ISO/ASTM 52628:2019(E)

Standard Practice for Dosimetry in Radiation Processing[1]

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INTRODUCTION

The use of ionizing radiation for the treatment of commercial products such as the sterilization of healthcare products, the reduction of microbial contamination in food or the modification of polymers is referred to as radiation processing. The types of radiation used may be gamma radiation (typically from cobalt-60 sources), X-radiation or accelerated electrons.

In some applications, it is necessary to ensure that the specified absorbed dose is applied. In these cases, the absorbed dose must be measured, and measurement systems have been developed for this purpose. Much of the development of these systems rests on the early development of dosimetry systems for personnel radiation protection and for medical treatment. However, the absorbed doses used in radiation processing are generally higher, ranging from ~10 Gy up to 100 kGy or more and new dosimetry systems have been developed for measurements of these doses.

Note that the terms “dose” and “absorbed dose” are used interchangeably in this standard (see 3.1.1).

The dose measurements required in radiation processing concern characterization of radiation facilities in installation qualification (IQ) and operational qualification (OQ), measurement of dose distribution in irradiated products in performance qualification (PQ) and routine monitoring of the irradiation process.

The literature is abundant with articles on dosimeters for radiation processing, and guidelines and standards have been written by several organizations (the International Atomic Energy Agency (IAEA) and the International Commission on Radiation Units and Measurements (ICRU), for example) for the operation of the dosimetry systems and for their use in the characterization and validation of the radiation processing applications. In particular, ICRU Report 80 provides information on the scientific basis and historical development of many of the systems in current use.

ASTM Subcommittee E10.01 on Radiation Processing: Dosimetry and Applications was formed in 1984 initially with the scope of developing standards for food irradiation, but its scope was widened to include all radiation processing applications. The subcommittee, now Committee E61, has under its jurisdiction approximately 30 standard practices and standard guides, collectively known as the E61 standards on radiation processing. A number of these standards have been published as ISO/ASTM standards, thereby ensuring a wider international acceptance. These practices and guides describe the dosimetry systems most commonly used in radiation processing, and the dose measurements that are required in the validation and routine monitoring of the radiation processes. A current list of the E61 standards on radiation processing is given in 2.1 and 2.2.

The development, validation and routine control of a radiation process comprise a number of activities, most of which rely on the ability to measure the delivered dose accurately. It is therefore necessary that dose is measured with traceability to national, or international, standards, and the uncertainty in measured dose is known, including the effect of influence quantities. The E61 standards on radiation processing dosimetry serve to fulfill these requirements.

The practices describing dosimetry systems have several common attributes, and there is a need to have one general standard that can act as a common reference and that can be used as a basis for the selection of dosimetry systems for defined tasks. ISO/ASTM Practice 52628 serves this purpose. It outlines general requirements for the calibration and use of dosimetry systems and for the estimation of measurement uncertainties. Details relating to each dosimetry system are found in the respective standards and each of these refer to ISO/ASTM Practice 52628 for the general requirements.

1. Scope

1.1 This practice describes the basic requirements that apply when making absorbed dose measurements in accordance with the ASTM E61 series of dosimetry standards. In addition, it provides guidance on the selection of dosimetry systems and directs the user to other standards that provide specific information on individual dosimetry systems, calibration methods, uncertainty estimation and radiation processing applications.

1.2 This practice applies to dosimetry for radiation processing applications using electrons or photons (gamma- or X-radiation).

1.3 This practice addresses the minimum requirements of a *measurement management system*, but does not include general quality system requirements.

1.4 This practice does not address personnel dosimetry or medical dosimetry.

1.5 This practice does not apply to *primary standard dosimetry systems*.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced documents

2.1 *ASTM Standards:*[2]

E2232 Guide for Selection and Use of Mathematical Methods for Calculating Absorbed Dose in Radiation Processing Applications
E3083 Terminology Relating to Radiation Processing: Dosimetry and Applications
F1355 Guide for Irradiation of Fresh Agricultural Produce as a Phytosanitary Treatment
F1356 Guide for Irradiation of Fresh, Frozen or Processed Meat and Poultry to Control Pathogens and Other Microorganisms
F1736 Guide for Irradiation of Finfish and Aquatic Invertebrates Used as Food to Control Pathogens and Spoilage Microorganisms
F1885 Guide for Irradiation of Dried Spices, Herbs, and Vegetable Seasonings to Control Pathogens and Other Microorganisms

