NIST Low-Energy Photon Brachytherapy Standards and Calibrations

Michael G. Mitch, Michelle O'Brien, and Stephen M. Seltzer
Ionizing Radiation Division
National Institute of Standards and Technology
Gaithersburg, MD 20899 USA

April10, 2009

Brachytherapy Seed Calibrations

The NIST has maintained a continuous effort in the calibration and characterization of ^{125}I, ^{103}Pd, and ^{131}Cs low-energy photon-emitting brachytherapy seeds for more than ten years. The primary air-kerma-strength standard for these seeds is the Wide-Angle Free-Air Chamber (WAFAC), which has been used to calibrate over 900 sources since its introduction in 1999 (see Table 1 for current sources). At least annually, seed manufacturers send batches of three to five seeds to the NIST for calibration. These seeds are then forwarded to three Accredited Dosimetry Calibration Laboratories (ADCLs) to establish and subsequently maintain the secondary standard at these laboratories for use in calibrating clinical well-ionization chambers. The NIST seed calibration program includes measures to ensure that seeds submitted for WAFAC calibration are consistent and representative of that particular seed design so that associated errors will not be propagated down the traceability chain to the ADCLs, seed manufacturers, and therapy clinics. To address this issue, several additional measurements are made to further characterize a seed beyond the initial air-kerma strength calibration. The calibration coefficients of several well-ionization chambers are determined for each seed, and compared to past results to confirm consistency of well-chamber-to-WAFAC relative response. Well-chamber-response-to air-kerma-strength-ratio histories are kept for all seed models, and the NIST data is compared to well-chamber measurement results from the ADCLs. Stability of the WAFAC is verified by periodic measurements of instrument response to an ^{241}Am source.

For at least one seed from each batch, the photon spectrum emergent in the plane bisecting the seed axis is measured using a collimated high-purity germanium (HPGe) detector. The pulse-height distribution is converted to the absolute energy distribution of fluence rate emerging from the seed, which is then used to calculate air-kerma strength. This completely independent determination is compared with WAFAC results. Seed anisotropy is characterized by three additional measurements, including relative WAFAC measurements at 45-degree intervals about the long axis of the seed, x-ray spectra measured with the seed positioned at 90-degree intervals about an axis perpendicular to the mid-point of the long axis of the seed, and radiochromic film measurements in contact-exposure geometry. Variations in the relative response of the WAFAC and well-ionization chambers have been attributed to a combination of differences in measurement geometry, fluorescence x-ray emission from non-radioactive seed components, and anisotropy of x-ray emission and self-absorption (attenuation) effects due to internal seed geometry. Seed-characterization measurements assist in the identification of aberrantly produced seeds that should be eliminated from the calibration process. Such complete characterization of a seed is necessary for quality assurance of WAFAC measurements, and to maintain accuracy in the transfer of standards to the ADCLs, seed manufacturers, and therapy clinics. A Measurement Quality Assurance

(MQA) test of the ability of the three ADCLs to accurately calibrate an ^{125}I seed in terms of air-kerma strength was administered by NIST and completed in late 2007.

Table 1. Low-energy photon-emitting brachytherapy sources with NIST calibrations.

Isotope	**Manufacturer**	**Distributor**	**Seed Model**
^{125}I	North American Scientific	North American Sci.	Prospera I-125 (MED3631-A/M)
^{125}I	Bebig	Bebig	IsoSeed I-125 (I25.S06)
^{125}I	Best Medical International	Best Medical	Best I-125 (2301)
^{125}I	Bard Brachytherapy	Bard Brachytherapy	BrachySource (STM1251)
^{125}I	Theragenics Corporation	Theragenics	I-Seed I-125 (I25.S06)
^{125}I on Ag	GE Healthcare	GE Healthcare	OncoSeed (6711)
^{125}I on Ag	GE Healthcare	GE Healthcare	EchoSeed (6733)
^{125}I on Ag	GE Healthcare	GE Healthcare	9011
^{125}I on Ag	Core Oncology	Core Oncology	ProstaSeed (125SL, 125SH)
^{125}I on Ag	IsoAid, LLC	IsoAid	Advantage I-125 (IAI-125A)
^{125}I on Ag	Isotron	Nucletron	selectSeed I-125 (130.002)
^{125}I on Ag	Bebig	Bebig	IsoSeed I-125 (I25.S17)
^{103}Pd	Theragenics Corporation	Theragenics	TheraSeed (200)
^{103}Pd	North American Scientific	North American Sci.	Prospera Pd-103 (MED3633)
^{103}Pd	Best Medical International	Best Medical	Best Pd-103 (2335)
^{103}Pd	IsoAid, LLC	IsoAid	Advantage Pd-103 (IAPd-103A)
^{131}Cs	IsoRay Medical Inc.	IsoRay	CS-1

Electronic Brachytherapy Source Calibrations

The NIST is currently developing a new facility for the calibration of the Xoft miniature x-ray source (and other similar devices), which provides low-energy x-rays (< 50 keV) for electronic brachytherapy applications. A reference air-kerma rate of the sources will be directly realized through use of the Lamperti free-air chamber. The energy spectrum from individual sources will be measured using a high-purity germanium (HPGe) spectrometer, which will be mounted opposite the free-air chamber to allow simultaneous measurement of the air-kerma rate and tube output spectrum. The free-air chamber and spectrometer will be rotated about the axis of the x-ray tube to characterize the anisotropy of emissions. The response of well-ionization chambers relative to air-kerma will be studied in preparation for dissemination of the new standard to the three ADCLs.