Designation: E 1320 – 95

Designation: E 1320 – 00

An American National Standard

Standard Reference Radiographs for Titanium Castings[1]

This standard is issued under the fixed designation E 1320; 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] This standard is under the jurisdiction of ASTM Committee ~~E-7~~ E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.02 on Reference Radiographs.

Current edition approved Dec. 10, ~~1995.~~ 2000. Published February ~~1996.~~ 2001. Originally published as E 1320 – 90. Last previous edition E 1320 – 9~~1~~5.

1. Scope

1.1 These reference radiographs 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. 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, thicknesses, or both, for which agreement has been reached between purchaser and manufacturer. 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).

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 parentheses 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:*

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. = 15.4 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. = 15.4 mm.

E 94 Guide for Radiographic ~~Testing~~ Examination[2]
E 1316 Terminology for Nondestructive Examinations[2]
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 document, see Terminology E 1316.

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 wth 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 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

[2] *Annual Book of ASTM Standards*, Vol 03.03.
[3] Available from ASTM Headquarters. Order RRE132001.
[4] Volumes I and II are available from ASTM Headquarters as a set. Order RRE1320CS.
[5] Available from ASTM Headquarters. Order RRE132002.

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 usually larger than a single gas hole would be. The cavity is formed during the cooling process due to a lack of feeding metal. The cavity compensates for the rapid solidification taking place at the surface of the casting, thereby forming the cavity in the center area of the wall. Shrinkage cavity has a definite tendency to occur near hot spots where walls are ½ in. (12.7 mm) thick or more.

5.1.3 *Less dense inclusions*—Appear as dark indications in a variety of shapes and sizes on a radiograph. Inclusions may be found in groups or appear singularly. Less dense inclusions can be caused by contaminants in the molten titanium, residual materials left on the surface of the mold, or broken pieces of the mold becoming entrapped during solidification.

5.1.4 *More dense inclusions*—Appear as light indications in a variety of shapes and sizes on a radiograph. More dense inclusions can be caused by contaminants introduced in the same manner as less dense inclusions, or tungsten introduced during weld repairs.

6. Method of Preparation

6.1 The original radiographs used to prepare the adjunct reference radiographs were produced on high contrast, fine grained film. The radiographs were made with a penetrameter sensitivity as determined by ASTM penetrameters (see Guide E 94) of 2-2T. The reproductions of the original radiographs have been made with a density within the range of 2.0 to 2.25. They have retained substantially the contrast of the original radiographs.

6.2 In selecting the individual reference radiographs, the aim was to obtain a graduated series for each type of discontinuity. It is not intended that like numbered levels or classes on the different reference radiograph pages be considered to cause equal degradation in the ultimate performance, or serviceability, or both, of any particular casting.

6.2.1 The criteria used to select the individual radiographs representing each severity level were based on the size, shape, spacing, alignment, and radiographic density of the discontinuities present.

6.3 In some cases, plates other than the thickness indicated on the reference radiographs were utilized to complete individual severity levels.

6.4 For the discontinuity classifications of gas hole, less dense inclusions, and more dense inclusions, only one series of eight gradations is displayed for each. These gradations are intended to be used over the entire thickness range applicable to the volume. Therefore, careful consideration should be taken when specifying allowable severity levels for the thicker wall sizes.

6.5 *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.

7. Basis for Application

7.1 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:

~~7.1.1 Unless otherwise specified, discontinuities~~

7.1.1 An area of ~~equal or lesser severity than~~ like size to that of the ~~specified~~ reference radiograph ~~are acceptable in any specified unit area of~~ shall be the ~~casting. The size of the~~ unit area ~~should be specified in~~ by which the ~~acceptance criteria. Discontinuities more severe than those in the specified reference~~ production radiograph is evaluated, and any such area shall ~~be considered rejectable.~~ meet the requirements as defined for acceptability.

7.1.2 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. Further, different grades may be specified for various regions or zones of the component.

7.1.3 Special consideration may be required where more than one discontinuity type is present in the same area. Any modification of the acceptance criteria required on the basis of multiple discontinuity types must be specified.

~~7.1.4 Where the reference radiograph contains multiple discontinuities, as in that case of~~

7.1.4 Production radiographs containing porosity, gas ~~holes, acceptance~~ or inclusions may be ~~based upon~~ rated by the ~~aggregate area of the discontinuities, the maximum discontinuity size~~ overall condition with regard to size, number, and distribution. These factors should be considered in ~~the reference radiograph, the spacing between discontinuities, or a combination of these or other criteria, or both.~~ balance.

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

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

8. Procedure for Evaluation

8.1 Compare the production radiographs of the casting submitted for evaluation with the reference radiographs applicable to designated wall thickness in accordance with the written acceptance criteria.

8.2 When the severity level of discontinuities per unit area in the production radiograph being evaluated ~~as~~ 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 per unit area of greater severity than the reference radiograph, that part of the casting shall not be accepted.

9. Application to Weld Repair Castings

9.1 When castings subject to this standard are repaired by welding, the reference radiographs to be used in the evaluation of the repaired sections must be specifically agreed upon between the purchaser and the supplier.

10. Keywords

10.1 castings; discontinuities; reference radiographs; titanium; X-ray