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Standard Digital Reference Images for Magnesium Castings[1]

This standard is issued under the fixed designation E2869; 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 the types and degrees of discontinuities that may be found in magnesium-alloy castings. The castings illustrated are in thicknesses of ¼ in. (6 mm) and ¾ in. (19.1 mm).

1.2 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.

1.3 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.

1.4 These digital reference images are not intended to illustrate the types and degrees of discontinuities found in magnesium-alloy castings when performing film radiography. If performing film radiography of magnesium-alloy castings, refer to Reference Radiographs E155.

1.5 Only licensed copies of the software and images shall be utilized for production examination. A copy of the ASTM/User license agreement shall be kept on file for audit purposes.

NOTE 1—The set of digital reference images consists of 14 digital files, software to load the desired format and specific instructions on the loading process. The 14 reference images illustrate eight grades of severity and contain an image of a step wedge and two duplex wire gauges.

1.6 *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]

E155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings

E1316 Terminology for Nondestructive Examinations

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 *SMPTE Practice*[3]

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

2.3 *ASTM Adjuncts*[4]

Digital Reference Images for Magnesium Castings

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 The terms relating to discontinuities used in these digital reference images are described based upon radiological appearance. (See Note 2.)

3.2.2 *aliasing*—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.

3.2.3 *contrast normalization*—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.

3.2.4 *DDL*—digital driving level also known as monitor pixel value.

[1] This standard 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.

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

[4] Available from ASTM International Headquarters. Order Adjunct No. RRE2869. Original adjunct produced in 2013.

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3.2.5 *foreign materials*—appear as isolated, irregular, or elongated variations in brightness, not corresponding to variations in thickness of material, nor to cavities. They may be due to the presence of sand, slag, oxide or dross, or metal of different density.

3.2.6 *gas holes*—appear as round or elongated, smooth-edged dark spots in a negative image, occurring individually, in clusters, or distributed throughout the casting.

3.2.7 *gas porosity*—represented by round or elongated dark spots in a negative image corresponding to minute voids usually distributed through the entire casting.

3.2.8 *measured resolution*—the characteristic resolution of a digital radiographic system as measured in accordance with 8.5.

3.2.9 *micro shrinkage (feathery type)*—micro shrinkage having an elongated appearance resembling feather-like streaks.

3.2.10 *micro shrinkage (sponge type)*—micro shrinkage having a sponge-like appearance, and more massive and equiaxed than the feathery type.

3.2.11 *reacted sand inclusions*—appear as "spotty segregation," which is, sharply defined round light areas (in a negative image) about 1 mm in diameter, and often with the rim lighter than the center. They are entrapped sand particles that underwent reaction with molten magnesium alloys containing zirconium (see Note 3).

3.2.12 *segregations*—appear as variations in image darkness, which can be explained by segregation of elements of atomic numbers different from that of the matrix.

3.2.12.1 *gravity segregation*—appears lighter in a negative image and may range from a mottling-type effect through white-diffused spots blending with the matrix, to a cloud-like appearance in more severe cases. They are agglomerations of particles precipitated at temperatures above liquidus (see Note 3).

3.2.12.2 *eutectic segregation*—type of segregation is generally represented when a defect or discontinuity develops during solidification and is fed with a near eutectic residual liquid rich with alloying elements that have a high X-ray density. One exception to this enrichment as illustrated in the reference images is flow line (or eutectic depletion), where there is a local impoverishment of the alloying elements that have a high X-ray density (see Note 3).

a) eutectic segregation—micro shrinkage type—type of segregation develops when a micro shrinkage develops during solidification, and is fed with residual liquid rich in dense alloying elements such as thorium. The area will show light on a radiographic image (see Note 3).

b) eutectic segregation—pipe shrink type—type of segregation develops during solidification when a pipe shrink forms and is immediately filled with eutectic liquid rich in high X-ray density alloying elements. The area shows light in a negative image as a feathery or dendritic feature (see Note 3).

c) eutectic segregation—hot tear type—type of segregation develops during solidification when the hot tear that takes place is immediately filled with liquid rich in alloying elements high in X-ray density. The defect shows as white or light irregular defined lines in a negative image (see Note 3).

