~~Designation:E746–02~~

~~Standard Test Method for Determining Relative Image Quality Response of Industrial Radiographic Film Systems~~Designation: E 746 – 07

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

This standard is issued under the fixed designation E 746; 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

~~1.1This test method covers the determination of the relative image quality response of industrial radiographic film systems when exposed to 200-kV X-rays. The evaluation of the film is based upon the threshold visibility of penetrameter holes in a special image quality indicator (IQI). Results for a given film type may vary, depending upon the particular development system used. It is, therefore, necessary to state the development system and geometric conditions used in this determination. 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.~~

~~1.2Alternately, this test method may be used for determination of the relative image quality response of a radiographic film system when exposed to 200-KV X-rays as any other single component of the system (such as screens) is varied.~~

~~1.3~~

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 E 1025 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 E 1815.

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 E 1735 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.*

[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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2. Referenced Documents

2.1 *ASTM Standards:* [2]

B ~~152~~ 152/B 152M Specification for Copper Sheet, Strip, Plate, and Rolled Bar

E 999 Guide for Controlling the Quality of Industrial Radiographic Film Processing

E 1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology

E 1079 Practice for Calibration of Transmission Densitometers

E 1316 ~~Terminology for Nondestructive Examinations~~[3] Terminology for Nondestructive Examinations

E 1735 Test Method for Determining Relative Image Quality of Industrial Radiographic Film Exposed to X-Radiation from 4 to 25 MeV

E 1815 ~~Test Method for Classification of Film Systems for Industrial Radiography~~[3] Test Method for Classification of Film Systems for Industrial Radiography

E 2002 Practice for Determining Total Image Unsharpness in Radiology

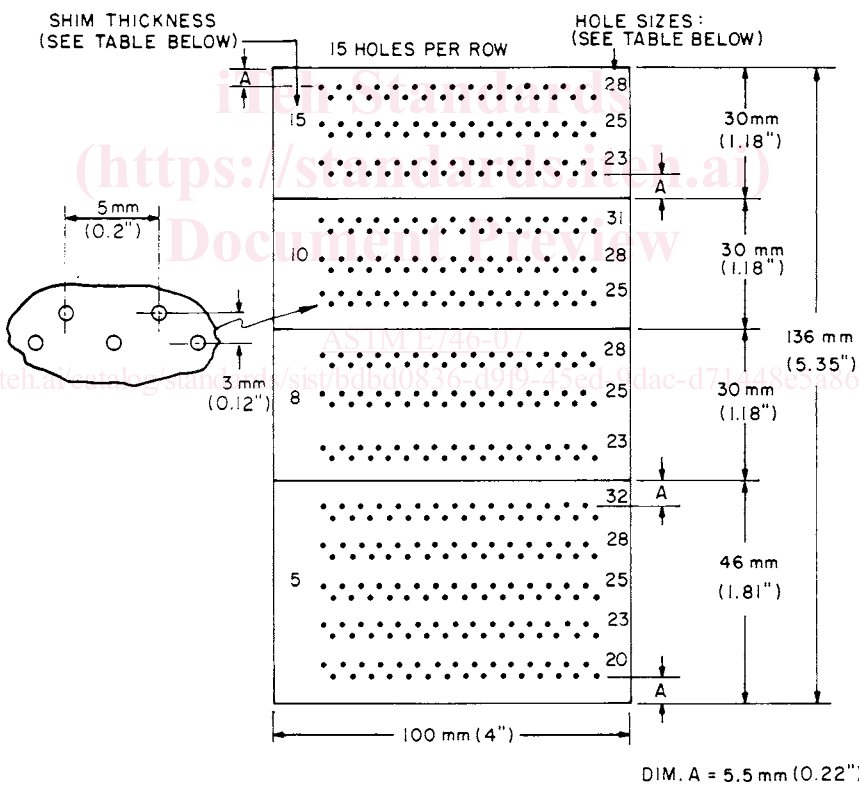
2.2 *ANSI Standard*[3]*:*

ANSI PH2.19 Photography Density Measurements-Part 2: Geometric Conditions for Transmission Density

[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* ~~, Vol 02.01.~~ volume information, refer to the standard's Document Summary page on the ASTM website.

