Designation: E 272 – 99

Standard Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings[1]

This standard is issued under the fixed designation E 272; 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 degrees of discontinuities occurring in high-strength copper-base, nickel-copper, and related types of alloys.

1.2 These reference radiographs are reproductions of original radiographs that contain indications of discontinuities in sand-cast manganese-nickel-aluminum bronze-alloy plates. These discontinuities are representative of those found in narrow freezing range (formerly "high shinkage"), high-strength copper and nickel-copper alloys.

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

1.4 *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:*

B 148 Specification for Aluminum-Bronze Sand Castings[2]

B 369 Specification for Copper-Nickel Alloy Castings[2]

B 584 Specification for Copper Alloy Sand Castings for General Applications[2]

E 94 Guide for Radiographic Testing[3]

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings[3]

E 192 Reference Radiographs of Investment Steel Castings for Aerospace Applications[3]

E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness[3]

E 1316 Terminology for Nondestructive Examinations[3]

2.2 *Military Specification:*

MIL-B-21230A Bronze, Nickel Aluminum and Manganese-Nickel Aluminum, Casting, Ship Propeller Application[4]

2.3 *ASTM Adjuncts:*

Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings[5]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this document, see Terminology E 1316.

4. Significance and Use

4.1 Reference radiographs for high-strength copper-base and nickel-copper alloy castings are intended to be used as a guide to the recognition of common discontinuities and their differentiation both as to type and severity level. A standard description of casting defects and corresponding radiographic indication types is available for reference in acceptance standards, specifications, and drawings. Purchasers and suppliers may, by mutual agreement, select particular radiographs to serve as standards representing minimum acceptability. The standards so established are identified by an alphabetic defect type and severity level (or class) designation.

4.2 The following ASTM specifications illustrate alloys that may be used with these standards. It is intended that these reference radiographs also apply to related government and commercial material specifications.

Alloys	ASTM Specifications[A]
Aluminum Bronze	B 148
Nickel-Aluminum Bronze	B 148
Copper-Nickel	B 369
Manganese Bronze	B 584
Alloys	**Government Specification[A]**
Manganese-Nickel-Aluminum Bronze	MIL-B-21230A—Alloy No. 2.
Nickel-Copper	MIL-B-21230A—Alloy No. 2.

[A] See Section 2 for the complete title(s) of these specification(s).

NOTE 1—The reference radiographs consist of forty-five 5 by 7-in. (127 by 178-mm) radiograph reproductions (twenty made from 1-in. (25.4-mm) plate castings with low-voltage X rays and twenty-five made from 3-in.

[1] These reference radiographs are under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and are the direct responsibility of Subcommittee E07.02 on Reference Radiographs.

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[2] *Annual Book of ASTM Standards*, Vol 02.01.

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

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094. Attn: NPODS.

[5] Available from ASTM Headquarters. Order RRE0272.

(76-mm) plate castings with 2-MV X rays or cobalt-60).

4.3 The discontinuity types and severity levels represented by the reference radiographs are shown in Table 1, which also indicates the code designation for each discontinuity type.

4.4 Discontinuity types most common to these alloys are illustrated. Other discontinuity types such as unfused inserts are illustrated in applicable Reference Radiographs E 446, E 186, and E 192.

4.5 The use of this document is not intended to be restricted to the specific energy levels given in Note 1 or to the thickness limits given in Table 1. The document may be used, where there is no other applicable document, for other energy levels or thicknesses, or both, for which it is found to be applicable and for which agreement has been reached between purchaser and manufacturer.

5. Descriptions of Discontinuities

5.1 The following paragraphs are provided to aid in the identification and classification of discontinuities. They briefly describe the radiographic appearance of common types of discontinuities and indicate their probable cause.

5.1.1 *Gas Holes*—Appear as round or elongated smooth-edged dark spots which may occur either individually, in clusters, or distributed throughout the casting section. They are generally caused by trapped air or mold gases.

NOTE 2—Discontinuities caused by evolved gases may occur as more or less spherical voids, but may also occur as elongated "worm holes" or cavities somewhat resembling certain types of shrinkage. It is recommended that the" worm hole" cavities be evaluated by the use of the feathery or spongy shrinkage category reference radiographs.

