Designation: E 1648 – 95 (Reapproved 2001)

Standard Reference Radiographs for Examination of Aluminum Fusion Welds[1]

This standard is issued under the fixed designation E 1648; 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 These reference radiographs illustrate various types and severity levels of discontinuities in aluminum fusion welds that may be revealed by radiographic examination. These reference radiographs do not specify the acceptable level of these discontinuities, rather they provide a visual reference for communicating the acceptable level.

NOTE 1—The reference radiographs consist of a set of eight plates (8½ by 11 in. (22 by 28 cm)), covering base material up to and including 0.75 in. (19 mm) in thickness.

1.2 These reference radiographs are based on two nominal weld thicknesses in wrought aluminum products and are applicable to the thickness ranges shown in Table 1. The welds were produced using base material plates of 6061 and 5083 alloys and 5356 and 4043 gas metal-arc (GMA) electrodes. These reference radiographs are intended for use in evaluating radiographs of welds in wrought aluminum products. They are not recommended for use with repair welds in cast materials; however, they are appropriate for use with assembly or fabrication welds. Reference radiographs for aluminum and magnesium castings are available in Reference Radiographs E 155 and E 505.

1.3 The adjunct contains illustrations of representative graded and ungraded discontinuities. Table 2 lists the discontinuity types and severities illustrated for each thickness of base material. Each of the graded discontinuity types has five severity levels, 1 through 5, in order of increasing severity. The ungraded discontinuities are included for informational purposes.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 94 Guide for Radiographic Examination[2]

E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings[2]

E 505 Reference Radiographs for Inspection of Aluminum and Magnesium Die Castings[2]

E 1032 Test Method for Radiographic Examination of Weldments[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *ASTM Adjuncts:*

Reference Radiographs for Aluminum Fusion Welds:

Volume 1, Thicknesses Up to and Including 0.75 in. (19 mm)[3]

3. Terminology

3.1 *Definitions*—Definitions of terms relating to X-ray and gamma radiology, as used in these reference radiographs, may be found in Terminology E 1316.

TABLE 2 Types of Discontinuities Illustrated for Each Thickness of Base Material

Discontinuity Type	Base Material Thickness, in. (mm) and Grading	
	0.125 (3.2)	0.50 (12.7)
Fine scattered porosity	Grades 1 through 5	Grades 1 through 5
Coarse scattered porosity	...	Grades 1 through 5
Aligned porosity	Grades 1 through 5	Grades 1 through 5
Clustered porosity	...	Ungraded
Incomplete penetration	Ungraded	Ungraded
Tungsten inclusions	...	Ungraded
Undercut	Ungraded	Ungraded
Cracks (longitudinal and transverse)	Ungraded	Ungraded
Crater crack	...	Ungraded

4. Significance and Use

4.1 Use of these reference radiographs requires agreement between the using parties as to the acceptable level of each discontinuity type. Illustrations are provided for welds in 0.125-in. (3.2-mm) thick material and 0.50-in. (12.7-mm) thick

[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 Radiological Images.

Current edition approved Aug. 15, 1995. Published October 1995.

[2] *Annual Book of ASTM Standards*, Vol 03.03.

[3] Available from ASTM Headquarters. Order RRE1648.

TABLE 1 Applicable Thickness Ranges

Illustration Thickness, in. (mm)	Base Material Thickness, in. (mm)
0.125 (3.2)	to and including 0.375 (9.5)
0.50 (12.7)	over 0.375 (9.5) to and including 0.75 (19)

material. These illustrations are intended to be representative of base material thicknesses up to 0.75 in. (19 mm). Use of these reference radiographs is not intended to be restricted to the specific energy level or the absolute thickness limits that are illustrated. These reference radiographs may be used, where there is no other applicable document, for other energy levels or thicknesses, or both, for which agreement has been reached between the purchaser and the manufacturer. Standard reference radiographs should be used in accordance with contractual specifications.

5. Preparation of Reference Radiographs

5.1 The illustrations in Volume 1 are photographic reproductions of a master radiographic set. The radiographs were made to a quality level of at least 2–2T in accordance with Guide E 94. Additional details regarding the radiographic technique used are provided in Test Method E 1032.

5.2 The radiographic exposures were controlled so as to produce a density of 2.00 to 2.25 in a selected location on the weld bead. Not all areas of the image will fall within this range. The reproductions used in Volume 1 were prepared to the same target density requirements and they substantially retain the contrast and detail of the original radiographs.

5.3 *Film Deterioration*—The extent to which images on the radiograph deteriorate over time is a function of storage conditions, care in handling, and amount of use. Reference radiographs are no exception and may exhibit signs of deterioration over time. The radiographs should therefore be periodically examined for signs of deterioration, including scratches, abrasions, stains, etc. Any reference radiographs that show signs of loss of image quality, excessive wear and tear which influence the interpretation and use should be replaced.

