INTERNATIONAL

Designation: E1114 – 20

Standard Test Method for Determining the Size of Iridium-192, Cobalt-60, and Selenium-75 Industrial Radiographic Sources[1]

This standard is issued under the fixed designation E1114; 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 covers the determination of the size of Iridium-192, Cobalt-60, and Selenium-75 radiographic sources. The determination is based upon measurement of the image of the source in a projection radiograph of the source assembly and comparison to the measurement of the image of a reference sample in the same radiograph or the source guide tube.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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]

E999 Guide for Controlling the Quality of Industrial Radiographic Film Processing
E1316 Terminology for Nondestructive Examinations
E1815 Test Method for Classification of Film Systems for Industrial Radiography
E2445 Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems
E2597 Practice for Manufacturing Characterization of Digital Detector Arrays
E2002 Practice for Determining Total Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy

2.2 *Other International Standards:*

EN 12679:2018 Industrial Radiography—Radiographic Method for the Determination of the Source Size for Radioisotopes[3]

3. Terminology

3.1 For definitions of terms relating to this test method, refer to Terminology E1316.

4. Significance and Use

4.1 One of the factors affecting the quality of a radiographic image is geometric unsharpness. The degree of geometric unsharpness is dependent upon the size of the source, the distance between the source and the object to be radiographed, and the distance between the object to be radiographed and the film or digital detector. This test method allows the user to determine the size of the source and to use this result to establish source to object and object to film or detector distances appropriate for maintaining the desired degree of geometric unsharpness.

NOTE 1—The European standard CEN EN 12579 describes a simplified procedure for measurement of source sizes of Ir-192, Co-60, and Se-75. The resulting source size of Ir-192 is comparable to the results obtained by this test method.

5. Apparatus

5.1 *Subjects are Iridium-192, Cobalt-60, and Selenium-75 Sources* where the source sizes are to be determined. The appropriate apparatus and equipment for the safe storage, handling, and manipulation of the subject source, such as a radiographic exposure device (also referred to as a gamma ray

[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.

Current edition approved Dec. 1, 2020. Published February 2021. Originally approved in 1986. Last previous edition approved in 2014 as E1114 – 09(2014). DOI: 10.1520/E1114-20.

[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.

projector or gamma camera), remote control, source guide tube, and source stop are also required.

5.2 *Reference Sample (see* Figs. 1-3*)*—The reference sample for film radiography shall be of material which is not radioactive. The recommended material is Iridium, Cobalt (also steel), or Selenium (also SeO_2), respectively. However, substitutes such as platinum, tungsten, or other material of similar radiopacity may be used. The sample should be of the same geometric shape as the subject source, should be approximately the same size as the subject source, and should be positioned on or within a shim or envelope to simulate the source capsule wall. The resulting radiographic contrast, with reference to adjacent background density of the image of the reference sample, should be approximately the same as that of the subject source. The actual dimensions of the reference sample should be determined to the nearest 0.025 mm (0.001 in.). If digital radiography and image processing is applied with imaging plates or DDAs, the source guide can be used as reference sample for dimensional measurement.

5.3 *X-ray Generator,* capable of producing a radiation intensity (roentgen per hour at one metre / 39 in.) at least ten times greater than that produced by the subject source. Examples of typical X-ray generator output requirements that satisfy this criterion are presented in Table 1.

5.4 *Film Systems*—Only film systems having cognizant engineering organization approval or meeting the system class requirements of Test Method E1815, for system classes I, II, or Special, shall be used. Selection of film systems should be determined by such factors as the required radiographic quality level, equipment capability, materials, and so forth. The film system selected shall be capable of demonstrating the required image quality. No intensifying screens shall be used. Radiographic films shall be processed in accordance with Guide E999.

5.5 *Image Measurement Apparatus*—This apparatus is used to measure the size of the image of the spot. The apparatus shall be an optical comparator with built-in graticule (see 8.2 for requirements).

5.6 *Digital Detectors*—Digital detectors, which are either imaging plates or digital detector arrays, may be used as film replacement. The digital detector shall possess a pixel pitch which is at least 40 times smaller than the nominal source size to measure and a basic spatial resolution smaller than 1⁄20 of the nominal source size. The basic spatial resolution of the detector shall be measured in accordance with Practice E2002 (see an example in 9.2), the procedure of Practice E2597 for DDAs or Practice E2445 for the imaging plate scanner systems or taken from manufacturer statements. In the area of free beam a detector SNR > 100 shall be achieved. The measurement procedure of the SNR shall be in accordance with the procedure of Practice E2597 for DDAs or Practice E2445 for imaging plate scanner systems.

