



Standard Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing¹

This standard is issued under the fixed designation E 1204; 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.

^{ε1} NOTE—Footnote 1 was editorially altered in June 1999.

1. Scope

1.1 This practice outlines dosimetric procedures to be followed in irradiator characterization, process qualification, and routine processing of food with ionizing radiation from isotopic gamma sources to ensure that all product has been treated within a predetermined range of absorbed-dose. Other procedures related to irradiator characterization, process qualification, and routine processing that may influence absorbed-dose in the product are also discussed. Information about effective or regulatory dose limits for food products is not within the scope of this practice (see Guides F 1355 and F 1356).

NOTE 1—Dosimetry is only one component of a total quality assurance program for adherence to good manufacturing practices used in the production of safe and wholesome food.

NOTE 2—Practice E 1431 describes dosimetric procedures for electron beam and bremsstrahlung (X-ray) irradiation facilities for food processing.

1.2 For guidance in the selection and calibration of dosimeters, and interpretation of measured absorbed-dose in the product, see Guide E 1261 and Practice E 666. For the use of specific dosimetry systems, see Practices E 668, E 1026, E 1205, E 1275, E 1276, E 1310, E 1401, E 1538, E 1540, E 1607, and E 1650. For discussion of radiation dosimetry for gamma rays and X-rays also see ICRU Report 14.

1.3 *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

¹ This practice is under the jurisdiction of ASTM Committee E-10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E 10.01 on Dosimetry for Radiation Processing.

Current edition, which includes substantial revisions to the last previous edition, was approved June 10, 1997. Published October 1997. Originally published as E 1204 – 87. International Standard ISO 15554:1998(E) is identical to the last previous edition E 1204 – 93.

² Annual Book of ASTM Standards, Vol 12.02.

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 for Statistical Methods³

E 666 Practice for Calculating Absorbed Dose from Gamma or X Radiation²

E 668 Practice for Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices²

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 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 1401 Practice for Use of a Dichromate Dosimetry System²

E 1431 Practice for Dosimetry in Electron Beam and Bremsstrahlung Irradiation Facilities for Food Processing²

E 1538 Practice for Use of an Ethanol-Chlorobenzene Dosimetry System²

E 1539 Guide for the Use of Radiation-Sensitive Indicators²

E 1540 Practice for the Use of a Radiochromic Liquid Dosimetry System²

E 1607 Practice for the Use of the Alanine-EPR Dosimetry System²

³ ASTM Standards on Precision and Bias for Various Applications, 4th ed., 1992.

⁴ Annual Book of ASTM Standards, Vol 14.01.

E 1650 Practice for the Use of a Cellulose Acetate Dosimetry System²

E 1707 Guide for Estimating Uncertainties in Dosimetry for Radiation Processing²

F 1355 Guide for the Irradiation of Fresh Fruits for Insect Disinfestation as a Quarantine Treatment⁵

F 1356 Guide for the Irradiation of Fresh and Frozen Red Meats and Poultry (to Control Pathogens)⁵

F 1736 Guide for the Irradiation of Finfish and Shellfish to Control Pathogens and Spoilage Microorganisms⁵

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

ICRU Report 14 Radiation Dosimetry: X-Rays and Gamma Rays with Maximum Photon Energies Between 0.6 and 50 MeV⁶

ICRU Report 33 Radiation Quantities and Units⁶

2.3 Codex Alimentarius Commission Reports:

CAC vol. 1, 2nd edition (1992), section 8.1: Recommended International Code of Practice for the Operation of Irradiation Facilities used for the Treatment of Foods (CAC/RCP 19-1979 (Rev. 1))⁷

3. Terminology

3.1 *Definitions*—Other terms used in this practice, in addition to those in 3.1.1-3.1.15-3.1.16, are defined in Terminology E 170 and in ICRU Report 33.

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).

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

3.1.2 *absorbed-dose mapping*—measurement of the absorbed-dose within a process load using dosimeters placed at specified locations to produce a one-, two- or three-dimensional distribution of absorbed dose, thus rendering a map of absorbed-dose values.

