



Designation: E446-98 (Reapproved 2004)^{ε1} Designation: E446 - 10

Standard Reference Radiographs for Steel Castings Up to 2 in. [51 mm] (50.8 mm) in Thickness¹

This standard is issued under the fixed designation E446; 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.

This standard has been approved for use by agencies of the Department of Defense.

^{ε1}Note—Editorial changes were made throughout the standard in January 2004.

1. Scope

~~1.1~~ These reference radiographs

~~1.1~~ These reference radiographs² illustrate various types and degrees of discontinuities occurring in steel castings that have section thicknesses up to 2 in. [51 mm] (Note 1); illustrate various categories, types, and severity levels of discontinuities occurring in steel castings that have section thicknesses up to 2 in. (50.8 mm) (see Note 2). The reference radiograph films are an adjunct to this standard and must be purchased separately from ASTM International, if needed (see 2.2). Categories and severity levels for each discontinuity type represented by these reference radiographs are described in 1.2.

~~NOTE 1—Reference radiographs previously used for this thickness range carried the designation E71, but included a now rarely used gamma source, that is, radium. The current document is also updated by inclusion of several recognized— 1—The basis of application for these reference radiographs requires a prior purchaser supplier agreement of radiographic examination attributes and classification criterion as described in Sections 4, 6, and 7 of this standard.~~

~~NOTE 2—Reference radiographs previously used for this thickness range carried the designation E71, but included a now rarely used gamma source, that is, radium. The current document is also updated by inclusion of several recognized shrinkage or C categories and by elimination of the crack and hot tear categories except for one example of each of these discontinuity types. Reference radiographs for thicker sections may be found in Reference Radiograph standards E186 and E280.~~

~~1.2~~ These reference illustrations consist of three separate sets (Note 2). Reference Radiograph standards E446 and E186 provide some overlap of severity levels for similar discontinuity categories within the same energy level range (see 4.2, 5.1, and 6.3).

1.2 These reference radiographs consist of three separate volumes (see Note 3) as follows: (1) medium voltage (nominal 250-kVp) 250-kV X rays, (2) 1-MV X rays and Iridium-192 radiation, and (3) 2-MV to 4-MV X rays and cobalt-60 radiation. Each set is for comparison only with radiographs produced with equivalent radiation. It should be recognized that each energy level is not applicable to the entire thickness range covered by this document. Each set consists of 6 categories of graded discontinuities in increasing severity level and 4 categories of ungraded discontinuities furnished as examples only, as follows: III) 2-MV to 4-MV X rays and cobalt-60 radiation. Unless otherwise specified in a purchaser supplier agreement (see 1.1), each volume is for comparison only with production radiographs produced with radiation energy levels within the thickness range covered by this standard. Each volume consists of six categories of graded discontinuities of increasing severity level and four categories of ungraded discontinuities. Reference radiographs containing ungraded discontinuities are provided as a guide for recognition of a specific casting discontinuity type where severity levels are not needed. Following is a list of discontinuity categories, types and severity levels for the adjunct reference radiographs of this standard:

1.2.1 Category A—Gas porosity; severity levels 1 through 5.

1.2.2 Category B—Sand and slag inclusions; severity levels 1 through 5.

1.2.3 Category C—Shrinkage; 4 types:

1.2.3.1 ϵ ACa—linear shrinkage—Severity levels 1 through 5.

1.2.3.2 ϵ BCb—feathery shrinkage—Severity levels 1 through 5.

1.2.3.3 ϵ CCc—sponge shrinkage—Severity levels 1 through 5.

1.2.3.4 ϵ DCd—combinations of linear, feathery and sponge shrinkage—Severity levels 1 through 5.

1.2.4 Category D—Crack; 1 illustration.

¹ These reference radiographs are under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and are the direct responsibility of Subcommittee E07.02 on Reference Radiographs.

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² For ASME Boiler and Pressure Vessel Code applications see related Reference Radiographs SE-446 in Section V of that Code.

- 1.2.5 *Category E*—Hot tear; 1 illustration.
 1.2.6 *Category F*—Insert; 1 illustration.
 1.2.7 *Category G*—Mottling; 1 illustration.

