Designation: E 545 – 99

Standard Test Method for Determining Image Quality in Direct Thermal Neutron Radiographic Examination[1]

This standard is issued under the fixed designation E 545; 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 the use of an Image Quality Indicator (IQI) system to determine the relative[2] quality of radiographic images produced by direct, thermal neutron radiographic examination. The requirements expressed in this test method are not intended to control the quality level of materials and components.

1.2 *This standard does not purport to address 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.*

1.3 The values stated in SI units are regarded to be standard.

2. Referenced Documents

2.1 *ASTM Standards:*

E 543 Practice for Agencies Performing Nondestructive Testing[3]

E 748 Practices for Thermal Neutron Radiography of Materials[3]

E 803 Method for Determining the L/D Ratio of Neutron Radiography Beams[3]

E 1316 Terminology for Nondestructive Examinations[3]

E 2003 Practice for Fabrication of Neutron Radiographic Beam Purity Indicators[3]

E 2023 Practice for Fabrication of Neutron Radiographic Sensitivity Indicators[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, see Terminology E 1316, Section H.

4. Summary of Test Method

4.1 The judgment of the quality of a neutron radiograph is based upon the evaluation of images obtained from indicators that are exposed along with the test object. In cases of limited film size or extended object size, the indicators may be exposed on another film immediately prior to or following exposure of the test object under exactly the same conditions (refer to Process Control Radiographs, Section 10). The IQI values must be determined from films with an optical density between 2.0 to 3.0. Two types of IQIs are used.

4.1.1 *Beam Purity Indicator (BPI)*—The BPI is a device used for quantitative determination of radiographic quality. It is a polytetrafluoroethylene block containing two boron nitride disks, two lead disks, and two cadmium wires. A key feature of the BPI is the ability to make a visual analysis of its image for subjective information, such as image unsharpness and film and processing quality. Densitometric measurements of the image of the device permit quantitative determination of the effective value for the thermal neutron content, gamma content, pair production content, and scattered neutron content. The BPI shall be constructed in accordance with Practice E 2003. Optionally, any BPI fabricated prior to publication of Practice E 2003 which conforms to Test Method E 545 - 81 through 91 may be used.

4.1.2 *Sensitivity Indicator (SI)*—The SI is one of several devices used for qualitative determination of the sensitivity of detail visible on a neutron radiograph. The SI is a step-wedge device containing gaps and holes of known dimensions. Visual inspection of the image of this device provides subjective information regarding total radiographic sensitivity with respect to the step-block material. The SI shall be in accordance with Practice E 2023. Optionally, any SI fabricated prior to publication of Practice E 2023 which conforms to Test Method E 545-81 through 91 may be used.

4.2 Neutron radiography practices are discussed in Practices E 748.

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[1] This test method is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.05 on Neutron Radiography.

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[2] The numerical values obtained in the calculations described herein may vary between different film processing systems, film types, and within one processing system if processing variables changes.

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

5. Significance and Use

5.1 The BPI is designed to yield quantitative information concerning neutron beam and image system parameters that contribute to film exposure and thereby affect overall image quality. In addition, the BPI can be used to verify the day-to-day consistency of the neutron radiographic quality. Gadolinium conversion screens and single-emulsion silver-halide films, exposed together in the neutron imaging beam, were used in the development and testing of the BPI. Use of alternative detection systems may produce densitometric readings that are not valid for the equations used in Section 9.

5.2 *The only truly valid sensitivity indicator is a reference standard part. A reference standard part is a material or component that is the same as the object being neutron radiographed except with a known standard discontinuity, inclusion, omission, or flaw. The sensitivity indicators were designed to substitute for the reference standard and provide qualitative information on hole and gap sensitivity.*

5.3 The number of areas or objects to be radiographed and the film acceptance standard used should be specified in the contract, purchase order, specification, or drawings.

6. Basis of Application

6.1 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated in accordance with Practice E 543. The applicable revision of Practice E 543 shall be specified in the contractual agreement.

6.2 *Procedures and Techniques*—The procedures and techniques to be utilized shall be as described in this test method unless otherwise specified. Specific techniques may be specified in contractual documents.

6.3 *Extent of Examination*—The extent of examination shall be in accordance with Section 7 unless otherwise specified.

