Designation: E 155 – 05

Standard Reference Radiographs for Inspection of Aluminum and Magnesium Castings[1]

This standard is issued under the fixed designation E 155; 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.

These Reference Radiographs have been developed in cooperation with the Quality Control Committee and Aerospace Research and Testing Committee of the Aerospace Industries Association.

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

1. Scope

1.1 These reference radiographs illustrate the types and degrees of discontinuities that may be found in aluminum-alloy and magnesium-alloy castings. The castings illustrated are in thicknesses of ¼ in. [6.35 mm] and ¾ in. [19.1 mm]. The reference radiograph films are an adjunct to this document and must be purchased separately from ASTM International if needed.

1.2 These film reference radiographs are not intended to illustrate the types and degrees of discontinuities found in aluminum-alloy castings when performing digital radiography. If performing digital radiography of aluminum-alloy castings, refer to Digital Refererence Image Standard E 2422. Magnesium-alloy digital reference images are not currently available from ASTM International.

1.3 This document may be used where no other applicable document exists, for other material thicknesses for which it has been found to be applicable and for which agreement has been reached between the purchaser and the manufacturer.

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

1.5 *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.*

NOTE 1—Vol I: The set of reference radiographs consists of 13 plates covering discontinuities in aluminum-alloy castings and 10 plates covering discontinuities in magnesium-alloy castings. Each plate is held in an 8½ by 11-in. [216 by 279-mm] cardboard frame and each plate illustrates eight grades of severity for the discontinuity in approximately a 2 by 2-in. [51 by 51-mm] area. The cardboard frames are contained in a 10½ by 11½-in. [267 by 292-mm] ring binder.

Vol. II: The set of reference radiographs consists of four plates covering discontinuities in magnesium-alloy castings only. Each plate is held in an 8½ by 11-in. [216 by 279-mm] cardboard frame and illustrates eight grades of severity for the discontinuity (with the exception of discrete discontinuities, where only one example of each discontinuity is given).

NOTE 2—Reference radiographs applicable to aluminum and magnesium die castings up to 1 in. [25 mm] in thickness are contained in Reference Radiographs E 505.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 94 Guide for Radiographic Examination

E 505 Reference Radiographs for Inspection of Aluminum and Magnesium Die Casting

E 1316 Terminology for Nondestructive Examinations

E 2422 Digital Reference Images for Inspection of Aluminum Castings

2.2 *ASTM Adjuncts:*

Reference Radiographs for Inspection of Aluminum and Magnesium Castings:

Volume I, Aluminum and Magnesium Castings[3]

Volume II, Magnesium Castings[4]

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 The terms relating to discontinuities used in these reference radiographs are described based upon radiographic appearance.

3.2.2 *foreign materials*—appear as isolated, irregular, or elongated variations of film density, not corresponding to variations in thickness of material, nor to cavities. They may be due to the presence of sand, slag, oxide or dross, or metal of different density.

[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.

Current edition approved Nov. 15, 2005. Published December 2005. Originally approved in 1960. Last previous edition approved in 2005 as E 155 - 00(2005)ε1.

[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.

[3] Available from ASTM International Headquarters. Order Reference Radiograph No. RRE015501.

[4] Available from ASTM International Headquarters. Order Reference Radiograph No. RRE015502.

3.2.3 *gas holes*—appear as round or elongated, smooth-edged dark spots, occurring individually, in clusters, or distributed throughout the casting.

3.2.4 *gas porosity*—represented by round or elongated dark spots corresponding to minute voids usually distributed through the entire casting.

3.2.5 *microshrinkage (feathery type)*—microshrinkage having an elongated appearance resembling feather-like streaks.

3.2.6 *microshrinkage (sponge type)*—microshrinkage having a spongelike appearance, and more massive and equiaxed than the feathery type.

3.2.7 *reacted sand inclusions*—appear on radiograph as "spotty segregation," that is, sharply defined round light areas, about 1 mm in diameter, and often with the rim lighter than the center. They are entrapped sand particles that underwent reaction with molten magnesium alloys containing zirconium (Note 3).

3.2.8 *segregations*—appear as variations in film density which can be explained by segregation of elements of atomic numbers different from that of the matrix.