2.2 *ISO/ASTM Standards:*[2]

51026 Practice for Using the Fricke Dosimetry System
51205 Practice for Use of a Ceric-Cerous Sulfate Dosimetry System
51261 Practice for Calibration of Routine Dosimetry Systems for Radiation Processing
51275 Practice for Use of a Radiochromic Film Dosimetry System
51276 Practice for Use of a Polymethylmethacrylate Dosimetry System
51310 Practice for Use of a Radiochromic Optical Waveguide Dosimetry System
51401 Practice for Use of a Dichromate Dosimetry System
51538 Practice for Use of the Ethanol-Chlorobenzene Dosimetry System
51540 Practice for Use of a Radiochromic Liquid Dosimetry System
51607 Practice for Use of an Alanine-EPR Dosimetry System
51608 Practice for Dosimetry in an X-Ray (Bremsstrahlung) Facility for Radiation Processing at Energies between 50 keV and 7.5 MeV
51631 Practice for Use of Calorimetric Dosimetry Systems for Electron Beam Dose Measurements and Dosimetry System Calibration
51649 Practice for Dosimetry in an Electron Beam Facility for Radiation Processing at Energies Between 300 keV and 25 MeV
51650 Practice for Use of a Cellulose Triacetate Dosimetry System
51702 Practice for Dosimetry in a Gamma Facility for Radiation Processing
51707 Guide for Estimation of Measurement Uncertainty in Dosimetry for Radiation Processing
51818 Practice for Dosimetry in an Electron Beam Facility for Radiation Processing at Energies Between 80 and 300 keV
51900 Guide for Dosimetry in Radiation Research on Food and Agricultural Products
51939 Practice for Blood Irradiation Dosimetry
51940 Guide for Dosimetry for Sterile Insect Release Programs
51956 Practice for Use of a Thermoluminescence-Dosimetry (TLD) System for Radiation Processing
52116 Practice for Dosimetry for a Self-Contained Dry-Storage Gamma Irradiator
52303 Guide for Absorbed Dose Mapping in Radiation Processing Facilities
52701 Guide for Performance Characterization of Dosimeters and Dosimetry Systems for Use in Radiation Processing

2.3 *ISO Standards:*[3]

ISO 11137-1 Sterilization of health care products – Radiation – Part 1: Requirements for development, validation and routine control of a sterilization process for medical devices
ISO 11137-3 Sterilization of health care products – Radiation – Part 3: Guidance on dosimetric aspects of

[1] This practice is under the jurisdiction of ASTM Committee E61 on Radiation Processing and is the direct responsibility of Subcommittee E61.01 on Dosimetry, and is also under the jurisdiction of ISO/TC 85/WG 3.

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[2] For referenced ASTM and ISO/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 Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, https://www.iso.org/contact-iso.html

development, validation and routine control

ISO 10012 Measurement managements systems – Requirements for measurement processes and measuring equipment

ISO 14470 Food irradiation – Requirements for the development, validation and routine control of the process of irradiation using ionizing radiation for the treatment of food

ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories

2.4 *International Commission on Radiation Units and Measurements (ICRU) Reports:*[4]

ICRU Report 80 Dosimetry Systems for Use in Radiation Processing

ICRU Report 85a Fundamental Quantities and Units for Ionizing Radiation

2.5 *Joint Committee for Guides in Metrology (JCGM) Reports:*

JCGM 100:2008, GUM , 1995, with minor corrections, Evaluation of measurement data – Guide to the Expression of Uncertainty in Measurement[5]

JCGM 200:2012, VIM , International vocabulary of metrology – basic and general concepts and associated terms[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *absorbed dose (D)*—quotient of $d\bar{\varepsilon}$ by dm, where $d\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter of mass dm, thus

$$D = d\bar{\varepsilon}/dm$$

ICRU 85a

3.1.1.1 *Discussion*—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).

