Designation: E181 – 23

Standard Guide for Detector Calibration and Analysis of Radionuclides in Radiation Metrology for Reactor Dosimetry[1]

This standard is issued under the fixed designation E181; 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 covers general procedures for the calibration of radiation detectors and measurement for radiation metrology for reactor dosimetry. For any particular radionuclide, one or more of these methods may apply.

1.2 These techniques are concerned only with specific radionuclide measurements. The chemical and physical properties of the radionuclides are not within the scope of this standard.

1.3 E3376, Standard Practice for Calibration and Usage of Germanium Detectors in Radiation Metrology for Reactor Dosimetry, was previously in Guide E181 and is now found in Volume 12.02 of the *Annual Book of ASTM Standards*. The discussion herein is not a sufficient substitute for the full standard. This guide is specifically NOT to be used as a direct reference to Practice E3376. Only the standard listed provides sufficient information to serve as a reference.

1.4 Additional information on the setup, calibration, and quality control for radiometric detectors and measurements is given in Guide C1402 and Practice D7282.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C1402 Guide for High-Resolution Gamma-Ray Spectrometry of Soil Samples

D7282 Practice for Setup, Calibration, and Quality Control of Instruments Used for Radioactivity Measurements

E170 Terminology Relating to Radiation Measurements and Dosimetry

E3376 Standard Practice for Calibration and Usage of Germanium Detectors in Radiation Metrology for Reactor Dosimetry

3. Terminology

3.1 *Definitions:*

3.1.1 *certified radioactivity standard source*—a calibrated radioactive source, with stated accuracy, whose calibration is certified by the source supplier as traceable to the National Radioactivity Measurements System (**1**).[3]

3.1.2 *check source*—a radioactivity source, not necessarily calibrated, that is used to confirm the continuing satisfactory operation of an instrument.

3.1.3 *correlated photon summing*—the simultaneous detection of two or more photons originating from a single nuclear disintegration.

3.1.4 *dead time*—the time after a triggering pulse during which the system is unable to retrigger.

3.1.5 *FWHM*—(full width at half maximum) the full width of a gamma-ray peak distribution measured at half the maximum ordinate above the continuum.

3.1.6 *national radioactivity standard source*—a calibrated radioactive source prepared and distributed as a standard reference material by the U.S. National Institute of Standards and Technology.

[1] This guide is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.05 on Nuclear Radiation Metrology.

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[2] For referenced 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] The boldface numbers in parentheses refer to the list of references at the end of these methods.

3.1.7 *resolution, gamma ray*—the measured FWHM, after background subtraction, of a gamma-ray peak distribution, expressed in units of energy.

3.2 *Abbreviations:*

3.2.1 *MCA*—multichannel analyzer.

3.2.2 *SCA*—single channel analyzer.

3.2.3 *ROI*—region of interest.

3.3 For other relevant terms, see Terminology E170.

NOTE 1—The terms "standard source" and "radioactivity standard" are general terms used to refer to the sources and standards of National Radioactivity Standard Source and Certified Radioactivity Standard Source.

CALIBRATION AND USAGE OF GERMANIUM DETECTORS

4. E3376 Standard Practice for Calibration and Usage of Germanium Detectors in Radiation Metrology for Reactor Dosimetry

4.1 *Scope*—This standard establishes techniques for calibration, usage, and performance testing of germanium detectors for the measurement of gamma-ray emission rates of radionuclides in radiation metrology for reactor dosimetry. The practice is applicable only to samples of small size, approximating to point sources. It covers the energy and full-energy peak efficiency calibration as well as the determination of gamma-ray energies in the 0.06 MeV to 2 MeV energy region and is designed to yield gamma-ray emission rates with an uncertainty of ±3 %. This technique applies to measurements that do not involve overlapping peaks, and in which peak-to-continuum considerations are not important.

4.2 *Use*—This practice replaces content in E181–17 relevant to the use of germanium detectors in gamma spectroscopy.

4.3 *Summary*—This practice describes the calibration and usage of germanium detectors for measurement of gamma-ray emission rates of radionuclides in radiation metrology for nuclear reactors. The practice is intended for use by knowledgeable persons who are responsible for the development of correct procedures for the calibration and usage of germanium detectors.

CALIBRATION AND USAGE OF SCINTILLATION DETECTOR SYSTEMS

5. Scope

5.1 This method establishes methods for calibration, usage, and performance testing of scintillation detector systems, for example, sodium iodide (thallium activated) [NaI(Tl)]. Scintillation detector systems are used for the measurement of gamma-ray emission rates of radionuclides, the assay for radioactivity, and the determination of gamma-ray energies. The method covers both energy calibration and efficiency calibration. The following two techniques are considered:

5.1.1 *Multichannel Analyzer Counting for Simple Spectra* (see Section 8)—This technique applies to measurements that do not involve overlapping peaks and those for which the continuum under the full-energy peak can be subtracted without introducing unacceptable error (**2**). This technique applies to total spectrum counting and single-channel analyzer counting.

5.1.2 *Multichannel Analysis Counting for Complex Spectra* (see Section 9)—This technique applies to measurements that involve multiple nuclides, overlapping peaks, and those for which the continuum under the full-energy peak cannot be subtracted without introducing unacceptable error (**3**).

5.2 The theory of operation of sodium iodide detectors is presented in numerous publications, including Refs (**3-5**).

6. Apparatus

6.1 A typical spectrometry system consists of a scintillating medium; for example, NaI(Tl), one or more photomultipliers, optically coupled to the scintillator, a photomultiplier power supply, detector preamplifier, linear amplifier, multichannel analyzer, and data readout device, for example, a printer, plotter, oscilloscope, or computer. Ionizing radiation interacts with the detector to produce a flash of light, the photomultipliers convert the light flash to an amplified electrical impulse, and the supportive electronics analyze and count the pulses.

7. Preparation of Apparatus

7.1 Follow the manufacturer's instructions for setting up and preliminary testing of the equipment. Observe all the manufacturer's limitations and cautions. All preparations in Section 11 should be observed during calibration and sample analysis, and all corrections shall be made when required. A check source should be used to check the stability of the system at least before and after calibration.

8. Multichannel Analyzer (MCA) Counting for Simple Spectra

8.1 *Summary of Method:*

8.1.1 The purpose of this method is to provide a standardized basis for the calibration, usage, and performance testing of scintillation detector systems for measurement of gamma-ray emission rates of single nuclides or from simple mixtures of nuclides that do not involve overlapping peaks.

8.1.2 The source emission rate for a gamma ray of a selected energy is determined from the counting rate in a full-energy peak of a spectrum, together with the measured efficiency of the spectrometry system for that energy and source location. It is usually not possible to measure the efficiency directly with emission rate standards at all desired energies. Therefore, a curve or function is constructed to permit interpolation between available calibration points.

8.2 *Energy Calibration*—Establish the energy calibration of the system over the desired energy region at fixed gain. Using known sources, record a spectrum containing full-energy peaks which span the gamma-ray energy region of interest. Determine the channel numbers which correspond to two gamma-ray energies that are near the extremes of the energy region of interest. From these data determine the slope and the intercept of the energy calibration curve. For most applications such a linear energy calibration curve will be adequate. Determine nonlinearity correction factors if necessary (**3, 4**). The energy