Designation: E 1649 – 00

An American National Standard

Standard Practice for Dosimetry in an Electron Beam Facility for Radiation Processing at Energies Between 300 keV and 25 MeV[1]

This standard is issued under the fixed designation E 1649; 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 electron beam radiation to ensure that the entire product has been treated with an acceptable range of absorbed doses. Other procedures related to facility characterization (including equipment documentation), process qualification, and routine product processing that may influence and may be used to monitor absorbed dose in the product are also discussed.

NOTE 1—For guidance in the selection and calibration of dosimeters, see Guide E 1261. For further guidance in the selection, calibration, and use of specific dosimeters, and interpretation of absorbed dose in the product from dosimetry, also see Practices E 668, E 1275, E 1276, E 1431, E 1607, E 1631, and E 1650. For use with electron energies above 5 MeV, see Practices E 1026, E 1205, E 1401, E 1538, and E 1540 for discussions of specific large volume dosimeters. For discussion of radiation dosimetry for pulsed radiation, see ICRU Report 34. When considering a dosimeter type, be cautious of influences from dose rates and accelerator pulse rates and widths (if applicable).

1.2 The electron energy range covered in this practice is between 300 keV and 25 MeV, although there are some discussions for other energies.

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.

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 Dosimetry[2]
E 668 Practice for the Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices[2]
E 1026 Practice for Using the Fricke Reference Standard Dosimetry System[2]
E 1205 Practice for Use of a Ceric-Cerous Sulfate Dosimetry System[2]
E 1261 Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing[2]
E 1275 Practice for Use of a Radiochromic Film Dosimetry System[2]
E 1276 Practice for Use of a Polymethylmethacrylate Dosimetry System[2]
E 1401 Practice for Use of a Dichromate Dosimetry System[2]
E 1431 Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing[2]
E 1538 Practice for Use of an Ethanol-Chlorobenzene Dosimetry System[2]
E 1539 Guide for the Use of Radiation-Sensitive Indicators[2]
E 1540 Practice for Use of a Radiochromic Liquid Solution Dosimetry System[2]
E 1607 Practice for Use of the Alanine–EPR Dosimetry System[2]
E 1608 Practice for Dosimetry in an X-Ray (Bremsstrahlung) Irradiation Facility for Radiation Processing[2]
E 1631 Practice for Use of Calorimetric Dosimetry Systems for Electron Beam Measurements and Dosimeter Calibrations[2]
E 1650 Practice for Use of a Cellulose Acetate Dosimetry System[2]

[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.

Current edition, which is the same as the last previous Edition E 1649–94ε1 except for some changes to the Scope section, was approved Jan. 10, 2000. Published February 2000. Originally published as E 1649–94. Except for renumbering the Notes, International Standard ISO 15569:1998(E) is identical to this practice.

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

2.2 *International Commission on Radiation Units and Measurements (ICRU) Reports:*

ICRU Report 33 Radiation Quantities and Units[3]

ICRU Report 34 The Dosimetry of Pulsed Radiation[3]

ICRU Report 35 Radiation Dosimetry: Electron Beams with Energies Between 1 and 50 MeV[3]

ICRU Report 37 Stopping Powers for Electrons and Positrons[3]

3. Terminology

3.1 *Definitions*—Other terms used in this practice may be found in Terminology E 170 and ICRU Report 33.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *absorbed dose*, *D*—the quotient of $d\bar{e}$ by dm, where $d\bar{e}$ is the mean energy imparted by ionizing radiation to the matter of mass dm (see ICRU Report 33).

$$D = \frac{d\bar{e}}{dm} \quad (1)$$

The special name of the unit for absorbed dose is the gray (Gy):

$$1\ Gy = 1\ J \cdot kg^{-1} \quad (2)$$

Formerly, the special unit for absorbed dose was the rad:

$$1\ \text{rad} = 10^{-2}\ J \cdot kg^{-1} = 10^{-2}\ Gy \quad (3)$$

and:

$$1\ \text{Mrad} = 10\ \text{kGy} \quad (4)$$

3.2.2 *average beam current*—time-averaged electron beam current; for a pulsed machine, the averaging shall be done over a large number of pulses.

3.2.3 *beam length*—dimension of the irradiation zone perpendicular to the beam width and direction of the electron beam specified at a specified distance from the accelerator window.

3.2.3.1 *Discussion*—See Fig. 1.

3.2.4 *beam power*—product of the average electron energy and the average beam current.

3.2.5 *beam width*—dimension of the irradiation zone perpendicular to the beam length and direction of the electron beam specified at a specific distance from where the beam exits the accelerator.

