Designation: E689 – 15

Standard Reference Radiographs for Ductile Iron Castings[1]

This standard is issued under the fixed designation E689; 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 standard extends the application of steel casting reference radiographs E446, E186, and E280 to ductile iron castings when determined appropriate for specific applications (see Section 4).

1.2 The reference radiograph films are an adjunct to E446, E186, or E280, and must be purchased separately from ASTM International, if needed (see 2.1). Categories and severity levels for each discontinuity type represented by these reference radiographs are described within each applicable standard above.

NOTE 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, 5, and 6 of this standard.

1.3 From time to time, there may be minor changes to the process for manufacturing of the reference radiograph adjunct materials. These changes could include changes in the films or processing chemicals used, changes in the dies or printing for the cardboard mats, etc.; however, in all cases, these changes are reviewed by the Illustration Monitoring Subcommittee and all reference radiographs are reviewed against a fixed prototype image to ensure that there are no changes to the acceptance level represented by the reference radiographs. Therefore, the adjunct reference radiographs remain valid for use with this standard regardless of the date of production or the revision level of the text 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:*[2]

E94 Guide for Radiographic Examination

E186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (50.8 to 114-mm)) Steel Castings

E242 Reference Radiographs for Appearances of Radiographic Images as Certain Parameters are Changed

E280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings

E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions*—For definitions of terms relating to radiographic examination, see Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *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.

3.2.3 *discontinuity class*—an assigned 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".

3.2.4 *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. For

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[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.

example, a severity level of "1" is more restrictive (requires a higher level of fabrication quality) than a severity level of "2".

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

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

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

3.2.8 *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.

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

4. Significance and Use

4.1 The casting process has demonstrated radiographic similarities between internal discontinuities for ductile cast iron and cast steel to the extent that the reference radiographs for steel castings are applicable. The exact application and usage of discontinuity classifications contained within steel casting reference radiographs must, however, give consideration to the differences in material properties between cast steel and ductile cast iron. In some applications, reference radiographs for steel castings may not be entirely applicable to ductile cast iron material dependent upon design or other usage criteria.

4.2 When employing steel casting reference radiographs to evaluate ductile iron castings, the applicable E446, E186, or E280 steel casting written standard shall also be used for specific guidance and evaluation procedures.

4.3 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. Reference radiographs represented by these steel casting standards may be used, as agreed upon in a purchaser supplier agreement, for radiation energy levels, thicknesses or both outside the range of these standards when determined applicable for the casting service application

5. Determination of Radiographic Classification

5.1 For purposes of evaluation of castings, a determination must be made of the radiographic discontinuity classifications to be assigned to individual castings or specific areas of castings. The determination of the applicable radiographic discontinuity 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, vibration, shock, resistance to corrosion, involvement of penetrating radiations or radiation products, and involvement of dangerous gases or liquids.

5.2 For each individual casting or specific area of a casting to be radiographed, the discontinuity class must be clearly specified. For example, severity level 2 might be specified for linear shrinkage, Category Ca, and severity level 3 for gas porosity, Category A, since the latter are generally much less deleterious to tensile properties (see Section 6).

5.3 When determining discontinuity severity levels for individual castings spanning multiple thickness ranges outside the range of this standard, consideration should be given to the potential for overlapping severity levels as described in the applicable written standard.

5.4 Production radiographs which are compared to reference radiographs should have an optical density in the area of interest in accordance with Guide E94 and a specified minimum radiographic sensitivity (quality level) of 2 % (2-2T).1 Other radiographic quality levels or optical densities may be designated, but then a corresponding change in severity level for each discontinuity category should be anticipated and hence specified.

6. Classification Specifications

6.1 The applicable radiographic discontinuity classification should be designated by the contracting agency in formal specifications, on drawings, or within specific contracts or orders. The specifications, drawings, contracts or order should also designate the examination sampling plan for the castings to be radiographed, the extent of radiographic coverage, radiographic practice to be followed (that is, Guide E94), image quality desired (see Note 2) as well as the severity of the acceptable discontinuity for the graded discontinuities.

NOTE 2—For description of radiographic sensitivity or quality levels, see Guide E94 and Reference Radiograph standard E242.

7. Evaluation Procedure

7.1 Compare the production radiographs of the casting submitted for evaluation with the reference radiographs exposed at an equivalent energy range within the thickness range of the applicable standard (unless otherwise specified—see Section 4).

7.2 When the severity level of discontinuities in the production radiograph being evaluated is equal to or less 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.

7.3 A unit area on the production radiograph shall be evaluated to a unit area of like size on the reference radiograph. Any evaluation unit area that shares a discontinuity with an adjacent unit evaluation area shall meet the minimum unit area acceptability requirements within the combined unit area. When the unit area of interest of a production radiograph is less than the unit area of the applicable reference radiograph, such unit area of the production radiograph shall be prorated to the reference radiographic area.

7.4 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 discontinuity and the casting rejected.

7.5 When two or more categories of discontinuity are present to an extent equal to the maximum permissible level as shown in the applicable standards for each category, then that part of the casting shall be judged unacceptable. When two or more categories of discontinuity are present in the same radiograph to an extent less than the maximum permissible level, as shown in the applicable standards for each category, the severity shall be evaluated by the overall aggregate condition. The aggregate condition is defined as the balance of quantity, size and distribution of the collection of discontinuities and shall not exceed the aggregate condition of the applicable reference radiograph.

7.6 Reference radiographs are provided showing a variety of shrinkage discontinuity types. Production radiographs showing shrinkage shall be judged by the most representative reference radiograph.

7.7 This standard does not specify limiting criteria for a single size of discontinuity, maximum number of discontinuities per unit area evaluated, specific dimensional spacing and/or alignment criterion between individual discontinuities or any other undefined discontinuity patterns. Unless otherwise specified by a purchaser supplier agreement (see Section 4), these discontinuity conditions on production radiographs shall be evaluated as aggregate conditions as defined in 7.5.

7.8 In general, there is no limit as to the extent of acceptable discontinuities in a casting, provided that no unit evaluation area throughout the casting contains discontinuities that exceed the severity of discontinuities in the applicable reference radiographs.

7.9 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.

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

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

7.10 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 (see Note 3). 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 3—Mottling is often associated with thin sections of austenitic steels, and copper base alloys such as copper nickel, tin bronzes, and nickel copper.

7.11 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, that indication shall be considered shrinkage.

7.12 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.

8. Weld Repair of Castings

8.1 When radiographic quality castings are repaired by welding, the reference radiographs to be used in the evaluation of the repaired sections must be specifically agreed upon between purchaser and supplier.

8.2 When casting discontinuities are removed for repairs, only the extent of discontinuity required to meet applicable reference standards need be removed

9. Keywords

9.1 classification; discontinuity; ductile iron castings; gamma ray; reference radiographs; X-ray