Designation: E1814 – 14 (Reapproved 2022)

Standard Practice for Computed Tomographic (CT) Examination of Castings[1]

This standard is issued under the fixed designation E1814; 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 This practice covers a uniform procedure for the examination of castings by the computed tomography (CT) technique. The requirements expressed in this practice are intended to control the quality of the nondestructive examination by CT and are not intended for controlling the acceptability or quality of the castings. This practice implicitly suggests the use of penetrating radiation, specifically X rays and gamma rays.

1.2 This practice provides a uniform procedure for a CT examination of castings for one or more of the following purposes:

1.2.1 Examining for discontinuities, such as porosity, inclusions, cracks, and shrink;

1.2.2 Performing metrological measurements and determining dimensional conformance; and

1.2.3 Determining reverse engineering data, that is, creating computer-aided design (CAD) data files.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

E1441 Guide for Computed Tomography (CT)

E1570 Practice for Fan Beam Computed Tomographic (CT) Examination

E1672 Guide for Computed Tomography (CT) System Selection

E1695 Test Method for Measurement of Computed Tomography (CT) System Performance

E1935 Test Method for Calibrating and Measuring CT Density

E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)

E2767 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for X-ray Computed Tomography (CT) Test Methods

2.2 *ASNT Documents:*[3]

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

ANSI/ASNT CP-189 Standard for Personnel Qualification and Certification of Nondestructive Testing Personnel

2.3 *Military Standards:*[4]

NAS 410 Certification and Qualification of Nondestructive Test Personnel

3. Terminology

3.1 *Definitions*—Definitions of terms applicable to this practice may be found in Terminology E1316 and Guide E1441.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *fixturing*—the mounting hardware used to place the object in the CT system.

3.2.2 *scan plan*—scan locations and the system configuration parameters for a specific part examination.

4. Significance and Use

4.1 CT may be performed on an object when it is in the as-cast, intermediate, or final machined condition. A CT examination can be used as a design tool to improve wax forms

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) Method.

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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 American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://assist.daps.dla.mil.

*A Summary of Changes section appears at the end of this standard

and moldings, establish process parameters, randomly check process control, perform final quality control (QC) examination for the acceptance or rejection of parts, and analyze failures and extend component lifetimes.

4.2 The most common applications of CT for castings are for the following: locating and characterizing discontinuities, such as porosity, inclusions, cracks, and shrink; measuring as-cast part dimensions for comparison with design dimensions; and extracting dimensional measurements for reverse engineering.

4.3 The extent to which a CT image reproduces an object or a feature within an object is dictated largely by the competing influences of spatial resolution, contrast discrimination, the specific geometry and material of the object itself, and artifacts of the imaging system. Operating parameters strike an overall balance between image quality, examination time, and cost.

4.4 Artifacts are often the limiting factor in CT image quality. (See Practice E1570 for an in-depth discussion of artifacts.) Artifacts are reproducible features in an image that are not related to actual features in the object. Artifacts can be considered correlated noise because they form repeatable fixed patterns under given conditions yet carry no object information. For castings, it is imperative to recognize what is and is not an artifact since an artifact can obscure or masquerade as a discontinuity. Artifacts are most prevalent in castings with long straight edges or complex geometries, or both.

5. Basis of Application

5.1 The following items shall be agreed upon between the purchaser and the supplier and specified in the contract or job order:

5.1.1 *Nondestructive Testing Agency Evaluation*—The use of a nondestructive testing (NDT) agency, as defined in Practice E543. If a systematic assessment of the capability of the agency is specified, a documented procedure, such as that described in Practice E543, should be used as the basis for evaluation.

5.1.2 *Personnel Qualifications*—All CT examination personnel shall be qualified and certified in accordance with a written procedure conforming to ANSI/ASNT CP-189, SNT-TC-1A, NAS 410, or a similar document. The written procedure shall include training that addresses CT issues specifically.

