Designation: E 192 – 04

Standard Reference Radiographs of Investment Steel Castings for Aerospace Applications[1]

This standard is issued under the fixed designation E 192; 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 The reference radiographs provided in the adjunct to this standard illustrate various types and degrees of discontinuities occurring in thin-wall steel investment castings.[2] Use of this standard for the specification or grading of castings requires procurement of the adjunct reference radiographs which illustrate the discontinuity types and severity levels. They are intended to provide the following:

1.1.1 A guide enabling recognition of thin-wall steel casting discontinuities and their differentiation both as to type and degree through radiographic examination.

1.1.2 Example radiographic illustrations of discontinuities and a nomenclature for reference in acceptance standards, specifications and drawings.

1.2 Two illustration categories are covered as follows:

1.2.1 *Graded*—Six common discontinuity types each illustrated in eight degrees of progressively increasing severity.

1.2.2 *Ungraded*—Twelve single illustrations of additional discontinuity types and of patterns and imperfections not generally regarded as discontinuities.

1.3 The reference radiographs were developed for casting sections up to 1 in. [25.4 mm] in thickness.

1.4 This document may be used where there is no other applicable document existing or for other material thicknesses for which it is found to be applicable and for which agreement has been reached between the purchaser and manufacturer.

NOTE 1—The set of reference radiographs, produced with X-rays in the range from 130 to 250 kVp, consist of 16 plates (8½ by 11 in. [216 by 279 mm]) in a 9¾ by 11½-in. [248 by 292-mm] ring binder.

1.5 The values stated in inch-pound units are to be regarded as the standard.

1.6 *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]

E 94 Guide for Radiographic Examination

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

E 1316 Terminology for Nondestructive Examinations

2.2 *ASTM Adjuncts:*

Reference Radiographs of Investment Steel Castings for Aerospace Applications[4]

3. Terminology

3.1 *Definitions*—Definitions of terms used in this standard may be found in Terminology E 1316, Section D.

3.2 The terms relating to discontinuities present in these reference radiographs are described based upon radiographic appearance. The terms “darker” and “lighter” as used in this standard refer to the optical density of a radiographic film. Where other radiographic imaging media are used, these terms should be understood to refer to areas of greater or lesser radiologic transmission, respectively.

3.2.1 *Gas*:

3.2.1.1 *gas holes*—round or elongated, smooth edged dark spots, occurring individually, in clusters, or distributed randomly throughout the casting.

3.2.2 *Shrinkage*:

3.2.2.1 *shrinkage cavity*— an area with distinct jagged boundaries.

3.2.2.2 *shrinkage, sponge*—an area, lacy in texture, with a very diffuse outline.

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[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] The reference radiographs are considered to be applicable to all thin-wall steel castings, requiring close tolerances. Such castings generally include those made by the lost wax, frozen mercury, ceramicast or shell mold processes.

[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, Order RRE0192.

3.2.2.3 *shrinkage, dendritic*—a distribution of very fine lines or small elongated cavities that may vary in darkness and are usually unconnected.

3.2.2.4 *shrinkage, filamentary*—usually a continuous structure of connected lines or branches of variable length, width and darkness, or occasionally, a network.

3.2.3 *Heterogeneities*:

3.2.3.1 *foreign material less dense*—irregularly shaped indications darker than the adjacent material, but lighter than gas holes of similar magnitude.

3.2.3.2 *foreign material more dense*—irregularly shaped indications lighter than the adjacent material.

3.2.4 *Discrete Discontinuities*:

3.2.4.1 *hot tears*—ragged dark lines of variable width and numerous branches. They have no definite lines of continuity and may exist in groups. They may originate internally or at the surface.

3.2.4.2 *cold cracks*— straight or jagged lines usually continuous throughout their length. Cold cracks generally appear singly. They start at the surface.

3.2.4.3 *cold shut*—a distinct dark line or band of variable length and definite smooth outline.

3.2.4.4 *misruns*—prominent dark areas of variable dimensions with a definite smooth outline.

3.2.4.5 *core shift*—a variation in wall thickness.

3.2.5 *defective mold*, is illustrated by such common defects as mold crack, mold ridge, rattail, scab, and fin. These conditions appear as areas or lines of different darkness than the adjacent material. Illustrations of the defect include:

3.2.5.1 *mold buckle, positive*—a lightened irregularly shaped area lightest near the center and gradually increasing in darkness away from the center.

3.2.5.2 *mold buckle, negative*—a darkened irregularly shaped area darkest near the center and gradually getting lighter away from the center.

3.2.6 *Diffraction Pattern*:

3.2.6.1 *columnar*—few or many lines or arrays of linear indications that are both darker and lighter than the surrounding area.

3.2.6.2 *mottled*—indistinct areas of darker and lighter images.

4. Description

4.1 The range of radiographic illustrations is given in Table 1. The graded discontinuities are illustrated in eight grades. These grades range from that discernible at a 2-1T quality level or better to that evident of poor workmanship and commonly rejectable in commercial practice.[5] The ungraded illustrations have been included to establish the appearance of the radiographic indications they represent in thin-wall steel castings. The alloys used are listed in Table 2.

