Designation: E2973 – 15

Standard Digital Reference Images for Inspection of Aluminum and Magnesium Die Castings[1]

This standard is issued under the fixed designation E2973; 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 digital reference images illustrate various categories, types, and severity levels of discontinuities that may occur in aluminum-alloy and magnesium-alloy die castings. They are intended to provide:

1.1.1 A guide enabling recognition of discontinuities and their differentiation both as to type and severity level through digital radiographic imaging.

1.1.2 Example digital radiographic illustrations of discontinuities and a nomenclature for reference in acceptance standards, specifications, and drawings.

NOTE 1—The basis of application for these reference images requires a prior purchaser supplier agreement of radiographic examination attributes and acceptance criteria as described in Sections 5 and 6 of this standard.

1.2 These digital reference images consist of nine images covering discontinuities in aluminum and magnesium alloy die castings. Four contain graded sequences of four levels of increasing severity in aluminum castings. Four contain graded sequences of four levels of increasing severity in magnesium castings. The last image contains ungraded illustrations of inclusions in aluminum and magnesium alloy die castings.

1.3 Two kinds of illustration categories are covered as follows:

1.3.1 *Graded*—Three discontinuity categories for aluminum die castings and three discontinuity categories for magnesium die castings, each illustrated in four levels of progressively increasing severity. Category A discontinuities are illustrated for aluminum and magnesium die castings having thicknesses of ⅛ in. (3.2 mm) and ⅝ in. (15.9 mm); Category B discontinuities are illustrated for ⅛ in. thick aluminum and magnesium die castings; and Category C discontinuities are illustrated for ⅝ in. (15.9 mm) thick aluminum and magnesium die castings.

1.3.2 *Ungraded*—One illustration of one discontinuity for 0.20 in. (5.1 mm) thickness aluminum die casting and one illustration of one discontinuity for ⅛ in. (3.2 mm) thickness magnesium die casting.

1.4 This document may be used for other materials, thicknesses or with other energy levels for which it has been found to be applicable and agreement has been reached between purchaser and supplier.

1.5 All areas of this standard may be open to agreement between the cognizant engineering organization and the supplier, or specific direction from the cognizant engineering organization. These items should be addressed in the purchase order or the contract.

1.6 These digital reference images are not intended to illustrate the types and degrees of discontinuities found in aluminum and magnesium die castings when performing film radiography. If performing film radiography of aluminum or magnesium die castings, refer to Reference Radiographs E505.

1.7 Only licensed copies of the software and images shall be utilized for production inspection. A copy of the ASTM/User license agreement shall be kept on file for audit purposes. (See Note 2.)

NOTE 2—The set of digital reference images consists of nine digital data files, and software to load the desired format and specific instructions on the loading process. The nine reference images illustrate eight sets of graded discontinuities and one category of ungraded discontinuities. Available from ASTM International Headquarters, Order No: RRE2973.

1.8 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units.

1.9 *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]

E505 Reference Radiographs for Inspection of Aluminum and Magnesium Die Castings

E1316 Terminology for Nondestructive Examinations

[1] This test method is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.02 on Reference Radiological Images.

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[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.

E2002 Practice for Determining Total Image Unsharpness in Radiology
E2446 Practice for Classification of Computed Radiology Systems
E2597 Practice for Manufacturing Characterization of Digital Detector Arrays

2.2 *ASTM Adjuncts:*[2]

Digital Reference Images for Inspection of Aluminum and Magnesium Die Castings

2.3 *SMPTE Standard*[3]

RP133 SMPTE Recommended Practice Specifications for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard-Copy Recording Cameras

3. Terminology

3.1 *Definitions*—Definitions of terms used in this standard may be found in Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aliasing, n*—artifacts that appear in an image when the spatial frequency of the input is higher than the output is capable of reproducing. This will often appear as jagged or stepped sections in a line or as moiré patterns.

3.2.2 *contrast normalization, v*—the adjustment of contrast between the production image and the reference image that makes the change in digital driving level versus change in thickness equal for both images.

3.2.3 *DDL, n*—digital driving level, also known as monitor pixel value.

3.2.4 *discontinuity type, n*—a specific discontinuity characterized by its cause and appearance. For example: shrinkage is a specific discontinuity type.

