INTERNATIONAL

Designation: ~~E1735 – 07 (Reapproved 2014)~~ E1735 – 19

Standard ~~Test Method~~ Practice for Determining Relative Image Quality Response of Industrial Radiographic ~~Film Exposed to X-Radiation~~ Imaging Systems from 4 to 25 MeV[1]

This standard is issued under the fixed designation E1735; 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 test method covers determination of the relative image quality response of industrial radiographic film when exposed to X-radiation sources having photon energies from 4 to 25 MeV. Evaluation of the film is based on the visibility of holes in a special image quality indicator (IQI). Since results for a given film type may vary, depending on the particular processing system and processing conditions used, it is essential to state the exposure parameters and achieved density, processing chemistry, processing cycle, and processing temperature. For the purposes of this test method, it is assumed that all components of the X-ray system are operating properly and are capable of producing a given image quality. This test method is not intended to be used for films exposed with Cobalt 60 sources or X-ray sources below 4 MeV.~~

~~1.2 The values stated in either SI or inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.~~

~~1.3 *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]~~

~~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 Radiography~~

~~E1079 Practice for Calibration of Transmission Densitometers~~

~~E1316 Terminology for Nondestructive Examinations~~

~~E1815 Test Method for Classification of Film Systems for Industrial Radiography~~

~~3. Terminology~~

~~3.1 *Definitions*—Definitions of terms relating to gamma and X-radiology are found in Terminology E1316.~~

~~4. Significance and Use~~

~~4.1 This test method provides a test for determining the relative image quality response of radiographic film when exposed to 4 to 25 MeV X rays as any single component of the total X-ray system (for example, screens) is varied. By holding the technique parameters (except exposure time) and processing parameters constant, the image quality response of radiographic film may be evaluated on a relative basis.~~

~~4.2 Alternately, this test method provides a test for measuring the image quality of the X-ray system or any component of the system.~~

~~5. Test Specimen~~

~~5.1 The test specimen will consist of a 15-cm (6-in.) steel absorber with a special IQI placed on the radiation (source) side of the absorber.~~

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[1] This ~~test method~~ 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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5.1.1 *Absorber*—The absorber shall be made of carbon steel or Type 300 stainless steel. The thickness of 15 cm (6 in.) can be achieved by stacking thinner plates whose length and width shall be at least 20 by 25 cm (8 by 10 in.). The surface finish of the top and bottom of the absorber shall be a maximum of 6.3-μm (250-μin.) R_a ground finish.

5.1.2 *Image Quality Indicator*—The IQI shall be fabricated of carbon steel or Type 300 stainless steel and shall conform to Fig. 1. The IQI steps, identified as Plaques A-D, may be fabricated separately and then taped together, as shown in Fig. 1, using suitable tape to form the array as shown. The tape shall not cover any of the holes in the IQI. The surface finish of the IQI top and bottom surfaces shall be a maximum of 6.3-μm (250-μin.) R_a ground finish.

6. Radiation Source

6.1 The source of radiation shall be an X-ray generator capable of operating in any part (or all) of the range from 4 to 25 MeV.

7. Film Holder and Screens

7.1 *Film Holder*—The film holder shall be a medical-type, hard-backed cassette or a flexible film holder with a vacuum or mechanical means for providing good film-screen contact.

7.2 *Screens*—Lead foil screens with a front thickness of 0.010 to 0.050 in. (0.25 mm to 1.27 mm) and back thickness of 0.010 in., minimum, shall be used. Thicker screens may be used at the user's discretion, provided that the actual thickness used is documented on the data sheet (Fig. 2) and agreed upon by all parties concerned.

8. Test Procedure

8.1 *Source to Film Distance*—The source to film distance is based on achieving a geometrical unsharpness (U_g) of 0.15 mm (0.006 in.) or less when used with the test specimens described in Section 5. The minimum source to film distance to be used shall be 1 m (39.4 in.).

8.2 *Film/Test Specimen: Source Relationship and Film Placement*—The plane of the film and test specimen shall be normal to the central ray of the radiation source. Collimate the source so as to limit the radiation source to the film. Place the film holder/cassette opposite the source side and in contact with the absorber.

8.3 *Film Identification*—Identify the film number and source energy used by means of lead numbers and letters placed on the corner of the plate so as not to interfere with the images of the holes in the IQI. Note that the letters and numbers will be magnified when placed on the source side of the absorber.

8.4 *Exposure*—Adjust the exposure time to provide a film density of 2.00 ± 0.1 in the center of the film, as measured with a densitometer calibrated in accordance with Practice E1079. Make three exposures using the same film holder/cassette in accordance with 7.1.

