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Standard Test Method for
Determining Relative Image Quality Response of Industrial Radiographic Film 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.

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[1] This test method is under the jurisdiction of ASTM Committee ~~E-7~~ E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on ~~Radiographic Practice~~ Radiology (X and ~~Penetrameters.~~ Gamma) Method.

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1. Scope

1.1 This 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.

1.2 Alternately, 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 *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:*

B 152 Specification for Copper Sheet, Strip, Plate, and Rolled Bar[2]

E 999 Guide for Controlling the Quality of Industrial Radiographic Film[3]

E 1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators IQI Used for Radiology[3]

E 1079 Practice for Calibration of Transmission Densitometers[3]

E 1316 Terminology for Nondestructive Examinations[3]

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

2.2 *ANSI Standard:*[4]

ANSI ~~PH2.8 Sensitometry of Industrial X-ray Films~~ PH2.19 Photography Density Measurements-Part 2: Geometric Conditions for ~~E~~ Transmission Density

2.3 *ISO Standards:*[4]

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

ISO 7004 Photography- Industrial Radiographic Film, Determination of ISO Speed and Average Gradient When Exposed to ~~3 Million Electron Volts~~[3] X and Gamma Radiation

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[2] *Annual Book of ASTM Standards*, Vol 02.01.

[3] ~~Available from American National~~

[3] *Annual Book of ASTM Standards* ~~Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.~~, Vol 03.03.

[4] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology E 1316.

4. Significance and Use

4.1 This 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.

4.2 Film chemistry image quality performance is described by EPS, Equivalent Penetrameter Sensitivity. For a detailed description of EPS, see Practice E 1025.

4.3 It is not the intent of this standard to specify performance requirements of the film chemistry system. Test Method E 1815 can be used to specify performance requirements at 200 kV. This test method was used, and can be used to corroborate Test Method E 1815 results at 200 kV. This test method is a subjective means of determining film chemistry image quality performance, whereas Test Method E 1815 uses instrument measurements to calculate performance and is therefore an objective test method.

4.4 This 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

35.1 The 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.

35.1.1 The 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 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.

35.1.2 The absorber plate shall be made of Lucite plastic for 30–kV, and mild steel for 200–kV. I 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 the both absorber plates shall be a maximum of 6.3 µm (250 µin.) R_a, ground finish (both faces).

46. Calibration of X-Ray Source

46.1 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 30–kV is based on ANSI PH2.8. ISO 7004 method for 100–kV calibration, modified for 30–kV. With an 8–mm (0.32-in.) copper a 7.62-mm (0.30-in.) aluminum filter at the X-ray tube and a target to detector distance 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-haslf that with 75.62–mm (0.30–in.) aluminum at the tube port. Exposures shall be made using the voltage thus determined and with 7.62 mm (29.5 in.), (0.30 in.) of aluminum at the tube port. No lead screen shall be used.

6.3 The 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 B 152). 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.

46.24 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 machine settings and use for the film tests. During tests, remove all of the 8 mm (0.32 in.) filters for both 200–kV and 3.5 mm (0.14 in.) 30–kV methods.
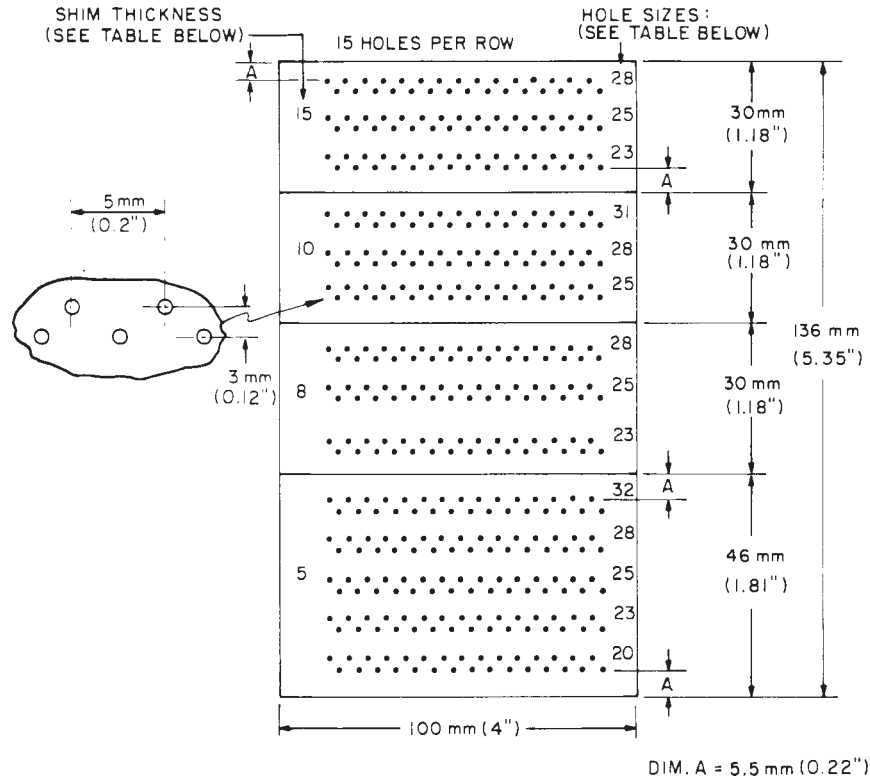
7. Density Measurements