3.2.5 *discontinuity severity level, n*—a relative rank in terms of "quantity, size, and distribution" of a collection of discontinuities where "1" is the least and "4" is the greatest "quantity, size, and distribution" present on the reference image.

3.2.6 *graded illustrations, n*—a category of discontinuity that is assigned a severity level.

3.2.7 *measured resolution, n*—the characteristic resolution of a digital radiographic system as measured in accordance with 10.5.

3.2.8 *production image, n*—an image under review for compliance with this standard.

3.2.9 *ungraded illustrations, n*—a category of discontinuity without an assigned severity level.

4. Appearance of Radiographic Indications

4.1 The following descriptions are for use in discontinuity identification and classification. These descriptions apply to these reference images only.

4.1.1 *Category A (Porosity)*—Round or elongated, smooth-edged spots of greater X-ray transmission occurring individually distributed or in clusters.

4.1.2 *Category B (Cold Fill)*—A distinct line or band of variable length and definite smooth outline, usually continuous or interconnected.

4.1.3 *Category C (Shrinkage)*—Filamentary or jagged areas of greater X-ray transmission, usually continuous or interconnected.

4.1.4 *Category D (Foreign Material)*—Isolated irregular variation in film density, either lighter or darker than surrounding areas. They may indicate the inclusion of oxide or dross or metallic compounds of different density. Illustration shows a more dense material.

5. Significance and Use

5.1 Graded reference images are intended to provide a guide enabling recognition of specific casting discontinuity types and relative severity levels that may be encountered during typical manufacturing processes. Reference images containing ungraded discontinuities are provided as a guide for recognition of a specific casting discontinuity type where severity levels are not needed. These reference images are intended as a basis from which manufacturers and purchasers may, by mutual agreement, select particular discontinuity classes to serve as standards representing minimum levels of acceptability (see Sections 7 and 8). The reference images are intended to be used for casting thickness ranges in accordance with Table 1.

5.2 Reference images 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.

5.3 Procedures for evaluation of production images using applicable reference images 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 specifically called-out in the purchaser supplier agreement or contractual document.

TABLE 1 Reference Radiographs for Aluminum and Magnesium Die Castings

Discontinuity	Plate Thickness, in. (mm)	Applicable Casting Thickness, in. (mm)
Aluminum Die Castings		
Category A (Porosity)	1/8 (3.2)	Up to 3/8 (9.5), incl.
Category A (Porosity)	5/8 (15.9)	Over 3/8 to 1 (9.5 to 25.4), incl.
Category B (Cold Fill)	1/8 (3.2)	Up to 3/8 (9.5), incl.
Category C (Shrinkage)	5/8 (15.9)	Over 3/8 to 1 (9.5 to 25.4), incl.
Category D (Foreign Material)	0.200 (5.08)	Up to 1 (25.4), incl
Magnesium Die Castings		
Category A (Porosity)	1/8 (3.2)	Up to 3/8 (9.5), incl.
Category A (Porosity)	5/8 (15.9)	Over 3/8 to 1 (9.5 to 25.4), incl.
Category B (Cold Fill)	1/8 (3.2)	Up to 3/8 (9.5), incl.
Category C (Shrinkage)	5/8 (15.9)	Over 3/8 to 1 (9.5 to 25.4), incl.
Category D (Foreign Material)	1/8 (3.2)	Up to 1 (25.4), incl

[3] Available from the Society of Motion Picture and Television Engineers, 3 Barker Avenue, White Plains, NY 10601, www.smpte.org/smpte_store.

Section 10 addresses purchaser supplier requisites for where weld repairs may be required.

5.4 Agreement should be reached between the cognizant engineering organization and the supplier that the system used by the supplier is capable of detecting and classifying the required discontinuities.

5.5 *Image Deterioration*—Many conditions can affect the appearance and functionality of digital reference images. For example, electrical interference, hardware incompatibilities, and corrupted files or drivers may affect their appearance. The Practice E2002 line pair gauges located in the lower right hand region of each digital reference can be used as an aid to detect image deterioration by comparing the measured resolution using the gauges to the resolution stated on the digital reference image. Do not use the digital reference images if their appearance has been adversely affected such that the interpretation and use of the images could be influenced.