TABLE 1 Range of Illustration

Illustrations	Illustration Plate Thickness, in. [mm]	Applicable Casting Thickness, in. [mm]
Graded:		
Gas holes	⅛ [3.2]	¼ [6.4] and under
Gas holes	⅜ [9.5]	Over ¼ to ½ [6.4 to 12.7], incl
Gas holes	¾ [19]	Over ½ to 1 [12.7 to 25.4], incl
Shrinkage cavity	¾ [19]	All thicknesses
Shrinkage, sponge	⅛ [3.2]	¼ [6.4] and under
Shrinkage, sponge	⅜ [9.5]	Over ¼ to ½ [6.4 to 12.7], incl
Shrinkage, sponge	¾ [19]	Over ½ to 1 [12.7 to 25.4], incl
Shrinkage, dendritic	⅛ [3.2]	¼ [6.4] and under
Shrinkage, dendritic	⅜ [9.5]	Over ¼ to ½ [6.4 to 12.7], incl
Shrinkage, dendritic	¾ [19]	Over ½ to 1 [12.7 to 25.4], incl
Shrinkage, filamentary	¾ [19]	All thicknesses
Foreign material, less dense	⅛ [3.2]	¼ [6.4] and under
Foreign material, less dense	⅜ [9.5]	Over ¼ to ½ [6.4 to 12.7], incl
Foreign material, less dense	¾ [19]	Over ½ to 1 [12.7 to 25.4], incl
Ungraded:		
Discrete Discontinuities:		
Foreign material, more dense	⅜ [9.5]	
Hot tear	⅜ [9.5]	
Cold crack	⅜ [9.5]	
Cold shut	⅜ [9.5]	
Misrun	⅜ [9.5]	
Core shift	⅜ [9.5]	
Defective Mold:		
Mold buckle, positive	⅜ [9.5]	
Mold buckle, negative	⅜ [9.5]	
Mold ridge	⅜ [9.5]	
Excess metal in cracked core	⅜ [9.5]	
Diffraction pattern:		
Columnar	⅜ [9.5]	
Mottled	⅜ [9.5]	

TABLE 2 Alloys Used

Illustration	Alloy
Gas holes, ⅛ in. [3.2 mm], ⅜ in. [9.5 mm], and ¾ in. [19 mm]	4330
Foreign material less dense, ⅛ in. [3.2 mm], ⅜ in. [9.5 mm] and ¾ in. [19 mm]	4330
Shrinkage cavity, ¾ in. [19 mm]	4330
Shrinkage, sponge, ⅛ in. [3.2 mm]	AMS 5355A
Shrinkage, sponge, ⅜ in. [9.5 mm] and ¾ in. [19 mm]	4330
Shrinkage, dendritic, ⅛ in. [3.2 mm], ⅜ in. [9.5 mm], and ¾ in. [19 mm]	4330
Shrinkage, filamentary, ¾ in. [19 mm]	4330
Foreign material more dense	4330
Cold shut	ACI HK
Hot tear	4330
Cold crack	4330
Misrun	4330
Core shift	4330
Mold buckle, positive	AMS 5382B
Mold buckle, negative	AMS 5360A
Mold ridge	AMS 5382B
Excess metal in cracked core	ACI CF-8M
Diffraction pattern, columnar	ACI HK
Diffraction pattern, mottled	ACI HK

[5] Each grade of a given discontinuity type is contained in an individual approximate 2 by 2¾-in. [51 by 70-mm] machined casting block. These blocks were inserted in steel keeper plates with radiographic characteristics equivalent to the casting blocks. The assembled plates were then radiographed to obtain the various gradations shown.

4.2 The ASTM penetrameters included on each graded plate were used for contrast and resolution control only, and in accordance with Practice E 1025. All of the references are original radiographs. The radiographic technique used was in accordance with Guide E 94 and produced a density of from 2.00 to 2.25.

5. Basis for Application

5.1 The reference radiographs may be applied as acceptance standards in a variety of ways tailored to the specific application. Application of these reference radiographs as acceptance standards should be based on the intended use of the product and the following considerations (see Note 2):

5.1.1 The discontinuities in the specified reference radiograph are acceptable in the specified unit area of the casting being examined. The size of this unit area should be specified in the acceptance criteria.

5.1.2 Any combination or portion of these radiographs may be used as is relevant to the particular application. Different grades or acceptance limits may be specified for each discontinuity type. Furthermore, different grades may be specified for different regions or zones of a component.

5.1.3 Special considerations may be required where more than one discontinuity type are present in the same area. Any modifications to the acceptance criteria required on the basis of multiple discontinuity types must be specified.

5.1.4 Where the reference radiographs provide only an ungraded illustration of a discontinuity, an acceptance level may be specified by referencing a maximum discontinuity size, or a percentage of the discontinuity size illustrated.

5.1.5 Where the reference radiograph contains multiple discontinuities, as in the case of gas holes, acceptance may be based upon the aggregate size of the discontinuities, maximum discontinuity size in the reference radiograph, the spacing between discontinuities, or a combination of these and/or other criteria.

5.1.6 As a minimum the acceptance criteria should contain information addressing; zoning of the part (if applicable), the maximum acceptable severity level for each discontinuity type, and the specified area that the reference radiograph is to be applied.

NOTE 2—Caution should be exercised in specifying the grade of discontinuity to be met in a casting. Casting design coupled with foundry practice should be considered. It is advisable to consult with the manufacturer/foundry before establishing the acceptance criteria to ensure the desired quality level can be achieved.

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. Keywords

6.1 aerospace; discontinuities; investment castings; reference radiographs; steel; x-ray