Monte Carlo Calculations of Free-Air Ionization Chamber Correction Factors for Electron Loss and Photon Scatter at INER

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ABSTRACT

Based on the original design by F. H. Attix, two improved free-air ionization chambers, one medium-energy and one low-energy, were constructed at the National Radiation Standard Laboratory (NRSL) of the Institute of Nuclear Energy Research (INER, Taiwan). The cylindrical free-air chamber geometry model was simplified, and the correction factors for electron loss (Ke) and photon scatter (Ksc) were calculated using the Monte Carlo code LSCAT (low-energy photon-scattering expansion for the EGS4 code).

In this study, the monoenergetic Ke and Ksc values were calculated. For the medium-energy chamber, calculations were made in 10 keV steps from 10 keV to 300 keV, with 10^8 histories at each energy. For the low-energy chamber, calculations were made from 2 keV to 50 keV in steps of 2 keV, also with 10^8 histories each. Statistical uncertainties were estimated for each energy by sub-dividing the histories into twenty batches, the statistical uncertainty of all values for monoenergetic Ke and Ksc were not more than 0.01%. Energy spectra weighting calculations of Ke and Ksc for BIPM reference qualities were also evaluated. For the medium-energy range, the spectra used were those calculated using the Monte Carlo code OMEGA/BEAM with NRSL simple x-ray unit geometry. For the low-energy range, the spectra were those using the measured photon fluence spectra for the BIPM reference qualities, but some of the energy spectra were calculated using the Monte Carlo code OMEGA/BEAM with NRSL simple x-ray unit geometry for comparison.

The calculated values of Ke and Ksc for the medium-energy chamber at the NRSL x-ray unit spectra were compared with NRSL's current values, and the energy spectra weighting values were also compared with the values calculated using the x-ray unit effective energies. The results for the Monte Carlo calculations for the medium-energy chamber were in close agreement with NRSL's current values. When using energy spectra weighting, the maximum difference observed for Ke was 0.05% (at radiation quality 180 kV) and for Ksc 0.25% (at radiation quality 100 kV). When using x-ray unit effective energies, the maximum difference observed for Ke was 0.11% (at radiation quality 250 kV) and for Ksc 0.22% (at radiation quality 100 kV).

For the Monte Carlo calculations of the low-energy chamber, energy spectra weighting values of Ke and Ksc for measured BIPM spectra were compared with the energy spectra calculated using NRSL simple x-ray unit geometry. The results

showed that Ke and Ksc using measured BIPM spectra were extremely close to those obtained using simple x-ray unit geometry calculated spectra and the maximum difference was 0.02%.