Designation: E592 – 15

Standard Guide to Obtainable ASTM Equivalent Penetrameter Sensitivity for Radiography of Steel Plates ¼ to 2 in. (6 to 51 mm) Thick with X-Rays and 1 to 6 in. (25 to 152 mm) Thick with Cobalt-60[1]

This standard is issued under the fixed designation E592; 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 guide to obtainable equivalent penetrameter sensitivity covers the minimum penetrameter thicknesses for which the image of the 1*T* and 2*T* holes is visible for a few practical radiographic conditions. The values represent near optimum sensitivity for flat steel plates. Radiographic conditions that give higher values of scatter buildup from the specimen or backscattered radiation at the image plane will give poorer sensitivity.

1.2 Eight radiographs that illustrate sensitivities obtainable with practical radiographic systems are included as adjuncts to this guide and may be obtained from ASTM.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *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]

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 Radiology

E1316 Terminology for Nondestructive Examinations

E1742 Practice for Radiographic Examination

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

2.2 *ISO Standard:*

ISO 7004 Photography—Industrial Radiographic Films—Determination of ISO Speed, ISO Average Gradient, and ISO Gradients G2 and G4 When Exposed to X- and Gamma-Radiation[3]

2.3 *Military Standard:*

NAVSEA Technical Publication T9074-AS-GIB-010/271 Requirements for Nondestructive Testing Methods

2.4 *ASTM Adjuncts:*

Guide for Equivalent Penetrameter Sensitivity Between X-Rays and Cobalt-60[4]

3. Terminology

3.1 *Definitions:* For definitions of terms used in this standard, refer to Terminology E1316, Section D.

4. Significance and Use

4.1 A key consideration with any radiographic system is its contrast resolution and spatial resolution capability (that is, sensitivity). The degree of obtainable sensitivity with a given system is dependent upon several radiographic parameters such as source energy level, film system class, type and thickness of intensifying screens, exposure (density), etc. This guide permits the user to estimate the degree of sensitivity that may be obtained with X-rays and cobalt-60 gamma rays when using a prescribed set of radiographic parameters. This guide may also be used in conjunction with Test Methods E746 or E1735 to provide a basis for developing data for evaluation of a user's

[1] This guide is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.02 on Reference Radiological Images.

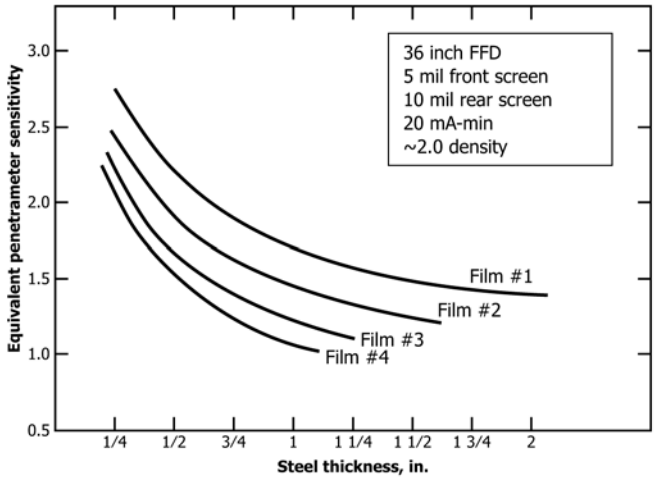
Current edition approved June 1, 2015. Published June 2015. Originally approved in 1977. Last previous edition approved in 2009 as E592 - 99(2009)ε1. DOI: 10.1520/E0592-99R15.

[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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] Available from ASTM Headquarters. Order RRE0592.

***A Summary of Changes section appears at the end of this standard**



NOTE 1—See 5.1.4 for exposure conditions.

FIG. 1 Obtainable Penetrameter Sensitivity for ¼ to 2-in. (6 to 51-mm) Thick Steel When Radiographing with X-Rays.

specific system. This data may assist a user in determining appropriate parameters for obtaining desired degrees of radiographic system sensitivity. An alternate to this approach is the use of those adjunct radiographic illustrations detailed in Section 6.