6. Description of Discontinuities

6.1 *Porosity*, occurs as voids caused by gas trapped in the weld metal deposit. The voids may occur as spherical, elongated, or“ worm hole” shapes and in patterns that are random, clustered, or aligned. On a radiograph the spherical voids have the appearance of a rounded dark area while the nonspherical voids have an elongated dark area with a smooth outline. Aligned porosity appears as a string of pores which are generally aligned with the direction of a weld pass. The spacing between the pores may be relatively uniform or irregular.

6.2 *Tungsten inclusions*, are tungsten particles entrapped in the weld deposit. These inclusions are particles broken off or melted from the electrodes and may be caused by faulty equipment or poor welding technique. On the radiograph, the tungsten inclusions are lighter than the surrounding areas and may be rounded or irregularly shaped.

6.3 *Incomplete penetration*, is a discontinuity that occurs at the root of welds where full penetration has not been achieved. The discontinuity generally appears on a radiograph as a straight dark line that may be either continuous or intermittent. The indication is typically a sharply defined line or two parallel lines depending upon the specific geometry of the joint and the width of the discontinuity (see Note 2).

NOTE 2—Some welds may be designed for, or permit, incomplete penetration of the weld. Appropriate drawings and specifications must be consulted to determine whether the indication represents an unacceptable condition. Where the condition exceeds specification limits, it is referred to by some specifications (for example, American Welding Society (AWS)) as *Inadequate Penetration*.

6.4 A *crack*, is a rupture of solidified metal. Cracks associated with welding may be longitudinal, transverse, or radially oriented and may occur in the weld metal, base metal, or through both. When the plane of the crack is aligned with the direction of the radiation beam, its radiographic image will appear as a well-defined jagged or a relatively straight line. As the plane of the crack deviates from the direction of the radiation beam, the appearance of the crack becomes increasingly broad and poorly defined.

6.4.1 *Longitudinal cracks*, are oriented in a direction that is generally parallel to the weld bead.

6.4.2 *Transverse cracks*, are oriented such that they tend to cross (at least partially) the weld bead.

6.4.3 Radially oriented cracks are called *crater cracks*, because they generally originate in a weld bead crater.

6.5 An *undercut*, is a longitudinal groove melted into the base metal adjacent to the edge of the weld. An undercut may be observed by visual examination. Another type of undercut may occur in backing strip joints where the backing strip is left in place. It is caused by a melting away of the base metal at the root. This type is generally termed“ root undercut.” It appears on the radiograph as a relatively straight and narrow or broad dark line and can be located on either or both sides of the root opening location.

7. Application of Reference Radiographs

7.1 The following procedures are recommended in specifying acceptance standards and in the application of such standards to film interpretation.

7.1.1 In specifying the use of these reference radiographs, the level of acceptance for each of the illustrated conditions must be specified. Additional acceptance criteria may also need to be specified for which these reference radiographs may or may not provide a useful vehicle for judging acceptance.

7.1.2 The graded reference radiographs may be used in whole or in part as applicable to the particular requirements.

7.1.3 The extent of the weldment to which the selected graded reference applies shall be established.

7.1.4 The agreed upon acceptance criteria should specify how the disposition of a part is to be made when two or more categories of discontinuity are present in the same radiograph or region of the component.

7.2 When the production radiograph is interpreted as showing equal or less severe discontinuities than the selected graded reference, the weld shall be judged acceptable. When the production radiograph is interpreted as showing greater severity than the selected graded reference, the weld shall be judged unacceptable and shall be rejected or repaired, or both, in accordance with contractual agreements.

7.2.1 When repair welding is permitted, the repair need only be to that extent which will bring the weld quality to within the acceptable limits.

7.3 Production radiographs showing indications of a distributed discontinuity, such as porosity, shall be evaluated by the overall condition with regard to size, number, and distribution. It is not the intent that the maximum size of the discontinuity shown on the reference radiograph shall be the limiting size for a single production radiographic discontinuity, or that the number of discontinuities shown on the reference radiograph shall be the limiting number for production radiographs. Each of the factors of size, number, and distribution must be considered in balance.

8. Keywords

8.1 aluminum; discontinuities; radiograph density; reference radiographs; welds; X-ray

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL INSTRUCTIONS

X1.1 In selecting the reference radiographs, the attempt was made to obtain a progressively increasing severity of grades for each discontinuity type. It is not implied that the same grade number designation represents equivalent severity for all types of discontinuities. To arrive at acceptance standards, each type of discontinuity should be considered individually, and an appropriate grade (severity) designation applicable to the type should be assigned.