6. Basis of Application

6.1 The digital reference images may be applied as acceptance standards tailored to the end use of the product. Application of these digital reference images as acceptance standards should be based on the intended use of the product and the following considerations (see Note 3).

6.1.1 Unless otherwise specified, discontinuities of equal or lesser severity than that in the specified reference radiograph are acceptable in any specified unit area of the casting. The size of the unit area should be specified in the acceptance criteria. Discontinuities more severe than those in the specified reference radiograph shall be considered rejectable.

6.1.2 Any combination or subset of these digital reference images may be used as is relevant to the particular application. Different grades or acceptance limits may be specified for each discontinuity type. Furthermore, different grades may be specified for different regions or zones of a component.

6.1.3 Special considerations may be required where more than one discontinuity type is present in the same area. Any modifications to the acceptance criteria required on the basis of multiple discontinuity types must be specified.

6.1.4 Where the reference image contains multiple discontinuities, as in that case of gas holes or porosity, acceptance may be based upon the aggregate area of the discontinuities, the maximum discontinuity size in the reference radiograph, the spacing between discontinuities, or a combination of these or other criteria, or both.

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

NOTE 3—Caution should be exercised in specifying the acceptance criteria to be met in a casting. Casting design coupled with foundry practice should be considered. It is advisable to consult with the manufacturer/foundry before establishing the acceptance criteria to ensure the desired quality level can be achieved.

7. Evaluation Procedure

7.1 Select the appropriate digital reference image to match the condition to be evaluated in the production image.

7.2 Apply contrast adjustments to the reference image using the method described in subsection 10.5.

7.3 Evaluation shall be performed against the adjusted reference image.

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

7.5 A unit area on the production image shall be evaluated to a unit area of like size on the reference image. 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 image is less than the unit area of the applicable reference image, such unit area of the production image shall be prorated to the reference image area.

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

7.7 When two or more categories of discontinuity 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 image to an extent less than the maximum permissible level, as shown in the applicable standards for each category, the severity level 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 image.

7.8 This standard does not specify limiting criteria 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, these discontinuity conditions on production images shall be evaluated as aggregate conditions as defined in 7.7.

7.9 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 image.

7.10 The radiographic contrast of discontinuities in comparison with background density is a variable dependent on technical factors. It shall not be used as a criterion for acceptance or rejection in comparison with reference images.

8. Weld Repair of Castings

8.1 When radiographic quality castings are repaired by welding, the reference images to be used in the evaluation of

the repaired sections must be specifically agreed upon between purchaser and supplier.

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

9. Digital Image Installation Procedure

9.1 Follow the instructions provided with the digital reference images to load the reference image software.

9.2 The software files will be saved to a default location during installation unless instructed otherwise during the load process.

9.3 The software will require the user to specify either a positive or negative image. Select the option to match the viewing format (positive or negative image) of the systems viewing software.

9.4 The software load process will require the digital reference image resolution to be specified to the nearest 10-micron increment. Select the resolution that will most closely match the effective system resolution. The theoretical effective system resolution is the detector resolution divided by the geometric magnification to be used during inspection. (See Note 4.)

9.5 Determine the measured effective system resolution at the magnification to be used for production imaging using the duplex wire gauge as described in Practice E2597 for digital detector arrays (DDA) and for CR systems in Practice E2446.

9.6 Compare the measured effective system resolution to the theoretical resolution determined as the nominal pixel size divided by the geometric magnification. Where parts are placed directly on the detector, use the nominal pixel size as the theoretical resolution. If the measured effective system resolution differs by no more than 30 % from the theoretical system resolution, use the theoretical system resolution as the effective system resolution.

9.7 If the measured system resolution differs from the theoretical system resolution by more than 30 % adjust the process parameters and measure the resolution again. For computed radiography, a suggested parameter to change is the sampling resolution.

NOTE 4—The resolution conversion process is performed by the provided load software. This process is performed by grouping pixels into bins and calculating the average value of the pixels in the bin. This average value is then the pixel value for the pixels of the same size and location as the subject bins. Where partial pixels are included in the destination pixel, the proportion of value of the pixel is averaged with a weighting factor proportional to the area of the pixel to be included.