~~NOTE 2—The illustrations consist of the following:~~ 3—The reference radiographs consist of the following:

~~Volume I: Medium Voltage (Nominal 250 kVp) X-Ray Reference Radiographs—Set of 34 illustrations (nominal 5 by 7 in.) in a 15 by 17-in. ring binder.~~

~~Volume II: 1-MV X Rays and Iridium-192 Reference Radiographs—Set of 34 illustrations (nominal 5 by 7 in.) in a 15 by 17-in. ring binder.~~

~~Volume III: 2-MV to 4-MV X Rays and Cobalt-60 Reference Radiographs—Set of 34 illustrations (nominal 5 by 7 in.) in a 15 by 17-in. ring binder.~~

~~NOTE 3—Although Category G—Mottling is listed for all three volumes, the appearance of mottling is dependent on the level of radiation energy. Mottling appears reasonably prominent in Volume I; however, because of the higher radiation energy levels mottling may not be apparent in Volume II nor Volume III.~~

1.3 The values stated in inch-pound units are to be regarded as the standard. SI values are shown 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:³

E94 [Guide for Radiographic Examination](#)—Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

E186 [Reference Radiographs for Heavy-Walled \(2 to 412-in. \(50.8 to 114-mm\)\) Steel Castings](#)—Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

~~E242 [Reference Radiographs for Appearances of Radiographic Images as Certain Parameters are Changed](#)—Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)~~

E280 [Reference Radiographs for Heavy-Walled \(412 to 12-in. \(114 to 305-mm\)\) Steel Castings](#)—Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

E1316 [Terminology for Nondestructive Examinations](#)
~~2.2~~ [Practice for Numbering Metals and Alloys in the Unified Numbering System \(UNS\)](#)

2.2 ASTM Adjuncts:⁴

Reference Radiographs for Steel Castings Up to 2 in. [51 mm](50.8 mm) in Thickness:

Volume I, Medium Voltage (Nominal 250 kVp) X-Rays⁵

Volume II, 1-MV X-Rays and Iridium-192⁶

Volume III, 2-MV to 4-MV X-Rays and Cobalt-60⁷

3. Terminology

3.1 *Definitions*—for definitions of terms used in this document, see Terminology—For definitions of terms relating to radiographic examination, see Terminology E1316, section D.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *production radiograph*—a radiograph under review for compliance with this standard.

3.2.2 *discontinuity type*—a specific discontinuity characterized by its cause and appearance. For example: linear shrinkage is a specific discontinuity type.

3.2.3 *discontinuity category*—a nomenclature system used for grouping discontinuity types. For example: linear shrinkage is assigned category “Ca” where “C” represents the general shrinkage category and “a” represents the specific linear shrinkage discontinuity type.

3.2.4 *discontinuity severity level*—a relative rank in terms of “quantity, size and distribution” of a collection of discontinuities where “1” is the least and “5” is the greatest “quantity, size and distribution” present on the reference radiograph. Example: a severity level of “1” is more restrictive (requires a higher level of workmanship fabrication quality) than a severity level of “2”.

3.2.5 *discontinuity class*—an assigned workmanship fabrication quality rating characterized by a discontinuity type, category and severity level. For example: “Ca 2” is a discontinuity class comprised of linear shrinkage with a severity level of “2”.

3.2.6 *classification specification*—a set of user defined acceptance criterion that prescribes the radiographic workmanship discontinuity class requirements for a specified user casting service application (see Sections 6 and 7).

3.2.7 *graded illustration*—a category of discontinuity that is assigned a severity level.

3.2.8 *ungraded illustration*—a category of discontinuity without an assigned severity level.

³ 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.

⁴ Available from ASTM Headquarters.

⁵ Order [RRE044601](#).

⁶ Order [RRE044602](#).

⁷ Order [RRE044603](#).

3.2.9 prorating—assignment of quantity, size and distribution on a production radiograph in proportion to a similar size area of a reference radiograph. For example: a production radiograph covers an area that is smaller than the unit area of a reference radiograph and the extent of discontinuity on the applicable reference radiograph is reduced proportionately.

4. Significance and Use

4.1 These reference radiographs are intended to provide a guide enabling recognition of discontinuities and their differentiation both as to type and severity level, where applicable.

4.2 They also provide example radiographic illustrations of discontinuities, that are ungraded, for reference in acceptance standards, specifications and drawings.