8.5 *Film Processing*—In order to minimize any effects caused by the latent image instability, process the exposed film not more than 4 hours after exposure. Either manual or automatic processing may be used, in accordance with Guide E999 and as follows:

8.5.1 *Automatic Processing*—Use industrial X-ray film automatic processing solutions. Maintain a record on the data sheet of the following:

8.5.1.1 The brand name and type of processor;

8.5.1.2 The length of time (±1 s) that the film is in the developer, that is, leading edge in to leading edge out;

8.5.1.3 The brand name of the processing chemicals, including the starter, processing temperature to within 0.5°C, and replenishment rate; and

8.5.1.4 The total quantity of film used in seasoning fresh developer solutions. With fresh developer solutions, process a minimum of ten films (360 by 430 mm (14 by 17 in.))/gal of developer. Each film should be half-flashed[3] to a density of 4.0 or greater using white light or, alternatively, fully flash alternate sheets.

8.5.2 *Manual Processing*—Use industrial X-ray film processing solutions in the tests. Maintain a record on the data sheet of the following:

8.5.2.1 The time of development (± 2 s);

8.5.2.2 The temperature of the developer within 0.5°C;

8.5.2.3 The total quantity of films used in seasoning fresh developer solutions. With fresh developer solutions, process a minimum of ten films (360 by 430 mm (14 by 17 in.))/gal of developer. Each film should be half-flashed[3] to a density of 4.0 or greater using white light or, alternatively, fully flash alternate sheets;

8.5.2.4 The replenishment system used; and

8.5.2.5 The brand name of the processing chemicals.

8.5.3 *Dry Processing*—Use the manufacturer's recommended processing procedures. Maintain a record on the data sheet of the following:

8.5.3.1 The brand name of the processor; and

8.5.3.2 The length of time that the film is in the processor, that is, leading edge in to leading edge out.

9. Data Collection and Evaluation

9.1 The three test films for any one film type should be read independently by three readers. Each reader shall record the number of holes of a given size visible at each step of the IQI. A magnifier up to 3× is permitted for viewing the film. A sample data sheet is shown in Fig. 2.

9.2 The data are evaluated by averaging the number of holes of a given size (hole set) visible on each plaque image of the IQI for each film type. This average is based on the evaluation of three readers of three radiographs for each film type. This averaging procedure is repeated for each film type and is a measure of the relative image quality response of a given film type.

9.2.1 The relative image quality response for different film types is illustrated in Table 1. The visibility index shown in Table 1 is the sum of the total number of holes detected and can be used as a measure of image quality under the conditions employed and tabulated in accordance with Fig. 2.

9.3 *First Alternate (Optional) Method of Evaluation*—Each hole set is converted to equivalent image quality sensitivity (EPS), as prescribed in the Appendix of Practice E1025. Plot the number of visible holes after averaging versus the EPS values for each hole set. This gives a set of points on a graph through which a continuous smooth curve is drawn. The image quality response is determined at the point where 50 % of the holes are visible. This value is the classification index for the film under testing. Fig. 3 is an idealized illustration of this curve plotting method.

9.4 *Second Alternate (Optional) Method of Evaluation:*

9.4.1 In addition to the two methods previously described, the classification index may be calculated mathematically between two adjacent hole sets by interpolating between the EPS values of the hole set with more than 15 visible holes and the set with less than 15 visible holes by use of the following formula:

$$C = Q_b + \frac{(15 - N_b)(Q_a - Q_b)}{N_a - N_b} \quad (1)$$

where:

C = classification index (the midpoint or 50 % point on the graph in 9.3),
N_a = total number of visible holes in the hole set immediately above the midpoint, and Q_a = corresponding EPS value, and
N_b = total number of visible holes in the hole set immediately below the midpoint, and Q_b = corresponding EPS value.

9.4.2 The following example is given for illustration. A set having 23 visible holes has an EPS value of 1.57. An adjacent set has 12 visible holes and an EPS value of 1.49. Inserting these values into the formula yields the following:

$$C = 1.49 + \frac{(15 - 12)\,(1.57 - 1.49)}{23 - 12} \quad (2)$$

$$C = 1.51$$

10. Precision and Bias

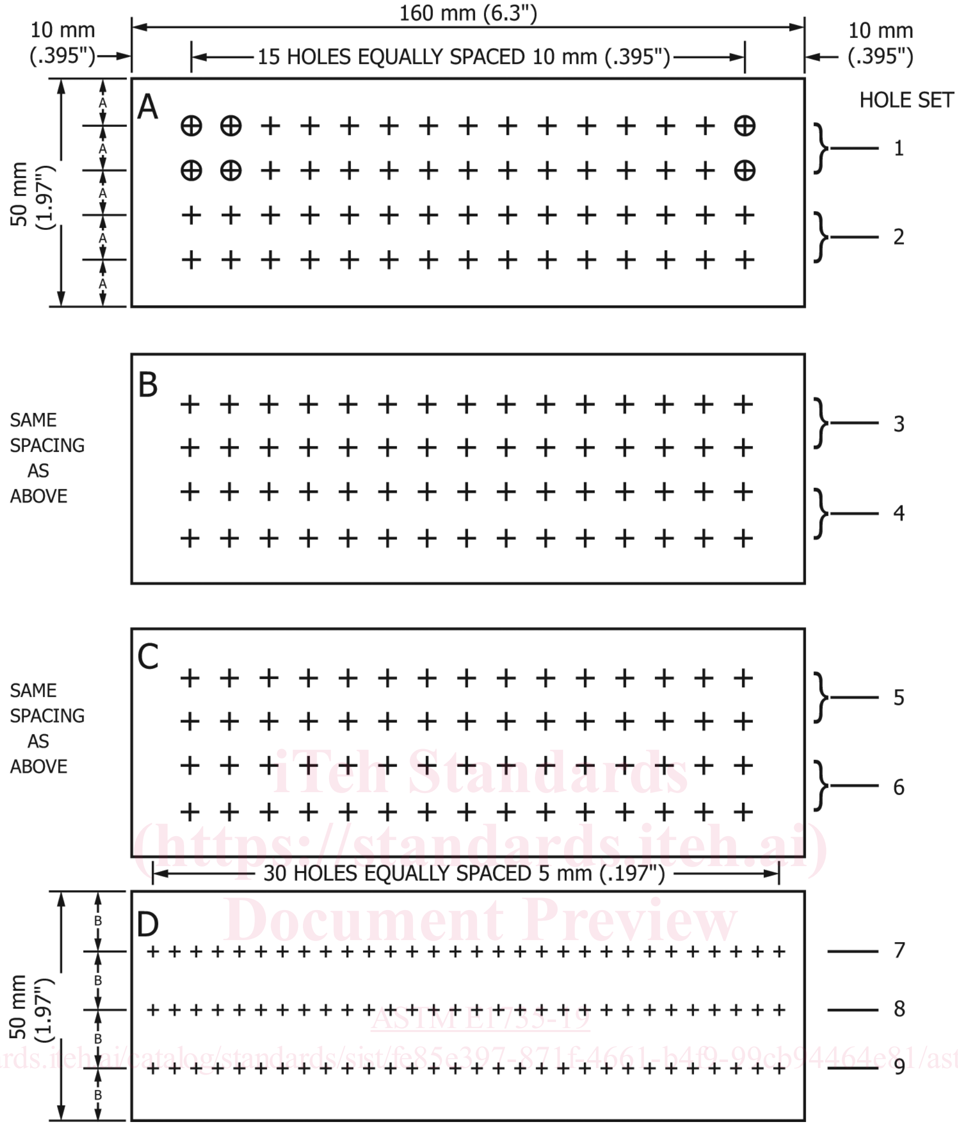
10.1 No statement is made about the precision and bias for indicating the quality of radiographs since the results state merely whether there is conformance to the criteria for success specified in this test method.

11. Keywords

11.1 EPS; film; IQI; radiation; radiographic; X-ray

1. Scope

1.1 This standard provides a practice whereby industrial radiographic imaging systems or specific factors that affect image quality (that is, hardware, techniques, etc.) may be comparatively assessed using the concept of relative image quality response (RIQR) when exposed to X-radiation sources having photon energies from 4 to 25 MeV. The RIQR method presented within this



NOTE 1—All plaques identical except hole size and plaque thickness hole: row spacing tolerance ± 0.1 mm (± 0.004 in.), nonaccumulative Dimension A = 10 ± 0.1 mm (0.395 ± 0.004 in.) and Dimension B = 12.5 ± 0.1 mm (0.492 ± 0.004 in.); other dimensions in accordance with standard engineering practice.

