Ionization Chamber Wall Correction Factors and Angular Dependences of Responses in Measuring Air Kerma for Gamma Rays

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The problems of correction factors for ionization chamber wall absorption and scattering of gamma rays in measuring air kerma were first pointed out in 1990 by Bielajew(1) and discussed at the 10th meeting of CCRI(I) in 1991(2). The values for the correction factors were obtained(3) by calculation for 2 different size NMIJ cylindrical ionization chambers. The smaller chamber has an ionization volume of 20 mm in diameter and 19.3 mm long and has an inner electrode of 2 mm in diameter and 14.3 mm long. The larger chamber has an ionization volume of 40 mm in diameter and 50 mm long and has an inner electrode of 2 mm in diameter and 45 mm long. Calculation values for the correction factors were used instead of experimental values for intercomparison between BIPM and NMIJ standards of air kerma for ^{137}Cs and ^{60}Co gamma rays performed in 2001. Calculation values have been used for calibration at NMIJ since August 2002.

The difference between the calculation values and the experimental values was less than 0.3 % for the ionization chambers in most ^{137}Cs and ^{60}Co gamma ray fields at NMIJ. The chambers were usually fixed at 45° to the gamma ray beams. Figure 1 shows the angular dependence of a signal current from a larger ionization chamber when it is placed at a source-chamber distance of 1 m in a ^{60}Co gamma ray field. The values are normalized at 45°. The solid symbols show the signal currents that were corrected for absorption and scattering due to the chamber walls by using values for the correction factors obtained by the calculation(4). It was noticed that the values for the corrections were small at 45° and became larger at 0° and 90°. The corrections became larger at these angles because the gamma ray attenuation increased at the cylindrical side wall or at the both end walls.

When a cylindrical chamber is placed at 45° to the gamma ray beam as shown in Figure 2 (A), the length of the gamma rays passing through the wall becomes zero for extrapolating the chamber wall thickness to zero(5). However, the attenuation length at the end walls does not become zero when the chamber is fixed at 90° (Figure 2 (B)). This makes the large discrepancies between the values for the wall correction factors obtained by calculation and those by experiment. The effects of gamma ray attenuation along the end walls of ionization chambers were originally studied in 1957(6). NMIJ started fixing cylindrical ionization chambers at 45° before 1974(7) according to the study(8).

The open symbols in Figures 3 and 4 show signal currents from the smaller and the larger ionization chambers measured near 90° in ^{137}Cs and ^{60}Co gamma ray fields when the chambers are placed at a source chamber distance of 1 m. The signal currents are normalized by each value at 90°. The smaller chamber showed no peak at 90° in either the ^{137}Cs or the ^{60}Co gamma ray fields. However, the larger chamber showed peaks in both fields. We expected these peaks to occur because the signal currents on both sides of these peaks decreased due to the attenuation of the gamma rays along the long path in the end walls of the ionization chambers. The direction of the gamma rays did not coincide with the plane of these walls at 90°, but coincided when the chamber was slightly rotated from the angle. It was expected that the response peaks should emerge only in the larger chamber and not in the smaller because the gamma rays did not originate from an exact point source.

The solid symbols in the Figures 3 and 4 show the angular dependence obtained by calculations for both chambers placed in gamma ray fields at 1 m from a gamma ray point source. The result for the smaller chamber in a ^{137}Cs gamma ray field has a peak at 90° but it also shows a peak at 91.5° (Figure 3). The reason for the peak at 91.5° is not clear. Calculations showed no peak for the smaller chamber in a ^{60}Co gamma ray field. One of the inner surfaces of the end walls of the smaller chamber was directed toward the gamma ray source when the chamber was rotated $\pm 0.56^{o}$ from 90^{o}. The calculation results for the larger chamber shows a steep peak for the ^{137}Cs point source and also shows a peak similar to that obtained by experiment for ^{60}Co (Figure 4). Thus we should pay close attention to measurements and also to the Monte Carlo calculations of responses of cylindrical ionization chambers fixed perpendicular to gamma ray beams. The response of such experiments can be affected by a small change in angle near 90^{o}. The correction factors obtained by calculations for a gamma ray point source could be quite different from those for an actual gamma ray source.