4.3 Sets of reference radiographs from which purchasers and suppliers may, by mutual agreement, select particular illustrations to serve as standards representing minimum acceptability are provided. At the same time, the standards so established may be unambiguously identified by alphabetic defect category (or type) designation and severity level.

4.4 The use of this document is not intended to be restricted to the specific energy level or to the absolute thickness limits that are contained in the document title. The title is intended to be descriptive and not restrictive. The document may be used, where there is no other applicable document, for other energy levels or thicknesses or both, for which it is found to be applicable and for which agreement has been reached between purchaser and manufacturer. Significance and Use

4.1 Graded reference radiographs are intended to provide a guide enabling recognition of specific casting discontinuity types and relative severity levels that may be encountered during typical fabrication processes. Reference radiographs containing ungraded discontinuities are provided as a guide for recognition of a specific casting discontinuity type where severity levels are not needed. These reference radiographs are intended as a basis from which manufacturers and purchasers may, by mutual agreement, select particular discontinuity classes to serve as standards representing minimum levels of acceptability (see Sections 6 and 7).

4.2 Reference radiographs represented by this standard may be used, as agreed upon in a purchaser supplier agreement, for energy levels, thicknesses or both outside the range of this standard when determined applicable for the casting service application. Severity levels of similar discontinuity categories and energy level range of E186 reference radiographs may alternatively be used, as determined appropriate for the casting service application, if so agreed upon in the purchaser supplier agreement (see Note 2 and 5.1).

4.3 Procedures for evaluation of production radiographs using applicable reference radiographs of this standard are prescribed in Section 8; however, there may be manufacturing-purchaser issues involving specific casting service applications where it may be appropriate to modify or alter such requirements. Where such modifications may be appropriate for the casting application, all such changes shall be specifically called-out in the purchaser supplier agreement or contractual document. Section 9 addresses purchaser supplier requisites for where weld repairs may be required.

5. Method of Preparation

5.1 The original radiographs used to prepare these three sets of reference illustrations were made from selected sections of actual production castings by the respective use of 250-kVp X rays, iridium-192 radiation, and cobalt-60 radiation on Class I and II film with a sensitivity as determined by standard 2-2T penetrameters (Guide

5.1 The original radiographs used to prepare the adjunct reference radiographs were produced on ASTM Class I or II film systems by the respective use of 250-kV X-ray, Iridium-192 and Cobalt-60 sources of radiation. The original radiographs were made with penetrameter sensitivity as determined by ASTM penetrameters (see Guide E94). The illustrations have been prepared to an optical density of 2.00 to 2.25 and have been made to retain the contrast of the original radiographs.) of 2-2T. The adjunct reference radiographs are reproductions prepared to an optical density of 2.00 to 2.25 and have substantially retained the contrast of the original radiographs. In preparing these reference radiographs, the objective was to obtain progressively graduated severity levels for each graded discontinuity category of this standard. Additionally, some overlap of severity levels may occur for discontinuity categories of this standard and similar discontinuity categories of E186 reference radiographs within the same energy level range. For example, aggregate gas porosity severity level 5 of this standard exceeds aggregate gas porosity severity level 1 of Reference Radiograph E186 (see 6.3).

5.2 Film Deterioration—Radiographic films are subject to wear and tear from handling and use. The extent to which the image deteriorates over time is a function of storage conditions, care in handling and amount of use. Reference radiograph films are no exception and may exhibit a loss in image quality over time. The radiographs should therefore be periodically examined for signs of wear and tear, including scratches, abrasions, stains, and so forth. Any reference radiographs which show signs of excessive wear and tear which could influence the interpretation and use of the radiographs should be replaced.

6. Determination of Radiographic Classification

6.1 For purposes of evaluation of castings, a determination must be made of the radiographic classification to be assigned to individual castings or specific areas of castings. The determination of the applicable radiographic classification shall be based on an evaluation of the casting applications, design, and service requirements. In these evaluations, consideration shall be given to such factors as pressure, temperature, section thickness, applicable design safety factor (preferably based on stress analysis), vibration, shock, resistance to corrosion, involvement of penetrating radiations or radiation products, and involvement of dangerous gases or liquids.