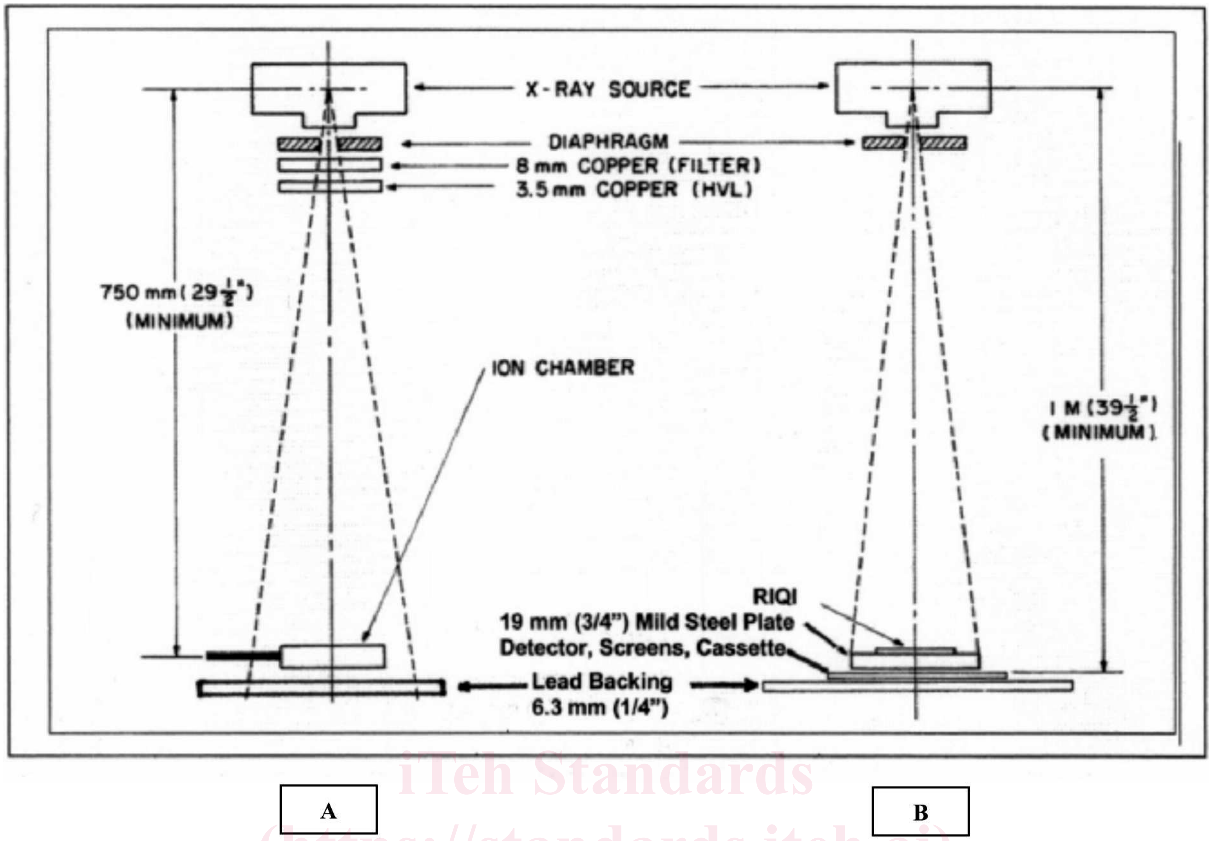


FIG. 2 (A) Setup for Energy Calibration (B) Setup for RIQR Exposures

6. Calibration of X-Ray Source

6.1 Use a target 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–keV is based on ISO 7004. With an 8-mm (0.32-in.) 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–keV is based on ISO 7004 method for 100–keV calibration, modified for 30–keV. 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–keV and 30–keV 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–keV and 30–keV methods, remove all HVL and filter materials at the X-ray tube port.

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 cassette. 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 film 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 36 mm (1.375 in.) thick plastic plate for 30–keV and a 19 mm (0.750 in.) thick absorber plate for 200–keV. Calculate the minimum SDD, in millimetres, as follows:

$$SDD = 381\ \varphi$$

where:

SDD = source-to-detector distance, mm, and