3.2.8.1 *gravity segregation*—appears white on radiograph and may range from a mottling-type effect through white-diffused spots blending with the matrix, to a cloud-like appearance in more severe cases. They are agglomerations of particles precipitated at temperatures above liquidus (Note 3).

3.2.8.2 *eutectic segregation*—type of segregation is generally represented when a defect or discontinuity develops during solidification and is fed with a near eutectic residual liquid rich with alloying elements that have a high X-ray attenuation. One exception to this enrichment as illustrated in Reference Radiographs E 155 is flow line (or eutectic depletion), where there is a local impoverishment of the alloying elements that have a high X-ray attenuation (Note 3).

(*1*) *eutectic segregation—microshrinkage type*—type of segregation develops when a microshrinkage develops during solidification, and is fed with residual liquid rich in dense alloying elements such as thorium. The area will show light on a radiograph (Note 3).

(*2*) *eutectic segregation—pipe-shrink type*—type of segregation develops during solidification when a pipe shrink forms and is immediately filled with eutectic liquid rich in high X-ray attenuation alloying elements. The area shows light on a radiograph as a feathery or dendritic feature (Note 3).

(*3*) *eutectic segregation—hot-tear type*—type of segregation develops during solidification when the hot tear that takes place is immediately filled with liquid rich in alloying elements high in X-ray attenuation. The defect shows as white or light irregular defined lines (Note 3).

(*4*) *eutectic depletion—flow line*—type of segregation develops when a section of a mold is filled by liquid and solidifies at the front before liquid from another feed meets the solid front. A portion of the solid front then partially melts; otherwise, the discontinuity would be a cold shut. Solidification begins after this remelt and the initial crystals are of high purity and contain fewer high-density alloying elements than the melt average. Since the metal is still flowing across these crystals, the composition ahead of this solidifying front is depleted. This depletion of the eutectic shows on the radiograph as a dark diffused line (Note 3).

(*5*) *oxide inclusions in magnesium alloys containing zirconium*—show on a radiograph as well defined light area of irregular shape and size resembling a radiograph of a compacted fine steel wool. It is composed of complex magnesium oxide film with high zirconium content, and, if present, rare earths and thorium oxides also. It is often associated with zirconium-rich particles.

NOTE 3—More detailed descriptions of these discontinuities can be found in the article, "New Reference Radiographs for Magnesium Alloy Castings," by B. Lagowski, published in the *Journal of Testing and Evaluation*, Vol 2, No. 4, July 1974.

3.2.9 *shrinkage cavity*—appears as a dendritic, filamentary, or jagged darkened area.

3.2.10 *shrinkage porosity or sponge (nonferrous alloys)*—a localized lacy or honeycombed darkened area.

4. Significance and Use

4.1 These radiographs are intended for reference only but are so designed that acceptance standards, which may be developed for particular requirements, can be specified in terms of these radiographs. The illustrations are radiographs of castings that were produced under conditions designed to develop the discontinuities. The radiographs of the ¼-in. [6.35-mm] castings are intended to be used in the thickness range up to and including ½ in. [12.7 mm]. The radiographs of the ¾-in. [19.1-mm] castings are intended to be used in the thickness range of over ½ in. to and including 2 in. [51 mm]. The grouping and system of designations are based on considerations of the best practical means of making these reference radiographs of the greatest possible value.

4.2 *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.

5. Basis for Application

5.1 The reference radiographs may be applied as acceptance standards tailored to the end use of the product. Application of these reference radiographs as acceptance standards should be based on the intended use of the product and the following considerations (see Note 4).

5.1.1 An area of like size to that of the reference radiograph shall be the unit area by which the production radiograph is evaluated, and any such area shall meet the requirements as defined for acceptability.

5.1.2 Any combination or portion of these reference 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 is 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, acceptance criteria may be specified by referencing a maximum discontinuity size, or percentage of the discontinuity size illustrated.

5.1.5 Production radiographs containing porosity, gas or inclusions may be rated by the overall condition with regard to size, number, and distribution. These factors should be considered in balance.

