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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 E 592; 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:*

E 746 Test Method for Determining Relative Image Quality Response of Industrial Radiographic Film[2]

E 999 Guide for Controlling the Quality of Industrial Radiographic Film Processing[2]

E 1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *ANSI Standard:*

ANSI PH2.8 Sensitometry of Industrial X-ray Films for Energies up to 3 Million Electron Volts[3]

2.3 *Military Standard:*

MIL-STD-271 Nondestructive Testing Requirements for Metals[4]

2.4 *ASTM Adjuncts:*

Guide for Equivalent Penetrameter Sensitivity Between X Rays and Cobalt-60[5]

3. Terminology

3.1 *Definitions:* —For definitions of terms used in this standard, refer to Terminology E 1316, Section D.

4. Significance and Use

4.1 A key consideration with any radiographic system is its capability to resolve detail (that is, sensitivity). The degree of obtainable sensitivity with a given system is dependent upon several radiographic parameters such as source energy level, film type, 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 Method E 746 to provide a basis for developing data for evaluation of a user's 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*:

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[1] This guide is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E7.02 on Reference Radiographs.

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

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from ASTM Headquarters. Order RRE0592.

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 Fig. 1 illustrates obtainable equivalent penetrameter sensitivity (see Appendix X1 of Practice E 1025) for four X-ray films. The films are identified by reciprocal roentgen speed when exposed in accordance with ANSI PH2.8 in a 200-kV range, and processed in accordance with the manufacturer's recommendations (see Guide E 999).

Film No.	Speed
1	17
2	4.0
3	1.2
4	0.35

5.1.3 The radiographic exposure conditions 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.

5.1.4 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.

5.1.5 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. The intersection projected to the left ordinate gives the minimum penetrameter marking (thickness in mils) in accordance with Practice E 1025 for which the image of the 2*T* hole will be visible. The right ordinate gives the minimum marking in accordance with MIL-STD-271 for which the image of the 2*T* hole will be visible.

5.1.6 Fig. 3 gives the ASTM and military markings for which the image of the 1*T* hole will be visible.

5.1.7 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 ASTM penetrameter thickness that will show the 2*T* hole image is 15. The corresponding military marking is 0.75 (see dashed lines). On Fig. 3 the sensitivity is, of course, 1.45 %. The minimum ASTM penetrameter thickness that will show the 1*T* hole image is 22 and the military specification marking is 1.1.

5.1.8 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:

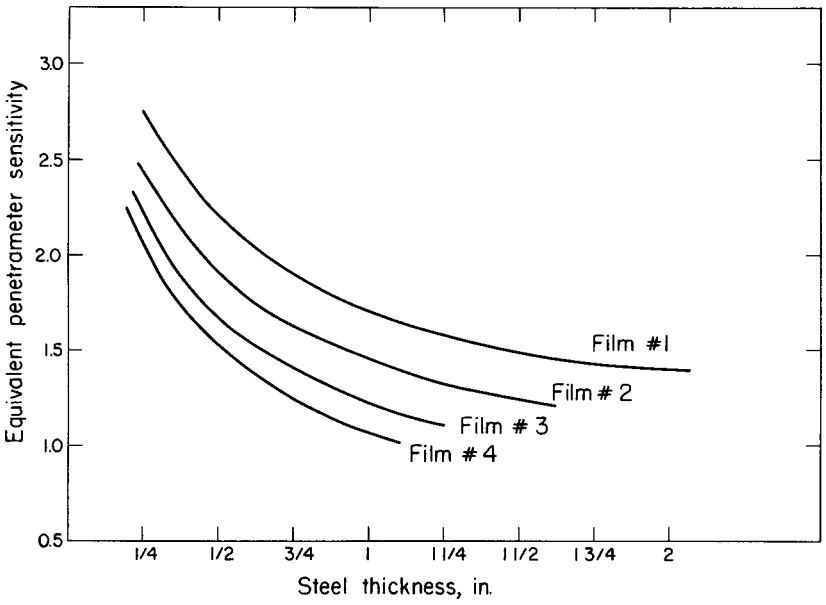
$$EPS_D = EPS_2\ (2/D)^{1/4} \tag{1}$$

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

NOTE 1—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 follows:

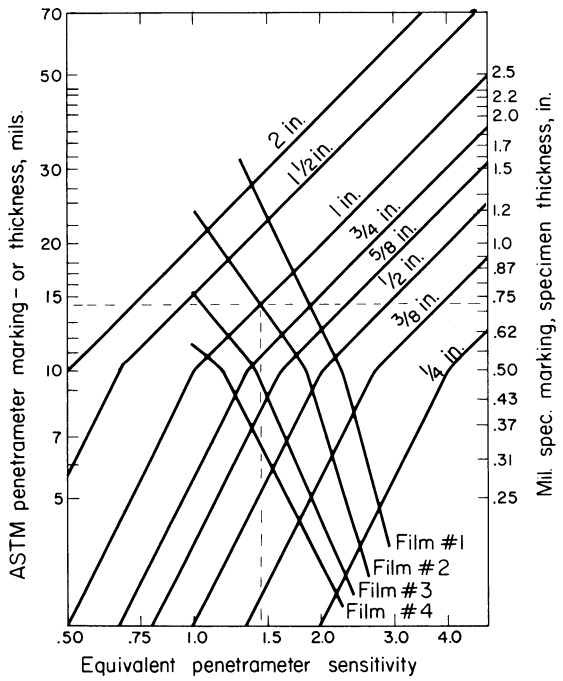
$$EPS, \% = 70.7\ (dT)^{1/2}/t \tag{2}$$