6. Procedure

6.1 Set up the exposure arrangement as shown in Figs. 4-7. Position the X-ray tube directly over the center of the film or digital detector. The film or detector plane must be normal to the central ray of the X-ray beam. The X-ray spot should be 0.90 m (36 in.) from the film or detector. Position the reference sample and apparatus used to locate the subject source (source stop) as close together as possible and directly over the center of the film or detector. The plane of the source stop and reference sample must be parallel to the film or detector and normal to the central ray of the X-ray beam. The source stop and reference sample should be 0.15 m (6 in.) from the film or detector. The source stop should be connected to the radiographic exposure device by the shortest source guide tube practicable in order to minimize fogging of the film or detector during source transit.

6.2 Place identification markers to be imaged on the film or detector to identify, as a minimum, the identification (serial number) of the subject source, the size of the reference sample, the identification of the organization performing the determination, and the date of the determination. Care should be taken to ensure that the images of the subject source and reference sample will not be superimposed on the image of the identification markers.

6.3 *Exposure*—Select the X-ray tube potential (kV), X-ray tube current (mA), and exposure time such that the density in the image of the envelope surrounding the reference sample does not exceed 3.0 and that the density difference between the image of the reference sample and the image of the envelope surrounding the reference sample is at least 0.10. In digital images, the linear pixel value difference between the image of the reference sample and the image of the envelope surrounding the reference sample shall be at least ten times larger than the image noise σ (σ = standard deviation) of the pixel value fluctuations in an area of homogeneous exposure, measured in a window (of at least 20 by 55 pixels) in a homogeneous neighbourhood area.

NOTE 2—The actual parameters that will produce acceptable results may vary between X-ray units, and trial exposures may be necessary.

6.3.1 Energize the X-ray generator and, at the same time, manipulate the subject source into the exposure position in the source stop. It is important that this be performed as quickly as possible to minimize fogging of the film or detector.

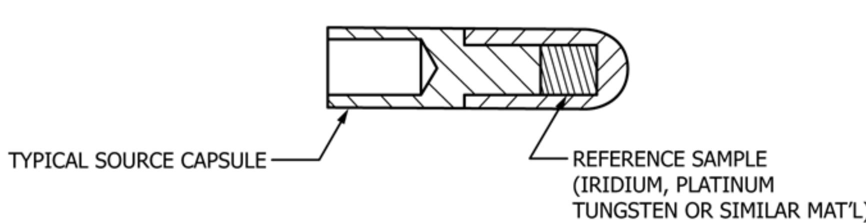

FIG. 1 Reference Sample in Standard Source Encapsulation

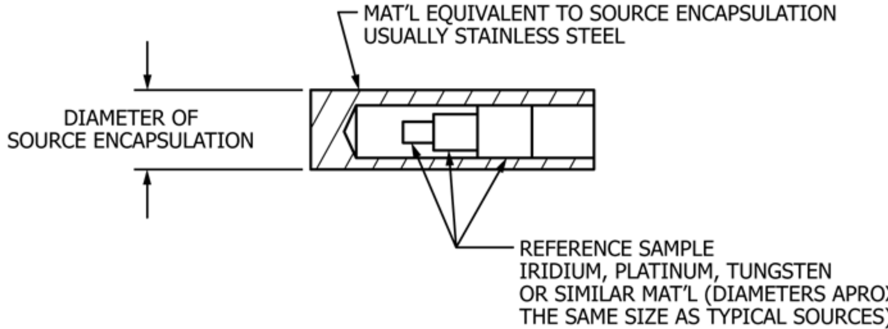

FIG. 2 Alternate Reference Sample Arrangement

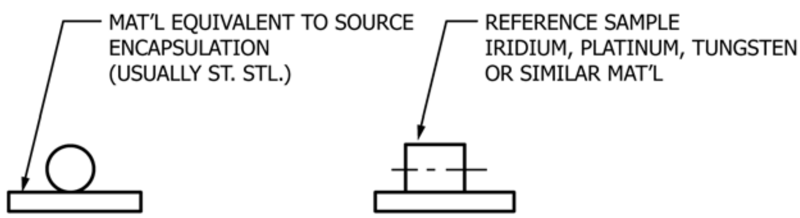

FIG. 3 Alternate Reference Sample Arrangement

TABLE 1 Examples of Typical X-ray Generator Output Requirements for Related Iridium^{192} Source Activities