d) eutectic depletion—flow line—type of segregation develops when a section of a mold is filled by liquid and solidifies at the front before liquid from another feed meets the solid front. A portion of the solid front then partially melts, otherwise the discontinuity would be a cold shut. Solidification begins after this remelt and the initial crystals are of high purity and contain fewer high-density alloying elements than the melt average. Since the metal is still flowing across these crystals, the composition ahead of this solidifying front is depleted. This depletion of the eutectic shows in a negative image as a dark diffused line (see Note 3).

e) oxide inclusions in magnesium alloys containing zirconium—show on a radiograph as well defined light area of irregular shape and size resembling a radiograph of a compacted fine steel wool. It is composed of complex magnesium oxide film with high zirconium content, and, if present, rare earths and thorium oxides also. It is often associated with zirconium-rich particles.

3.2.13 *shrinkage cavity*—appears as a dendritic, filamentary, or jagged darkened area in a negative image.

3.2.14 *shrinkage porosity or sponge (nonferrous alloys)*—a localized lacy or honeycombed darkened area in a negative image.

3.2.15 *system resolution*—the detector-measured resolution divided by the geometric magnification.

NOTE 2—In the descriptions of terms above, references to darkness of the image refer to cases where the images are being reviewed in negative format such that the images appear similar to the way the images would appear on film (that is, air or lower density materials show dark while higher density materials show as a lighter shade of gray). Where images are reviewed in positive format, the terms light or dark or lighter or darker will need to be reversed.

NOTE 3—More detailed descriptions of these discontinuities can be found in the article referenced below[5].

4. Significance and Use

4.1 These digital reference images are intended for reference only, but are so designed that acceptance standards, which may be developed for particular requirements, can be specified in terms of these digital reference images. The illustrations are digital images prepared from castings that were produced under conditions designed to develop the discontinuities. The images of the ¼ in. (6.4 mm) castings are intended to be used in the thickness range up to and including ½ in. (12.7 mm). The images of the ¾ in. (19.1 mm) castings are intended to be used in the thickness range of over ½ in. (12.7 mm), up to and including 2 in. (50.8 mm).

4.2 *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 ASTM E2002 line pair gauges located in the lower right hand corner of each digital reference can be used as an aid to detect

[5] Lagowski, B.,"New Reference Radiographs for Magnesium Alloy Castings," *Journal of Testing and Evaluation,* Vol 2, No. 4, July 1974.

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.

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

5. Basis for Application

5.1 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 4).

5.1.1 An area of like size to that of the digital reference image shall be the unit areas by which the production digital image is evaluated, and any such area shall meet the requirements as defined for acceptability.

5.1.2 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.

5.1.3 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.

5.1.4 Production digital images containing porosity, gas, or inclusions may be rated by the overall condition with regard to size, number, and distribution. These factors should be considered in balance.

5.1.5 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 4—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.

6. Procedure for Evaluation

6.1 Select the appropriate Digital Reference Image.

6.2 Apply contrast adjustments to the reference image by either method described in 9.5.

6.3 Evaluation shall be performed against the adjusted reference image.

7. Description

7.1 The digital reference images listed in Table 1 illustrate each type of discontinuity in eight grades. The digital reference images listed in Table 2 illustrate each type of discontinuity in eight grades, with the exception of discrete discontinuities of eutectic segregation, where only one example of pipe shrink, flow line, hot tear, and oxide inclusion is given. Although eight grades of each discontinuity are shown (with the above exceptions), a numerically smaller graded set of discontinuities based on these digital reference images could be used for acceptance standards. (See Note 5.)

7.2 The alloys used to reproduce the various discontinuities are as listed in Table 3.

7.3 The step wedges shown in the digital reference images are made of AZ91E, EV31, WE43 or ZE41A magnesium with the thickness of the steps listed in Table 4.

NOTE 5—Misruns, core shift, cold shut, and surface irregularities are not illustrated, as they are readily identifiable by surface examination or by other means of nondestructive testing.

8. Digital Image Installation Procedure

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

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

8.3 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 system's viewing software.

8.4 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 system resolution. System resolution is the detector resolution divided by the geometric magnification to be used during examination. (See Note 6.)

8.5 Determine the detector resolution for digital detector arrays (DDA) as described in Practice E2597 and for CR systems in Practice E2446.