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



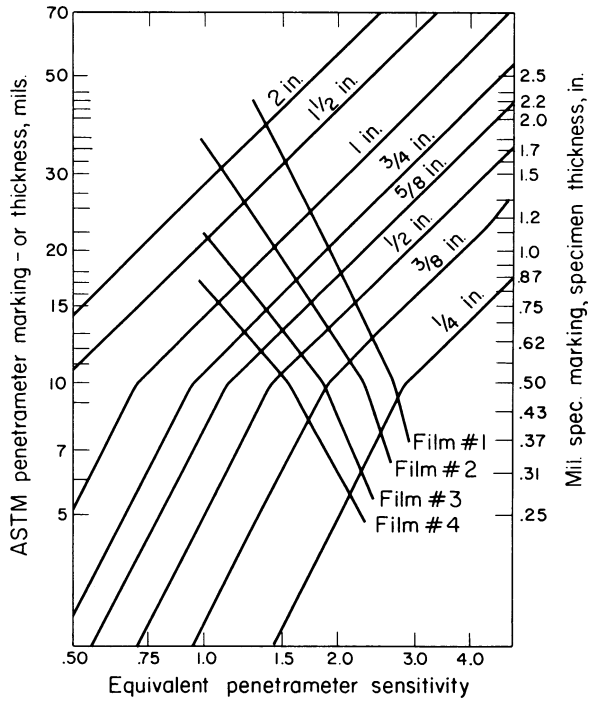
NOTE 1—See 5.1.3 for exposure conditions.

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



NOTE 1—See 5.1.3 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.



NOTE 1—See 5.1.3 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.

The change in slope of the steel thickness curves on Figs. 2 and 3 is a result of the established 10-mil minimum hole diameter.

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 ANSI PH2.8 using cobalt-60 radiation and processed in accordance with the manufacturer's recommendations.

Film No.	Speed
1	3.5
2	0.67
3	0.13
4	0.04

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)

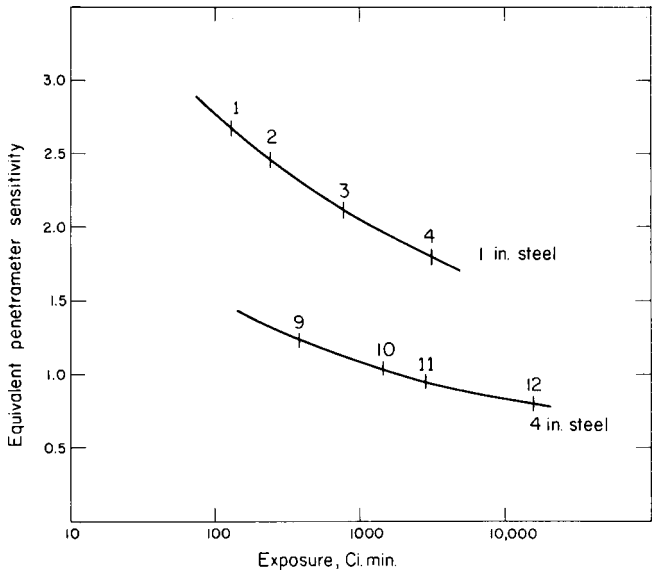
6.1 Eight radiographs were chosen to illustrate sensitivities obtainable with practical radiographic systems. Table 2 lists films and exposure conditions for reference illustrations Nos. 1 through 6 (for X-ray) and Table 1 lists films and exposure conditions for illustrations Nos. 7 and 8 (for cobalt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

6.2 Each radiographic illustration has an array of ASTM 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 5.1.3.

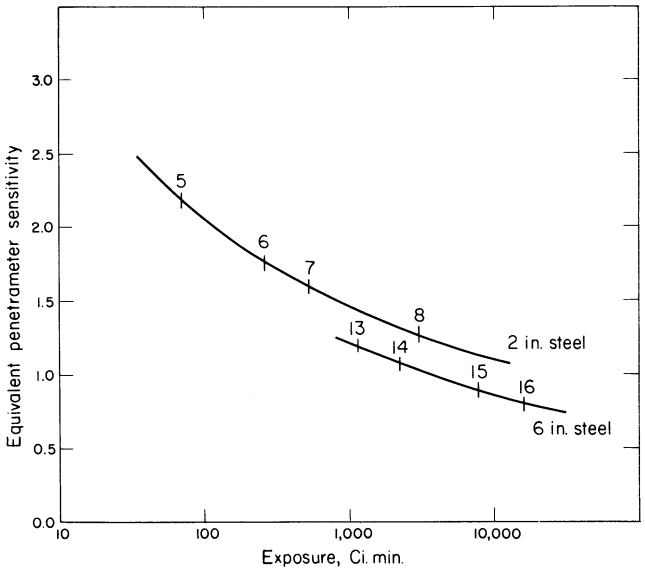
6.4 Reference radiograph No. 4 illustrates penetrameter sensitivity for ½ -in. (13-mm) steel using film No. 4. A comparison of reference radiograph Nos. 1 and 4 illustrates the effect of film speed on penetrameter sensitivity for a constant milliampere-minute exposure with adjusted kilovoltage.

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.



NOTE 1—The 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 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.

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

Thickness of Steel	Radio-graph	Film	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	1	copper	380
	10	2	lead	1 430
	11	2	copper	2 800
	12	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

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.

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.

Radiograph No.	Thickness of Steel, in. (mm)	Film No.	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

7. Precision and Bias

7.1 No statement is made about either the precision or bias of Guide E 592, 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