6.4 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with Section 11 unless otherwise specified. Acceptance criteria (for example, for reference radiographs) shall be specified in the contractual agreement.

7. Procedure

7.1 The direction of the beam of radiation should be as perpendicular as possible to the plane of the film.

7.2 Use Conversion screens that respond to neutrons of thermal energies, such as metallic gadolinium.

7.3 Each radiograph shall include a beam purity indicator and a sensitivity indicator (refer to Section 10 for exceptions). The indicators shall be located no less than 25 mm from any edge of the exposed area of the film when feasible. The indicators shall be located such that the image of the indicators on the film do not overlap the image of the object.

7.4 The SI should be oriented parallel to and as close as possible to the film.

7.5 The SI should be oriented such that its thickest step is not adjacent to the BPI or the objects being radiographed.

7.6 The BPI surface must be parallel against the film cassette face during exposure or density readings will be invalid.

7.7 The cadmium wires in the BPI shall be oriented such that their longitudinal axis is perpendicular to the nearest film edge.

7.8 Measure the film densities using a diffuse transmission densitometer. The densitometer shall be accurate to ±0.02 density units.

7.9 For the purpose of determining image quality, the background optical density shall be between 2.0 and 3.0 measured at the hole in the center of the BPI.

7.10 The only true measurement of the beam uniformity is with a radiograph made without objects. Background film optical density in the range from 2.0 to 3.0 across the film should not vary more than ±5 % from the numerical mean of five measurements: one measurement at the center and one measurement approximately 25 to 30 mm toward the center from each corner of the film. If the beam diameter is smaller than the film, the four outside measurements shall be taken 25 to 30 mm from the edge of the beam located at 90° intervals.

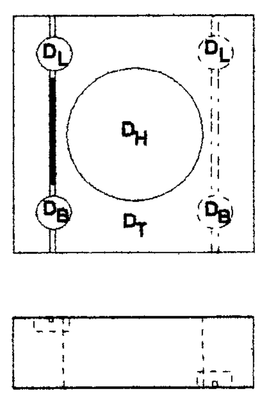
7.11 Radiographs shall be free of any blemish that may interfere with subsequent examination of the image.

7.12 Determine the thermal neutron content (NC), scattered neutron content (S), gamma content (γ), and pair production content (P) by densitometric analysis of the BPI image. Make a determination of the constituents of film exposure by measuring the densities in the BPI image as shown in Table 1. Calculate the various exposure contributors by the equations given in Section 9.

7.13 Determine the sensitivity level by visually analyzing the image of the SI. Determine the values for *G* and *H* using Tables 2 and 3.

7.14 Determine the neutron radiographic category from Table 4.

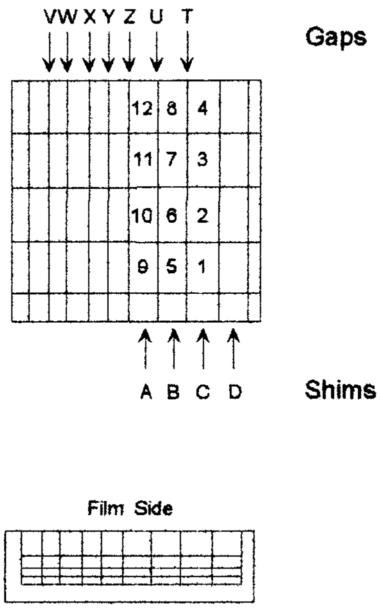
7.15 Visually compare the images of the cadmium wires in the BPI. An obvious difference in image sharpness indicates an *L/D* ratio of 35 or less. Use Method E 803 for quantifying the *L/D* ratio.



Beam Purity Indicator

TABLE 1 Definitions of *D* Parameters

D_B	Film densities measured through the images of the boron nitride disks.
D_L	Film densities measured through the images of the lead disks.
D_H	Film density measured at the center of the hole in the BPI.
D_T	Film density measured through the image of the polytetrafluoroethylene.
ΔD_L	Difference between the D_L values.
ΔD_B	Difference between the two D_B values.



Sensitivity Indicator

TABLE 2 Determination of *H*

NOTE 1—The value of *H* reported is the largest consecutive numbered hole that is visible in the image.