5.1.2 *Shrinkage*—Shrinkage is generally associated with improper feeding and manifests itself in the following different indication forms:

5.1.2.1 *Sponge Shrinkage*—Found in heavier sections (generally over 2 in. in thickness). It appears on the radiographs as a dark area or areas, lacy in texture, usually with a diffuse outline.

5.1.2.2 *Feathery Shrinkage*—Found in thinner sections (under approximately 2 in.). It appears on radiographs as sponge but with a more feathery outline.

TABLE 1 Discontinuity Types and Severity Levels Illustrated by the Reference Radiographs

Discontinuity Type	Code	Severity Levels or Classes[A,B]	
		Up to 2-in. Thickness	2 to 6-in. Thickness
Gas porosity	A	1 through 5	1 through 5
Sand inclusions	Ba	1 through 5	1 through 5
Dross inclusions	Bb	1 through 5	1 through 5
Shrinkage, linear	Ca	...	1 through 5
Shrinkage, feathery	Cd	1 through 5	...
Shrinkage, spongy	Cd	...	1 through 5

[A] The radiographs of the 1-in. (25.4-mm) thick plates are applicable to and include 2-in. (51-mm) thick sections. The radiographs of the 3-in. (76-mm) thick plates are recommended for sections over 2 and up to 6 in. (152 mm). However, upon agreement between manufacturer and purchaser they may be used for larger section thicknesses.

[B] The discontinuity types are numbered according to severity level or class, Class 1 representing the highest quality castings.

5.1.2.3 *Linear Shrinkage*—Usually a continuous structure of connected lines, branches or network of variable length, width, and density.

5.1.3 *Hot Tears*—The similarly appearing "hot tear" and "linear shrinkage" have distinctive characteristics. The following information is presented as a guide to interpreters to minimize confusion in distinguishing hot tears from linear shrinkage:

TABLE 2 Alloy Type Used to Produce Plate Castings for Original Radiographs (Composition MIL-B-21230A (SHIPS)—Alloy No. 2)

Chemical Composition, %	
Copper	71, min
Manganese	11 to 14
Nickel	1.5 to 3.0
Iron	2.0 to 4.0
Aluminum	7.0 to 8.5
Silicon	0.10, max
Lead	0.03, max
Others	0.50, max
Mechanical Properties	
Tensile strength, min, psi (MPa)	90 000 (620)
Yield strength, min, psi (MPa)	40 000 (275)
Elongation in 2 in. or 51 mm, min, %	20.0

5.1.3.1 Hot tears usually occur singly; shrinkage will generally be multiple.

5.1.3.2 Hot tears propagate at or near the surface; shrinkage appears to propagate at or near the midsection.

5.1.3.3 Hot tears generally occur at hot spots or section changes; linear strinkage frequently occurs at uniform sections also.

5.1.3.4 Hot tears occur where temperature gradients are high; shrinkage occurs where temperature gradients are low.

5.1.3.5 Hot tears occur transverse to the direction of greatest stress.

5.1.3.6 Hot tears can only be counteracted by altering the stress pattern or thermal pattern; shrinkage can always be countered by sufficient feed metal.

5.1.4 *Nonmetallic Inclusions*:

5.1.4.1 *Sand*—Irregularly, angularly shaped indications, more dense than the background, caused by clumps of trapped sand particles or pebbles.

5.1.4.2 *Dross*—A series of lines in a swirl pattern sometimes combined with agglomerated irregular indications. Dross is generally considered to represent oxidized metal.

6. Description and Method of Preparation

6.1 These reference radiographs were produced by the use of manganese-nickel-aluminum bronze plate castings. Table 2 lists the chemical composition and mechanical property limits for the alloy type. The references illustrate the appearance of the various radiographic severity levels when the original radiographs are produced to a photographic density of from 2.00 to 2.25 on high-contrast, fine-grain film with a sensitivity (quality level), as determined by standard penetrameters, of

2 % (2-2T).[6] In selecting these reference radiographs the aim was to obtain a progressively graduated series for each type of discontinuity. It was not intended that like numbered levels or classes be considered of equal severity (as far as deterioration of mechanical properties is concerned) for the various categories.

6.2 The reproductions have been prepared to a density from 2.00 to 2.25 and have retained substantially the contrast of the original radiographs.