~~[3] Annual Book of ASTM Standards, Vol 03.03.~~

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



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

2.3 *ISO Standards*[3]:

ISO 5-2Photography5-2 Photography Density Measurements-Part 2: Geometric Conditions for Transmission Density

ISO 7004Photography- Industrial Radiographic Film, Determination of ISO Speed and Average Gradient When Exposed to X and Gamma Radiation 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*—For definitions of terms used in this test method, refer to Terminology E1316. —The definitions of terms relating to gamma and X-radiology in Terminology E 1316 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.

3.2.4 *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

4.1This test method provides a relative means for determining the image quality performance response for a given film chemistry system used for industrial radiography. It is only to be used for relative comparisons. It is not intended to qualify performance of a film chemistry system to detect specific discontinuities in a product or specimen undergoing X-ray examination.

4.2Film chemistry image quality performance is described by EPS, Equivalent Penetrameter Sensitivity. For a detailed description of EPS, see Practice E1025Significance 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 E 2002. 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.

4.3It is not the intent of this standard to specify performance requirements of the film chemistry system. Test Method E1815 can be used to specify performance requirements at 200 kV. This test method was used, and can be used to corroborate Test Method E1815 results at 200 kV. This test method is a subjective means of determining film chemistry image quality performance, whereas Test Method E1815 uses instrument measurements to calculate performance and is therefore an objective test method.

4.4This test method could be used to evaluate relative film chemistry system image quality performance at Net Density 4.0 where some instrument measurements are currently not feasible.

5.Test Specimen

5.1The test specimen shall consist of a special image quality indicator (IQI) placed on the tube side of a 36–mm (1⅜-in.) plastic plate for 30–kV, and a 19–mm (¾ –in.) steel plate for 200–kV.

5.1.1The special image quality indicator (IQI) shall be fabricated from Lucite plastic for 30–kV, and mild steel for 200–kV. The dimensions shall conform to

5.2 The RIQI shown in Fig. 1 . The IQI steps may be fabricated separately and taped together to form the penetrameter array as shown. The tape shall not cover any of the holes in the IQI.

5.1.2The absorber plate shall be made of Lucite plastic for 30–kV, and mild steel for 200–kV. Both 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. Thickness of the plastic plate shall be 36 ± 0.12 mm (1⅜ ± 0.005 in.). The surface finish of both absorber plates shall be a maximum of 6.3 µm (250 µin.) R_a, ground finish (both faces). 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 (E 1025):

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

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).

6. Calibration of X-Ray Source

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

6.2The voltage calibration of the X-ray source for 30–kV 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 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. Exposures shall be made using the voltage thus determined and with 7.62 mm (0.30 in.) of aluminum at the tube port. No lead screen shall be used.

6.3The voltage calibration of the X-ray source for 200–kV 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 in copper is 3.5 mm (0.14 in.) (see Specification B152). 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.) at the tube.

6.4For 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 machine settings and use for the film tests. During tests, remove all of the filters for both 200–kV and 30–kV methods.

7.Density Measurements

7.1Measure the visual diffuse transmission density of the processed films with a densitometer complying with the requirements of ANSI PH2.19 and ISO 5–2 and calibrated by the method of Practice E1079. Use a minimum aperture of 7 mm (0.275 in.).

8.Film Holder and Screens

8.1Enclose a single film in a cassette with low absorption. When using the 30–kV method, and after the X-ray beam has been calibrated for 30–kV, a film holder absorption factor shall be determined. With the 7.62–mm (0.3–in.) aluminum filter at the X-ray tube make an exposure with film in the film holder. Films exposed to X-ray without a holder will need to be handled in lighting conditions that are appropriate (safe light). Determine an exposure that produces 2.00 ± 15% film density on the film exposed in the film holder. Use the densitometer in accordance with Section 6. Use the same exposure on the film exposed outside the film holder. Subtract the film density from the film exposed in a holder from the film density of the film exposed outside the film holder. The difference shall not exceed 2%. *The cassette shall provide a means for ensuring good film-screen contact.*

8.2For the 200–kV method. Place the film between lead-foil screens, the front screen being 0.130 ± 0.013 mm (0.005 ± 0.0005