References

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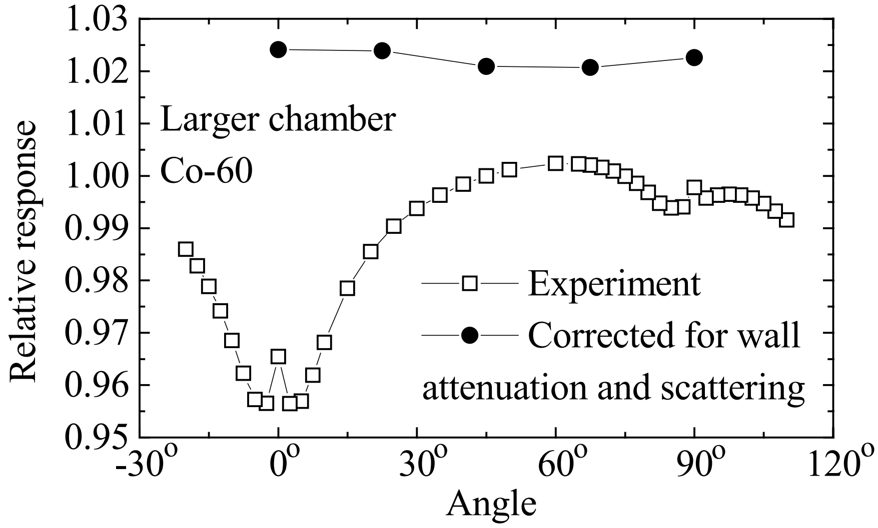

Figure 1. Angular dependence of a signal current from a larger ionization chamber at a source-chamber distance of 1 m in a ^{60}Co gamma ray field. The solid symbols show the signal currents that were corrected for absorption and scattering by chamber walls

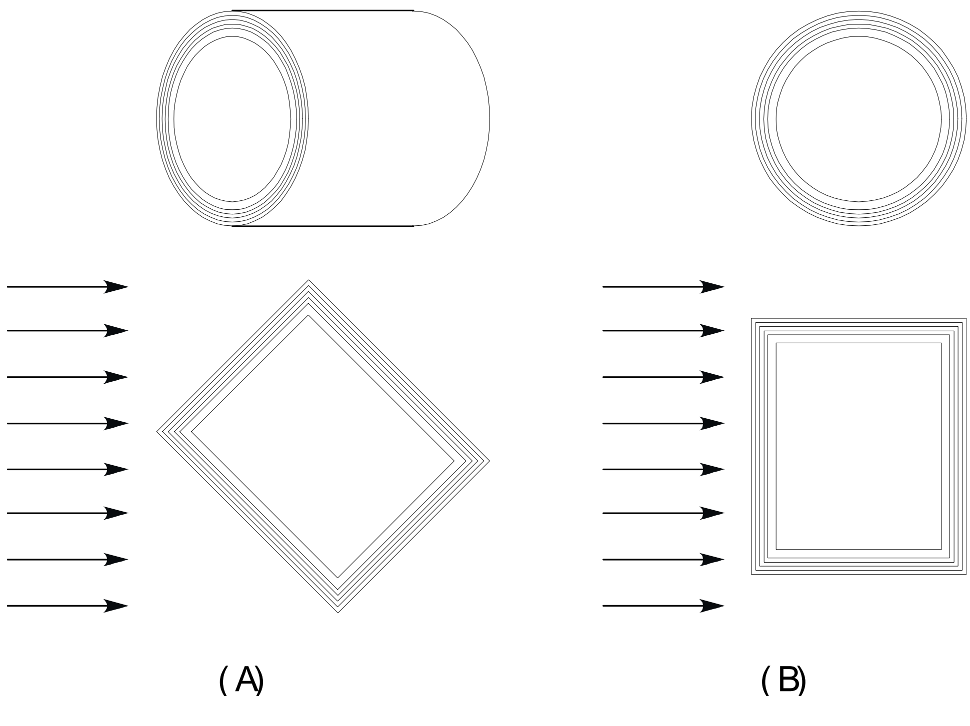

Figure 2. Placements of cylindrical ionization chambers in gamma ray fields: (A) at 45° to gamma ray beam, (B) perpendicular, i.e. at 90°.