3.1.2 *calibration*—operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication. **VIM**

3.1.3 *calibration curve*—expression of the relation between indication and corresponding measured quantity value. **VIM**

3.1.4 *dosimeter*—device that, when irradiated, exhibits a quantifiable change that can be related to a dosimetric quantity using appropriate measurement instrument(s) and procedures.

3.1.5 *dosimeter characterization / dosimetry system characterization*—determination of performance characteristics, such as dose range, reproducibility and the effect of influence quantities, for a dosimeter or dosimetry system under defined test conditions.

3.1.6 *dosimeter response (indication)*—reproducible, quantifiable change produced in the dosimeter by ionizing radiation.

3.1.6.1 *Discussion*—The dosimeter response value (indication), obtained from one or more measurements, is used in the estimation of the dosimetric quantity. The response value (indication) may be obtained from such measurements as optical absorbance, intensity of EPR spectra, or electropotential between solutions.

3.1.7 *dosimetry*—measurement of a dosimetric quantity by the use of a dosimetry system.

3.1.8 *dosimetry system*—interrelated elements used for measuring a dosimetric quantity, including dosimeters, instruments and their associated reference standards, and procedures for their use.

3.1.8.1 *Discussion*—As discussed in ICRU-85a, dosimetric quantities provide a physical measure to correlate with actual or potential effects. They are products of radiometric quantities and interaction coefficients. In calculations, the values of these quantities and coefficients must be known, while measurements might not require this information. Dosimetric quantities include air kerma, exposure and absorbed dose to a specified material.

3.1.8.2 *Discussion*—In radiation processing applications the quantity of interest is usually absorbed dose to water. Absorbed dose to silicon might be used in semiconductor irradiations.

3.1.9 *influence quantity*—quantity that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the indication and the measurement result. **VIM**

3.1.9.1 *Discussion*—In dosimetry for radiation processing, typical examples of influence quantities include radiation type and energy, irradiation temperature, dose rate and the time interval between irradiation and determination of the indication of the dosimeter.

3.1.10 *measurement management system*—set of interrelated or interacting elements necessary to achieve metrological confirmation and continual control of measurement processes. **ISO 10012**

3.1.10.1 *Discussion*—See 7.6 for further details.

3.1.11 *(measurement) uncertainty*—non-negative parameter characterizing characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used. **VIM**

3.1.12 *(metrological) traceability*—property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty. **VIM**

3.1.13 *primary standard dosimetry system* —dosimetry system that is designated or widely acknowledged as having the highest metrological qualities and whose value is accepted without reference to other standards of the same quantity.

3.1.14 *radiation processing*—intentional irradiation of products or materials to preserve, modify or improve their characteristics.

[4] Available from the International Commission on Radiation Units and Measurements, 7910 Woodmont Ave, Suite 800, Bethesda, MD 20815, USA.

[5] Document produced by Working Group 1 of the Joint Committee for Guides in Metrology (JCGM/WG 1). Available free of charge at the BIPM website (http://www.bipm.org).

[6] Document produced by Working Group 2 of the Joint Committee for Guides in Metrology (JCGM/WG 2). Available free of charge at the BIPM website (http://www.bipm.org).

3.1.15 *reference standard dosimetry system*—dosimetry system, generally having the highest metrological quality available at a given location or in a given organization, from which measurements made there are derived.

3.1.16 *reference standard radiation field*—calibrated radiation field, generally having the highest metrological quality available at a given location or in a given organization, from which measurements made there are derived.

3.1.17 *routine dosimetry system*—dosimetry system calibrated against a reference standard dosimetry system and used for routine absorbed dose measurements, including dose mapping and process monitoring.

3.1.18 *transfer standard dosimetry system*—dosimetry system used as an intermediary to calibrate other dosimetry systems.

3.1.19 *type I dosimeter*—dosimeter of high metrological quality, the response of which is affected by individual influence quantities in a way that is well-defined and capable of expression in terms of independent correction factors.

3.1.19.1 *Discussion*—See Section 6 for examples and further details.

3.1.20 *type II dosimeter*—dosimeter, the response of which is affected by influence quantities in a complex way that cannot practically be expressed in terms of independent correction factors.

3.1.20.1 *Discussion*—See Section 6 for examples and further details.