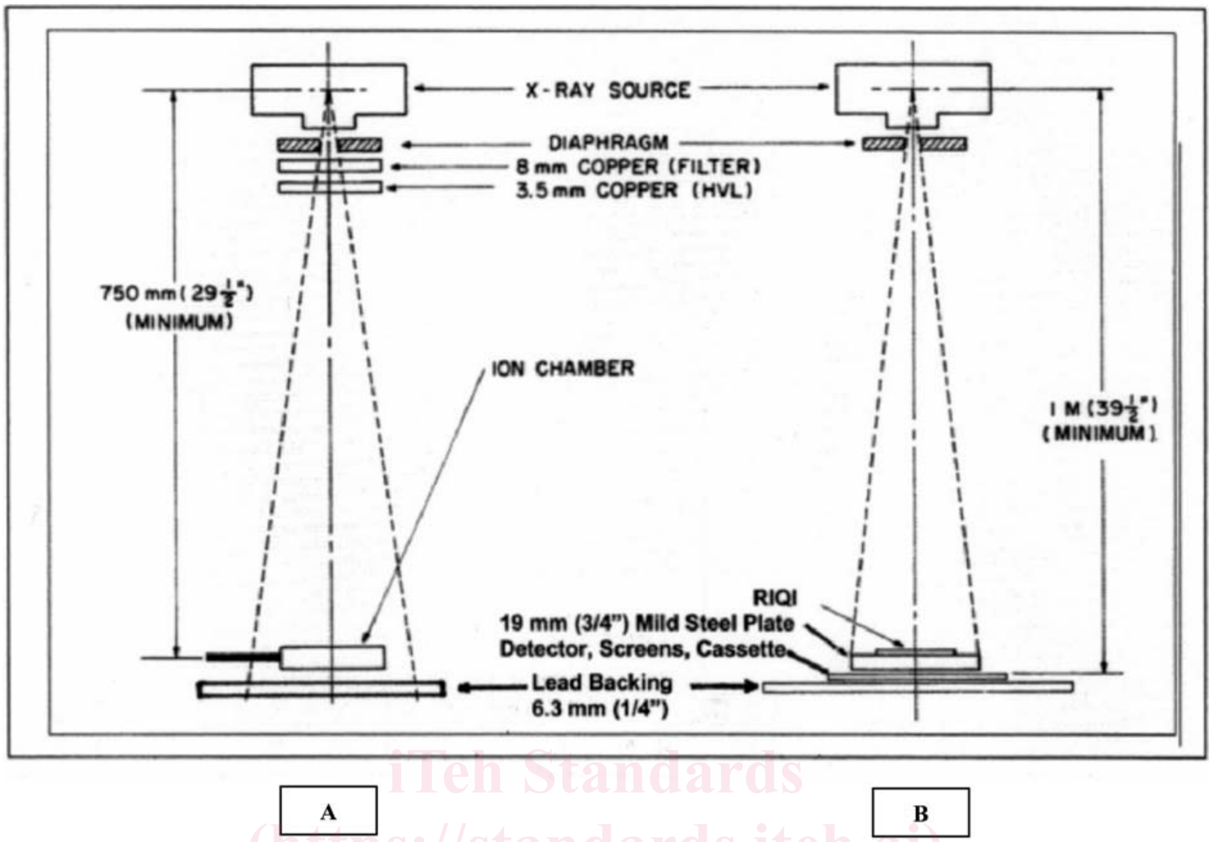


FIG. 2 (A) Setup for Energy Calibration (B) Setup for RIQR Exposures

~~in.) thick and the back screen 0.250 ± 0.025 mm (0.010 ± 0.001 in.) thick.~~

~~NOTE1—These thicknesses reflect commercially available tolerances in lead foil for use as radiographic screens.~~

~~8.3When the component to be evaluated is a screen or screen system, other than lead screen as specified in 8.2, place the film in the proper position with the screen or screen system.~~

~~8.4Use a 6.3 ± 0.8 mm (1/4 ± 1/32 in.) thick lead "backup" behind the cassette. The backup lead shall extend at least 25 mm (1 in.) beyond each edge of the cassette.~~

~~9.~~

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 B 152/B 152M). 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

~~9.1The source to film distance is based upon achieving a geometrical unsharpness (Ug) of 0.05 mm (0.002 in.) or less on a 36 mm (1 3/8 in.) thick plastic plate for 30–kV and a 19 mm (3/4 in.) thick absorber plate for 200–kV. Calculate the minimum source to film distance, *D*, in millimetres, as follows:~~

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:

~~$D = 381\phi$~~

$SDD = 381\ \phi$

where:

~~*D*~~*SDD* = ~~source to film distance, mm, and~~ source-to-detector distance, mm, and
φ = focal spot size, mm.