Subject Iridium^{192} Source Radiation			Typical X-ray Generator Output Requirements	
Activity (Curie)	Output (R/h at 1 m)		Potential	Current
30	14.4		160 kV	5 mA
		or	200 kV	3 mA
100	48.0		160 kV	10 mA
		or	250 kV	4 mA
200	96.0		160 kV	20 mA
		or	250 kV	8 mA
		or	300 kV	6 mA

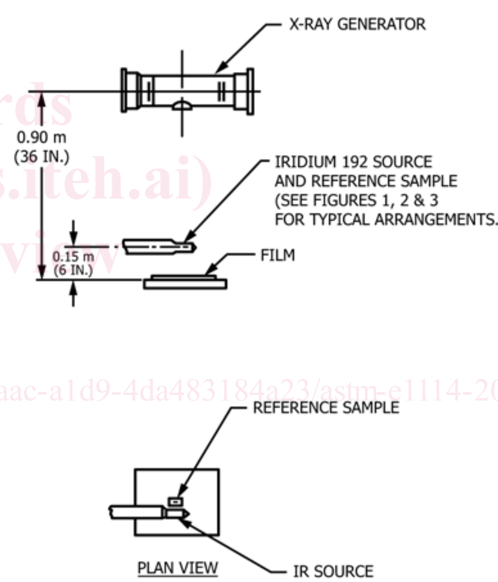

FIG. 4 Typical Exposure Arrangement

6.3.2 At the conclusion of the exposure time, de-energize the X-ray generator and, at the same time, return the subject source to the proper shielded storage position.

6.3.3 Process the film or read out the digital detector array or scan the imaging plate.

7. Measurement of Source Dimensions

7.1 The source size for a given technique is the maximum projected dimension of the source in the plane perpendicular to a line drawn from the source to the object being radiographed. Therefore, sufficient measurements of the image of the sources must be made to determine the size of the source in any orientation. Subsections 7.2 – 7.5 serve as examples.

7.2 *Uniform Right Circular Cylinder* (see Fig. 8)—Determine the source size of a uniform right circular cylindrical source by measuring the diameter, *d*, the height, *h*, and the diagonal, *m*, as illustrated in Fig. 8 and computing the actual dimensions as described in 8.1. Fig. 8 shows a stack of disks, which is typically used for Ir-192 sources.

7.3 *Sphere* (see Fig. 9)—Determine the size of a spherical source by measuring the diameter, *d*, as illustrated in Fig. 9 and computing the actual dimension as described in 8.1.

7.4 *Nonuniform Stack of Right Circular Cylinders* (see Fig. 10)—Determine the size of a nonuniform stack of right circular cylindrical components of a source by measuring the intrinsic diameter, *d*, the height, *h*, and the effective maximum dimension, *m*, as illustrated in Fig. 10 and computing the actual dimensions as described in 8.1.

7.5 *Separated Stack of Right Circular Cylinders* (see Fig. 11)—Determine the size of a separated stack of right circular cylindrical components of a source by measuring the intrinsic

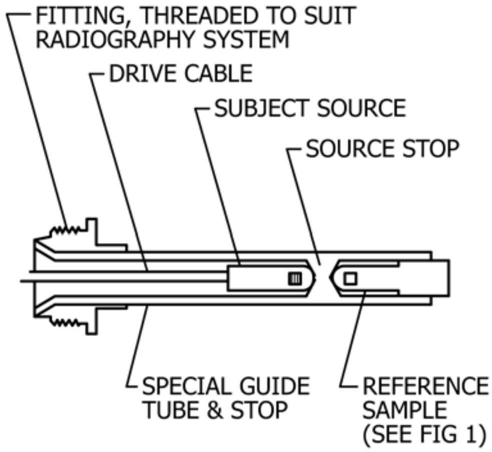

FIG. 5 Typical Arrangement Using a Specially Designed Guide Tube

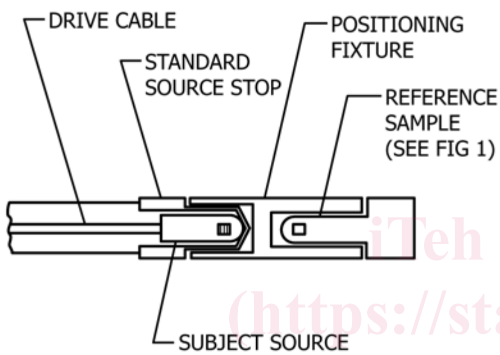

FIG. 6 Typical Arrangement Using a Standard Guide Tube and Special Positioning Fixture

