Designation: ~~E2903 – 13~~ E2903 – 18

Standard Test Method for Measurement of the Effective Focal Spot Size of Mini and Micro Focus X-ray Tubes[1]

This standard is issued under the fixed designation E2903; 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~~ Scope*

1.1 The image quality and the resolution of X-ray images highly depend on the characteristics of the focal spot. The imaging qualities of the focal spot are based on its two dimensional intensity distribution as seen from the imaging place.

1.2 This test method provides instructions for determining the effecting size (dimensions) of mini and micro focal spots of industrial X-ray tubes. It is based on the European standard, EN 12543–5, Non-destructive testing - Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing - Part 5: Measurement of the effective focal spot size of mini and micro focus X-ray tubes.

1.3 This standard specifies a method for the measurement of effective focal spot dimensions from 5 up to 300 µm of X-ray systems up to and including 225 kV tube voltage, by means of radiographs of edges. Larger focal spots should be measured using Test Method E1165 Standard Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging.

1.4 The same procedure can be used at higher kilovoltages by agreement, but the accuracy of the measurement may be poorer.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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

1.7 *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]

E1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging

E1255 Practice for Radioscopy

~~E1742~~E1742/E1742M Practice for Radiographic Examination

E1815 Test Method for Classification of Film Systems for Industrial Radiography

E2002 Practice for Determining Total Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy

E2033 Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)

E2446 Practice for Manufacturing Characterization of Computed Radiography Systems

~~E2597~~E2597/E2597M Practice for Manufacturing Characterization of Digital Detector Arrays

E2698 Practice for Radiological Examination Using Digital Detector Arrays

2.2 *European Standards:*[3]

EN 12543–5 Non-destructive testing—Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing - Part 5: Measurement of the effective focal spot size of mini and micro focus X-ray tubes

[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] 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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *actual focal spot*—the X-ray producing area of the target as viewed from a position perpendicular to the target surface.

3.1.2 *effective focal spot*—the X-ray producing area of the target as viewed from the image plane.

4. Summary of Test Method

4.1 This method is based on indirect measurement of the focal spot size by measuring the geometric unsharpness then using a geometric calculation to determine the effective focal spot dimensions (see Section 8). For this purpose, edges are imaged either on a film or by means of a radioscopic or digital radiographic device using a relatively high geometric magnification. For a full description see reference below.[4]

5. Significance and Use

5.1 One of the factors affecting the image quality of a radiographic image is geometric unsharpness. The degree of geometric unsharpness is dependent upon the focal spot size of the radiation source, the distance between the source and the object to be radiographed, the distance between the object to be radiographed and the image plane (film, imaging plate, Digital Detector Array (DDA), or radioscopic detector). This test method allows the user to determine the effective focal spot size (dimensions) of the X-ray source. This result can then be used to establish source to object and object to image detector distances appropriate for maintaining the desired degree of geometric unsharpness or maximum magnification possible, or both, for a given radiographic imaging application. The accuracy of this method is dependent upon the spatial resolution of the imaging system, magnification, and signal-to-noise of the resultant images.

6. Apparatus

6.1 The following equipment is required for the measurement if using X-ray film:

6.1.1 A test object as described in 6.5.

6.1.2 X-ray films, without screens, of sufficient size to image magnified test object and region around test object to obtain a profile as shown in Fig. 1.

6.1.3 Film cassettes made of low absorbing material (for example polyethylene).

6.1.4 A film holder.

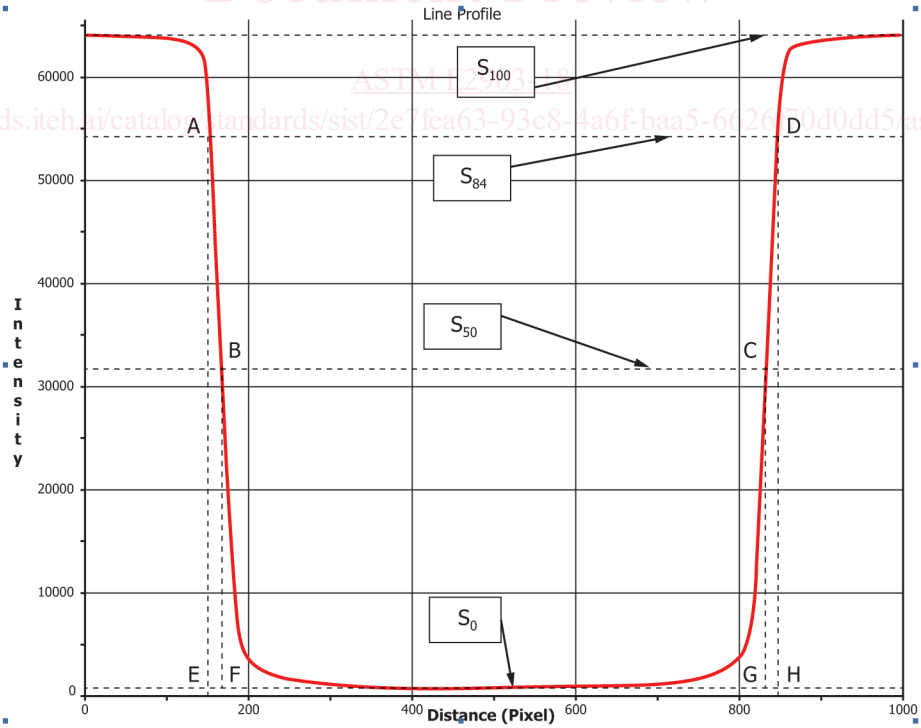

FIG. 1 Profile of Test Object Image (Test Object: Pt wire 1 mm)