~~The distance shall be not less than 1 m (39.4 in.).~~

~~9.2See the physical set up as shown in Fig. 2. Position the X-ray tube directly over the center of the test specimen and film. The plane of the film and test specimen 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.~~

~~9.3*Exposure*:~~

~~9.3.1Expose the film at the kV setting as determined in Section~~ The SDD shall be not less than 1 m (39.4 in.).

7.3 *Detector Cassettes and Screens* —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–keV method, place the detector between lead-foil screens, the front screen being 0.130 ± 0.013 mm (0.005 ± 0.0005 in.) thick and the back screen 0.250 ± 0.025 mm (0.010 ± 0.001 in.) thick. The cassette shall provide a means for good detector-screen contact. No lead screens shall be used with the 30 keV method. The same type cassette and screens (absorption characteristics and thicknesses) shall be used to produce all exposures required for the relative image quality response evaluations. When using this practice with computed radiography systems, it is recommended that a minimum of 0.020 in. (.5 mm) steel plate be positioned between the backing lead and cassette.

7.4 *Backing Lead*— Use a 6.3 ± 0.8 mm (¼ ± 1⁄32 in.) thick lead "backup" behind the cassette. The backup lead shall exceed each edge of the cassette by at least 25 mm (1 in.).

7.5 Identify the detector number, type, exposure, and other technique data by means of lead letters, or numerals, placed in the upper right hand corner of the base absorber plate(s). Do not place so as to interfere with the image of the holes in the RIQI. Make these identification symbols as small and unobtrusive as possible. Record this identification number on the data sheet for this exposure (see Section 8).

7.6 Make three separate exposures as specified in 9.1 through 9.3. Expose the detector at the keV setting as determined in Section 6~~. Remove all filters at the tube before the exposure. Adjust the exposure time to give a film density of 2.00 ± 15% in the center of the film as measured with a densitometer. Use the densitometer in accordance with Section 7~~. Remove all filters at the tube before conducting exposures. Adjust exposure time to criteria specified in 7.2 (film systems) or 7.3 (non-film systems). In order to preclude any detector latent image instability, process (as applicable) any exposed detector within eight hours of exposure.

7.7 *Film Systems*—in addition to the basic requirements of 7.1, the following requirements apply:

7.7.1 Adjust the exposure time to render an optical film density of 2.00 ± 15 % within the approximate center of the radiograph as measured with a densitometer. Optical density shall be determined with a densitometer complying with requirements of Practice E 1079.

~~9.3.2Make three separate exposures using the same film cassette each time.~~

~~9.3.3Identify the film number, type, exposure, and other technique data by means of lead letters, or numerals, placed in the upper righthand corner of the steel plate(s). Do not place so as to interfere with the image of the holes in the IQI. Make these identification symbols as small and unobtrusive as possible. Record this identification number on the data sheet for this exposure (see Section 10).~~

~~9.3.4In order to minimize any effects caused by latent image instability, process the exposed film not more than 8 h after exposure.~~

~~9.4*Film Processing*—The image quality response of the film may vary with the processing variables such as chemistry, temperature, and method of processing (manual or automatic). The solutions must be fresh and properly seasoned (see 9.4.1 and 9.4.2). The film processing and record requirements shall be in accordance with Guide E999~~

7.7.2 The image quality response of the film system may vary with the processing variables such as chemistry, temperature and method of processing (manual or automatic). The solutions must be fresh and properly seasoned (see 7.7.2.1 and 7.7.2.2). Film processing and record requirements shall be in accordance with Guide E 999.

~~9.4.1~~

7.7.2.1 *Automatic Processing*~~—Use industrial X-ray processing solutions in the tests. Keep a record of:~~

~~9.4.1.1The brand name of the processor.~~

~~9.4.1.2The length of time (±1 s) that the film is in the developer, that is, leading edge in to leading edge out.~~

~~9.4.1.3The brand name of the developer, including the "starter," the temperature measured to within 0.5°C (0.9°F), and the rate of replenishment to within ±5%.~~

~~9.4.1.4The brand name and total quantity of film used in seasoning fresh developer solution before processing test films. Process~~