3.1.21 *uncertainty budget*—statement of a measurement uncertainty, of the components of that measurement uncertainty, and of their calculation and combination. **VIM**

3.2 Definitions of other terms used in this standard that pertain to radiation measurement and dosimetry may be found in ASTM Terminology E3083. Definitions in ASTM E3083 are compatible with ICRU Report 85a; that document, therefore, may be used as an alternative reference. Where appropriate, definitions used in this standard have been derived from, and are consistent with, general metrological definitions given in the VIM.

4. Significance and use

4.1 Radiation processing of articles in both commercial and research applications may be carried out for a number of purposes. These include, for example, sterilization of health care products, reduction of the microbial populations in foods and modification of polymers. The radiations used may be accelerated electrons, gamma-radiation from radionuclide sources such as cobalt-60, or X-radiation.

4.2 To demonstrate control of radiation processes that are dependent on the delivery of a known dose, the absorbed dose must be measured using a dosimetry system, the calibration of which, is traceable to appropriate national or international standards. The radiation-induced change in the dosimeter is evaluated and related to absorbed dose through calibration. Dose measurements required for particular processes are described in other standards referenced in this practice.

5. Dosimetry system requirements

5.1 Dosimetry system requirements are a necessary part of a *measurement management system*. The following requirements shall be included as a minimum, but additional requirements may be appropriate depending on the nature of the process. Guidance on these requirements is given in Section 7.

5.1.1 The selection and use of a specific dosimetry system in a given application shall be justified and documented. The justification shall take into account at least the following:

dose range
radiation type and energy
effect of influence quantities
level of uncertainty
spatial resolution

5.1.2 The dosimetry system shall be calibrated in accordance with the requirements of ISO/ASTM Practice 51261.

5.1.3 The uncertainty associated with measurements made with the selected dosimetry system shall be established and documented. All dose measurements shall be accompanied by an estimate of uncertainty. See ISO/ASTM 51707, NPL Report CIRM 29[7], GUM and NIST Technical Note 1297[8] for guidance.

5.1.4 Documentation shall be established and maintained to ensure compliance with the minimum requirements specified in the ASTM or ISO/ASTM standard relevant to the specific dosimetry system. The user's quality system might be more detailed than these minimum requirements.

6. Classification

6.1 Classification of dosimeters and dosimetry systems in the ASTM E61 series of dosimetry standards is based on two distinct criteria: *(1)* the inherent metrological properties of the dosimeter (see 3.1.19 and 3.1.20), and *(2)* the field of application of the dosimetry system (see 3.1.15 and 3.1.17). These classifications are important in both the selection and calibration of dosimetry systems.

6.2 *Classification of Dosimeters Based on Metrological Properties:*

6.2.1 This classification of dosimeters is based on knowledge of their inherent metrological properties. The method of measurement may be important in the classification (see below), but the classification does not include consideration of the quality of the actual instrumentation used, or the quality of preparation (manufacture) of the dosimeter. For example, acidic solutions of dichromate ions have certain inherent properties in terms of their response to radiation and the effect of irradiation temperature that means they are classified as *type I dosimeters*. The actual performance of a given dosimetry system based on dichromate dosimeters will depend, however, on the quality of preparation of the dosimetric solution and the quality of the spectrophotometers used for optical absorbance measurement.

[7] Sharpe, P., and Miller, A., "Guidelines for the Calibration of Routine Dosimetry Systems for use in Radiations Processing," NPL Report CIRM 29, Teddington, UK, 2009.

[8] Taylor, B. N., and Kuyatt, C. E., "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," NIST TN-1297, Gaithersburg, MD: NIST 1994.

6.2.2 Knowledge of the inherent properties of a dosimeter is important when selecting a dosimeter for a particular application. For example, when selecting a dosimeter to be used to transfer dose between radiation fields of differing temperatures, it is essential to choose a dosimeter whose response can be corrected for the effect of irradiation temperature, that is, a *type I dosimeter*.