3.1.3 *calibration facility*—combination of an ionizing radiation source and its associated instrumentation that provides, at a specified location and within a specific material, a uniform and reproducible absorbed dose, or absorbed-dose rate, traceable to national or international standards and that may be used to derive the dosimetry system's response function or calibration curve.

3.1.4 *compensating dummy*—simulated product used during routine production runs in process loads that contain less product than specified in the product loading configuration, or simulated product used at the beginning or end of a production run, to compensate for the absence of product.

3.1.5 *dosimeter response*—the reproducible, quantifiable radiation effect produced by a given absorbed dose.

3.1.6 *dosimeter set*—one or more dosimeters used to measure the absorbed dose at a location and whose average reading is used as the absorbed-dose measurement of that location.

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 *irradiation time*—total time during which a process load is exposed to radiation.

3.1.9 *primary standard dosimeter*—a dosimeter of the highest metrological quality, established and maintained as an absorbed-dose standard by a national or international standards organization (see Guide E 1261).

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

3.1.11 *production run* (continuous-flow and shuffle-dwell irradiations)—a series of process loads consisting of materials, or products having similar radiation-absorption characteristics, that are irradiated sequentially to a specified range of absorbed dose.

3.1.12 *reference standard dosimeter*—a dosimeter of high metrological quality, used as a standard to provide measurements traceable to and consistent with measurements made using primary standard dosimeters (see Guide E 1261).

3.1.13 *response function*—mathematical representation of the relationship between dosimeter response and absorbed dose for a given dosimetry system.

3.1.14 *routine dosimeter*—a dosimeter calibrated against a primary, reference, or transfer standard dosimeter and used for routine absorbed-dose measurements (see Guide E 1261).

3.1.15 *simulated product*—a mass of material with attenuation and scattering properties similar to those of the product, material or substance to be irradiated.

3.1.15.1 *Discussion*—Simulated product is used during irradiator characterization as a substitution for the actual product, material or substance to be irradiated. When used in routine production runs, it is sometimes referred to as “compensating dummy.” When used for absorbed-dose mapping, simulated product is sometimes referred to as “phantom material.”

3.1.16 *transfer standard dosimeter*—a dosimeter, often a reference standard dosimeter, suitable for transport between different locations used to compare absorbed-dose measurements (see Guide E 1261).

4. Significance and Use

4.1 Food products may be treated with ionizing radiation, such as gamma rays from ⁶⁰Co or ¹³⁷Cs sources, for numerous purposes, including control of parasites and pathogenic microorganisms, insect disinfestation, growth and maturation inhibition, and shelf-life extension. Food irradiation specifications usually include an upper and lower limit of absorbed dose: a minimum to ensure the intended beneficial effect and a maximum to avoid product degradation. For a given application, one or both of these values may be prescribed by regulations that have been established on the basis of available scientific data. Therefore, it is necessary to determine the

⁵ Annual Book of ASTM Standards, Vol 15.09.

⁶ Available from the International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

⁷ Available from the Joint FAO/WHO Food Standards Program, Joint Office, Food and Agriculture Organization of the United Nations, Via Della Terme de Caracalla, 00100 Rome, Italy.

capability of an irradiation facility to process within these absorbed-dose limits prior to the irradiation of the food product. Once this capability is established, it is necessary to monitor and record the absorbed-dose during each production run to verify compliance with the process specifications within a predetermined level of confidence.

NOTE 3—The Codex Alimentarius Commission **(1)**⁸ uses the term “overall average absorbed-dose” in discussing broad concepts such as the wholesomeness of foods irradiated to an overall average absorbed-dose of less than 10 kGy. The overall average dose should not, however, be used in place of minimum or maximum absorbed-doses for specific applications. The CAC confirms this in the following statement from CAC/RCP 19-1979 Annex A: “[T]he design of the facility and the operational parameters have to take into account minimum and maximum dose values required by the process.”

NOTE 4—In some countries regulations require that the dose absorbed by a food item should not exceed some specified overall average dose in addition to minimum and maximum dose values. In this case, the overall averaged dose is the mean value of the lower and upper limits.

4.2 Some food products are processed in the chilled or frozen state. Therefore, it is necessary to confirm that the dosimeters used for routine monitoring are usable at low temperature and that the dosimeter temperature during irradiation is sufficiently stable to allow correction for temperature effects on the dosimeter response.

