Designation: F3094 – 14

# Standard Test Method for Determining Protection Provided by X-ray Shielding Garments Used in Medical X-ray Fluoroscopy from Sources of Scattered X-Rays[1]

This standard is issued under the fixed designation F3094; 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 a procedure for measuring the relative reduction in the intensity of X-radiation provided by shielding garments to the human user under conditions simulating actual use.

1.2 This test method provides a condition simulating X-rays generated between 60 and 130 kV that are scattered through an angle of 90° by a water equivalent material.

1.3 This test method applies to both leaded and no-leaded radiation protective materials.

1.4 This test method provides a method for inclusion of secondary radiations generated within the protective material into a more realistic evaluation of radiation protection.

1.5 The values given 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 and health practices and determine the applicability of regulatory limitations prior to use.* Some specific hazards statements are given in Section 7.

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

F1494 Terminology Relating to Protective Clothing

F2547 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

2.2 *IEC Standard:*[3]

IEC 61331-1 Ed. 2.0 Protective Devices Against Diagnostic Medical X-radiation: Part 1 – Determination of Attenuation Properties of Materials

## 3. Terminology

3.1 *Definitions:*

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

3.1.1.1 *Discussion*—It is important to note that the measurement of attenuation (as specified by Test Method F2547) specifically excludes the contribution of secondary radiation from the measurement. The present standard provides a method for incorporating those contributions of radiation dose to the wearer of protective garments. (See 3.1.10.)

3.1.2 *coefficient of variation*—the ratio of the standard deviation of a sample to the sample mean.

3.1.3 *exposure, n*—for radiological purposes the amount of ionization charge of one sign produced in a defined volume of dry air at standard temperature and pressure, caused by interaction with X-rays. Exposure is expressed in units of coulombs/kg of air in SI units. An older unit called the Roentgen (R) is also used, where 1 R = $2.58 \times 10^{-4}$ C/kg.

3.1.4 *fluorescent radiation, n*—a form of secondary radiation following photoelectric collisions between X-rays and orbital electrons of heavier elements such as those used in protective materials, whereupon electron rearrangements at the atomic level result in the emission of one or more fluorescent photons.

3.1.4.1 *Discussion*—Measurements to include fluorescent radiation are important because they may contribute to the radiation exposure to the wearer of radiation protective garments.

[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] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland, http://www.iec.ch.

3.1.5 *half-value layer (HV), n*—the thickness of 99.9 % pure aluminum in millimetres (commonly designated mm Al) that reduces the intensity of an X-ray beam by one half of its initial value.

3.1.5.1 *Discussion*—HVL is commonly used to designate the penetrating ability of an X-ray beam containing many X-ray energies (as is the case with standard X-ray sources). A higher value of Al in mm Al would indicate a more penetrating X-ray beam. Note that HVL may also be specified in materials other than Al, although only Al is used in this document.

3.1.6 *ionization chamber*—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 kg of air.

3.1.6.1 *Discussion*—The measurement of exposure is defined for an air ionization chamber. The chamber used in this method must be of a flat, parallel-plate design.

3.1.7 *kilovolts, or kilovolts peak (kV or kVp), n*—for the purposes of radiological protection, the maximum electrical potential across an X-ray tube during exposure.

3.1.7.1 *Discussion*—The kV or kVp determines the maximum photon energy in kilo-electron volts (keV) of an X-ray beam; standard X-ray beams contain many photon energies most of which are less than this maximum value.

3.1.8 *lead equivalency*—for radiological protective material the thickness in millimetres (commonly designated mm Pb) of greater than 99.9 % purity that provides the same attenuation as a given protective material.

3.1.8.1 *Discussion*—Radiation protective materials are commonly made with little or no lead thus lead equivalence will vary with X-ray energy and with the composition of the protective material. Lead equivalence should be specified at a specific energy. This test method specifies a method for determining the attenuation in pure lead materials but does not require a specific lead equivalence. If lead equivalence is specified, it should be specified at a single scatter equivalent condition.

3.1.9 *primary X-rays, n*—the X-rays emitted from the target of an X-ray tube subjected to an accelerating potential sufficient to cause X-ray emission.

3.1.9.1 *Discussion*—Primary X-rays are distinguished from secondary X-rays emitted from a material exposed to primary X-rays. Secondary X-rays are generally less penetrating than primary X-rays.

3.1.10 *protection rating, n*—for the purposes of radiological protection in this test method, the percentage of exposure at the skin surface of the wearer of the protective garment relative to the exposure on that surface in the absence of the protective garment, measured under scatter equivalent conditions for a particular radiation quality.

3.1.11 *scatter equivalent conditions*—specific primary X-ray spectra defined in terms of kV and HVL that simulate radiation scattered from a water equivalent medium measured at 90° to the beam incidence on that medium.[4]

3.1.11.1 *Discussion*—Measuring the actual degree of protection from scattered X-rays provided by radiation protective garments under real world conditions is technically difficult and subject to large uncertainties. Actual scatter intensities are too low and measurements have excessively high uncertainties when evaluated in practical conditions. The scatter equivalent conditions describe conditions that conservatively approximate the energies of 90° scatter produced when a water medium (body of a human or animal) is exposed to Test Method F2547 beam qualities. Use of the surrogate primary beams provides conditions that are practical to test under field conditions.

3.1.12 *scatter radiation, n*—a form of secondary radiation where X-radiation is deflected to a changed direction with or without a loss in energy by collisions between X-ray photons and orbital electrons of atoms in the path of the X-rays; scattering events in medical procedures mainly occur with loss of energy due to the Compton Effect such that the average energies of scattered X-rays are less than that of the direct primary beam.

3.1.13 *secondary radiation, n*—radiation that is produced in a material by scattering or emission when the material is exposed to a source of X-rays.

3.1.13.1 *Discussion*—Secondary radiation is of importance because: (*1*) the hazard to medical X-ray fluoroscopy workers is principally from X-rays scattered from the patient and other materials within the primary X-ray beam, (*2*) fluorescent radiation produced within the protective material can contribute to the radiation exposure to the wearer of the radiation protective garments.

3.1.14 *standard sample dimensions*—test samples and lead standards cut to an area suited to the measurement setup in Fig. 1, ideally by using a template.

3.1.14.1 *Discussion*—It may be desired to test finished protective clothing that are not cut to standard sample dimensions using this test method. This may be done, but may require a special test jig to support the material in proper orientation and configuration to meet this test method. Such a procedure is not described in this test method.

3.1.15 *wave form ripple, n*—for radiological purposes the peak to peak variation in the voltage potential applied to the X-ray tube during exposure. Greater voltage ripple (common in older X-ray generators) tends to reduce the intensity and penetrating ability of the resulting X-ray beam compared to units with little or no voltage ripple.

3.2 Some definitions are reproduced for convenience from Test Method F2547. For definitions of other terms related to protective clothing used in this test method, refer to Terminology F1494.



[4] McCaffrey, J. P., Tessier, F., and Shen, H., "Radiation Shielding Materials and Radiation Scatter Effects for Interventional Radiology (IR) Physicians," *Med. Phys.*, Vol 39 (7), July 2012.