Designation: E 446 – 98

Standard Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness[1]

This standard is issued under the fixed designation E 446; 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.

1. Scope

1.1 These reference radiographs[2] illustrate various types and degrees of discontinuities occurring in steel castings that have section thicknesses up to 2 in. (51 mm) (Note 1).

NOTE 1—Reference radiographs previously used for this thickness range carried the designation E 71, 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 E 186 and E 280.

1.2 These reference illustrations consist of three separate sets (Note 2) as follows: (*1*) medium voltage (nominal 250-kVp) 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 discontinuites furnished as examples only, as follows:

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 *CA*—Severity levels 1 through 5.

1.2.3.2 *CB*—Severity levels 1 through 5.

1.2.3.3 *CC*—Severity levels 1 through 5.

1.2.3.4 *CD*—Severity levels 1 through 5.

1.2.4 *Category D*—Crack; 1 illustration.

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:

Volume I: Medium Voltage (*Nominal 250 kVp*) X-Ray Reference Radiographs—Set of 34 illustrations (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 (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 (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.

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 94 Guide for Radiographic Testing[3]

E 142 Method for Controlling Quality of Radiographic Testing[3]

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings[3]

E 242 Reference Radiographs for Appearances of Radiographic Images as Certain Parameters Are Changed[3]

E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings[3]

E 1316 Terminology for Nondestructive Examinations[3]

2.2 *ASTM Adjuncts:*[4]

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

Volume I, Medium Voltage (Nominal 250 kVp) X Rays[5]

[1] These reference radiographs are under the jurisdiction of ASTM Committee E-7 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.

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

[4] Available from ASTM Headquarters.

[5] Order RRE044601.

Volume II, 1-MV X Rays and Iridium-192[6]
Volume III, 2-MV to 4-MV X Rays and Cobalt-60[7]

3. Terminology

3.1 *Definitions*—for definitions of terms used in this document, see Terminology E 1316, section D.

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.

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 E 94 and Method E 142). The illustrations have been prepared to an *H* and *D* density of from 2.00 to 2.25 and have been made to retain the contrast of the original radiographs.

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.

6.2 For each portion of casting radiographed, the severity level for each class of discontinuity category should be clearly specified. Thus, Severity Level 2 might be specified for shrinkage, Category CA, and Severity Level 3 for Gas Porosity, Category A, since the latter are generally much less deleterious to tensile properties.

7. Classification Specifications

7.1 The applicable radiographic severity classification should be designated by the contracting agency in formal specifications or on drawings and in specific contracts or orders. The specifications, drawings, contracts, or order should also designate the sampling plan for the castings to be radiographed and the extent of radiographic coverage, radiographic practice to be followed (Guide E 94 and Method E 142), image quality desired (Note 4) as well as the severity of the acceptable discontinuity for the graded categories.

NOTE 4—For description of sensitivity or quality levels, see Guide E 94, Method E 142, and Reference Radiographs E 242.

8. Procedure for Evaluation

8.1 Compare the production radiographs of the casting submitted for evaluation with the reference radiographs of similar thickness that were exposed at an equivalent energy range.

8.2 When the severity level of discontinuities in the production radiograph being evaluated is equal to or better than the severity level in the specified reference radiograph, that part of the casting represented by the production radiograph shall be acceptable. If the production radiograph shows discontinuities of greater severity than the reference radiograph, that part of the casting shall be rejected.

8.3 An area of like size to the reference radiograph shall be the unit area by which the production radiograph is evaluated, and any such area or any area that shares a discontinuity with an adjacent film area shall meet the requirements as defined for acceptability. When the are of interest of a production radiograph is less than the unit area, such area of interest shall be prorated to the reference radiographic area.

8.4 When two or more categories of discontinuity are present in the same production radiograph, the predominating discontinuities, if unacceptable, shall govern without regard to the other categories of discontinuities, and the casting rejected until satisfactorily repaired.

8.5 When two or more categories of discontinuity are present to an extent equal to the maximum permissible level as shown in the pertinent standards for each category, then that part of the casting shall be judged unacceptable until satisfactorily repaired.

[6] Order RRE044602.
[7] Order RRE044603.

8.6 Reference radiographs are provided showing a variety of forms of shrinkage cavities. Production radiographs showing shrinkage shall be judged by the most representative reference radiograph.

8.7 Production radiographs showing porosity, gas, or inclusions shall be evaluated by the overall condition with regard to size, number, and distribution. The aggregate size of discontinuities shall not exceed the total accumulation in area of the discontinuities of the reference radiograph. It is not the intent that the maximum size of the illustrated discontinuity shall be the limiting size for a single production radiographic discontinuity, or that the number of discontinuities shown on the reference radiograph shall be the limiting number for production radiographs. Also, caution should be exercised in judging a large discontinuity against a collection of small discontinuities on the basis of size alone. Each of the factors of size, number, and distribution must be considered in balance.

8.8 Reference radiographs in this standard do not illustrate elongated or "worm hole" type of gas discontinuities. When this condition occurs in a production radiograph, it shall be evaluated by comparison with the most representative reference radiograph.

8.8.1 When the source has been placed perpendicular to the length of the gas hole, evaluate the production radiograph with a shrinkage reference radiograph.

8.8.2 When the source has been placed diametrically or"into" the diameter of the gas hole, evaluate the production radiograph with a gas reference radiograph.

8.9 A diffraction mottling pattern can occur on films of parts and sections where the grain size is large enough to be an appreciable fraction of the material thickness (Note 5). If diffraction mottling is suspected, there are a number of ways to demonstrate its presence. The diffraction mottling pattern shown in these cases is dependent principally upon the crystal geometry and the orientation of the crystals to the incident radiation. Therefore, for a given specimen, any change in this orientation will affect the diffraction pattern dramatically. This can be accomplished by a slight, 1 to 5° tilt of the part, with respect to the radiation beam or simply by shifting the center line of the radiation beam to a slightly different location from the first exposure. Indications from any porosity, shrinkage, or other discontinuity will move only slightly, while any mottling patterns present will change dramatically. If it is necessary or desirable to eliminate the mottling, the kV may be raised to reduce the amount of diffraction radiation. However, caution should be used so that the kV is not raised to the point that sensitivity is reduced excessively. If diffraction mottling is demonstrated to be present on a radiograph, this condition shall not be considered as prejudicial in evaluating the radiograph.

NOTE 5—Mottling is often associated with thin sections of austenitic steels, and copper base alloys such as copper nickel, tin bronzes, and nickel copper.

8.10 Hot tears and cracks exhibited on production radiographs may at times resemble linear type shrinkage. When doubt exists whether such indications are cracks or tears, or are linear shrinkage, all surfaces in the area of interest shall be ground and magnetic particle or liquid penetrant inspected as applicable. The extent and depth of grinding may require engineering judgment. If the indication does not appear on the surface, it shall be considered to be shrinkage.

8.11 The radiographic density of discontinuities in comparison with background density is a variable dependent on technical factors. It shall not be used as a criterion for acceptance or rejection in comparison with reference radiographs.

9. Keywords

9.1 castings; discontinuities; gamma ray; reference radiographs; steel; x-ray