5.1.3 *General Requirements*—General requirements shall be specified in accordance with Section 8: (*1*) written procedure, 8.1; and (*2*) CT system validation measurements, 8.3.

5.1.3.1 Specific requirements regarding preparation and approval of the written procedures should be agreed upon in advance by the purchaser and the supplier.

5.1.4 *Fixturing*—The object fixturing shall be determined by agreement between the purchaser and the supplier in accordance with 9.2.

5.1.5 *Image Processing*—Image processing routines used in analysis of the CT data shall be specified in accordance with 6.2: (*1*) dimensional measurements, 6.2.1; and (*2*) discontinuity characterization, 6.2.2.

5.1.6 *Discontinuity Types*—A listing of the expected kinds of discontinuities shall be provided or referenced, and the acceptance and rejection criteria shall be stipulated.

5.1.7 *Records*—Records requirements shall be specified in accordance with Section 10.

6. Apparatus

6.1 The success of the CT application depends on the overall system configuration and the selection of appropriate subsystem components. Guidance on the selection of subsystem components and the overall system configuration is provided in Guide E1672. Guidance on the initial system performance evaluation for baseline and periodic system performance check of the CT system is provided in Test Method E1695. Guidance on calibrating and measuring CT density measurements is provided in Test Method E1935. The suitability of the CT system shall be demonstrated by attainment of the required image quality and compliance with all other requirements stipulated herein.

6.2 *Computer/Image Processing Software*—Image processing software may be used for image enhancement operations that will facilitate dimensional measurements and discontinuity detection or characterization.

6.2.1 Dimensional measurements, with tolerance, can be obtained from the CT image. There is a degree of blurring in the CT image that makes sharp boundaries indistinct. A common approach for on-screen dimensional measurements is to generate a density profile along a straight line between the points in the image representing the distance to be measured. The end points of the measurement are generally taken to be the density profile values located at the half maximum value point on each slope. This is called the full-width-at-half-maximum (FWHM) method. This method or various other techniques, that is, the area under the curve or determining contours for CAD output, can be generalized for wall thickness, hole diameter, and crack width measurements.

6.2.2 Each dimensional measurement technique has its own precision, and for its determination, the creation of the CT image must be understood thoroughly. A point-like object will not appear in an image as a sharp point. Instead, the “true” image will be convolved with a Gaussian distribution-like function called the point spread function (PSF). Therefore, when looking at a density profile along a line in a CT image, an abrupt density change (that is, from material to air) will not appear as a step but as a curve. See Guide E1441 and Sections 5, 8, and 9 for further discussion.

6.2.3 Some tools require the availability of an object that can be scanned and then dissected (destructive evaluation) for comparison with actual dimensional measurements. The CT system can be “spatially calibrated” (determine the voxel size for dimensional measurements) for a specific object from this comparison data.

6.2.4 Various types of density analysis tools may be needed for discontinuity characterization, such as tools for measuring low-density indications, missing mass, area, and shape.

6.3 Purchasers are cautioned to test thoroughly, or have prior experience with, the proposed image processing parameters before authorizing routine use. For example, some spatial filter functions produce directional results and may suppress desired image information. Other spatial filters can introduce artifacts into the image.

7. Safety

7.1 The CT procedures shall comply with applicable local, state, and federal safety regulations.

8. Requirements

8.1 *Written Procedure*—The CT examination should be performed in accordance with a written procedure. The procedure should address all applicable portions of this practice and should be available for review during interpretation of the images.

8.1.1 Practice E1570 (System Configuration) details a list of the variables that can affect the examination outcome for a selected system configuration. The values used for these variables should be documented in the written procedure.

8.1.2 The written procedure or scan plan should also include the following:

8.1.2.1 Description of the object and engineering drawings.

8.1.2.2 Fixturing requirements and instructions.

8.1.2.3 Handling requirements and instructions.

8.1.2.4 Representative Quality Indicator (RQI) to be used.

8.1.2.5 Algorithms or methods to be used for measuring dimensions and discontinuities.

8.1.2.6 *Scan Locations*—For example, scan locations can be specified by sketch, photograph, or drawing or determined by a digital radiograph of the object from the same CT scanner.