5. Procedure

5.1 *Sensitivity for ¼ to 2-in. (6 to 51-mm) Thick Steel Using X-Rays:*

5.1.1 The values of sensitivity were determined from a statistical study of visibility of images of penetrameter holes. Near 100 % certainty of seeing the image of a hole on any radiograph was taken as the criterion for determining sensitivity. Most radiographs will show slightly better sensitivity than indicated in Figs. 1-3 because of the statistical nature of recording information from a beam of X-rays but occasionally, one will not show quite as good sensitivity.

5.1.2 Equivalent Penetrameter Sensitvity (EPS) is defined in Eq 1. For a full discussion of EPS see Appendix X1 of Practice E1025.

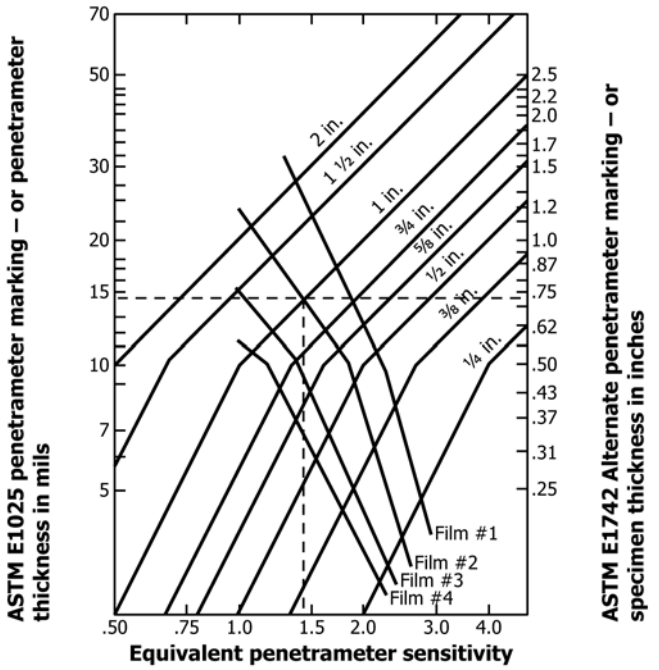
$$EPS,\ \% \ = \ 70.7\ (dT)^{1/2}/t \qquad (1)$$

where:

d = diameter of penetrameter hole,
T = thickness of penetrameter, and
t = specimen thickness.

A clear definition of equivalent penetrameter sensitivity has not been established for penetrameters less than 10 mils (0.25 mm) thick. For this work it was calculated as in Eq 1. The change in slope of the steel thickness curves on Fig. 2 and Fig. 3 is a result of the established 10-mil minimum hole diameter in Practice E1025 and Practice E1742, Appendix A1.

5.1.3 Fig. 1 illustrates obtainable equivalent penetrameter sensitivity for four X-ray films. The films are identified by reciprocal speed (see Test Method E1815) when exposed in accordance with ISO 7004 in a 200-kV range, and processed in accordance with the manufacturer's recommendations (see Guide E999).

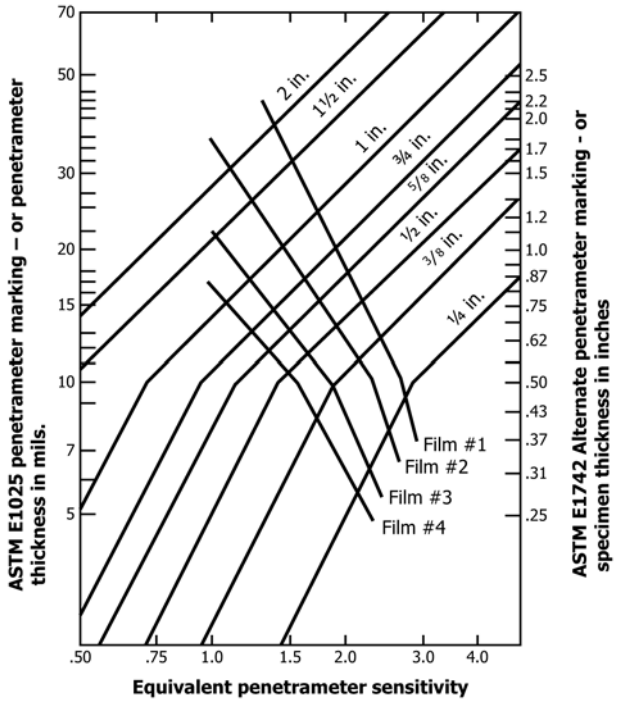


NOTE 1—See 5.1.4 for exposure conditions.

