Designation: E272 – 15

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

This standard is issued under the fixed designation E272; 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 U.S. Department of Defense.

1. Scope

1.1 These reference radiographs illustrate various categories, types, and severity levels of discontinuities occurring in high-strength copper-base, nickel-copper, and related alloy castings. The reference radiograph films are an adjunct to this document and must be purchased separately from ASTM International, if needed (see 2.3). Categories and severity levels for each discontinuity type represented by these reference radiographs are described in 1.2.

NOTE 1—The basis of application for these reference radiographs requires a prior purchaser supplier agreement of radiographic examination attributes and classification criterion described in Sections 4, 7, 8, 9, and 10 of this standard.

1.2 These reference radiographs consist of forty-five 5 by 7-in. (127 by 178-mm) nominal size reproductions (twenty made from 1-in. (25.4-mm) plate castings exposed with low voltage X-rays for thicknesses up to and including 2 in.) and twenty-five made from 3-in. (76-mm) plate castings exposed with 2 MV X-rays or Cobalt 60 isotope for thicknesses greater than 2 in. up to and including 6 in. Unless otherwise specified in a purchaser supplier agreement (see 1.1), each discontinuity category is for comparison only with production radiographs produced with radiation energy levels within the thickness range covered by the category. These reference radiographs illustrate discontinuities in sand-cast manganese-nickel-aluminum bronze-alloy plates and are representative of those found in narrow freezing range (formerly "high shrinkage"), high-strength copper and nickel-copper alloys. Following is a list of discontinuity categories, types and severity levels for the adjunct reference radiographs of this standard (see Note 2):

1.2.1 *Category A*—Gas porosity; severity levels 1 through 5 for two thickness ranges.

1.2.1.1 A_X—Up to and including 2 inches (50.8 mm) (called "Code A Discontinuity type" in previous revisions).

1.2.1.2 A_G—Greater than 2 in. (50.8 mm) up to and including 6 in. (152.4 mm) (called "Code A Discontinuity type" in previous revisions).

1.2.2 *Category B*—Inclusions

1.2.2.1 *Ba*—Sand inclusions, severity levels 1 through 5 for two thickness ranges.

(1) Ba_X—Up to and including 2 in. (50.8 mm) (called "Code Ba Discontinuity type" in previous revisions).

(2) Ba_G—Greater than 2 in. (50.8 mm) up to and including 6 in. (152.4 mm) (called "Code Ba Discontinuity type" in previous revisions).

1.2.2.2 Bb—Dross inclusions, severity levels 1 through 5 for two thickness ranges.

(1) Bb_X--Up to and including 2 in. (50.8 mm) (called "Code Bb Discontinuity type" in previous revisions).

(2) Bb_G—greater than 2 in. (50.8 mm) up to and including 6 in. (152.4 mm) (called "Code Bb Discontinuity type" in previous revisions).

1.2.3 *Category C*—Shrinkage; three types

1.2.3.1 *Ca*—linear shrinkage, severity levels 1 through 5 for 2 inches to and including 6 in. (50.8 to 152.4 mm) in thickness

1.2.3.2 *Cb*—feathery shrinkage, severity levels 1 through 5 for thicknesses up to and including 2 in. (50.8 mm). (Called "Cd feathery shrinkage" in previous revisions).

1.2.3.3 *Cc*——spongy shrinkage, severity levels 1 through 5 for 2 in. to and including 6 in. (50.8 to 152.4 mm) in thickness (called "Cd spongy shrinkage" in previous revisions).

NOTE 2—Discontinuity classes designated with a subscript "X" were produced with low energy X-ray radiation; discontinuity classes designated with subscript "G" were produced with Cobalt 60 and/or 2 MV X-rays and are the same reference radiographs and thickness ranges used in previous editions of this standard. Section 4 details the significance and use of these reference radiographs.

1.3 From time to time, there may be minor changes to the process for manufacturing of the reference radiograph adjunct materials. These changes could include changes in the films or processing chemicals used, changes in the dies or printing for the cardboard mats, etc.; however, in all cases, these changes are reviewed by the Illustration Monitoring Subcommittee and all reference radiographs are reviewed against a fixed prototype image to ensure that there are no changes to the acceptance

[1] These reference radiographs are under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and are the direct responsibility of Subcommittees E07.02 on Reference Radiological Images and E07.93 on Illustration Monitoring.

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level represented by the reference radiographs. Therefore, the adjunct reference radiographs remain valid for use with this standard regardless of the date of production or the revision level of the text standard.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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:*[2]

B148 Specification for Aluminum-Bronze Sand Castings
B369 Specification for Copper-Nickel Alloy Castings
B584 Specification for Copper Alloy Sand Castings for General Applications
E94 Guide for Radiographic Examination
E186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (50.8 to 114-mm)) Steel Castings
E242 Reference Radiographs for Appearances of Radiographic Images as Certain Parameters are Changed
E192 Reference Radiographs of Investment Steel Castings for Aerospace Applications
E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness
E1316 Terminology for Nondestructive Examinations

2.2 *Military Specification:*

MIL-B-21230A Bronze, Nickel Aluminum and Manganese-Nickel Aluminum, Casting, Ship Propeller Application[3]

2.3 *ASTM Adjuncts:*

Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings[4]

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *production radiograph*—a radiograph under review for compliance with this standard.

