Designation: E2868 – 13ε1

Standard Digital Reference Images for Steel Castings up to 2 in. (50.8 mm) in Thickness[1]

This standard is issued under the fixed designation E2868; 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.

ε[1] NOTE—Reference radiograph stock numbers updated editorially in October 2015.

1. Scope

1.1 These digital reference images illustrate various categories, types, and severity levels of discontinuities occurring in steel castings that have section thicknesses up to 2 in. (50.8 mm). The digital reference images are an adjunct to this standard and must be purchased separately from ASTM International, if needed (see 2.3). Categories and severity levels for each discontinuity type represented by these digital reference images are described in 1.2.

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 4, 6, and 7 of this standard.

1.2 These digital reference images consist of three separate volumes (see Note 2) as follows: (I) medium voltage (nominal 250-kV) X rays, (II) 1-MV X rays and Iridium-192 radiation, and (III) 2-MV to 4-MV X rays and Cobalt-60 radiation. Unless otherwise specified in a purchaser supplier agreement (see 1.1), each volume is for comparison only with production digital images produced with radiation energy levels within the thickness range covered by this standard. Each volume consists of six categories of graded discontinuities of increasing severity level and four categories of ungraded discontinuities. Reference images containing ungraded discontinuities are provided as a guide for recognition of a specific casting discontinuity type where severity levels are not needed. The following is a list of discontinuity categories, types, and severity levels for the adjunct digital reference images of this standard:

1.2.1 *Category A* – Gas porosity; severity levels 1 through 5.

1.2.2 *Category B* – Sand and slag inclusions; severity levels 1 through 5.

1.2.3 *Category C* – Shrinkage; 4 types:

1.2.3.1 *Ca–linear shrinkage*– Severity levels 1 through 5.

1.2.3.2 *Cb–feathery shrinkage*– Severity levels 1 through 5.

1.2.3.3 *Cc–sponge shrinkage*– Severity levels 1 through 5.

1.2.3.4 *Cd–combinations of linear, feathery, and sponge shrinkage* – Severity levels 1 through 5.

1.2.4 *Category D*–Crack; 1 illustration.

1.2.5 *Category E*–Hot Tear; 1 illustration.

1.2.6 *Category F*–Insert; 1 illustration.

1.2.7 *Category G*–Mottling; 1 illustration. (See Note 3.)

NOTE 2—The digital reference images consist of the following:
Volume I: Medium Voltage (nominal 250-kVp) X-Ray Reference Images – Set of 34 illustrations.
Volume II: 1-MV X Rays and Iridium-192 Reference Images – Set of 34 illustrations.
Volume III: 2-MV to 4-MV X Rays and Cobalt-60 Reference Images – Set of 34 illustrations.

NOTE 3—Although Category G – Mottling is listed for all three volumes, the appearance of mottling is dependent on the level of radiation energy. Mottling appears reasonably prominent in Volume I; however, because of the higher radiation energy levels mottling may not be apparent in Volume II nor Volume III.

1.3 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.

1.4 These digital reference images are not intended to illustrate the types and degrees of discontinuities found in steel castings up to 2 in. (50.8 mm) in thickness when performing film radiography. If performing film radiography of steel castings up to 2 in. (50.8 mm) in thickness, refer to Reference Radiographs E446.

1.5 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 4.)

NOTE 4—Each volume of digital reference images consists of 7 digital data files, software to load the desired format and specific instructions on the loading process. The 34 reference images in each volume illustrate six categories of graded discontinuities and four categories of ungraded discontinuities and contain an image of a step wedge. Available from ASTM International Headquarters, Order No: RRE286801 for Volume I, RRE286802 for Volume II, and RRE286803 for Volume III.

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

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conversions to SI units that are provided for information only and are not considered standard.