FIG. 2 Penetrameter Sensitivity and Minimum Penetrameter Markings for Showing the 2T Hole When Radiographing ¼ to 2-in. (6 to 51-mm) Thick Steel with X-Rays.

Film Type	Roentgen Speed	ISO Speed	ASTM Class
1	17	1700	none
2	4.0	400	III
3	1.2	120	I
4	0.35	35	Special

5.1.4 The radiographic exposure conditions for reference radiographs 1, 2, 3, and 4 were: 36-in. (914-mm) focus-film distance, 5-mil (0.13-mm) front and 10-mil (0.25-mm) back lead screens, 20 mA·min exposure, and kilovoltage adjusted to give a density of near 2.0. The focal spot size was not recorded with the original data.



NOTE 1—See 5.1.4 for exposure conditions.

FIG. 3 Penetrameter Sensitivity and Minimum Penetrameter Markings for Showing the 1T Hole When Radiographing ¼ to 2-in. (6 to 51-mm) Thick Steel with X-Rays.

5.1.5 Most high-quality industrial X-ray films intended for direct or lead screen exposure, that are exposed and developed accordingly to give these speed values, will provide similar illustrations of sensitivity. Interpolation will give illustrations of sensitivity for speeds obtained with other film systems.

5.1.6 In Fig. 2 the data are presented to show the thinnest penetrameter for which the image of the 2 *T* hole will be visible. The intersection of the line for a particular steel thickness and the line for a given film projected onto the abscissa gives the best obtainable equivalent penetrameter sensitivity. Two different penetrameter markings are displayed in the figure: those for Practice E1025 and those for Practice E1742, Annex A1 (also NAVSEA Technical Publication T9074-AS-GIB-010/271 and former MIL-STD-453 penetrameter markings). The intersection projected to the left ordinate gives the minimum penetrameter marking (thickness in mils) in accordance with Practice E1025 for which the image of the 2*T* hole will be visible. The right ordinate gives the minimum penetrameter marking in accordance with Practice E1742, Annex A1, for which the image of the 2*T* hole will be visible.

5.1.7 Fig. 3 gives the Practice E1025 and Practice E1742, Annex A1 markings for which the image of the 1*T* hole will be visible.

5.1.8 To take an example, on Fig. 2 the intersection of the curve for 1-in. (25-mm) thick steel and for Film No. 2 shows that the penetrameter sensitivity is 1.45 %. The minimum Practice E1025 penetrameter thickness that will show the 2*T* hole image is 15. The corresponding Practice E1742, Annex A1 marking is 0.75 (see dashed lines). On Fig. 3 the sensitivity is, of course, 1.45 %. The minimum Practice E1025 penetrameter thickness that will show the 1*T* hole image is 22 and the Practice E1742, Annex A1 specification marking is 1.1.

5.1.9 If radiographs are exposed to a density other than 2 by changing mA·min exposure, but not kilovoltage, the equivalent penetrameter sensitivity (EPS) that will be obtained in the density range 1.3 to 4 can be calculated approximately as follows:

$$EPS_D = EPS_2\ (2/D)^{1/4} \tag{2}$$

where:

D = density to which the radiograph is exposed,
EPS_2 = sensitivity for $D = 2.0$, and
EPS_D = sensitivity for D.

5.2 *Sensitivity for 1 to 6-in. (25 to 152-mm) Thick Steel Using Cobalt-60:*

5.2.1 For cobalt-60 radiography of steel, the variables that affect image quality and that can be controlled are the speed of the film and the recording of scattered radiation relative to the recording of image-forming radiation. The relative recording of scatter (the scatter buildup factor) can be decreased by the use of lead filtration between the specimen and the film or by the use of low-atomic-number metal screens. Either method gives nearly equal improvement in image quality for a given increase in exposure.

5.2.2 Radiographs of flat steel plates were made either with 10-mil (0.25-mm) thick front and back lead or copper screens. A30-Ci source, 4 by 4 mm, was used with a setup designed to give maximum buildup of scatter in the specimen and no backscatter. The source-to-film distance was 36 in. (914 mm). The exposure was adjusted for a density near 2.0.

