Designation: F2547 – 06 (Reapproved 2013)

# Standard Test Method for Determining the Attenuation Properties in a Primary X-ray Beam of Materials Used to Protect Against Radiation Generated During the Use of X-ray Equipment[1]

This standard is issued under the fixed designation F2547; 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 establishes procedures for measuring the attenuation of X-rays by protective materials at accelerating potentials from 60 to 130 kVp.

1.2 This test method provides attenuation values of primary beam X-radiation.

1.3 This test method applies to both leaded and non-leaded radiation protective clothing materials.

1.4 *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:*[2]
F1494 Terminology Relating to Protective Clothing

## 3. Terminology

3.1 *Definitions:*

3.1.1 *attenuation, n*—For radiological protective material, the reduction in the intensity of the X-ray beam resulting from the interactions between the X-ray beam and the protective material that occur when the X-ray beam passes through the protective material.

3.1.1.1 *Discussion*—In this test method, the attenuation is calculated as 1 minus the ratio of the measured exposure with a protective material in the beam to the measured exposure without the protective material in the beam at a specific accelerating potential. Multiplying the resulting value by 100 gives percent attenuation.

$$\text{Attenuation (percent)} = \left(1 - \frac{\text{exposure with sample}}{\text{exposure without sample}}\right) \times 100 \quad (1)$$

3.1.2 *lead equivalency, n*—For radiological protective material, the thickness in millimetres of lead (commonly designated mmPb) of greater than 99.9 percent purity that provides the same attenuation as a given protective material.

3.1.2.1 *Discussion*—This test method provides the attenuation of the material and not the lead equivalency. Determining lead equivalency would require testing lead of known thickness and purity, and comparing the attenuation of the protective material with the attenuation of the lead. Although lead equivalency has been the standard for reporting protective material capability, the drafters of this test method believe it is not feasible to obtain adequate standard lead samples for reporting lead equivalency values.

3.1.3 *secondary radiation, n*—radiation outside the primary X-ray beam.

3.1.4 *scatter radiation, n*—a form of secondary radiation resulting from the interaction of the primary X-ray beam and the target (for example, protective material being tested or a patient undergoing a medical procedure).

3.1.5 *half-value layer (HVL), n*—the thickness of aluminum, in millimetres (commonly designated mmAl), that reduces the intensity of the X-ray beam by one half.

3.1.5.1 *Discussion*—The HVL is dependent on the energy of the X-ray beam and, therefore, is different for X-rays produced at different accelerating potentials.

3.1.6 *kilovolts, peak (kVp), n*—the maximum electrical potential across an X-ray tube during an exposure, expressed in kilovolts.

3.1.7 *exposure, n*—for radiological purposes, the amount of ionization in air at standard conditions caused by interaction with X-rays, expressed in units of Roentgen (R) or milliroentgen (mR).

3.1.8 *wave form ripple, n*—for radiological purposes, the peak-to-peak variation in the output voltage of the X-ray generator.

[1] This test method is under the jurisdiction of ASTM Committee F23 on Personal Protective Clothing and Equipment and is the direct responsibility of Subcommittee F23.70 on Radiological Hazards.

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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.

3.1.9 *ionization chamber, n*—a device that measures the electrical charge liberated during the ionization of air molecules by electromagnetic radiation (X-rays for the purposes of this test method), expressed in units of coulombs per kilogram of air.

3.1.10 *shielding, n*—for radiological purposes, any material or obstruction that attenuates radiation to protect personnel or equipment from the effects of ionizing radiation.

3.1.11 *coefficient of variation, n*—the ratio of the standard deviation of a sample to the sample mean.

3.1.12 For definitions of other terms related to protective clothing used in this test method, refer to Terminology F1494.

## 4. Summary of Test Method

4.1 A primary X-ray beam with a standardized energy spectrum and constant intensity is configured to pass through the test set-up. An ionization chamber, calibrated for the energy range of X-rays produced at accelerating potentials between 60 to 130 kVp, is used to measure the exposure in the primary beam with and without the material specimen positioned between the X-ray source and the ionization chamber. The exposure is directly proportional to the intensity of the X-ray beam. The attenuation provided by the material specimen is defined as the percentage of the original beam intensity that is removed by the material specimen.

4.2 The attenuation of the sample is determined at an X-ray energy in the range produced by an accelerating potential from 60 to 130 kVp.

## 5. Significance and Use

5.1 This test method is intended to provide a standardized test procedure of protective materials to ensure comparable results among manufacturers and users.

5.2 This test method involves measurement of the attenuation of X-rays by protective clothing material at an accelerating potential (kVp) between 60 and 130 kVp. These energies are considered to be representative of those commonly used during medical diagnosis and treatment.

5.3 The reporting of the attenuation at a specific X-ray energy is intended to allow the end user organization to assess the attenuating properties of the protective clothing material at that energy level.

