
Guide for selection and calibration of dosimetry systems for radiation processing

*Guide de choix et d'étalonnage des appareils de mesure dosimétrique pour
le traitement par irradiation*



Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 15556 was prepared by the American Society for Testing and Materials (ASTM) Subcommittee E10.01 (as E 1261-94) and was adopted, under a special “fast-track procedure”, by Technical Committee ISO/TC 85, *Nuclear energy*, in parallel with its approval by the ISO member bodies.

A new ISO/TC 85 Working Group WG 3, *High-level dosimetry for radiation processing*, was formed to review the voting comments from the ISO “Fast-track procedure” and to maintain these standards. The USA holds the convenership of this working group.

International Standard ISO 15556 is one of 20 standards developed and published by ASTM. The 20 fast-tracked standards and their associated ASTM designations are listed below:

ISO Designation	ASTM Designation	Title
15554	E 1204-93	<i>Practice for dosimetry in gamma irradiation facilities for food processing</i>
15555	E 1205-93	<i>Practice for use of a ceric-cerous sulfate dosimetry system</i>
15556	E 1261-94	<i>Guide for selection and calibration of dosimetry systems for radiation processing</i>
15557	E 1275-93	<i>Practice for use of a radiochromic film dosimetry system</i>
15558	E 1276-96	<i>Practice for use of a polymethylmethacrylate dosimetry system</i>
15559	E 1310-94	<i>Practice for use of a radiochromic optical waveguide dosimetry system</i>
15560	E 1400-95a	<i>Practice for characterization and performance of a high-dose radiation dosimetry calibration laboratory</i>
15561	E 1401-96	<i>Practice for use of a dichromate dosimetry system</i>

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15562	E 1431-91	<i>Practice for dosimetry in electron and bremsstrahlung irradiation facilities for food processing</i>
15563	E 1538-93	<i>Practice for use of the ethanol-chlorobenzene dosimetry system</i>
15564	E 1539-93	<i>Guide for use of radiation-sensitive indicators</i>
15565	E 1540-93	<i>Practice for use of a radiochromic liquid dosimetry system</i>
15566	E 1607-94	<i>Practice for use of the alanine-EPR dosimetry system</i>
15567	E 1608-94	<i>Practice for dosimetry in an X-ray (bremsstrahlung) facility for radiation processing</i>
15568	E 1631-96	<i>Practice for use of calorimetric dosimetry systems for electron beam dose measurements and dosimeter calibrations</i>
15569	E 1649-94	<i>Practice for dosimetry in an electron-beam facility for radiation processing at energies between 300 keV and 25 MeV</i>
15570	E 1650-94	<i>Practice for use of cellulose acetate dosimetry system</i>
15571	E 1702-95	<i>Practice for dosimetry in a gamma irradiation facility for radiation processing</i>
15572	E 1707-95	<i>Guide for estimating uncertainties in dosimetry for radiation processing</i>
15573	E 1818-96	<i>Practice for dosimetry in an electron-beam facility for radiation processing at energies between 80 keV and 300 keV</i>



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Standard Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing¹

This standard is issued under the fixed designation E 1261; 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 guide provides the basis for selecting and calibrating dosimetry systems used to measure absorbed dose in gamma-ray or X-ray fields and in electron beams used for radiation processing. It discusses the types of dosimetry systems that may be employed during calibration or on a routine basis as part of quality assurance in commercial radiation processing of products. This guide also discusses interpretation of absorbed dose and briefly outlines the uncertainties associated with the dosimetry measurements. The details of the calibration of the analytical instrumentation are addressed in individual dosimetry system standard practices.

1.2 The absorbed-dose range covered is from about 1 Gy (100 rad) to 1 MGy (100 Mrad). Source energies covered are from 0.1 to 50 MeV photons and electrons.

1.3 Standard practices and guides for specific dosimetry systems and applications are covered in other standards. Dosimetry for radiation processing with neutrons or heavy charged particles is not covered in this guide.

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:

- E 170 Terminology Relating to Radiation Measurements and Dosimetry²
- E 178 Practice for Dealing with Outlying Observations³
- E 666 Practice for Calculating Absorbed Dose from Gamma or X Radiation²
- E 668 Practice for the Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices²
- 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 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
- E 1538 Practice for Use of the Ethanol-Chlorobenzene Dosimetry System²
- E 1540 Practice for Use of a Radiochromic Liquid Dosimetry System²
- E 1607 Practice for Use of the Alanine-EPR Dosimetry System²
- E 1631 Practice for Use of Calorimetric Dosimetry Systems for Electron Beam Dose Measurements and Dosimeter Calibrations²

2.2 International Commission on Radiation Units and Measurements Reports:

- ICRU Report 14 Radiation Dosimetry: X-rays and Gamma rays with Maximum Photon Energies Between 0.6 and 50 MeV⁴
- ICRU Report 17 Radiation Dosimetry: X-rays Generated at Potentials of 5 to 150 kV⁴
- ICRU Report 33 Radiation Quantities and Units⁴
- ICRU Report 34 The Dosimetry of Pulsed Radiation⁴
- ICRU Report 35 Radiation Dosimetry: Electron Beams with Energies between 1 and 50 MeV⁴
- ICRU Report 37 Stopping Powers for Electrons and Positrons⁴

3. Terminology

3.1 Descriptions of Terms Specific to This Standard:

3.1.1 *accredited dosimetry calibration laboratory*—a laboratory that meets specific performance criteria and has been tested and approved by a recognized accrediting organization.

