



Standard Practice for Dosimetry in an X-Ray (Bremsstrahlung) Facility for Radiation Processing¹

This standard is issued under the fixed designation E 1608; 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 practice covers dosimetric procedures to be followed in facility characterization, process qualification, and routine processing using X rays (bremsstrahlung) to ensure that the entire product has been treated within an acceptable range of absorbed doses. Other procedures related to facility characterization, process qualification, and routine processing that may influence absorbed dose in the product are also discussed. The establishment of effective or regulatory dose and X-ray energy limits are not within the scope of this practice.

1.2 In contrast to monoenergetic gamma rays, the bremsstrahlung energy spectrum extends from low values up to the maximum energy of the electrons incident on the X-ray target (see Section 5 and the Appendix).

1.3 Dosimetry is only one component of a total quality assurance program for an irradiation facility. Other controls besides dosimetry may be required for specific applications such as medical device sterilization and food preservation.

1.4 For the irradiation of food and the radiation sterilization of health care products, other specific ISO standards exist. For food irradiation, see ISO 15562:1998, *Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing* (ASTM Practice E 1431). For the radiation sterilization of health care products, see ISO 11137:1995, *Sterilization of Health Care Products- Requirements for Validation and Routine Control-Radiation Sterilization*. In those areas covered by ISO 11137, that standard takes precedence.

NOTE 1—For guidance in the selection, calibration, and use of specific dosimeters and interpretation of absorbed dose in the product from dose measurements, see the documents listed in 2.1, 2.2 and 2.3.

NOTE 2—Bremsstrahlung characteristics are similar to gamma rays from radioactive isotopes. See Practices E 1204 and E 1702 for the applications of dosimetry in the characterization and operation of gamma-ray irradiation facilities. For information concerning electron beam irradiation technology and dosimetry, see Practices E 1431 and E 1649.

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 170 Terminology Relating to Radiation Measurements and Dosimetry²
- E 177 Recommended Practice for Use of the Terms Precision and Accuracy as Applied to Measurement of a Property of a Material³
- E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers⁴
- E 456 Terminology Relating to Quality and Statistics³
- E 925 Practice for the Periodic Calibration of Narrow Band-Pass Spectrophotometers⁴
- E 958 Practice for Measuring Practical Spectral Bandwidth of Ultraviolet-Visible Spectrophotometers⁴
- E 1026 Practice for Using the Fricke Reference Standard Dosimetry System²
- E 1204 Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing²
- E 1205 Practice for Use of a Ceric-Cerous Sulfate Dosimetry System²
- E 1261 Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing²
- E 1275 Practice for Use of a Radiochromic Film Dosimetry System²
- E 1276 Practice for Use of a Polymethylmethacrylate Dosimetry System²
- E 1310 Practice for Use of a Radiochromic Optical Waveguide Dosimetry System²
- E 1400 Practice for Characterization and Performance of a High-Dose Radiation Dosimetry Calibration Laboratory²
- E 1401 Practice for Use of a Dichromate Dosimetry System²
- E 1431 Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing²

¹ This practice is under the jurisdiction of ASTM Committee E-10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.01 on Dosimetry for Radiation Processing.

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² *Annual Book of ASTM Standards*, Vol 12.02.

³ *Annual Book of ASTM Standards*, Vol 14.02.

⁴ *Annual Book of ASTM Standards*, Vol 14.01.

- E 1538 Practice for Use of the Ethanol-Chlorobenzene Dosimetry System²
- E 1539 Guide for Use of Radiation-Sensitive Indicators²
- E 1540 Practice for Use of a Radiochromic Liquid Dosimetry System²
- E 1607 Practice for Use of the Alanine-EPR Dosimetry System²
- E 1649 Practice for Dosimetry in an Electron Beam Facility for Radiation Processing at Energies Between 300 keV and 25 MeV²
- E 1650 Practice for Use of Cellulose-Acetate Dosimetry Systems²
- E 1702 Practice for Dosimetry in a Gamma Irradiation Facility for Radiation Processing²
- E 1707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing²
- 2.2 ICRU Reports:⁵
- ICRU Report 14—Radiation Dosimetry: X Rays and Gamma Rays with Maximum Photon Energies Between 0.6 and 50 MeV
- ICRU Report 33—Radiation Quantities and Units
- ICRU Report 35—Radiation Dosimetry: Electron Beams with Energies Between 1 and 50 MeV
- ICRU Report 37—Stopping Powers for Electrons and Positrons
- 2.3 ISO Standards:⁶
- ISO 11137 Sterilization of Health Care Products - Requirements for Validation and Routine Control - Radiation Sterilization
- ISO 15562 Practice for Dosimetry in Electron Beam and Bremsstrahlung Irradiation Facilities for Food Processing