5.2.3 The four films used are identified by reciprocal roentgen speed when exposed in accordance with ISO 7004 using cobalt-60 radiation and processed in accordance with the manufacturer's recommendations.

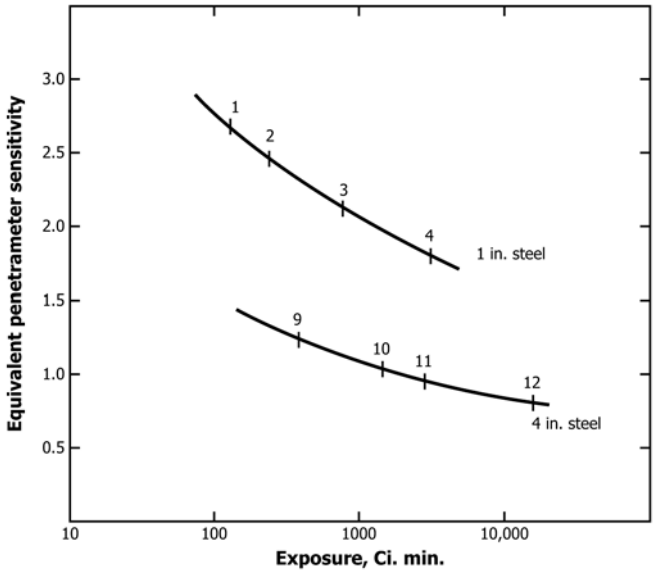
Film Type	Roentgen Speed	ISO Speed
1	3.5	350
2	0.67	67
3	0.13	13
4	0.04	4

5.2.4 Fig. 4 shows equivalent penetrameter sensitivity obtainable for 1 and 4-in. (25 and 102-mm) thick steel as a function of exposure in curie minutes. Fig. 5 shows equivalent penetrameter sensitivity obtainable for 2 and 6-in. (51 and 152-mm) thick steel as a function of exposure. The numbers on the curves indicate the various radiographic exposures shown in Table 1.

5.2.5 The films, screens, and exposures used for the radiographs were as specified in Table 1.

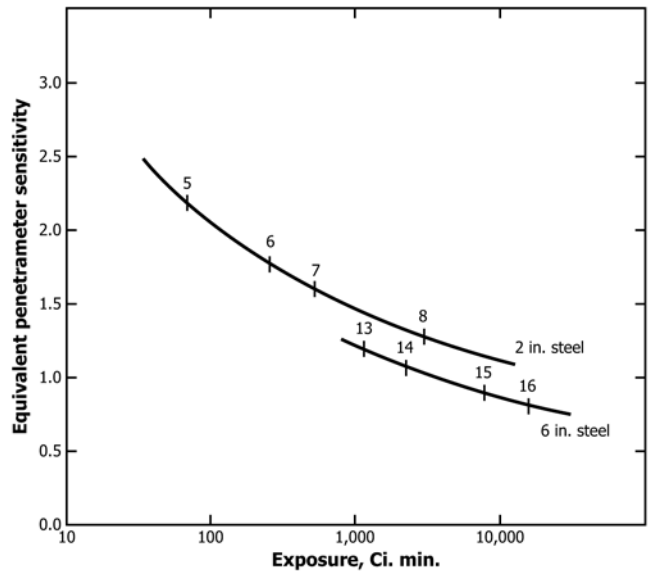
6. Descriptions and Suggested Uses of Reference Radiographic Illustrations (See 1.2)

6.1 Eight radiographs were chosen to illustrate sensitivities obtainable with practical radiographic systems. Table 2 lists films and exposure conditions for reference radiograph illustrations Nos. 1 through 6 (for X-ray) and Table 1 lists films and exposure conditions for reference radiograph illustrations Nos. 7 and 8 (for Cobalt-60). The reference radiograph illustrations for Cobalt-60 correspond to demonstration radiographs Nos. 9 and 12 in Table 1 and Fig. 4.



NOTE 1—The demonstration radiograph numbers on curves refer to exposure conditions given in Table 1.

FIG. 4 Obtainable Penetrameter Sensitivity for Cobalt-60 Radiography of 1 and 4-in. (25 and 102-mm) Thick Steel at 36-in. (914-mm) Distance.



