Designation: E 1814 – 96

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

This standard is issued under the fixed designation E 1814; 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 Inspecting 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 and health practices and determine the applicability of regulatory limitations prior to use.* For specific safety statements, see Section 7, *NBS Handbook 114*,[2] and 21 CFR 1020.40 and 29 CFR 1910.96.

2. Referenced Documents

2.1 *ASTM Standards:*

E 543 Practice for Evaluating Agencies that Perform Nondestructive Testing[3]

E 1316 Terminology for Nondestructive Examinations[3]

E 1441 Guide for Computed Tomography (CT) Imaging[3]

E 1570 Practice for Computed Tomographic (CT) Examination[3]

E 1672 Guide to Computed Tomography (CT) System Selection[3]

E 1695 Test Method for Measurement of Computed Tomography (CT) System Performance[3]

2.2 *ASNT Standards:*[4]

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

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

2.3 *Military Standard:*

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[5]

2.4 *Code of Federal Regulations:*[5]

21 CFR 1020.40 Safety Requirements of Cabinet X Ray Systems

29 CFR 1910.96 Ionizing Radiation

3. Terminology

3.1 *Definitions*—Definitions of terms applicable to this practice may be found in Terminology E 1316 and Guide E 1441.

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *representative quality indicator (RQI)*—a real part, or a fabrication of similar geometry in radiologically similar material to a real part, that has features of known characteristics that represent all of the features for which the test parts are being examined.

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

3.2.4 *test object*—a part or specimen being subjected to CT examination.

4. Significance and Use

4.1 The CT may be performed on a test 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 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

[1] This practice is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) Method.

Current edition approved May 10, 1996. Published July 1996.

[2] *NBS Handbook 114, General Safety Standard for Installations, Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies Up to 10 MeV*, National Institute of Standards and Technology (NIST), Gaithersburg, MD.

[3] *Annual Book of ASTM Standards*, Vol 03.03.

[4] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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, and artifacts of the imaging system. Operating parameters strike an overall balance between image quality, inspection time, and cost.

4.4 Artifacts are often the limiting factor in CT image quality. (See Practice E 1570 for an in-depth discussion of artifacts.) Artifacts are reproducible features in an image that are not related to actual features in the test object. Artifacts can be considered correlated noise because they form repeatable fixed patterns under given conditions yet carry no test 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 E 543. If a systematic assessment of the capability of the agency is specified, a documented procedure, such as that described in Practice E 543, 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, MIL-STD-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 test 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 E 1672. Guidance on the initial qualification and periodic requalification of the CT system is provided in Test Method E 1695. 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 System*—Image processing systems 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. Due to the finite spot size of the source, and the finite aperture size of the detector, 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 E 1441 and Sections 5, 8, and 9 for further discussion.

6.2.3 Some tools require the availability of a test object that can be scanned and then dissected (destructive evaluation) for comparison with actual dimensional measurements. The CT system can be “calibrated” for a specific test object from this comparitor 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 E 1570 (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 test object and engineering drawings.

8.1.2.2 Fixturing requirements and instructions.

8.1.2.3 Handling requirements and instructions.

8.1.2.4 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 test 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:

(*1*) *Detectability of Features in an RQI*—The use of an actual or simulated test object has two benefits. First, CT scans through a dimensionally known test object can help to calibrate the CT system when taking dimensional measurements. Second, an RQI demonstrates that the required system performance can be achieved, in both the CT examination and the interpretation and analysis.

(*2*) *Performance Measurements, Using a Disk Phantom, as Outlined in Test Method E 1695*—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 under test.

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.

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 *Test Object Fixturing*—Fixturing is typically incidental to the examination of castings since CT will image any hardware for fixturing along with the test 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, that is, 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 test object and the CT system, and how to mount and dismount the test 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 re-calibrating the CT scanner.

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

10. Records

10.1 Records shall be retained as stipulated in the contract or job order. As a minimum, the following records are sufficient in detail to allow the CT examination to be repeated:

10.1.1 Written procedure, and

10.1.2 CT examination data.

11. Keywords

11.1 castings; computed tomography; CT; examination; inspection; NDE; NDI; nondestructive evaluation; nondestructive inspection