7. Application of the Reference Radiographs

7.1 In establishing acceptance standards, these reference radiographs may be used in full or in part, as desired.

7.2 For each casting, the minimum acceptable severity level (or class) should be specified for each type of discontinuity; for example, Severity Level 2 (or Class 2) might be specified for shrinkage (Type C) defects and Class 4 for gas porosity (Type A) defects, since the latter are generally much less deleterious.

7.3 The acceptable quality level may vary in different locations of a casting, depending on the magnitude, direction and type of stress versus section contour.

7.4 Production radiographs which are compared to the reference radiographs should have a film density in the area of interest in the range from 1.5 to 3.5 and a specified minimum sensitivity (quality level) of 2 % (2-2T).[6] Other quality levels may be designated, but then a suitable change in the severity or class should be anticipated and hence specified. The recommended upper density level of 3.5 for production radiographs is consistent with the capabilities of commonly available viewing equipment. Radiographs of higher density are permitted if both producer and consumer have viewing equipment with adequately intense illuminators.

7.5 *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.

8. Interpretation

8.1 The following practice should be adhered to in evaluating production radiographs of castings against the selected standard radiographs:

8.1.1 When production radiographs, being evaluated with the selected references in a particular contract, show discontinuities which are equal to or less severe than those in the applicable reference radiographs, the casting shall be considered radiographically acceptable. If the production radiographs show a discontinuity of greater severity than the applicable reference radiograph, the casting shall be rejected until satisfactorily repaired (if permissible) (Section 9).

8.1.2 If more than one type of discontinuity is revealed in the same radiograph, the predominating type of defect alone shall govern acceptability unless the severity represented by the combination of discontinuity types is such as to make the overall condition unacceptable for the intended application.

8.1.3 When two or more categories of discontinuity are present to an extent equal to the maximum permissible level, as shown in the pertinent standards for each category, then that part of the casting shall be judged unacceptable until satisfactorily repaired (if repairs are permissible) (see Section 9).

8.1.4 In general, there is no limit as to the extent of acceptable discontinuities in a casting, provided that no 5 by 7-in. (127 by 152-mm) area throughout the casting contains discontinuities that exceed the severity of defects in the applicable reference radiographs.

8.1.5 Where the reference image consists of a collection of discontinuities, as in the case of porosity, for example, acceptability may be based on 1) the aggregate size of the discontinuities present on both the reference radiograph and the object radiograph, 2) the maximum defect size present, 3) the spacing between discontinuities, or 4) a combination of these or other criteria. These criteria must be determined based upon the particular application or part under consideration and must be specified by agreement between the purchaser and supplier.

8.1.6 A diffraction mottling pattern can occur on films of parts and sections where the grain size is large enough to be an appreciable fraction of the material thickness (see Note 3). If diffraction mottling is suspected, there are a number of ways to demonstrate its presence. The diffraction mottling pattern shown in these cases is dependent principally upon the crystal geometry and the orientation of the crystals to the incident radiation. Therefore, for a given specimen, any change in this orientation will effect the diffraction pattern dramatically. This can be accomplished by a slight, 1 to 5° tilt of the part, with respect to the radiation beam or simply by shifting the centerline of the radiation beam to a slightly different location from the first exposure. Indications from any porosity, shrinkage or other discontinuity will move only slightly, while any mottling patterns present will change dramatically. If it is necessary or desirable to eliminate the mottling, the kV may be raised to reduce the amount of diffraction radiation. However, caution should be used so that the kV is not raised to the point that sensitivity is reduced excessively. If diffraction mottling is demonstrated to be present on a radiograph, this condition shall not be considered as prejudicial in evaluating the radiograph.

NOTE 3—Mottling is often associated with thin sections of austenitic steels and copper base alloys such as copper nickel, tin bronzes, and nickel copper. Demonstration of mottling has also been shown in the duplex alloys as well.

9. Application to Weld Repair Castings

9.1 It is recognized that certain materials covered by these reference radiographs are weldable to various degrees. When radiographic quality castings are repaired by welding, the reference radiographs to be used in the evaluation of the repaired sections must be specifically agreed upon between producer and consumer.

[6] For a description of sensitivity or quality levels, see Guide E 94.

10. Keywords

10.1 aluminum bronze; castings; copper; copper-nickel; discontinuities; gamma ray; manganese bronze; manganese-nickel-aluminum bronze; nickel-aluminum; nickel-copper; reference radiographs; x-ray