Designation: E 1695 – 95 (Reapproved 2001)

Standard Test Method for Measurement of Computed Tomography (CT) System Performance[1]

This standard is issued under the fixed designation E 1695; 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 test method provides instruction for determining the spatial resolution and contrast sensitivity in X-ray and γ-ray computed tomography (CT) images. The determination is based on examination of the CT image of a uniform disk of material. The spatial resolution measurement is derived from an image analysis of the sharpness at the edge of the disk. The contrast sensitivity measurement is derived from an image analysis of the statistical noise at the center of the disk.

1.2 This test method is more quantitative and less susceptible to interpretation than alternative approaches because the required disk is easy to fabricate and the analysis is immune to cupping artifacts. This test method may not yield meaningful results if the disk image occupies less than a significant fraction of the field of view.

1.3 This test method may also be used to evaluate other performance parameters. Among those characteristics of a CT system that are detectable with this test method are: the mid-frequency enhancement of the reconstruction kernel, the presence (or absence) of detector crosstalk, the undersampling of views, and the clipping of unphysical (that is, negative) CT numbers (see Air Force Technical Report WL-TR-94-4021[2]). It is highly likely that other characteristics as well can be detected with this test method.

1.4 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only.

1.5 *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:*

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]

3. Terminology

3.1 *Definitions*—The definitions of terms relating to Gamma- and X-Radiology, which appear in Terminology E 1316 and Guide E 1441, shall apply to the terms used in this test method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *phantom*—a part or item being used to quantify CT system performance.

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

3.3 *Acronyms:*Acronyms:

3.3.1 *ERF*—edge response function.

3.3.2 *PSF*—point spread function.

3.3.3 *MTF*—modulation transfer function.

3.3.4 *CDF*—contrast discrimination function.

4. Significance and Use

4.1 Two factors affecting the quality of a CT image are geometrical unsharpness and random noise. Geometrical unsharpness limits the spatial resolution of a CT system, that is, its ability to image fine structural detail in an object. Random noise limits the contrast sensitivity of a CT system, that is, its ability to detect the presence or absence of features in an object. Spatial resolution and contrast sensitivity may be measured in various ways. ASTM specifies spatial resolution be quantified in terms of the modulation transfer function (MTF) and contrast sensitivity be quantified in terms of the contrast discrimination function (CDF) (see Guide E 1441 and Practice E 1570). This test method allows the purchaser or the provider of CT systems or services, or both, to measure and specify spatial resolution and contrast sensitivity.

5. Apparatus

5.1 *Disk Phantom*—The disk phantom shall be a right cylinder of uniform material conforming to the design and material requirements in Table 1 and Fig. 1. Since spatial resolution and contrast sensitivity depend on the examination task (that is, the examination object and the specified CT parameters), the application requirements must be fixed before

[1] This test method 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] X-Ray Computed Tomography Standards (WL-TR-94-4021). Bossi, R. H. and Nelson, J. M. Air Force Contract No. F33615-88-C-5404.

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

TABLE 1 Disk Phantom Design Requirements

Material	The material, in conjunction with the diameter of the disk, shall be such that the phantom approximates the attenuation range of the examination object. The material should preferably be the same as that of the examination object.
Diameter	The diameter shall be such that the reconstruction of the disk occupies a significant fraction of the resulting image. In conjunction with the material, the diameter shall be such that the phantom approximates the attenuation range of the examination object.
Thickness	The thickness of the disk shall be greater than the slice thickness used to inspect the examination object.
Shape	The perpendicularity of the axis of revolution with respect to the surface used to mount the phantom on the CT system shall not compromise the measurement of geometrical unsharpness.
Finish	The surface texture roughness of the curved surface shall not compromise the measurement of geometrical unsharpness.

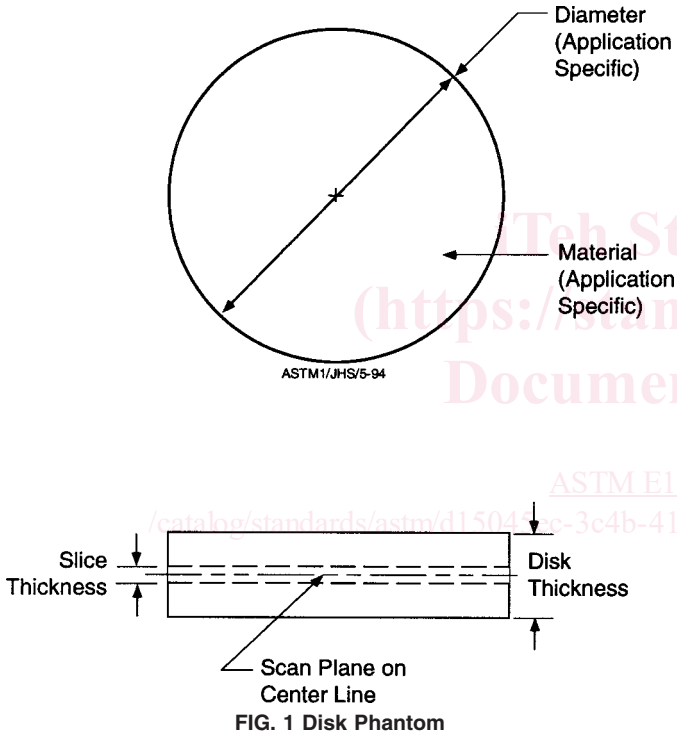

FIG. 1 Disk Phantom

the phantom can be designed. In general, each examination task will require a separate phantom. The diameter of the disk relative to the field of view shall be such that the reconstructed image of the disk occupies a significant fraction of the image matrix. Recommended sizes are given in Table 2. The diameter and opacity of the disk shall be such that the phantom approximates the attenuation range of the examination object. If possible, the phantom should be of the same material as the examination object, but the other requirements take precedence and may dictate the selection of another material. The design of the disk phantom is a matter of agreement between the purchaser and the supplier.

TABLE 2 Suggested Measurement Parameters

Image Matrix Size (Pixels)	Disk Image Diameter (Pixels)	Maximum Tile Size (Pixels)	ERF Bin Size (Pixels)	Number of Fit Points
256	235	12	0.100	11
512	470	24	0.050	21
1024	940	48	0.025	41

6. Procedure

6.1 The phantom shall be mounted on the CT system with the orientation of the axis of revolution of the disk normal to the scan plane. The alignment shall not compromise the measurement of geometrical unsharpness. Unless otherwise agreed upon between purchaser and supplier, the phantom shall be placed at the center of the field of view used for the examination object.

6.2 Unless otherwise agreed upon between purchaser and supplier, the data acquisition parameters shall be identical to those used for examination object scans. The slice plane shall intercept the phantom approximately midway between the flat faces of the disk.

6.3 Unless otherwise agreed upon between purchaser and supplier, the reconstruction parameters shall be identical to those used for examination object reconstructions.

6.4 Unless otherwise agreed upon between purchaser and supplier, the display parameters shall be identical to those used for examination object display. It shall be verified by examination that the disk image occupies an image at least two-thirds of the image matrix. Recommended guidelines are given in Table 2.

7. Interpretation of Results

7.1 *Spatial Resolution*—From the CT image data, generate the composite profile of the edge of the disk to obtain the edge response function (ERF). Calculate the derivative of the ERF to obtain the point spread function (PSF). Calculate the amplitude of the Fourier Transform[4] of the PSF and normalize the results to unity at zero frequency to obtain the modulation transfer function (MTF).

[4] The Fourier Transform and Its Applications, Ronald M. Bracewell, McGraw-Hill, NY, ISBN 0-07-007013-X.