10. Viewer Software Requirements

10.1 Viewer software shall be capable of importing the digital reference images as either a 16-bit grayscale uncompressed TIFF format or in the DICONDE format.

10.2 Viewer software shall be capable of importing and storing digital reference images at resolutions in 10 micron increments starting from 10 microns, and displaying these images without loss of data integrity or resolution.

10.3 Digital reference images shall be selectable by discontinuity category.

10.4 It shall be possible to view production and digital reference images simultaneously on a single monitor or optionally, on several monitors that are matched to provide equal brightness for a given digital driving level.

10.5 The contrast of the reference image shall be adjusted to assure the displayed image reflects a suitable gray value change commensurate with material thickness change. Contrast adjustment shall be performed in accordance with 10.5.1 or as directed by the cognizant engineering organization.

10.5.1 *Manual Contrast Method:* The Radiographic Level 3 shall adjust the contrast of the reference image to provide an appropriate presentation of discontinuities. This may be accomplished, for example, by comparison with the image in the equivalent film reference radiograph. Once established and secured, the window width of the reference image shall not be modified by the user. A stepped density scale of 12 steps covering a range of gray scale values is provided at the bottom of each reference image. They may be used to guide the establishment of the display contrast for the reference images. For many systems, a suitable contrast may be generated by performing a histogram normalization on the 12 steps of the contrast scale. Alternatively, the Level 3 may identify that improved representation is achieved using the contrast normalization on a reduced set of the stepped contrast scale, for example steps 3 through 11, or 4 through 12.

10.6 Viewer software shall provide the capability to lock the zoom levels of the production and reference digital images, so that both images are simultaneously adjusted.

10.7 Viewer software shall be capable of displaying the raw data value at the current cursor position.

10.8 Viewer software shall be capable of displaying the DDL at the current cursor position.

10.9 Viewer software shall be capable of displaying the distance between two selected points.

10.10 Viewer software shall allow the adjustment of the contrast (window width) of the production image.

10.11 Viewer software shall allow the independent adjustment of the brightness (window level) of the production image and reference image.

10.12 Viewer software shall be capable of generating line profiles in a graph or chart of the raw data pixel values as a function of distance or position.

10.13 Viewer software shall allow the user to select an area of interest and calculate the average and standard deviation of the raw data of the area selected by the user.

10.14 Viewer software shall have ability for one-to-one pixel mapping, that is, each pixel of data shall be mapped individually to a monitor pixel at a zoom of one.

10.15 Viewer software may apply image processing parameters to the displayed production images. This includes, but is not limited to, image processing functions such as filters, smoothing functions, edge enhancement or the conversion of

data through logarithmic or exponential transformation. Application of these functions or filters to the reference image shall only be made with the approval of the cognizant Level 3. The production image shall be adjusted to facilitate the comparison with the reference image. The reference image may be lightened or darkened to facilitate this comparison. This shall not be interpreted to mean that the window level must be the same for the production and reference images due to the possible difference in thickness between the area of interest of the production part and the reference hardware.

11. System Requirements

11.1 Minimum brightness as measured at the monitor screen at maximum digital driving level shall be at least 250 cd/m^2.

11.2 Minimum contrast as determined by the ratio of the monitor screen brightness at the maximum digital driving level compared to the monitor screen brightness at the minimum digital driving level shall be at least 250:1.

11.3 The monitor shall be capable of displaying linear patterns of alternating pixels at full contrast in both the horizontal and vertical directions without aliasing.

11.4 The monitor shall be capable of displaying linear patterns of alternating pixels at 100 % modulation.

11.5 The display shall be free of discernible geometric distortion.

11.6 The display shall be free of screen flicker, characterized by a high frequency fluctuation of high contrast image details.

11.7 The monitor shall be capable of displaying a 5 % DDL block against a 0 % DDL background and simultaneously displaying a 95 % DDL block against a 100 % background in a manner clearly perceptible to the user. (See Note 5.)

NOTE 5—System manufacturers often provide a test image that is suitable for making these measurements. The SMPTE test pattern as defined in RP133 may also be used in the validation of system requirements.

12. Keywords

12.1 aluminum; die casting; discontinuity classification; digital reference image; discontinuities; magnesium; X-ray