3.2.5.1 *Discussion*—For a radiation processing facility with a conveyor system, the beam width is usually perpendicular to the flow of motion of the conveyor (see Fig. 1). Beam width is the distance between the points along the dose profile which are at a defined level from the maximum dose region in the profile (see Fig. 2). Various techniques may be employed to produce an electron beam width adequate to cover the processing zone, for example, use of electromagnetic scanning of pencil beam (in which case beam width is also referred to as scan width), defocussing elements, and scattering foils.

3.2.6 *compensating dummy*—simulated product used during routine production runs with irradiation units containing less product than specified in the product loading configuration or at the beginning and end of a production run to compensate for the absence of product.

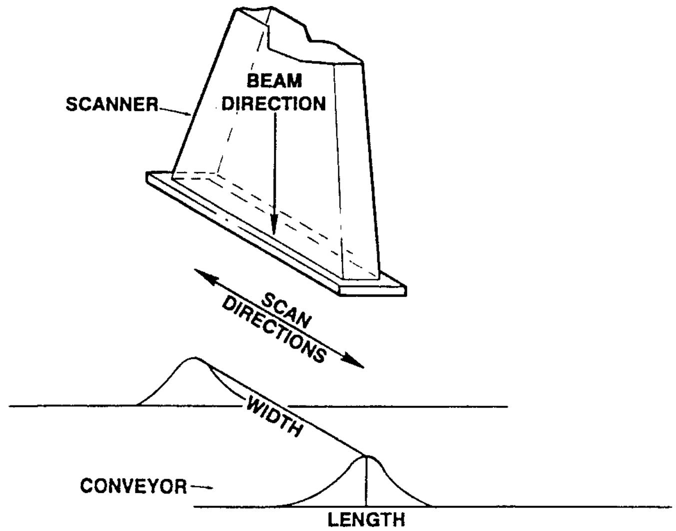

FIG. 1 Diagram Showing Beam Length and Width for a Scanned Beam Using a Conveyor Material Handling System

3.2.7 *depth-dose distribution*—variation of absorbed dose with depth from the incident surface of a material exposed to radiation.

3.2.7.1 *Discussion*—A typical distribution in homogeneous material produced by an electron beam along the beam axis is shown in Fig. 3. See Appendix X1.

3.2.8 *dose uniformity ratio*—ratio of the maximum to the minimum absorbed dose within the irradiation unit; it is a measure of the degree of uniformity of the absorbed dose; the concept is also referred to as the max/min dose ratio.

3.2.9 *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.

3.2.10 *duty cycle*—for a pulsed accelerator, the fraction of time the beam is effectively on; it is the product of the pulse width in seconds and the pulse rate in pulses per second.

3.2.11 *electron beam facility*—an establishment that uses energetic electrons produced by particle accelerators to irradiate product.

3.2.12 *electron energy*—kinetic energy of electron (unit: electron volt (eV))

3.2.13 *electron energy spectrum*—frequency or energy distribution of electrons as a function of energy; the energy spectrum of the electron beam impinging on the product depends on the type of the accelerator and the conditions of the irradiation process.

3.2.14 *electron range*—penetration distance along the beam axis of electrons within homogeneous material.

3.2.14.1 *Discussion*—Several range parameters may be defined to describe the characteristics of the electron beam. For more information, refer to ICRU Report 35.

3.2.15 *half-entrance depth* (R_{50e})—depth in homogeneous material at which the absorbed dose has decreased 50 % of the absorbed dose at the surface of the material.

3.2.15.1 *Discussion*—See Fig. 3.

[3] Available from International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