6.2.3 In order for a dosimeter to be classified as a *type I dosimeter*, it must be possible to apply accurate, independent, corrections to its response to account for the effects of relevant influence quantities, such as temperature, dose rate, etc., or to demonstrate that the influence quantity is not relevant and will not affect the dosimeter's response. The magnitude of the correction, the range of values of the influence quantity over which it is applicable and the range of doses over which it is applicable are determined as part of dosimeter characterization (see 7.3). In classifying a dosimeter as a *type I dosimeter*, it may be necessary to specify the method of measurement. For example, free radicals produced in irradiated alanine can, in principle, be measured by a number of different techniques, however, only the EPR technique has been shown to provide the high metrological quality (precision and accuracy) necessary to classify alanine as a *type I dosimeter*. Examples of *type I dosimeters* are given in Table 1.

6.2.4 The classification of a dosimeter as a *type II dosimeter* is based on the complexity of interaction between influence quantities, such as temperature and dose rate, which makes it impractical to apply independent correction factors to the dosimeter response. Examples of *type II dosimeters* are given in Table 2.

6.3 *Classification of Dosimetry Systems Based on the Field of Application:*

6.3.1 *Reference Standard Dosimetry Systems:*

6.3.1.1 The classification of a dosimetry system as a *reference standard dosimetry system* is based on its application. *Reference standard dosimetry systems* are used as standards to calibrate the dosimetry systems that are used for routine measurements. The uncertainty of the *reference standard dosimetry system* will affect the uncertainty of the system being calibrated and it is therefore important that the *reference standard dosimetry system* is of high metrological quality. In this context, the concept of high metrological quality implies a system with low uncertainty and with traceability to appropriate national or international standards.

6.3.1.2 *Reference standard dosimetry systems* may take the form of systems held at a given location or they may take the form of *transfer standard dosimetry systems* operated by a national standards laboratory or by a laboratory accredited to ISO/IEC 17025. In the case of *transfer standard dosimetry systems*, dosimeters are sent to a facility for irradiation and then returned to the issuing laboratory for measurement. The requirement to transport dosimeters without unduly increasing measurement uncertainty restricts the type of dosimeter that can be used. Alanine/EPR, dichromate or ceric-cerous dosimetry systems are commonly used in this way.

6.3.1.3 A *reference standard dosimetry system* comprises dosimeters and the associated measurement equipment and quality system documentation necessary to ensure traceability to appropriate national and international standards. The dosimeter used in a *reference standard dosimetry system* is generally a *type I dosimeter*, although there may be exceptions (see, for example, ISO/ASTM 51631).

6.3.1.4 The expanded uncertainty achievable with measurements made using a *reference standard dosimetry system* is typically of the order of 3 % (k=2). In certain specific applications, for example the use of electrons of energy below 1 MeV, practical limitations of the techniques may mean that the *reference standard dosimetry systems* have a larger uncertainty.

NOTE 1—An expanded uncertainty derived by multiplying a combined standard uncertainty by a coverage factor of k=2 provides a level of confidence of approximately 95 %. See ISO/ASTM 51707 and the GUM for further details.

6.3.2 *Routine Dosimetry Systems* —The classification of a dosimetry system as a *routine dosimetry system* is based on its application, i.e. routine absorbed dose measurements, including dose mapping and process monitoring. A *routine dosimetry system* comprises dosimeters and the associated measurement equipment and quality system documentation necessary to ensure traceability to appropriate national or international standards. The dosimeter used in a routine dosimetry system is often a *type II dosimeter*, although *type I dosimeters*, such as alanine, can also be used for routine dose measurements.

TABLE 1 Examples of type I dosimeters

Dosimeter	Description	Reference
Fricke solution	Liquid solution of ferrous and ferric ions in 0.4 mol dm^{-3} sulfuric acid. Measured by spectrophotometry.	ISO/ASTM 51026
Alanine/EPR	Pellet or film containing alanine. Measured by EPR spectroscopy of radiation induced radical.	ISO/ASTM 51607
Dichromate	Liquid solution of chromium ions in 0.1 mol dm^{-3} perchloric acid. Measured by spectrophotometry.	ISO/ASTM 51401
Ceric-Cerous Sulphate	Liquid solution of ceric and cerous ions in 0.4 mol dm^{-3} sulphuric acid. Measured by spectrophotometry or potentiometry.	ISO/ASTM 51205
Ethanol Chlorobenzene (Classification dependent on solution composition and method of measurement)	Liquid solutions of various compositions containing chlorobenzene in ethanol. Measured by titration.	ISO/ASTM 51538