NOTE 1—The demonstration radiograph numbers on curves refer to exposure conditions given in Table 1.

FIG. 5 Obtainable Penetrameter Sensitivity for Cobalt-60 Radiography of 2 and 6-in. (51 and 152-mm) Steel at 36-in. (914-mm) Distance.

6.2 Each reference radiograph illustration has an array of Practice E1025 penetrameters on the right-hand side and a corresponding array of steel plaques containing holes of varying diameters on the left-hand side. Illustrations Nos. 1 through 6 contain plaques which represent 2 % of steel thicknesses radiographed and each has ten holes of a given diameter. Illustrations Nos. 7 and 8 contain plaques 0.060-in. (1.51-mm) thick, and each has 10 and 15 holes respectively of a given diameter. The plaque for which all hole images are just visible represent near limiting penetrameter sensitivity.

6.3 Reference radiographs Nos. 1, 2, and 3 illustrate the visibility of penetrameter holes for radiography of ½, 1, and 1½-in. (13, 25, and 38-mm) thick steel using film No. 2. The exposure conditions were as specified in 5.1.4.

TABLE 1 Description of Cobalt-60 Radiographs Cited in Figs. 4 and 5

Thickness of Steel	Demonstration Radiograph	Film Type	Screens	Exposure, Ci·min
1 in. (25 mm)	1	2	lead	130
	2	2	copper	240
	3	3	lead	770
	4	4	copper	3 100
2 in. (51 mm)	5	1	copper	70
	6	2	lead	260
	7	2	copper	510
	8	3	copper	3 020
4 in. (102 mm)	9[A]	1	copper	380
	10	2	lead	1 430
	11	2	copper	2 800
	12[A]	3	copper	15 700
6 in. (152 mm)	13	1	lead	1 140
	14	1	copper	2 240
	15	2	lead	7 800
	16	2	copper	16 000

[A]Demonstration Radiograph 9 is Reference Radiograph 7 and Demonstration Radiograph 12 is Reference Radiograph 8.

6.4 Reference radiograph No. 4 illustrates penetrameter sensitivity for ½-in. (13-mm) steel using film No. 4. A comparison of reference radiograph Nos. 1 and 4 illustrates the effect of film speed on penetrameter sensitivity for a constant milliampere-minute exposure with adjusted kilovoltage.

6.5 A comparison of reference radiographs Nos. 1, 5, and 6 illustrates the effects on penetrameter sensitivity of changing exposure (2.5, 20, and 160 mA . min) for a given film by adjusting kilovoltage to maintain film density at 2.0.

TABLE 2 Description of Reference Radiographs Using X-Rays

NOTE 1—The focus-film distance was 36 in. (914 mm) and the kilovoltage was adjusted to give a density near 2.0 on all of the radiographs described below.

Reference Radiograph No.	Thickness of Steel, in. (mm)	Film Type	Exposure, mA·min
1	½ (13)	2	20
2	1 (25)	2	20
3	1½ (38)	2	20
4	½ (13)	4	20
5	½ (13)	2	2.5
6	½ (13)	2	160

6.6 Reference radiographs Nos. 7 and 8 are illustrations of results obtained for cobalt-60 sources of radiation. They illustrate the extremes in sensitivity for radiography of 4-in. (102-mm) thick steel.

7. Precision and Bias

7.1 No statement is made about either the precision or bias of Guide E592, since the guide merely provides information for estimating sensitivity values or for performing a user specific evaluation of a radiographic system.

8. Keywords

8.1 cobalt–60; density; equivalent penetrameter sensitivity; exposure; reference radiographic illustrations; X-rays

SUMMARY OF CHANGES

Committee E07 has identified the location of selected changes to this standard since the last issue (E592-99(2009)$^{\varepsilon 1}$) that may impact the use of this standard.

(1) Updated references throughout.
(2) Moved definition of EPS from a note to its own section.
(3) Added technique information to Fig. 1.
(4) Updated Fig. 2 and Fig. 3 axis titles.
(5) Differentiated film type numbers, demonstration radiograph numbers, and reference radiograph numbers.
(6) Added ISO speed and ASTM film class to table in 5.1.
(7) Added ISO speed to table in 5.2.3.