TABLE 1 Digital Reference Images for Magnesium-Alloy Castings

Discontinuity	Casting Thickness in.[A]	Applicable Casting Thickness in.[A]	Step Wedge Alloy used in the Reference Image
Gas holes	¼	up to ½, incl	EV31
Gas holes	¾	over ½ to 2, incl	AZ91E
Microshrinkage (feathery)	¼	up to ½, incl	AZ91E
Microshrinkage (feathery)	¾	over ½ to 2, incl	AZ91E
Microshrinkage (sponge)	¼	up to ½, incl	AZ91E
Microshrinkage (sponge)	¾	over ½ to 2, incl	AZ91E
Foreign material (less dense)	¼	up to ½, incl	AZ91E
Foreign material (less dense)	¾	over ½ to 2, incl	AZ91E
Foreign material (more dense)	¼	up to ½, incl	AZ91E
Foreign material (more dense)	¾	over ½ to 2, incl	AZ91E

[A] 1 in. = 25.4 mm

TABLE 2 Digital Reference Images for Magnesium-Alloy Castings

Discontinuity	Casting Thickness in.[A]	Applicable Casting Thickness in.[A]	Step Wedge Alloy used in the Reference Image
Eutectic segregation (discrete discontinuities) – pipe shrink, flow line, hot tears, oxide inclusions	¼	All thicknesses	ZE41
Reacted sand inclusion	¼	All thicknesses	ZE41
Eutectic segregation (microshrinkage type)	¼	All thicknesses	ZE41
Gravity segregation	¼	All thicknesses	WE43

[A] 1 in. = 25.4 mm

TABLE 3 Actual Magnesium Alloys Used to Reproduce Discontinuities

Discontinuity	Alloy Used
Gas holes	ZK51A
Eutectic segregation and flow line	EZ33A
Gravity segregation	ZK91
Microshrinkage (feathery)	AZ91C
Microshrinkage (sponge)	AZ91C
Foreign material (less dense)	AZ91C
Foreign material (more dense)	AZ91C
Reacted sand inclusions	HK31A
Oxide inclusion in magnesium alloys containing zirconium	HZ11

TABLE 4 Thicknesses of Steps of Included Step Wedges

Step Number	Wedge ¼-in. Plates	Wedge ¾-in. Plates
1	0.100 in.	0.500 in.
2	0.150 in.	0.620 in.
3	0.200 in.	0.750 in.
4	0.250 in.	0.900 in.
5	0.300 in.	1.200 in.
6	0.400 in.	1.500 in.
7	0.500 in.	2.000 in.

8.6 Compare the measured resolution to the theoretical resolution determined by pixel size. If the measured resolution differs by no more than 30 % from the theoretical resolution, use the theoretical resolution as the detector resolution.

8.7 If the measured resolution differs from the theoretical 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 6—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.

9. Viewer Software Requirements

9.1 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.

9.2 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.

9.3 Digital reference images shall be selectable by discontinuity type.

9.4 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.

9.5 The contrast of the reference image shall be adjusted to ensure the displayed image reflects a suitable gray value change commensurate with material thickness change. Contrast adjustment shall be performed in accordance with 9.5.1 or 9.5.2 as directed by the cognizant engineering organization.

9.5.1 *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 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.

9.5.2 *Contrast Normalization Method*—The user shall employ software tools approved by the cognizant engineering organization to establish a relationship between the reference and production image such that the change in gray scale versus change in material thickness will be similar in both images. Once established the normalized contrast relationship between the production and reference image shall not be modified further by the user.

9.6 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.

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

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

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

9.10 Viewer software shall allow the adjustment of the contrast (window width) of the production image. Contrast adjustment of the production image may direct the contrast of the reference image through contrast normalization. Refer to 9.5.2 for contrast normalization requirements.

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

9.12 Viewer software shall be capable of generating line profiles of the raw data values.

9.13 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.

9.14 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.

9.15 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. If the manual contrast normalization method is used (see 9.5.1), 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.

10. System Requirements

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

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

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

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

10.5 The display shall be free of discernible geometric distortion.

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

10.7 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 7.)

NOTE 7—The SMPTE test pattern as defined in RP113 may be used in the validation of system requirements.

11. Keywords

11.1 castings; digital reference image; discontinuities; magnesium; X-ray

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