Plaque Letter	Plaque Thickness		Hole Set	Hole Diameter	
	mm	(in.)		mm	(in.)
A	1.6 ± 0.025	(0.0625 ± 0.001)	1	3.0 ± 0.025	(0.118 ± 0.001)
B	1.3 ± 0.025	(0.050 ± 0.001)	2	1.8 ± 0.025	(0.072 ± 0.001)
C	0.97 ± 0.025	(0.038 ± 0.001)	3	1.8 ± 0.025	(0.072 ± 0.001)
D	0.64 ± 0.025	(0.025 ± 0.001)	4	1.5 ± 0.025	(0.060 ± 0.001)
			5	1.5 ± 0.025	(0.060 ± 0.001)
			6	1.22 ± 0.025	(0.048 ± 0.001)
			7	1.42 ± 0.025	(0.056 ± 0.001)
			8	1.17 ± 0.025	(0.046 ± 0.001)
			9	0.94 ± 0.025	(0.037 ± 0.001)

FIG. 1 Image Quality Indicator

practice is based upon the use of equivalent penetrameter sensitivity (EPS) described within Practice E1025 and Section 5 of this practice. 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 RT Level III.

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, manufacturer characterization of computed radiography (CR) systems may be found in Practice E2446, and manufacturer characterization of digital Detector Array (DDA) systems may be found in Practice E2597.

1.4 This standard is not intended to be used with Cobalt 60 sources or X-ray sources below 4 MeV. For low energy X-ray applications (below 4 MeV), Test Method E746 provides a similar RIQR standard practice.

1.5 The values stated in either SI or inch-pound units are to be regarded as the standard. The values 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.*

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]

E746 Practice for Determining Relative Image Quality Response of Industrial Radiographic Imaging Systems
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 Radiography
E1079 Practice for Calibration of Transmission Densitometers
E1316 Terminology for Nondestructive Examinations
E1815 Test Method for Classification of Film Systems for Industrial Radiography
E2002 Practice for Determining Total Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy
E2033 Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)
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

2.2 *ISO Standards:*[3]

ISO 5-2 Photography Density Measurements-Part 2: Geometric Conditions for Transmission Density
ISO 17636 Non-destructive Testing of Welds—Radiographic Testing—Part 2: X- and Gamma-Ray Techniques With Digital Detectors

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, 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 (that is, film, imaging plate, or digital detector array).

3.2.2 *cassette, n*—a device that is either flexible or rigid used to hold or protect a detector.

3.2.3 *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 determining the relative image quality response of a radiographic detector (film, CR imaging plate, or DDA) when exposed to 4 to 25 MeV X-rays as any single component of the total X-ray system (for example, screens) is varied.

4.2 The practice is not intended to be used to compare two different systems or imaging types.

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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.

[3] 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.

4.3 The approach uses RIQR evaluations of film and non-film imaging systems when exposed through an absorber material. Three alternate data evaluation methods are provided in Section 8. 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, technique 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.

4.4 In addition to the standard evaluation method described in Section 8, 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. RIQR may also be useful in evaluating imaging systems with alternate materials (RIQI and base plate). When using any of these specialized applications, the specific method or techniques used shall be as specified and approved by the RT Level III.

5. Relative Image Quality Indicator

5.1 Fig. 1 illustrates a relative image quality indicator (RIQI) that has four different plaque thicknesses (1.6, 1.3, 0.97, and 0.64 mm (0.063, 0.050, 0.038, and 0.025 in.)) sequentially positioned (from top to bottom) on an absorber plate of carbon steel or Type 300 stainless steel with a thickness of 15 cm (6 in.). The four plaques contain a total of 9 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.

5.2 The materials for the RIQI and absorber should be the same. For metals, use the same alloy and heat treat family. When situations arise which preclude the use of same or "like" materials (that is, excessive material grain variation affecting test results), alternate absorber materials may be used, provided the alternate material and thickness produces the same optical density (film) or pixel value (PV) (for CR/DDA) as the like material of the thickness used to calculate the EPS.

5.3 The RIQI steps, identified as plaques A-D, 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. The surface finish of the IQI top and bottom surfaces shall be a maximum of 6.3 µm (250 µin.) R_a ground finish.

5.4 The RIQI shown in Fig. 1 consists of 9 groups 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 group 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, and
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 1.03 % to 0.37 %.

5.5 The absorber base plate shall be made of carbon steel or Type 300 stainless steel. The thickness of 15 cm (6 in.) can be achieved by stacking thinner plates whose length and width shall be at least 20 by 25 cm (8 by 10 in.). (For CR and DDA applications it may be beneficial to use an absorber that covers the entire detector to prevent creation of a ghost image.) The surface finish of the top and bottom of the absorber plate(s) shall be a maximum of 6.3 µm (250 µin.) R_a ground finish.

5.6 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.

6. Radiation Source

6.1 The source of radiation shall be an X-ray generator capable of operating in any part (or all) of the range from 4 to 25 MeV.