TABLE 2 Examples of type II dosimeters

Dosimeter	Description	Reference
Calorimeter	Assembly consisting of calorimetric body (absorber), thermal insulation, and temperature sensor with wiring.	ISO/ASTM 51631
Cellulose Triacetate	Untinted cellulose triacetate (CTA) film. Measured by spectrophotometry.	ISO/ASTM 51650
Ethanol Chlorobenzene (Classification dependent on solution composition and method of measurement)	Liquid solution of various compositions containing chlorobenzene in ethanol. Measured by spectrophotometry or oscillometry.	ISO/ASTM 51538
PMMA	Specially developed PMMA materials. Measured by spectrophotometry.	ISO/ASTM 51276
Radiochromic Film	Specially prepared film containing dye precursors. Measured by spectrophotometry.	ISO/ASTM 51275
Radiochromic Liquid	Specially prepared solution containing dye precursors. Measured by spectrophotometry.	ISO/ASTM 51540
Radiochromic Optical Waveguide	Specially prepared optical waveguide containing dye precursors. Measured by spectrophotometry.	ISO/ASTM 51310
TLD	A phosphor, alone, or incorporated in a material. Measured by thermoluminescence.	ISO/ASTM 51956

6.3.2.1 The expanded uncertainty achievable with measurements made using a *routine dosimetry system* is typically of the order of 6 % (k=2), but can be greater or smaller depending on the nature of the measurement, the analytical equipment and the skill of the operator. For example, the uncertainty of measurements made using alanine dosimeters in gamma rays or megavoltage electron beams might be lower than 6 %, whereas it might be higher than 6 % for processes involving electron beams below 1 MeV or X-rays below 500 keV. The measurement uncertainty for a given situation has to be determined by the development of a full uncertainty budget (see 7.5).

TABLE 3 General dosimetry requirements for all radiation processing applications

Application	Dosimetry Requirements	Radiation Type	Reference
General Industrial Radiation Processing	Dosimetry is required for installation qualification (IQ), operational qualification, (OQ), performance qualification (PQ) and routine process monitoring	Gamma	ISO/ASTM 51702
		300 keV to 25 MeV electron beam	ISO/ASTM 51649
		80 to 300 keV electron beam	ISO/ASTM 51818
		X-Ray	ISO/ASTM 51608

7. Guidance

7.1 *Dosimetry System Components:*

7.1.1 A dosimetry system consists of a number of components used in the measurement of absorbed dose. These include the dosimeter, the instrumentation used and the written procedures necessary for the operation of the system. Instrumentation not only includes the instrument used for measuring the dosimeter response, but also ancillary instruments, such as thickness gauges and reference standard materials for assessing instrument performance.

TABLE 4 Dosimetry requirements for specific radiation processing applications

Application	Dosimetry Requirements	Reference
Food Irradiation	Dosimetry is required in process definition, IQ (e-beam, X-ray), OQ, PQ and routine process control	ISO 14470
Medical Device Sterilization		ISO 11137-1
Blood Irradiation		ISO/ASTM 51939

7.2 *Dosimetry System Selection:*

7.2.1 The selection of a dosimetry system for a particular application is the responsibility of the user.

7.2.2 Section 5.1.1 gives a list of factors that must, as a minimum, be taken into account when selecting a dosimetry system, but careful consideration needs to be given to additional factors that may be relevant to the specific application. Examples include pre- and post-irradiation stability, ease of use and ease of calibration. Safety related aspects, such as toxicity, might also be important, particularly with respect to the irradiation of foods.

7.2.3 Tables 3-6, inclusive, list ISO, ASTM and ISO/ASTM standards that give requirements or guidance, or both, on dosimetry as used in a range of radiation processing applications. There is some overlap in the scopes of a number of these standards, but the requirements in the standards listed in Table 4 always take precedence over those in the general standards listed in Table 3.

7.2.4 Summaries of the performance characteristics of dosimeters are given in Annex A1, but for detailed information the relevant ASTM or ISO/ASTM practice should be consulted. Brief guidance on issues that need to be considered when selecting a dosimetry system is given below:

7.2.4.1 *Dose range*—Doses used in radiation processing range from ~10 Gy to more than 100 kGy according to the application. The relatively restricted operating range of many