Update on NIST X-Ray Air-Kerma Standards and Calibrations

Michelle O'Brien and Stephen M. Seltzer
Ionizing Radiation Division
National Institute of Standards and Technology (NIST)
Gaithersburg, MD 20899 USA

April 10, 2009

The comparison SIM.RI(I)-K3, involving the members of the Sistema Interamericano de Metrología (SIM), is near completion. The five SIM laboratories (NIST, NRCC, ININ, CNEA and LNMRI) are involved. Four NIST reference-class transfer ionization chambers (0.6 cm^2) of two different models were calibrated by each of the participating laboratories for four tungsten-anode reference radiation qualities of energies between 100 kV and 300 kV. The reference radiation qualities are those recommended by the Consultative Committee for Ionizing Radiation (CCRI(I)). The comparison project was proposed at the SIM MWG6 (Ionizing Radiation) in April 2007 by the CNEA/CAE. The final measurements of the star-shaped comparison, piloted by the NIST, were concluded late summer of 2008. The draft report is in the final stages of review, with a projected date of May 2009 for the distribution to the participants for individual review.

Air-kerma calibration coefficients are currently being compared for narrow x-ray spectra (and for ^{137}Cs beams) between the NIST and the Kenya Bureau of Standards (KEBS). Upon the request of the KEBS, the NIST-designed comparison will demonstrate the ability of the KEBS facility to provide traceability. A NIST reference-class transfer ionization chamber was calibrated by each laboratory in terms of the quantity air kerma for four tungsten-anode reference radiation qualities of energies between 80 kV and 150 kV (and for Cs-137 gamma rays). The chamber has been returned to the NIST, and the final calibrations will be performed in April, with a comparison report soon to follow.

In an effort to improve direct traceability methods, the-low energy CCRI reference beam qualities have been developed at the NIST. A comparison has been made of the air-kerma standards for low-energy x-rays at the NIST and the Physikalisch-Technische Bundesanstalt (PTB). The comparison involved a series of measurements at the PTB and the NIST using the air-kerma standards and two NIST reference-class transfer ionization chamber standards. The included reference beam qualities are in the range from 10 kV to 50 kV from the CCRI beam series and mammography beams produced with molybdenum as the anode and filtration. Due to delays caused by two x-ray tube replacements and a re-evaluation of the correction factors, the final analysis and report has been delayed. The preliminary agreement is excellent, except for the 10 kV NIST-CCRI beam, which requires further analysis of the correction factors. The mammography results will serve as the third indirect comparison between the NIST and the PTB for mammography techniques. The low-energy tungsten-anode results will determine the continued use and final adoption of the CCRI 10 kV to 50 kV at the NIST.

Refining the low-energy techniques, which are determined by the Ritz primary standard, is especially important at this time. The low-energy tungsten-anode x-ray calibration range will no longer maintain two primary standards. The Lamperti free-air chamber, which was previously used in a limited capacity for the 10 kV to 20 kV beams, will be dedicated to the measurement of air-kerma rate of electronic brachytherapy sources. The Lamperti chamber has a history of direct traceability at the BIPM and is designed for the energy range required in electronic brachytherapy. The short air pathlength and the small size and weight of the Lamperti chamber make it the appropriate choice. The facility design will include a translation stage and aperture holder for a direct measurement of the air-attenuation correction, important at the low energies for this application.

The 100 kV low-energy range was resourced with a tube in December 2008, which then failed in March 2009. The tube was the last of the original design, and the seven-year shelf life is believed to have contributed to its premature failure. The process has begun to find a replacement tube to produce x-ray techniques that duplicate the historical parameters. The tungsten-anode techniques (20 kV to 50 kV) with filtration of Rh, Mo, Al, and Ag will resume after a full characterization of the x-ray tube. This new series of mammography reference radiation qualities is being developed using the Ritz primary standard. These techniques will better represent the changes in digital mammography.

The mammography x-ray range, which incorporates the molybdenum- and the rhodium-anode x-ray tubes and the Attix primary standard, has resumed calibrations and the establishment of NIST traceability through FDA-MQSA proficiency tests. The molybdenum tube was resourced after 14 years of service. Unfortunately, due to poor quality assurance by the x-ray tube provider, the wrong anode was initially provided to the NIST, tungsten instead of molybdenum, resulting in further delays. Currently calibrations are being performed to provide traceability to the IAEA for all mammography techniques (Mo/Mo, Mo/Rh and Rh/Rh, including exit beams). These repeat the calibrations provided in June of 2005.

In spite of all the activities in the 100 kV and the mammography range, the 300 kV range has not been ignored. Funding has been dedicated to the fabrication of a new free-air ionization chamber that was designed in 2006. The new standard will replace the Wyckoff-Attix chamber, which has been used at the NIST as a primary x-ray standard for more than fifty years, to realize air kerma for x-ray beams of 50 kV to 300 kV. Although construction has begun, final completion is estimated to be in 2010, with a full evaluation in a parallel measurement arrangement until the correction factors are established and tested.

Upgrades to all the x-ray data acquisition systems have been purchased and received; however implementation requires a pause in the calibration schedule that has been complicated by the unexpected tube failures. The upgrades are planned for the summer of 2009.