7.1 Measure 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 E 1079. Use a minimum aperture of 7 mm (0.275 in.).

8. Film Holder and Screens

58.1 Enclose 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.*

58.2 For the 200–kV method. Place the film 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.

SHIM THICKNESS (SEE TABLE BELOW)
15 HOLES PER ROW
HOLE SIZES: (SEE TABLE BELOW)

DIM. A = 5.5 mm (0.22")

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   Image Quality Indicator

NOTE 1—These thicknesses reflect commercially available tolerances in lead foil for use as radiographic screens.

8.3 When 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.

8.4 Use a 6.3 ± 0.8 mm (¼ ± 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. Procedure

9.1 The sources to film distance is based upon achieving a geometrical unsharpness (Ug) of 0.05 mm (0.002 in.) or less on a 36 mm (1³⁄₈ in.) thick plastic plate for 30–kV and a 19 mm (¾ in.) thick absorber plate for 200–kV. Calculate the minimum source to film distance, D, in millimetres, as follows:

$$D = 381\,\phi$$

where:
D = source to film distance, mm, and
ϕ = focal spot size, mm.

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

9.2 See 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.
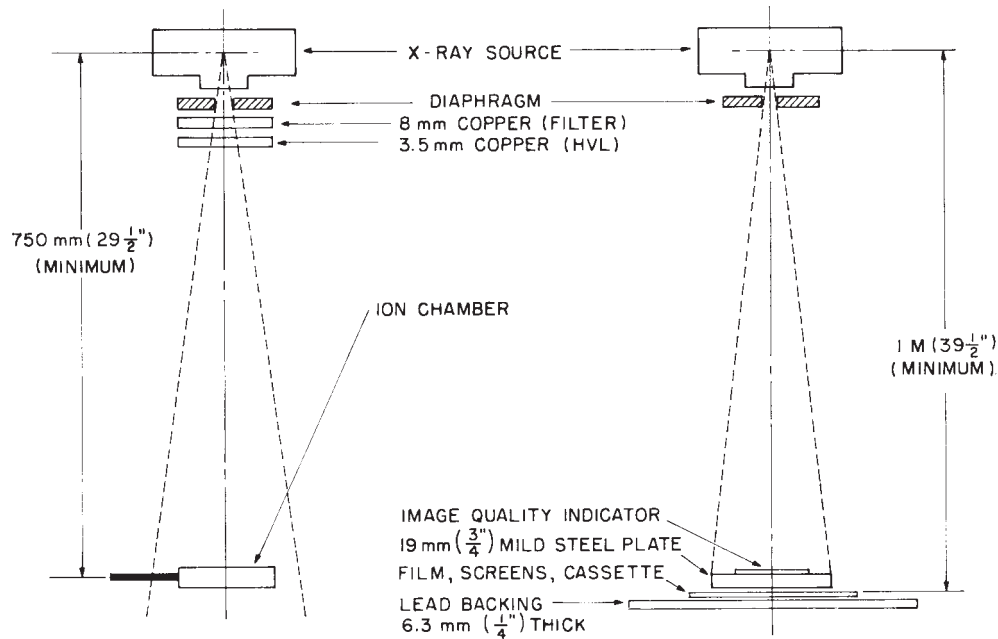
FIG. 2 Setup for Energy Calibration and Exposures