3.2.2 *discontinuity type*—a specific discontinuity characterized by its cause and appearance. For example: linear shrinkage is a specific discontinuity type.

3.2.3 *discontinuity category*—a nomenclature system used for grouping discontinuity types. For example: linear shrinkage is assigned category "Ca" where "C" represents the general shrinkage category and "a" represents the specific linear shrinkage discontinuity type.

3.2.4 *discontinuity severity level*—a relative rank in terms of "quantity, size and distribution" of a collection of discontinuities where "1" is the least and "5" is the greatest "quantity, size and distribution" present on the reference radiograph. Example: a severity level of "1" is more restrictive (requires a higher level of workmanship fabrication quality) than a severity level of "2".

3.2.5 *discontinuity class*—an assigned workmanship fabrication quality rating characterized by a discontinuity type, category and severity level. For example: "Ca 2" is a discontinuity class comprised of linear shrinkage with a severity level of "2".

3.2.6 *classification specification*—a set of user defined acceptance criterion that prescribes the radiographic workmanship discontinuity class requirements for a specified user casting service application (see Sections 7 and 8).

3.2.7 *graded illustration*—a category of discontinuity that is assigned a severity level.

3.2.8 *ungraded illustration*—a category of discontinuity without an assigned severity level.

3.2.9 *prorating*—assignment of quantity, size and distribution on a production radiograph in proportion to a similar size area of a reference radiograph. For example: a production radiograph covers an area that is smaller than the unit area of a reference radiograph and the extent of discontinuity on the applicable reference radiograph is reduced proportionately.

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. Discontinuity types most common to these alloys are illustrated. Other discontinuity types such as hot tears, cracks and unfused chaplets are illustrated in applicable Reference Radiographs E186, E192, and E446. For reference, descriptions of typical casting defects and corresponding radiographic indication types are contained in Section 5. Purchasers and suppliers may, by mutual agreement, select particular discontinuity classes (see 1.2) to serve as standards representing minimum levels of acceptability. (See Sections 7 and 8.)

4.2 Reference radiographs represented by this standard may be used, as agreed upon in a purchaser supplier agreement, for energy levels, thicknesses or both outside the range of this standard when determined applicable for the casting service application.

4.3 Procedures for evaluation of production radiographs using applicable reference radiographs of this standard are prescribed in Section 9; however, there may be manufacturing-purchaser issues involving specific casting service applications where it may be appropriate to modify or alter such requirements. Where such modifications may be appropriate for the casting application, all such changes shall be called-out in the

[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 Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098

[4] Available from ASTM Headquarters. Order RRE0272.

purchaser supplier agreement or contractual document. Section 10 addresses purchaser supplier requisites where weld repairs may be required.

4.4 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	B148
Nickel-Aluminum Bronze	B148
Copper-Nickel	B369
Manganese Bronze	B584
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).

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 3—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.

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:

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 shrinkage 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. Method of Preparation

6.1 The original radiographs used to prepare the adjunct reference radiographs were produced on ASTM Class I film systems using methods described in 1.2, including the use of manganese-nickel-aluminum bronze plate castings. Table 1 lists the chemical composition and mechanical property limits for the alloy type used. The original radiographs were made with penetrameter sensitivity, as determined by ASTM penetrameters (see Guide E94), of 2-2T. The adjunct reference radiographs are reproductions prepared to an optical density of 2.00 to 2.25 and have substantially retained the contrast of the original radiographs. In preparing these reference radiographs, the objective was to obtain progressively graduated severity levels for each graded discontinuity category. Similar discontinuity categories, that is, Ba and Bb, do not necessarily reflect similar levels of severity for specific casting design applications.

6.2 *Film Deterioration*—Radiographic films are subject to wear and tear from handling and use. The extent to which the images deteriorate over time is a function of storage conditions, care in handling and the amount of use. Reference radiograph films are no exception and may exhibit a loss in image quality over time. The radiographs, therefore, should be periodically examined for signs of wear and tear, including scratched, 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.

TABLE 1 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

7. Determination of Radiographic Classification

7.1 For purposes of casting evaluations, a determination must be made of the radiographic discontinuity classifications to be assigned to individual castings or specific areas of castings. The determination of the applicable radiographic discontinuity classification shall be based on an evaluation of the casting applications, design, and service requirements. In these evaluations, consideration shall be given to such factors as pressure, temperature, section thickness, applicable design safety factor (preferably based on stress analysis), vibration, shock, resistance to corrosion, involvement of penetrating radiations or radiation products, and involvement of dangerous gases or liquids.

7.2 For each individual casting or specific area of a casting to be radiographed, the discontinuity class must be clearly specified. For example: Category Ca, severity level 2 might be specified for linear shrinkage and Category A1, severity level 3 for gas porosity, since the latter are generally much less deleterious to tensile properties (see Section 8).