8.2 *CT System Validation*—The CT system performance parameters must be determined initially and monitored regularly to ensure consistent results. The CT performance level may be specified in terms of one or both of the following:

8.2.1 *Detectability of Features in an RQI*—If dimensional measurements are to be made from the CT data, a CT scan of a dimensionally known object shall be used to spatially calibrate the CT system. The use of an actual or simulated object has benefits. An RQI demonstrates that the required system performance can be achieved, in both the CT examination and the interpretation and analysis.

8.2.2 *Performance Measurements, Using a Disk Phantom, as Outlined in Test Method E1695*—The performance measurements determined using the disk phantom are the CT system spatial resolution and contrast sensitivity at specified scan parameters. These performance measurements are required to monitor the overall system performance and check for variations over time, as well as to determine the performance of the equipment prior to CT examination of the objects.

8.3 *Validation Measurement Intervals*—System stability over time must be demonstrated to the purchaser. There are two approaches, as follows:

8.3.1 System performance measurements, using the disk phantom, can be taken periodically to check the ratio of signal to noise levels at disk center, spatial resolution, and contrast resolution. These data will be made available to the purchaser for review, upon request. Interval for performance measurements is as agreed between purchaser and supplier with consideration of the CT system manufacturer recommendations. At least the previous 12 months performance data shall be available to the purchaser.

8.3.2 A disk phantom or RQI, or both, can be scanned before and after CT examination of the casting(s). If a variation exists, explanations and corrections will need to be made and validated.

9. Procedure

9.1 *Handling and Preparation*—Follow the handling instructions as documented in the written procedure. While no surface preparation is required for CT, the removal of surface blemishes and debris that could confuse the image is recommended.

9.2 *Object Fixturing*—Fixturing is typically incidental to the examination of castings since CT will image any hardware for fixturing along with the object. However, precision fixturing must be used when orientation or repeatability, or both, are of high importance. The fixtures usually vary from part to part and examination to examination. If possible, the fixtures should not be in the scan plane.

9.2.1 *Precision Fixturing*—Precision fixturing will be necessary if any of the following requirements pertain:

9.2.1.1 Dimensional measurements in a precise location or relative to a precise plane, or both, are specified.

9.2.1.2 Dimensional measurements are to be registered with other types of measurements, such as, ultrasonic.

9.2.1.3 Part to part comparisons are to be made.

9.2.2 *Precision Fixturing Procedure*—The fixturing procedure will include the type and amounts of hardware, the locations of the hardware relative to the object and the CT system, and how to mount and dismount the object. The precision fixturing should be: (*1*) specific to the casting to be examined; (*2*) out of the scan plane, whenever possible; and (*3*) made of material less dense than the casting, to reduce or avoid artifacts, if in the scan plane.

9.3 *Data Collection*—Data shall be collected in accordance with the written procedure or scan plan. A quick, qualitative image check, to verify proper operation of the equipment, should be performed before the casting is removed from the CT system.

9.4 *Image Analysis*—Image analysis will verify the image quality levels, process, and analyze the image as stipulated in the contract or job order. The validity of the image analysis will be attested as stipulated in the contract or job order.

9.4.1 *Image Artifacts*—Image artifacts can mask or be confused with a discontinuity. Regions of the CT image in which measurements are to be made should be free of artifacts. If any doubt exists concerning the true nature of a discontinuity exhibited in the image, the image shall be rejected and a new image of the area made. It may be possible to prevent certain system deficiency artifacts by re-fixturing the object being examined relative to the direction of motion of the CT system or the location of external supports, or both, or ensuring the mechanical handling system of the CT system is properly aligned.

9.5 *Documentation*—Documenting and archiving of the CT examination data must be performed in accordance with Section 10.