5.1.6 As a minimum the acceptance criteria should contain information addressing: zoning of the part (if applicable), the acceptable severity level for each discontinuity type, and the specified area to which the reference radiographs are to be applied.

NOTE 4—Caution should be exercised in specifying the acceptance criteria 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.

6. Description

6.1 The radiographs listed in Table 1 illustrate each type of discontinuity in eight grades. The radiographs listed in Table 2 illustrate each type of discontinuity in eight grades, with the exception of pipe shrink, flow line, hot tear and oxide inclusion, where a single ungraded illustration is given for each. Although eight grades of each discontinuity are shown (with the above exceptions), a numerically smaller graded set of discontinuities based on these reference radiographs could be used for acceptance standards. Each grade is illustrated in approximately a 2 by 2-in. [51 by 51-mm] area. The radiographic technique used is in agreement with Guide E 94, and produced a density of 2.0 to 2.25.

6.2 The alloys used to reproduce the various discontinuities were as listed in Table 3.

NOTE 5—Misruns, core shift, cold shut, and surface irregularities are not illustrated, as they are readily identifiable by surface inspection or by other means of nondestructive testing.

6.3 All of these references are original radiographs; they should be viewed by transmitted light.

TABLE 1 Reference Radiographs for Aluminum and Magnesium Castings—Volume I

Discontinuity	Casting Thickness, in.[A]	Applicable Casting Thickness, in.[A]
Aluminum-Alloy Castings		
Gas holes	¼	up to ½, incl
Gas holes	¾	over ½ to 2, incl
Gas porosity (round)	¼	up to ½, incl
Gas porosity (round)	¾	over ½ to 2, incl
Gas porosity (elongated)	¼	up to ½, incl
Gas porosity (elongated)	¾	over ½ to 2, incl
Shrinkage cavity	¼	All thicknesses
Shrinkage (sponge)	¼	up to ½, incl
Shrinkage (sponge)	¾	over ½ to 2, incl
Foreign material (less dense)	¼	up to ½, incl
Foreign material (less dense)	¾	over ½ to 2, incl
Foreign material (more dense)	¼	up to ½, incl
Foreign material (more dense)	¾	over ½ to 2, incl
Magnesium-Alloy Castings		
Gas holes	¼	up to ½, incl
Gas holes	¾	over ½ to 2, incl
Microshrinkage (feathery)	¼	up to ½, incl
Microshrinkage (feathery)	¾	over ½ to 2, incl
Microshrinkage (sponge)	¼	up to ½, incl
Microshrinkage (sponge)	¾	over ½ to 2, incl
Foreign material (less dense)	¼	up to ½, incl
Foreign material (less dense)	¾	over ½ to 2, incl
Foreign material (more dense)	¼	up to ½, incl
Foreign material (more dense)	¾	over ½ to 2, incl

[A] 1 in. = 25.4 mm.

TABLE 2 Reference Radiographs for Magnesium Castings—Volume II

Discontinuity	Casting Thickness, in.[A]	Applicable Casting Thickness, in.[A]
Eutectic segregation (discrete discontinuities)—pipeshrink, flow line, hot tears, oxide inclusions	¼	all thicknesses
Reacted sand inclusion	¼	all thicknesses
Eutectic segregation (microshrinkage type)	¼	all thicknesses
Gravity segregation	¼	all thicknesses

[A] 1 in. = 25.4 mm.

7. Keywords

7.1 aluminum; castings; discontinuities; magnesium; reference radiographs; X-ray

TABLE 3 Actual Alloys Used to Reproduce Discontinuities

Discontinuity	Alloy Used
Aluminum	
Gas holes	356
Gas porosity (round)	356
Gas porosity (elongated)	195
Shrinkage cavity	356
Shrinkage (sponge)	356
Foreign material (less dense)	356
Foreign material (more dense)	356
Magnesium	
Gas holes	ZK51A
Eutectic segregation and flow line	EZ33A
Gravity segregation	ZK91
Microshrinkage (feathery)	AZ91C
Microshrinkage (sponge)	AZ91C
Foreign material (less dense)	AZ91C
Foreign material (more dense)	AZ91C
Reacted sand inclusions	HK31A
Oxide inclusion in magnesium alloys containing zirconium	HZ11