7.3 Production radiographs which are compared to reference radiographs should have an optical density in the area of interest in accordance with Guide E94 and a specified minimum radiographic sensitivity (quality level) of 2 % (2-2T).[5] Other radiographic quality levels or optical densities may be designated, but then a corresponding change in severity level for each discontinuity category should be anticipated and hence specified.

8. Classification Specifications

8.1 The applicable radiographic discontinuity classification should be designated by the contracting agency in formal specifications or on drawings and in specific contracts or orders. The specifications, drawings, contracts, or order should also designate the sampling plan for the castings to be radiographed and the extent of radiographic coverage, radiographic practice to be followed (see Guide E94), image quality desired (see Note 4) as well as the severity level of the acceptable discontinuity for the graded categories.

NOTE 4—For description of sensitivity or quality levels, see Guide E94 and Reference Radiograph standard E242.

9. Evaluation Procedure

9.1 Compare the production radiographs of the casting submitted for evaluation with the applicable reference radiographs exposed at an equivalent energy level within the thickness range of this standard (unless otherwise specified—see Section 4).

9.2 When the severity level of discontinuities in the production radiograph being evaluated is equal to or less than the severity level of the specified reference radiograph, that part of the casting represented by the production radiograph shall be acceptable. If the production radiograph shows discontinuities of greater severity than the reference radiograph, that part of the casting shall be rejected.

9.3 A unit area on the production radiograph shall be evaluated to a unit area of like size on the reference radiograph. Any unit evaluation area that shares a discontinuity with an adjacent unit evaluation area shall meet the minimum unit area acceptability requirements within the combined unit area. When the unit area of interest of a production radiograph is less than the unit area of the applicable reference radiograph, such unit area of the production radiograph shall be prorated to the reference radiographic area.

9.4 When two or more categories of discontinuity are present in the same production radiograph, the predominating discontinuities, if unacceptable, shall govern acceptability without regard to other categories of discontinuity and the casting rejected.

9.5 When two or more categories of discontinuities are present to an extent equal to the maximum permissible level, as shown in the applicable standards for each category, then that part of the casting shall be judged unacceptable. When two or more categories of discontinuity are present in the same radiograph to an extent less than the maximum permissible level, as shown in the applicable standards for each category, the severity shall be evaluated by the overall aggregate condition. The aggregate condition is defined as the balance of quantity, size and distribution of the collection of discontinuities and shall not exceed the aggregate condition of the applicable reference radiograph.

9.6 Reference radiographs are provided showing a variety of shrinkage discontinuity types. Production radiographs showing shrinkage shall be judged by the most representative reference radiograph.

9.7 This standard does not specify limiting criterion for a single size of discontinuity, maximum number of discontinuities per unit area evaluated, specific dimensional spacing and/or alignment criterion between individual discontinuities or any other undefined discontinuity patterns. Unless otherwise specified by a purchaser supplier agreement (see Section 4), these discontinuity conditions on production radiographs shall be evaluated as aggregate conditions as defined in 9.5.

9.8 In general, there is no limit as to the extent of acceptable discontinuities in a casting, provided that no unit evaluation area throughout the casting contains discontinuities that exceed the severity of discontinuities in the applicable reference radiographs.

9.9 Reference radiographs of this standard do not illustrate elongated or "worm" hole type gas discontinuities. When this condition occurs in a production radiograph, it shall be evaluated by comparison with the most representative reference radiograph.

9.9.1 When the exposing radiation source has been placed perpendicular to the length of the gas hole, evaluate the production radiograph with a shrinkage reference radiograph.

9.9.2 When the exposing radiation source has been placed diametrically or "into" the diameter of the gas hole, evaluate the production radiograph with a gas reference radiograph.

9.10 A diffraction mottling pattern can occur on films of parts and sections where the grain size is large enough to be an

[5] For a description of sensitivity or quality levels, see Guide E94.

appreciable fraction of the material thickness (see Note 5). 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 affect 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 5—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.

9.11 Hot tears and cracks exhibited on production radiographs may, at times, resemble linear type shrinkage. When doubt exists whether such indications are cracks or tears, or are shrinkage, all surfaces in the area of interest shall be ground and liquid penetrant inspected. The extent and depth of grinding may require engineering judgment. If the indication does not appear on the surface, that indication shall be considered shrinkage.

9.12 The radiographic density of discontinuities in comparison with background radiographic density is a variable dependant upon radiographic techniques and shall not be used as a criterion for acceptance or rejection in comparison with reference radiographs.

10. Weld Repair of Castings

10.1 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 purchaser and supplier.

10.2 When casting discontinuities are removed for repairs, only the extent of discontinuity required to meet applicable reference standards need be removed.

11. Keywords

11.1 aluminum bronze; casting discontinuities; copper; copper-nickel; gamma ray; manganese bronze; manganese-nickel-aluminum bronze; nickel-aluminum; nickel-copper; reference radiographs; X-ray