1.7 *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]

E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness

E1316 Terminology for Nondestructive Examinations

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 Adjunct:*[4]

RRE286801 Digital Reference Images for Inspection of Steel Castings Up to 2 in. (50.8 mm) in Thickness (Volume I) : Medium Voltage (nominal 250-kVp) X-Ray Reference Images

RRE286802 Digital Reference Images for Inspection of Steel Castings Up to 2 in. (50.8 mm) in Thickness (Volume II): 1-MV X Rays and Iridium-192 Reference Images

RRE286803 Digital Reference Images for Inspection of Steel Castings Up to 2 in. (50.8 mm) in Thickness (Volume III): 2-MV to 4-MV X Rays and Cobalt-60 Reference Images

3. Terminology

3.1 *Definitions:*

3.1.1 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 *classification specification, n*—a set of user defined acceptance criterion that prescribes the radiographic workmanship discontinuity class requirements for a specified user casting service application (see Sections 6 and 7).

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

3.2.5 *discontinuity category, n*—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.

3.2.6 *discontinuity class, n*—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."

3.2.7 *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 "5" is the greatest "quantity, size, and distribution" present on the reference image. Example: a severity level of "1" is more restrictive (requires a higher level of workmanship fabrication quality) than a severity level of "2".

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

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

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

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

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

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

4. Significance and Use

4.1 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 fabrication 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 6 and 7).

4.2 Reference images represented by this standard may be used, as agreed upon in a purchaser supplier agreement, for

[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 the 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 No: RRE286801 for Volume I, RRE286802 for Volume II, and RRE286803 for Volume III.

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 images using applicable reference images of this standard are prescribed in Section 8; 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. Section 9 addresses purchaser supplier requisites for where weld repairs may be required.

4.4 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. Determination of Radiographic Acceptance Criteria

5.1 For purposes of evaluation of castings, a determination must be made of the radiographic discontinuity acceptance criteria to be assigned to individual castings or specific areas of castings. The determination of the applicable radiographic discontinuity criteria 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.

5.2 For each individual casting or specific area of a casting to be radiographed, the discontinuity criteria must be clearly specified. For example, severity level 2 might be specified for linear shrinkage, Category Ca, and severity level 3 for gas porosity, Category A, since the latter are generally much less deleterious to tensile properties (see Section 6).

6. Acceptance Criteria Specifications

6.1 The applicable radiographic discontinuity acceptance criteria 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, image quality desired as well as the severity of the acceptable discontinuity for the graded categories.

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 Section 10.5.

7.3 Evaluation shall be performed against the adjusted reference image.

7.4 Compare the production images of the casting submitted for evaluation with the reference images representing the same general energy range within the thickness range of this standard (unless otherwise specified—see Section 4).

7.5 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.

7.6 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.

7.7 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.

7.8 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.

7.9 Reference images are provided showing a variety of shrinkage discontinuity types. Production images showing shrinkage shall be judged by the most representative reference image.

7.10 This standard does not specify limiting criteria for a single size of discontinuity, maximum number of discontinuities per unit area evaluated, specific dimensional spacing, or alignment criterion between individual discontinuities, or combinations thereof, or any other undefined discontinuity patterns. Unless otherwise specified by a purchaser supplier agreement (see Section 4), these discontinuity conditions on production images shall be evaluated as aggregate conditions as defined in 7.8.

7.11 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.

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

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

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

7.13 A diffraction mottling pattern can occur on images of parts and sections where the grain size is large enough to be an appreciable fraction of the material thickness (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 center line 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 an image, this condition shall not be considered as prejudicial in evaluating the image.

NOTE 5—Mottling is often associated with thin sections of austenitic steels and copper based alloys such as copper nickel, tin bronzes, and nickel copper.

7.14 Hot tears and cracks exhibited on production images may at times resemble linear type shrinkage. When doubt exists whether such indications are cracks or tears, or are linear shrinkage, all surface in the area of interest shall be ground and magnetic particle or liquid penetrant inspected as applicable. 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.

7.15 The radiographic density 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 system resolution. System resolution is the detector resolution divided by the geometric magnification to be used during inspection. (See Note 6).

9.5 Determine the 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 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 resolution differs by no more than 30 % from the theoretical resolution, use the theoretical resolution as the detector resolution.

9.7 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. 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 20 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 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 14 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 14 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 2 through 13.

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 a region of interest and calculate the average and standard deviation of the raw data of the region 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 7.)

NOTE 7—The SMPTE test pattern as defined in RP133 may be used in the validation of system requirements.

12. Keywords

12.1 discontinuities; discontinuity classification criterion; digital reference images; gamma ray; X-ray