6̶9.3 *Exposure*:

6̶9.3.1 Expose the film at the kV setting as determined in Section 4̶. 6. Remove all c̶o̶p̶p̶e̶r̶ filters at the tube before the exposure. Adjust the exposure time to give a film density of 2.00 $\pm\frac{0.10}{0.00}$ i̶n̶ 15 % in the center of the film as measured with a densitometer. Use the densitometer c̶a̶l̶i̶b̶r̶a̶t̶e̶d̶ in accordance with a̶ ̶d̶e̶n̶s̶i̶t̶y̶ ̶s̶t̶e̶p̶ ̶w̶e̶d̶g̶e̶ ̶t̶r̶a̶c̶e̶a̶b̶l̶e̶ ̶t̶o̶ ̶N̶a̶t̶i̶o̶n̶a̶l̶ ̶I̶n̶s̶t̶i̶t̶u̶t̶e̶ ̶o̶f̶ ̶S̶t̶a̶n̶d̶a̶r̶d̶s̶ ̶a̶n̶d̶ T̶e̶c̶h̶n̶o̶l̶o̶g̶y̶,̶ ̶(̶N̶I̶S̶T̶)̶.̶

6̶.̶3̶.̶2̶ ̶M̶a̶k̶e̶ Section 7.

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

6̶9.3.3 Identify 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 7̶ 10).

6̶9.3.4 In order to minimize any effects caused by latent image instability, process the exposed film not more than 8 h after exposure.

6̶9.4 *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 6̶ 9.4.1 and 9.4.2). The film processing and record requirements shall be in accordance with Guide E 999.

6̶9.4.1 *Automatic Processing*—Use industrial X-ray processing solutions in the tests. Keep a record of:

6̶9.4.1.1 The brand name of the processor.

6̶9.4.1.2 The length of time (±1 s) that the film is in the developer, that is, leading edge in to leading edge out.

6̶9.4.1.3 The brand name of the developer, including t̶h̶e̶"̶ ̶s̶t̶a̶r̶t̶e̶r̶,̶"̶ the "starter," the temperature measured to within 0.5°C (0.9°F), and the rate of replenishment to within ±5 %.

6̶9.4.1.4 The brand name and total quantity of film used in seasoning fresh developer solution before processing test films. Process a minimum of ten film s̶ (360 by 430-mm (14 by 17-in.)) per gallon of developer; expose half f̶l̶a̶s̶h̶ of each sheet to a maximum density by white light. An acceptable alternative to exposing half f̶l̶a̶s̶h̶i̶n̶g̶ of each film sheet is to flash alternate film sheets fully in equal numbers.

6̶9.4.2 *Manual Processing*—Use industrial X-ray film processing solutions in the tests. Keep a record on the data sheet of:

6̶9.4.2.1 The time of development (±2 s).

6̶9.4.2.2 The temperature of developer measured within 0.5°C (0.9°F).

6̶9.4.2.3 The brand name and the total quantity of film used in seasoning the fresh developer solution before processing test films. Process a minimum of four 360 by 3̶ 4̶30-mm (14 by 17-in.) sheets of film per gallon of developer solution; expose half f̶l̶a̶s̶h̶ of each sheet of film to maximum density by white light before processing or use alternative method (see 6̶ 9.4.1.4).

7̶10. Data Collection and Evaluation

7̶10.1 The three test films for any one film type shall be read independently by three readers. Each reader shall record the number of holes of a given size visible on each step of the IQI. The viewing box should be masked to prevent stray light from

distracting the reader, and the room should be darkened with minimal background lighting. A magnifier up to 3× is permitted. A sample data sheet is shown in Fig. 3.