3. Terminology

3.1 Definitions:

3.1.1 *absorbed dose (D)*—Quantity of ionizing radiation energy imparted per unit mass of a specified material. The SI unit of absorbed dose is the gray (Gy), where 1 gray is equivalent to the absorption of 1 joule per kilogram of the specified material (1 Gy = 1 J / kg). The mathematical relationship is the quotient of $d\epsilon$ by dm , where $d\epsilon$ is the mean incremental energy imparted by ionizing radiation to matter of incremental mass dm (see ICRU Report 33).

$$D = d\epsilon / dm \quad (1)$$

3.1.1.1 *Discussion*—The discontinued unit for absorbed dose is the rad (1 rad = 100 erg / g = 0.01 Gy).

3.1.2 *absorbed dose enhancement*—the increase or decrease in the absorbed dose, as compared to the equilibrium dose, at a point in the material of interest. This will occur near an interface between materials with different atomic numbers.

3.1.3 *bremsstrahlung*—broad-spectrum electromagnetic radiation emitted when an energetic electron is influenced by a strong magnetic or electric field, such as that in the vicinity of an atomic nucleus.

3.1.3.1 *Discussion*—When a beta particle (electron) passes close to a nucleus, the strong attractive coulomb force causes the beta particle to deviate sharply from its original path. The change in direction is due to radial acceleration, and in accordance with classical theory the beta particle loses energy by electromagnetic radiation at a rate proportional to the square of the acceleration. This means that the bremsstrahlung photons have a continuous energy distribution that ranges downward from a theoretical maximum equal to the kinetic energy of the beta particle. Practically, bremsstrahlung is produced when an electron beam strikes any material (converter). The bremsstrahlung spectrum depends on the electron energy, converter material, and its thickness.

3.1.4 *calibration curve*—graphical representation of the dosimetry system's response function.

3.1.5 *dose uniformity ratio*—ratio of the maximum to the minimum absorbed dose within the process load. The concept is also referred to as the max/min dose ratio.

3.1.6 *dosimeter*—a device that, when irradiated, exhibits a quantifiable change in some property of the device which can be related to the absorbed dose in a given material using appropriate analytical instrumentation and techniques.

3.1.7 *dosimetry system*—a system used for determining absorbed dose, consisting of dosimeters, measurement instruments and their associated reference standards, and procedures for the system's use.

3.1.8 *electron energy*—the kinetic energy of an electron that is usually given in units of electron volts (eV), kiloelectron volts (keV), or megaelectron volts (MeV).

3.1.9 *electron energy spectrum*—particle fluence distribution of electrons as a function of energy.

3.1.10 *equilibrium absorbed dose*—the absorbed dose in a finite volume within the material in which the condition of approximate electron equilibrium exists.

3.1.11 *measurement quality assurance plan*—a documented program for the measurement process that ensures on a continuing basis that the overall uncertainty meets the requirements of the specific application. This plan requires traceability to, and consistency with, nationally or internationally recognized standards.

3.1.12 *measurement traceability*—the ability to demonstrate by means of an unbroken chain of comparisons that a measurement is in agreement within acceptable limits of uncertainty with comparable nationally or internationally recognized standards.

3.1.13 *process load*—a volume of material with a specified loading configuration irradiated as a single entity.

3.1.14 *X rays*—the common name for the short wavelength electromagnetic radiation emitted by high-energy electrons when they are accelerated, decelerated or deflected by strong electric and magnetic fields. The term includes both bremsstrahlung from nuclear collisions and the characteristic monoenergetic radiation emitted when atomic electrons make transitions to more tightly bound states.

3.1.15 *X-ray converter*—a device for generating X rays (bremsstrahlung) from an electron beam, consisting of a target, means for cooling the target, and a supporting structure.

3.1.16 *X-ray target*—that component of the X-ray converter

⁵ Available from the International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, U.S.A.

⁶ Available from the International Organization for Standardization, 1 Rue de Varembe, Case Postale 56, CH-1211, Geneva 20, Switzerland.