3.1.2 *calibration curve*—graphical or mathematical rela-

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² Annual Book of ASTM Standards, Vol 12.02.

³ Annual Book of ASTM Standards, Vol 14.02.

⁴ Available from International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

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tionship between dosimeter response and absorbed dose for a given dosimetry system.

DISCUSSION—This term is also referred to as the response function.

3.1.3 *calibration facility*—combination of an ionizing radiation source and its associated instrumentation that provides uniform and reproducible absorbed-dose rates at specific locations in a specific material traceable to national standards, and therefore, may be used to calibrate the absorbed-dose response of routine or other types of dosimeters.

3.1.4 *dosimeter batch*—quantity of dosimeters made from a specific mass of material with uniform composition, fabricated in a single production run under controlled, consistent conditions, and having a unique identification code.

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

3.1.6 *electron equilibrium*—a condition that exists in material under irradiation when the energies, number, and direction of electrons induced by the radiation are constant throughout the volume of interest; thus, within such a volume, the sum of the energies of the electrons entering it is equal to the sum of the energies of all the electrons leaving it.

3.1.7 *measurement quality assurance plan*—a documented program for a measurement process that quantifies the total uncertainty of the measurement (both random and non-random components); this plan shall demonstrate traceability to national standards, and shall show that the total uncertainty meets the requirements of the specific application.

3.1.8 *primary standard dosimeter*—dosimeter, of the highest metrological quality, established and maintained as an absorbed dose standard by a national or international standards organization.

3.1.9 *quality assurance*—all systematic actions necessary to provide adequate confidence that a measurement is performed to a predefined level of quality.

3.1.10 *reference standard dosimeter*—dosimeter, of high metrological quality, used as a standard to provide measurements traceable to, and consistent with, measurements made using primary standard dosimeters.

3.1.11 *routine dosimeter*—dosimeter calibrated against a primary, reference, or transfer standard dosimeter and used for routine dosimetry measurements.

3.1.12 *simulated product*—mass of material with attenuation and scattering properties similar to those of a particular material or combination of materials.

DISCUSSION—This term is sometimes referred to as dummy product.

3.1.13 *stock*—part of a batch held by the user.

3.1.14 *traceability*—the ability to show that a measurement is consistent with appropriate national or international standards through an unbroken chain of comparisons.

3.1.15 *transfer standard dosimeter*—dosimeter, often a reference standard dosimeter, intended for transport between different locations for use as an intermediary to compare absorbed dose measurements.

3.2 Other terms used in this guide may be found in Terminology E 170, ICRU Report 33, and Ref (1).⁵

4. Significance and Use

4.1 Ionizing radiation is used to produce various desired effects in products. Examples include the sterilization of medical products, processing of food, modification of polymers, irradiation of electronic devices, and curing of inks, coatings, and adhesives (2, 3). The absorbed doses employed vary according to the application. The doses cover a range from about 10 Gy to more than 100 kGy.

4.2 Regulations for sterilization of medical products and radiation processing of food exist in many countries. These regulations may require that the response of the dosimetry system be calibrated and traceable to national standards (4, 5, 6). Adequate dosimetry, with proper statistical controls and documentation, is necessary to ensure that the products are properly processed.

4.3 Proper dosimetric measurements must be employed to ensure that the product receives the desired absorbed dose. The dosimeters must be calibrated. Calibration of a routine dosimetry system can be carried out directly in a national or secondary standards laboratory by standardized irradiation of routine dosimeters. It may be carried out through the use of a local (in-house) calibration facility (7) or in a production irradiator. All possible factors that may affect the response of dosimeters, including environmental conditions and variations of such conditions within a processing facility, should be known and taken into account. The associated analytical instrumentation must also be calibrated.

5. Dosimeter Classes and Applications

5.1 Dosimeters may be divided into four basic classes in accordance with their relative quality and areas of applications (see Section 3).

5.1.1 *Primary Standard Dosimeter*—Primary standard dosimeters are established and maintained by national standards laboratories for calibration of radiation fields. The two most commonly used primary standard dosimeters are ionization chambers and calorimeters (for details, see ICRU Reports 14, 17, 34, and 35).

5.1.2 *Reference Standard Dosimeter*—Reference standard dosimeters are used to calibrate radiation fields and routine dosimeters. A widely used reference dosimeter is the ferrous sulfate (Fricke) aqueous solution (see Practice E 1026). Examples of reference dosimeters are listed in Table 1; more details of the characteristics of several systems may be found in Appendix X3.

5.1.3 *Routine Dosimeters*—Examples of routine dosimeters are listed in Table 2; more details of the characteristics of several of these systems may be found in Appendix X3.

5.1.4 *Transfer Standard Dosimeters*—Transfer standard dosimeters are specially selected dosimeters used for transferring dose information from an accredited or national standards laboratory to a local irradiation facility in order to establish traceability for the local calibration facility. Normally, these dosimeters are used under conditions that are

⁵ The boldface numbers in parentheses refer to the list of references at the end of this guide.