710.2 *Data Evaluation*—The data is evaluated by calculating the sum of the number of holes of a given size visible on each step. The sum is based upon three readers and three radiographs. Convert the step/hole size to equivalent penetrameter sensitivity (EPS) as follows:

$$\text{EPS, \%} = \frac{100}{X} \times \sqrt{\frac{Th}{2}}$$

Date _____

1.　Film and Exposure Data:　　　　　　　　　　　　Lab. _____

Film Type _____ Reader _____

Kilovoltage: _____

Source to Film Distance _____ mAS _____ Source Size _____

Screens: Front _____ Back _____

Remarks: _____

PROCESSING

　　　　Automatic　　　　　　　or　　　　　　　　Manual

Name _____　　Developer Type _____
Developer Type _____　　Developer Temp. _____
Developer Temp. _____　　Developer Time _____
Developer Time _____　　Seasoning _____
Developer Rep. Rate _____

Seasoning _____

| Interpretation IQI | | | Number of Holes Visible | | |
Step Size	Hole Size	EPS(%)	Expos. #1	Expos. #2	Expos. #3
.38 mm (.015")	.71 mm (.028")	1.92			
"	.64 mm (.025")	1.82			
"	.58 mm (.023")	1.71			
.25 mm (.010")	.79 mm (.031")	1.66			
"	.71 mm (.028")	1.57			
"	.64 mm (.025")	1.49			
.20 mm (.008")	.71 mm (.028")	1.41			
"	.64 mm (.025")	1.33			
"	.58 mm (.023")	1.25			
.13 mm (.005")	.81 mm (.032")	1.19			
"	.71 mm (.028")	1.12			
"	.64 mm (.025")	1.05			
"	.58 mm (.023")	1.00			
"	.50 mm (.020")	0.94			

FIG. 3　Data Sheet

where:
h = hole diameter, mm,
T = step thickness of IQI, mm, and
X = thickness of test object, mm.

The number of detectable holes versus the equivalent penetrameter sensitivity is plotted for each step of the IQI and for each film type as shown in Fig. 4. The image quality response is determined for the point where 50 % of the holes are visible. This value is the classification index for the film under test.

710.2.1 *Alternate-One Method for Data Evaluation*—In addition to the curve plotting method described in 7 10.2, the classification index may be calculated mathematically between two adjacent 30 hole rows by interpolating between the EPS values of the row with more than 15 visible holes and the row with less than 15 visible holes by use of the formula:

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

where:
C = the classification index (the midpoints or 50 % point) on the graph (Fig. 4).
N_a = the total number of visible holes in the row immediately above the midpoint and Q_a is the corresponding EPS value.
N_b = the total number of visible holes in the row immediately below the midpoint and Q_b is the corresponding EPS value.

The following example is given for illustration—A row having 23 visible holes has an EPS value of 1.57. An adjacent row has 12 visible holes and an EPS value of 1.49.

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

$$C = 1.51$$

710.2.2 *Alternate-Two Method for Data Evaluation*—In addition to the curve plotting method described in 7 10.2, the data may be evaluated by averaging the number of holes of a given size (hole set) visible on each plaque image of the IQI for a given film type. This average is based on the evaluation by three readers of three radiographs of each film type. This same averaging procedure is repeated for each hole set. The number of visible holes for each different hole set is then summed. This sum is the visibility index for each film type and is a measure of the relative image quality response of a given film type. This method of evaluating the relative image quality response for different film types is illustrated in Table 1.

TABLE 1 Average Number of Visible Holes

Film Type	Hole Set 1	2	3	4	5	6	7	8	9	Visibility Index
1	30	30	30	23	12.7	0	0	0	0	125.7
2	30	27.7	25.2	12.2	0	0	0	0	0	95.1
3	30	26.5	21.7	8.7	0	0	0	0	0	86.9
4	30	25.2	15.7	5.3	1	0	0	0	0	76.2

811. Keywords

811.1 Image Quality Indicator; IQI; penetrameter; radiographic film
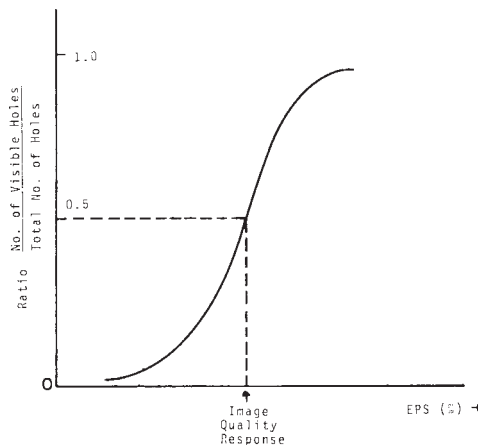
FIG. 4   Visibility versus EPS Values