[4] Fry, Ewert, Gollwitzer, Neuser, and Selling, "Measuring microfocal spots using digital radiography" *Materials ~~Evaluation,~~Evaluation*, Vol 70, No. 8, August 2012, p. 981.

6.1.5 A film processing unit.

6.1.6 A film scanner capable of reading densities greater than 3.0 configured such that the pixel size is appropriate for the measurement (refer to Section 7). The film shall be of sufficient size to image the magnified test object and region around test object to obtain a profile as shown in Fig. 1.

6.1.7 The film system shall meet the requirements of Test Method E1815 film system class I, II, or Special.

6.2 The following equipment is required for the measurement if using computed radiography (CR):

6.2.1 A test object as described in 6.5.

6.2.2 A computed radiography system, consisting of an imaging plate and scanner, configured such that the pixel size is appropriate for the measurement (refer to Section 7). The imaging plate shall be of sufficient size to image test object and region around test object to obtain a profile as shown in Fig. 1.

6.2.3 The computed radiography system shall meet the requirements of Practice E2446 class I, II, or Special, and image plates shall be packed in low absorption cassettes using no screens.

6.3 The following equipment is required for the measurement if using a radioscopic or digital detector array device:

6.3.1 A test object as described in 6.5.

6.3.2 A radioscopic device, for example any image intensifier with video equipment or Digital Detector Array, configured such that the pixel size is appropriate for the measurement (refer to Section 7), or

6.3.3 A Digital Detector Array system meeting the requirements of Practice ~~E2597~~E2597/E2597M. The digital Detector Array cover should be constructed of low X-ray absorption material and should be free of cluster kernel pixels as defined in Practice ~~E2597~~E2597/E2597M.

6.3.4 The imaging area shall be of sufficient size to image magnified test object and region around test object to obtain a profile as shown in Fig. 1.

6.4 Image processing equipment as follows:

6.4.1 An image processing device with the capability of producing linearized intensity profiles (signal is linear with dose), integration of profiles, and profile plots within the digital image in two directions perpendicular to each other, and with the capability to measure distances.

6.5 The test object shall be either a set of wires or a sphere consisting of highly absorbing material (for example tungsten, tungsten alloy, or platinum). The diameter of the wire or sphere should be greater than 20 times the focal spot dimension if the focal spot is less than 40 µm to minimize edge penetration; otherwise, the diameter should be 0.8 to 1.0 mm for focal spots greater than 40 µm. The diameter shall be known to within ±1 %.

6.5.1 In case of using two single crossed wires they shall cross each other at an angle of 90° ± 3°. The wires shall be mounted across a circular aperture in a stable frame, in such a manner that the crossing point is located in the center of the aperture. In case of using the sphere it shall be mounted on a thin polyethylene support or placed into a thin polyethylene envelope.

6.5.2 The Unsharpness Gauge of Practice E2002 is recommended as a test object of defined accuracy. Two exposures shall be taken with the wire set in perpendicular directions to obtain the length and width of the focal spot.

6.5.3 The mounting frame shall be of a size that enables the test object to be positioned very close to or on the window of the X-ray tube.

7. Procedure

7.1 Any use of additional X-ray pre-filtering should be avoided.

7.2 The X-ray voltage (in kV) should not exceed ten times the focal spot size in µm for precise measurements of focal spots below 20 µm.

7.3 Image capture requirements:

7.3.1 The distance between test object and detector shall enable projective magnification (see Fig. 2), where smaller focal spots require larger magnification.

7.3.2 Precision is dependent upon the spatial resolution of the imaging system, magnification, and signal-to-noise of the resultant images (See Footnote 4). If an estimate of the focal spot size, s, is available, then an optimal magnification can be computed:

$$M_{optimal} = 1+1.1\ SNR\ (P/\ s_{optimal}) \quad (1)$$

~~$$M_{optimal} = 1+1.1\ SNR\ (P/\ s_{optimal})$$~~ ~~(1)~~

where:

SNR = unattenuated Signal-to-Noise ratio outside the object

P = pixel size

7.3.2.1 If the actual magnification is less than or equal to $M_{optimal}$, then the estimated precision is:

$$Precision_{estimated} = 0.71\sqrt{[1/n\,(u1)]^2 + [1/n\,(u2)]^2} \times 100\% \quad (2)$$