diameter, *d*, the effective height, *h*, and the effective maximum dimension, *m*, as illustrated in Fig. 11 and computing the actual dimensions as described in 8.1.

8. Measurement and Evaluation with Film

8.1 When viewing the film radiograph, view it with sufficient light intensity for adequate viewing. Using an optical comparator with built-in graticule as described in 5.5, measure the linear dimensions of the image of the spot size of the subject source and the reference sample. Take measurements from the perceptible edges of the image. When performing the physical measurements with the optical comparator, the actual measured values shall be to the nearest graduation on the graticule scale being used.

8.2 The film radiograph shall be examined visually on a film illuminator using a magnifying lens with a built-in measurement scale (graticule) with divisions of ≤ 0.1 mm (0.004 in.) for source sizes ≥ 1 mm (0.04 in.) or of ≤ 0.05 mm (0.002 in.) for source sizes < 1 mm (0.04 in.) and an optical magnification between 5 and 10. The magnifying factor, ν, according to Fig. 4 shall be taken into account for calculation of the actual dimension, d, from the measured values at film or digitized film. The image of the radiation source shall have sufficient contrast sensitivity to be easily measured.

9. Measurement and Evaluation with Digital Detectors

9.1 Digital images shall be evaluated by an image processing software with contrast, brightness (window levelling), profile, pixel size calibration, and zoom function. The digital images shall be magnified at the monitor to a degree that allows the image viewing with at least one pixel of the image at one pixel of the monitor.

9.2 Digital images show the gamma source with a certain magnifying factor. It shall be normalized by the magnifying factor for measurement of the source size. The measurement shall consider a known dimension as, for example, the diameter of a reference object (for example, a steel or tungsten cylinder) or the known sample guide tube diameter to determine the overall magnifying factor and the real dimensions of the source (see Section 10). The measurement of the source size shall be performed with a profile function as shown in Fig. 12 to achieve sufficient accuracy.

10. Calculation and Evaluation

10.1 Measure the linear dimension of interest in the subject source image and measure the same linear dimension in the reference sample image (that is, the diameter of each). The actual dimension of the subject source is calculated from the following:

$$a = bc/d$$

where:

a = actual dimension of the subject source,
b = actual dimension of the reference sample,
c = measured dimension of the subject source image, and
d = measured dimension of the reference sample image.

11. Report

11.1 A description of the shape of the source (or an appropriate sketch) should be provided.

11.2 A test report shall contain at least the following information:

11.2.1 Reference to this standard;
11.2.2 Identification of source and holder, activity;
11.2.3 Focal spot size of the X-ray equipment,
11.2.4 Magnification factor used (see Fig. 4);
11.2.5 Dimension of reference object as, for example, source guide tube;
11.2.6 Parameters of X-ray equipment;
11.2.7 Exposure parameter; kV, mA, SDD, SOD, exposure time;
11.2.8 Technique used;
11.2.9 Detection system:
11.2.9.1 Film system class;
11.2.9.2 Optical density in free beam area and in the gamma source projection;
11.2.9.3 Film screen thickness, if any;
11.2.9.4 CR: IP type, CR scanner type and scan parameters, scan pixel size, $SR_b^{detector}$, SNR_N in free beam area;
11.2.9.5 DDA: brand and acquisition parameter, detector pixel size, $SR_b^{detector}$, SNR_N in free beam area;
11.2.10 Distances *a*, *b* and exposure time *t*;
11.2.11 Source size *d*, in millimetres;