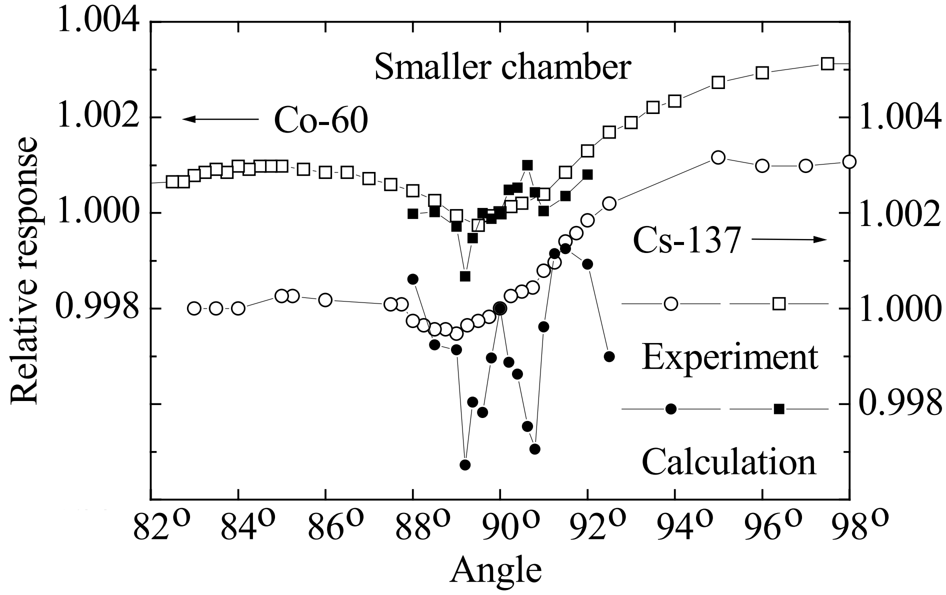

Figure 3. Responses of smaller ionization chamber near 90° in ^{137}Cs and ^{60}Co gamma ray fields at 1 m from the source. Open symbols show experimental results and solid symbols show calculations.

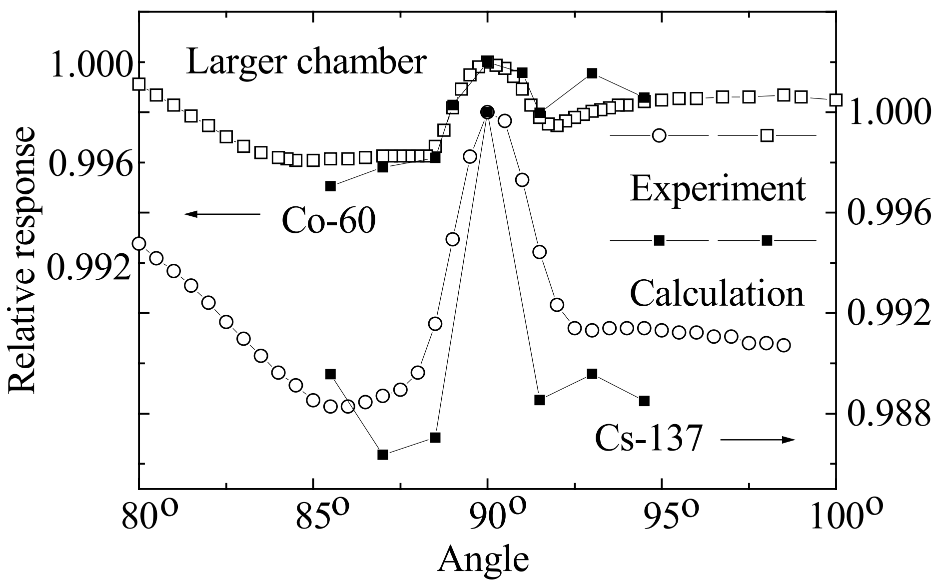

Figure 4. Responses of larger ionization chamber near 90° in ^{137}Cs and ^{60}Co gamma ray fields at 1 m from the source. Open symbols show experimental results and solid symbols show calculations.