Designation: E1320 – 05

Standard Reference Radiographs for Titanium Castings[1]

This standard is issued under the fixed designation E1320; 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 are reproductions of original radiographs and are supplied as a means for establishing some of the categories and severity levels of discontinuities in titanium castings that may be revealed by radiographic examination. 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 should be used in accordance with contractual specifications.

NOTE 1—The original radiographs produced for Volume I were taken with X-rays in the range of 110 KV to 220 KV. The original radiographs produced for Volume II were taken with X-rays in the range of 200 K to 340 KV.

1.2 These reference radiographs consist of two volumes. Volume I, described in Table 1, is applicable to a wall thickness of up to 1 in. [0 to 25.4 mm]. Volume II, described in Table 2, is applicable to a wall thickness of over 1 in. to 2 in. [25.4 mm to 50.8 mm]. The standard may be used, where there is no other applicable standard, for other thicknesses for which agreement has been reached between purchaser and manufacturer.

1.3 The plates produced to serve for use in this standard were purposely cast to exhibit the desired discontinuity. The plates were cast using different processes as shown in Table 1 and Table 2. Hot isostatic pressing was not used on any of the plates.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in brackets are for informational purposes only.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E94 Guide for Radiographic Examination

E1316 Terminology for Nondestructive Examinations

2.2 *ASTM Adjuncts:*

Reference Radiographs for the Inspection of Titanium Castings

Volume I, applicable up to 1 in. [25.4 mm][3,4]

Volume II, applicable over 1 in. to 2 in. [25.4 mm to 50.8 mm][4,5]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, see Terminology E1316.

4. Significance and Use

4.1 These reference radiographs are designed so that acceptance standards, which may be developed for particular requirements, can be specified in terms of these radiographs. The radiographs are of castings that were produced under conditions designed to produce the discontinuities. The reference radiographs are intended to be used for casting thickness ranges in accordance with Table 1 and Table 2.

5. Description of Discontinuities

5.1 This section is provided to aid in the identification and classification of discontinuities. It briefly describes the radiographic appearance of those discontinuities in the reference radiograph adjuncts and indicates their probable cause in titanium. The radiographic appearance of different discontinuities can at times be very similar. Therefore, care should always

[1] This standard is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.02 on Reference Radiographs.

Current edition approved January 1, 2005. Published January 2005. Originally approved in 1990. Last previous edition approved in 2000 as E1320 - 00. DOI: 10.1520/E1320-05.

[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. RRE132001.

[4] Volumes I and II are available from ASTM International Headquarters as a set. Order Reference Radiographs RRE1320CS.

[5] Available from ASTM International Headquarters. Order Reference Radiograph No. RRE132002.

TABLE 1 VOLUME I—0 to 1 in.

Discontinuity	Casting Process	Alloy	Plate Thickness, in.	Applicable Casting Thickness, in.
Gas hole	Centrifugal ram graphite	Ti 6AL 4V	N/A	up to 1
Clustered holes	Centrifugal precision	Ti 6AL 4V	¼	up to ⅜
Clustered holes	Centrifugal precision	Ti 6AL 4V	½	over ⅜ to ⅝
Clustered holes	Centrifugal precision	Ti 6AL 4V	¾	over ⅝ to 1
Scattered gas holes	Top pour lost wax	Ti 6AL 4V	¼	up to ⅜
Scattered gas holes	Top pour lost wax	Ti 6AL 4V	½	over ⅜ to ⅝
Scattered gas holes	Top pour lost wax	Ti 6AL 4V	¾	over ⅝ to 1
Shrinkage cavity	Centrifugal ram graphite	Ti 6AL 4V	½	over ¼ to ⅝
Shrinkage cavity	Centrifugal ram graphite	Ti 6AL 4V	¾	over ⅝ to 1
Scattered shrinkage cavity	Top pour lost wax	Ti 6AL 4V	¼	up to ⅜
Scattered shrinkage cavity	Top pour lost wax	Ti 6AL 4V	½	over ⅜ to ⅝
Scattered shrinkage cavity	Top pour lost wax	Ti 6AL 4V	¾	over ⅝ to 1
Centerline shrinkage	Centrifugal ram graphite	Ti 6AL 4V	¼	up to ⅜
Centerline shrinkage	Centrifugal ram graphite	Ti 6AL 4V	½	over ⅜ to ⅝
Centerline shrinkage	Centrifugal ram graphite	Ti 6AL 4V	¾	over ⅝ to 1
Less dense inclusions	Varied	Ti 6AL 4V	N/A	up to 1
More dense inclusions	Varied	Ti 6AL 4V	N/A	up to 1

NOTE 1—1 in. = 25.4 mm.