## 6. Apparatus

6.1 *Primary X-ray Beam Source*—A variable power high frequency X-ray generator coupled with X-ray tube equipped with Tungsten anode with the following characteristics:

6.1.1 The wave form ripple does not exceed three percent.

6.1.2 The coefficient of variation for the exposure does not exceed 0.05 as determined using four consecutive exposures.

6.1.3 The coefficient of variation for kVp does not exceed 0.05 determined using four consecutive test measurements at the kVp setting used in testing.

6.2 An invasive or non-invasive kVp measuring device capable of measuring the kVp accuracy within 0.5 kVp.

6.3 An ionization chamber and electrometer capable of measuring from 1 mR to 5 R.

6.4 Shielding material may be used around apparatus to improve precision.

## 7. Hazards

7.1 All individuals performing tests using this test method shall wear X-ray protective clothing or be positioned behind stationary shielding when the X-ray beam is activated.

## 8. Sampling and Test Specimens

8.1 Test specimens may come from protective material sheets or from protective material obtained from garments.

8.1.1 Specimens may be single sheets or multiple sheets tested as a stack, as appropriate for the application.

8.2 Randomly select a total of five specimens from the material or protective clothing sample for evaluation.

8.3 Test specimens shall have a circular or square shape with an area sufficient for testing.

## 9. Preparation of Apparatus

9.1 Measure and document the kVp accuracy for each kVp setting used in the testing prior to every testing session.

9.2 Measure and document the exposure reproducibility of the combination of tube current and exposure time used in the testing prior to every testing session.

9.2.1 If the length of the testing session exceeds one hour measure and document kVp accuracy at least once each hour.

9.3 Measure and document HVL for the kVp setting used in the testing at the beginning of the testing session.

9.4 Measure and document the kVp accuracy for the kVp setting used in the testing at the end of the testing session.

## 10. Calibration and Standardization

10.1 The kVp meter and ionization chamber shall be calibrated not less than annually to NIST-traceable standards.

10.2 At the desired kVp setting determine the half-value layer in millimetres of type 1100 aluminum (mm Al). The half-value layer shall fall within 0.1 mm Al of the value specified in Table 1.

10.3 The focal spot size shall be as small as practicable.

**TABLE 1 Half-Value Layers at Different X-ray Energy Levels**

| 60kVp | 70 kVp | 80 kVp | 90 kVp | 100 kVp | 110 kVp | 120 kVp | 130 kVp |
|---|---|---|---|---|---|---|---|
| 2.9 mm Al | 3.3 mm Al | 4.0 mm Al | 4.3 mm Al | 5.2 mm Al | 5.5 mm Al | 6.3 mm Al | 6.7 mm Al |

## 11. Conditioning

11.1 There are no special conditioning requirements for the test.

## 12. Procedure

12.1 Set the X-ray accelerating potential to the desired kVp for the X-ray beam source.

12.2 Set the distance between the focal spot to the specimen at 400 mm [15¾ in.] and the distance between the ionization chamber and the specimen at 1000 mm [39⅜ in.].

12.3 Ensure that the closest source of back-scatter (such as a table top or the floor) is not less than 450 mm [17¾ in.] from the ionization chamber.

12.4 Set the X-ray field dimensions to match the dimensions of the ionization chamber.

12.4.1 Ensure that the X-ray field does not exceed the size of the specimen.

12.5 Conduct one exposure measurement without a specimen in the X-ray beam and record the exposure reading from the exposure meter.

12.6 Place a specimen in the field.

12.7 Perform two exposure measurements with the specimen in the X-ray beam and record the exposure readings from the exposure meter.

12.7.1 The exposure measurements acquired with the specimen in the beam shall not vary by more than three percent.

12.8 Conduct a post-specimen exposure measurement with no specimen in the X-ray beam.

12.8.1 The second no-specimen exposure measurement shall not vary from pre-specimen exposure by more than three percent.

12.9 Repeat measurements for remaining specimens.

## 13. Calculations

13.1 Calculate the arithmetic mean (simple average) exposure with no specimen in the X-ray beam for all no-specimen measurements. This value becomes the mean exposure (no specimen).

13.2 Calculate the mean of the exposures with a specimen in the X-ray beam for all measurements involving a specimen. This value is the mean exposure (with specimen).

13.3 Calculate the attenuation for the protective clothing material.

## 14. Report

14.1 State that the test was conducted as directed in Test Method F2547 - 06.

14.2 Provide the following information with each test set:

14.2.1 *Test Information*—Date of testing, place of testing, name of individual(s) performing the testing, equipment (manufacturer and model of X-ray generator and X-ray tube) used in testing, test parameters (kVp, HVL Al mm, current, exposure time)

14.2.2 *Sample Identification*—Description of the material tested (indicate, as applicable and available: manufacturer, type of material, presence of coatings, number of sheets, other identifying data).

14.2.3 The attenuation for each of the five samples and the mean attenuation.

## 15. Precision and Bias

15.1 *Precision*—The precision of the procedure in this test method is being determined.

15.2 *Bias*—No information can be presented on the bias for the procedure in this test method, for measuring the X-ray attenuation of protective clothing materials, because no material having an accepted reference value is available at this time.

## 16. Keywords

16.1 attenuation; protective material; radiation protective clothing; X-ray