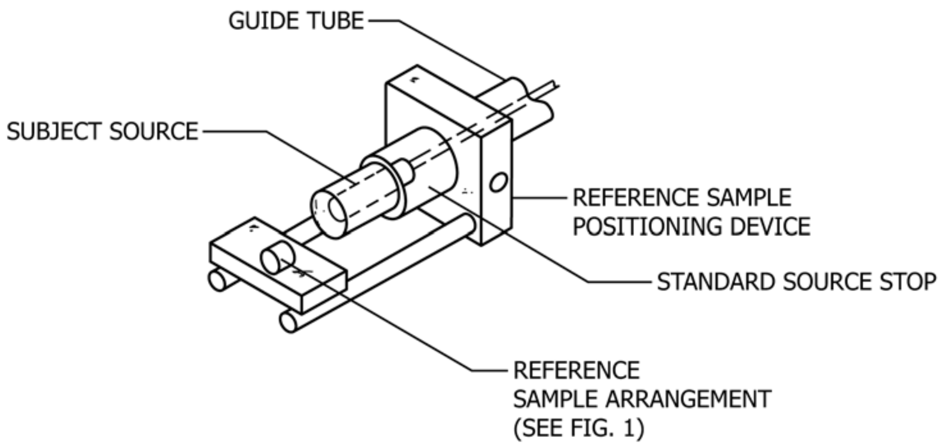

FIG. 7 Typical Arrangement Using Reference Sample Positioning Device

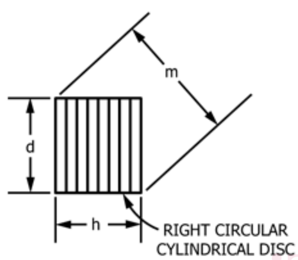

FIG. 8 Uniform Right Circular Cylinder

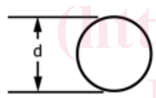

FIG. 9 Sphere

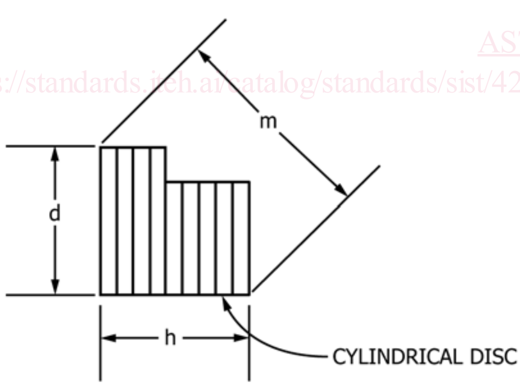

FIG. 10 Nonuniform Cylindrical Stack

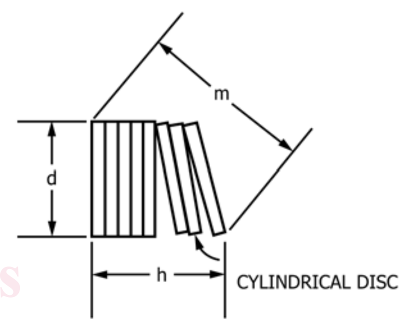

FIG. 11 Separated Cylindrical Stack

11.2.12 Source width, source length, and its maximum dimension;

11.2.13 Date of the measurement;

11.2.14 Name of test organization;

11.2.15 Name and signature of tester.

12. Precision and Bias

12.1 *Precision of Measurement with Digital Radiography*—The precision can be estimated for digital radiography based on the nominal source size, a, the magnification, M, the focal spot size of the X-ray tube, φ, and the basic spatial resolution of the detector, $SR_b^{detector}$. The following equation provides an estimate for the standard deviation, σ, in % of the source size, if CNR > 10:

$$\sigma(\%) = 100 \cdot \frac{\sqrt{((\phi \cdot (M - 1))^2 + (2 \cdot SR_b^{detector})^2)}}{a \cdot M} \quad (1)$$

NOTE 3—The contrast is typically measured as the difference between the pixel value mean in the gamma source area and the area of the holder next to the gamma source. The noise may be measured in the area next to the gamma source. In the example of Fig. 12a, this corresponds to the holder area left of the gamma source.

12.2 *Precision of Film Measurement*—The estimation of the precision of the film measurement is more difficult due to the physiological factor of the human observer. Basically, a precision of better than 20 % of the real source size is expected as result of observer evaluations, but not better than the limitation by the image unsharpness, U_{im}, with:

$$\sigma(\%) = 100 \cdot (\phi \cdot (M - 1)) / (aM) \quad (2)$$

12.3 *Bias*—No bias of the procedure is known for this test method, measuring the size of the gamma radiographic sources.

13. Keywords

13.1 Cobalt 60; Iridium 192; radiographic source; reference sample; Selenium 75; source size