NOTE 2—For hole sizes and shim thicknesses, refer to Practice E 2023.

NOTE 3—The dots on the SI represent holes in the optional lead shim.

Value of *H*	Shim
1	C
2	C
3	C
4	C
5	B
6	B
7	B
8	B
9	A
10	A
11	A
12	A

TABLE 3 Determination of *G*

NOTE 1—The value of *G* reported is the smallest gap that can be seen at all absorber thicknesses.

NOTE 2—For gap sizes, refer to Practice E 2023.

Value of *G*	Gap
1	T
2	U
3	V
4	W
5	X
6	Y
7	Z

7.16 If a lead shim is in the sensitivity indicator, visually inspect the image of the lead steps. If the holes are not visible, the exposure contribution from gamma radiation is very high.

TABLE 4 Neutron Radiographic Categories

NOTE 1—It should be recognized that these categories favor contrast factors because the sensitivity indicators do not permit accurate determination of sharpness alone. It may, therefore, be advantageous to use a lower number category when sharpness is a more important factor than contrast.

Category	*NC*	*H*	*G*	*S*	γ	*P*
I	65	6	6	5	3	3
II	60	6	6	6	4	4
III	55	5	5	7	5	5
IV	50	4	5	8	6	6
V	45	3	5	9	7	7

8. Image Quality Levels

8.1 The ASTM designation of quality level shall include thermal neutron content and sensitivity level. The designation is NC-H-G (see 9.1 and 7.13). Values for scattered neutron content, gamma content, and pair production content may be specified at the option of the user. (When no designation of NC-H-G is specified by the customer, radiographs shall be Category II.)

8.2 Visual analysis of the BPI requires inspection of two areas – the image of the cadmium wires and the image of the areas containing the lead disks. If either of the cadmium wire appears significantly less sharp than the other image, the *L/D* ratio is lower than normally required. If the lead disks noticeably appear either darker or lighter than the surrounding polytetrafluoroethylene, there is either a high gamma content (lighter image) or a high pair production content (darker image). Any of these observations indicates the need for further image analysis and subsequent determination of the usefulness of the radiograph for that particular examination.

9. Determination of Exposure Contributors

9.1 Calculate the effective thermal neutron content, *NC*, as follows:

$$NC = \frac{D_H - (\text{higher } D_B + \Delta D_L)}{D_H} \times 100 \qquad (1)$$

where definitions of *D* parameters are given in Table 1.

9.2 Calculate the effective scattered neutron content, *S*, as follows:

$$S = (\Delta D_B / D_H) \times 100 \qquad (2)$$

9.3 Calculate the effective gamma content, γ, as follows:

$$\gamma = (D_T - \text{lower } D_L)/D_H) \times 100 \qquad (3)$$

9.4 Calculate the effective pair production content, *P*, as follows:

$$P = (\Delta D_L / D_H) \times 100 \qquad (4)$$

10. Process Control Radiographs

10.1 A process control radiograph (as defined in Terminology E 1316, Section H) may be prepared for verification of exposure and sensitivity requirements when the following occur:

10.1.1 The size or setup of objects is such that the object-scattered neutron level relative to background density, sensitivity, or facility-scattered neutrons' exposure requirements is cause for nonconformance.

10.1.2 The object configuration necessitates a film-to-beam orientation that does not permit satisfactory density measurements for calculation of exposure by collimated thermal neutrons.

10.1.3 The object setup or size does not permit the location of image quality indicators to give adequate readings.

10.1.4 The radiograph background density does not meet the requirements of 7.10.

10.2 The process control radiograph shall be prepared with a background film optical density of 2.0 to 3.0 and the same image quality indicators and exposure conditions as the suspect nonconforming exposure. Similar test objects may be in the image.

10.3 The film shall be normal to the beam axis.

11. Certification

11.1 Upon request of the purchaser by contract or purchase order, the radiographing facility shall certify that the radiograph was prepared and examined in accordance with this test method.

12. Records

12.1 Complete records of the technique details shall be maintained by the examining facility for three years or as specified in the basis of purchase.

13. Keywords

13.1 beam purity indicator; direct method; image quality indicator; neutron radiography; sensitivity indicator