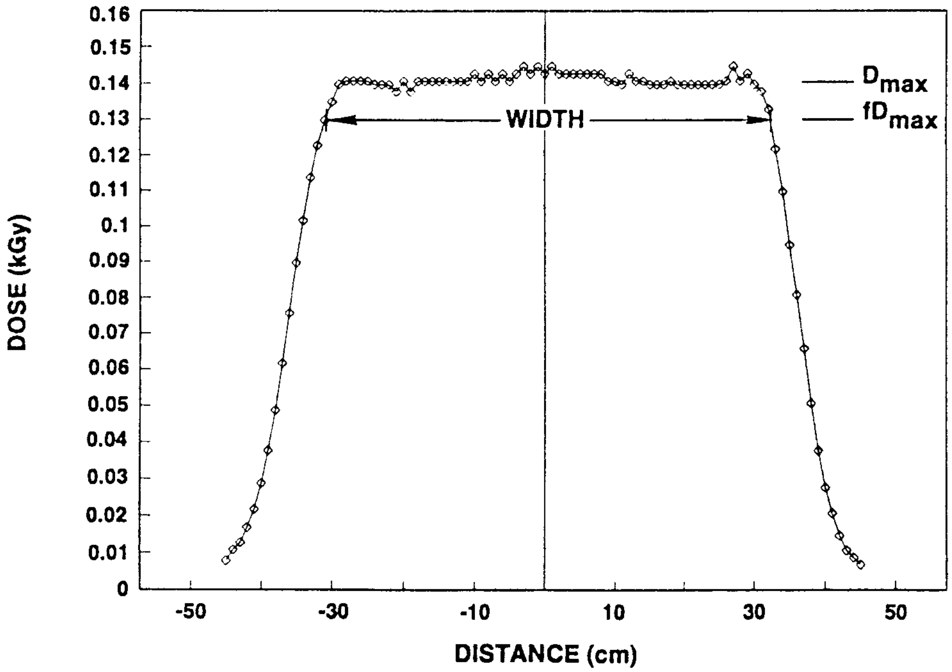

FIG. 2 Example of Electron-beam Dose Distribution Along the Beam Width[4] with the Width Noted at Some Defined Fractional Level *f* of the Average Maximum Dose D_{max}

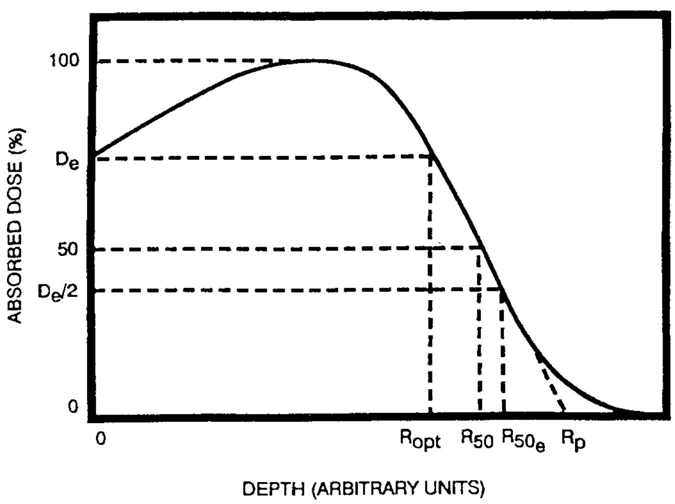

FIG. 3 A Typical Depth-Dose Distribution for an Electron Beam

3.2.16 *half-value depth (R_{50})*—depth in homogeneous material at which the absorbed dose has decreased 50 % of its maximum value.

3.2.16.1 *Discussion*—See Fig. 3.

3.2.17 *irradiation unit*—a volume of product with a specified loading configuration processed as a single entity; this term is not relevant to bulk-flow processing.

3.2.18 *optimum thickness (R_{opt})*—depth in homogeneous material at which the absorbed dose equals the absorbed dose at the surface where the electron beam enters.

3.2.18.1 *Discussion*—See Fig. 3.

3.2.19 *practical range (R_p)*—distance from the surface of homogeneous material where the electron beam enters to the point where the tangent at the steepest point (the inflection point) on the almost straight descending portion of the depth-dose distribution curve meets the depth axis.

3.2.19.1 *Discussion*—See Fig. 3.

3.2.20 *production run*—series of irradiation units containing the same product, and irradiated sequentially to the same absorbed dose.

3.2.21 *pulse beam current*—for a pulsed accelerator, the beam current averaged over the top ripples (aberrations) of the pulse current waveform; this is equal to I_{avg}/wf, where I_{avg} is the average beam current, w is the pulse width, and f is the pulse rate.

3.2.21.1 *Discussion*—See Fig. 4.

3.2.22 *pulse rate*—for a pulsed accelerator, the pulse current repetition frequency in hertz, or pulses per second; this is also referred to as the repetition (rep) rate.

3.2.23 *pulse width*—for a pulsed accelerator, the time interval between the half peak beam current amplitude points on the leading and falling edges of the pulse beam current waveform.

3.2.23.1 *Discussion*—See Fig. 4.

3.2.24 *reference material*—homogeneous material of

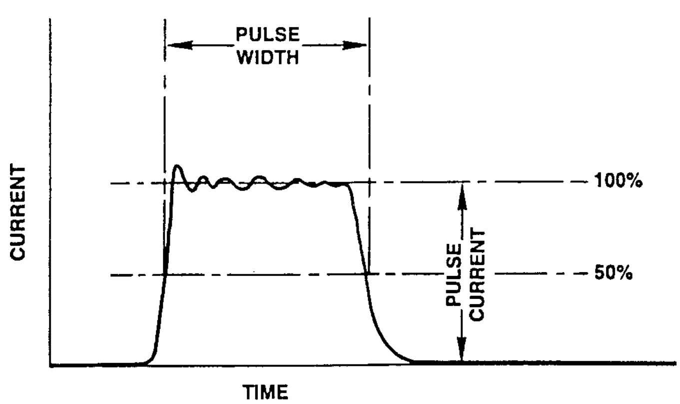

FIG. 4 Typical Pulse Current Waveform with Pulse Current and Pulse Width Noted