4.3 For more detailed discussions of radiation processing of various foods, see Guides F 1355, F 1356, and F 1736 and References **(1-10)**.

5. Radiation Source Characteristics

5.1 The radiation source used in a facility considered in this practice consists of sealed elements of ⁶⁰Co or ¹³⁷Cs which are typically linear (rods or “pencils”) arranged in one or more planar or cylindrical arrays.

5.2 Cobalt-60 emits photons with energies of approximately 1.17 and 1.33 MeV in nearly equal proportions. Cesium-137 produces photons with energies of approximately 0.662 MeV **(11)**.

5.3 The half-lives for ⁶⁰Co and ¹³⁷Cs are approximately 5.27 years and 30.2 years, respectively **(11)**.

5.4 Between source replenishments, removals, or redistributions, the only variation in the source output is the steady reduction in the activity caused by the radioactive decay.

6. Types of Facilities

6.1 Food processing facilities may be categorized by irradiator type (for example, container or bulk flow), conveyor system (for example, shuffle-dwell or continuous), and operating mode (for example, batch or continuous). Food products may be moved to the location in the facility where the irradiation will take place, either while the source is fully shielded (batch operation) or while the source is exposed (continuous operation). Food products may be transported past the source at a uniform and controlled speed (continuous conveyance), or may instead undergo a series of discrete controlled movements separated by controlled time periods

during which the process load is stationary (shuffle-dwell). For irradiators with rectangular source arrays, the process load generally makes one or more passes on each side of the source. Process loads may move past a rectangular source array in a configuration in which the source either extends beyond the process load or the process load extends beyond the source. In the latter configuration, the process load is usually moved past the source at two or more different levels. In bulk-flow irradiators, products such as grain or flour flow in loose form past the source.

6.2 Because of mechanical speed limitations, various techniques may be used to reduce the absorbed-dose rates for low absorbed-dose applications. These techniques include using only a portion of the source (eg. raising only one of several source racks to the irradiation position), using attenuators, and irradiating at greater distances from the source.

6.3 The design of an irradiator affects the delivery of absorbed-dose to a product. Therefore, the irradiator design must be considered when performing the absorbed-dose measurements required in Sections 8, 9, and 10.

7. Dosimetry Systems (see Guide E 1261, Practices E 1026, E 1205, E 1275, E 1276, E 1310, E 1401, E 1538, E 1540, E 1607, and E 1650).

7.1 *Dosimeter Classes and Applications:*

7.1.1 *Reference or Transfer Standard Dosimeters* are used to calibrate radiation fields (environments) and dosimetry systems employed in routine radiation processing. Reference or transfer dosimeters may also be used as routine dosimeters (7.1.2).

7.1.2 *Routine Dosimeters* are used for monitoring and quality assurance in food irradiation processing.

7.1.3 Operational and technical criteria for the selection of a dosimetry system are given in Guide E 1261.

7.2 *Calibration of Dosimetry Systems:*

7.2.1 Prior to use, dosimetry systems shall be calibrated in accordance with the user’s documented procedure that specifies details of the calibration process and quality assurance requirements. This calibration procedure shall be repeated at regular intervals to ensure that the accuracy of the absorbed dose measurement is maintained within required limits. Irradiation is a critical component of the calibration of the dosimetry system. Detailed calibration procedures are provided in Guide E 1261.

7.2.2 *Calibration Irradiation of Reference or Transfer Dosimeters*—Calibration irradiations shall be performed by irradiating the reference or transfer standard dosimeters using a calibration facility that provides an absorbed dose or an absorbed-dose rate having measurement traceability to nationally or internationally recognized standards.

7.2.3 *Calibration Irradiation of Routine Dosimeters*—Calibration irradiations shall be performed in several ways, including irradiating the routine dosimeters using:

7.2.3.1 A calibration facility that provides an absorbed dose or an absorbed-dose rate having measurement traceability to nationally or internationally recognized standards, or

7.2.3.2 An in-house calibration facility that provides an absorbed dose or an absorbed-dose rate having measurement

⁸ The boldface numbers in parentheses refer to the list of references at the end of this practice.