TABLE 2 VOLUME II—Over 1 in. to 2 in.

Discontinuity	Casting Process	Alloy	Plate Thickness, in.	Applicable Casting Thickness, in.
Gas hole	Centrifugal ram graphite	Ti 6AL 4V	1¼	over 1 to 2
Clustered gas holes	Centrifugal ram graphite	Ti 6AL 4V	1¼ to 1¾	over 1 to 2
Scattered gas holes	Centrifugal ram graphite	Ti 6AL 4V	1¼	over 1 to 1½
Scattered gas holes	Centrifugal ram graphite	Ti 6AL 4V	1¾	over 1½ to 2
Shrinkage cavity	Centrifugal ram graphite	Ti 6AL 4V	1¼	over 1 to 1½
Shrinkage cavity	Centrifugal ram graphite	Ti 6AL 4V	1¾	over 1½ to 2
Centerline shrinkage	Centrifugal ram graphite	Ti 6AL 4V	1¼	over 1 to 1½
Centerline shrinkage	Centrifugal ram graphite	Ti 6AL 4V	1¾	over 1½ to 2

NOTE 1—1 in. = 25.4 mm.

be taken during the process of identification. In extreme cases other methods of identification, either nondestructive or destructive, may need to be employed to obtain positive identification.

5.1.1 *Gas*—Gas in its various forms is usually caused by the reaction of molten titanium with the mold or residual material left in the mold. Gas tends to migrate to the upper portions of the casting. The formation of clustered or scattered gas holes results from the generation of larger amounts of gas than a single gas hole. Whether the larger amount of gas spreads out or is confined to a small area is dependent upon a number of factors including casting process, reaction area, solidification rate, wall thickness, and geometry.

5.1.1.1 *Gas hole*—A spherical void formed through the release and subsequent entrapment of gas during solidification. A gas hole will appear as a dark round spot on the radiograph.

5.1.1.2 *Clustered gas holes*—A closely nested group of dark round voids concentrated within a self-defined boundary area.

5.1.1.3 *Scattered gas holes*—Multiple voids appearing as dark round spots on the radiograph. They are randomly spread throughout a part or area of a part to a lesser concentration than clustered gas holes but with the potential to degrade the casting through their interaction which precludes their evaluation on an individual basis.

5.1.2 *Shrinkage*—While at times the appearance of shrinkage in titanium may be radiographically similar to shrinkage in steel, the faster solidification rate of titanium has a dramatic effect on the conditions under which each shrinkage type will occur in titanium. Other factors which influence the formation of shrinkage are wall thickness and thickness transition gradients, gate size and orientation, mold design, casting configuration, metal/mold temperature, and pouring rate and method. All the types of shrinkage described in 5.1.2.1 through 5.1.2.3 have a degree of overlap. However, each is most likely to occur under a specific set of conditions primarily influenced by metal feed, section thickness and cooling rate.

5.1.2.1 *Scattered shrinkage*—Appears on a radiograph as dark fine lacy or filamentary voids of varying densities. These voids are usually uniformly spread throughout the area of the casting where shrinkage is occurring and are relatively shallow. Scattered shrinkage cavities are most common in wall thicknesses ranging from ⅛ in. to ¾ in. [3.175 mm to 19.05 mm] being more prevalent in the thinner sections of the range. Scattered shrinkage cavities are caused by varying cooling rates in the same area of a casting that can result from differences in wall thickness or other factors.

5.1.2.2 *Centerline shrinkage*—Characterized by a more discrete dark indication than scattered shrinkage. The indication has definite borders consisting of a lacy network of varying density or a network of interconnected elongated voids. Centerline shrinkage is located primarily in the center of the material cross section with a tendency to orient toward gates or risers. It is more common in thickness over ¼ in. [6.35 mm].

5.1.2.3 *Shrinkage cavity*—Appears as a dark void with smooth sides taking an appearance very similar to a gas hole. A shrinkage cavity, particularly in thicker wall sections, is