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ANGULAR DEPENDENCE OF WALL CORRECTION FOR CYLINDRICAL CAVITY CHAMBER

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Abstract

The cylindrical graphite cavity chambers are used for primary standard of air kerma rate of Co-60 and Cs-137. We measured wall attenuation correction factor (K_{at}) at several irradiation angles using extrapolation technique because of angular dependence. From these results, it can be seen that it is insufficient technique for evaluation of K_{at}. The Monte Carlo simulations were also done to estimate wall correction factor (K_{wall}) and the corrected value by calculations becomes constant at any angle.

1. Introduction

The cylindrical graphite cavity chambers are used for measurements of air kerma rate of gamma-ray at primary standard laboratories. In our laboratory, we set a cylindrical chamber at 45 degree against beam direction because of angular dependence of cylindrical chamber.[1] Several constant values and correction factor are used to estimate air kerma rate from measured ionizing current in cavity region of chamber. Attenuation and scatter of primary photons in the chamber wall are accounted for by a correction factor, K_{wall} in air-kerma measurements by standard cavity ionization chambers. At NMIJ-AIST, as in other NMIs, the factor K_{wall} for gamma-rays air-kerma measurements had been traditionally determined by a procedure based on a linear extrapolation of the chamber current to zero wall thickness. Wall attenuation correction factor is also include in them and this value depends on the irradiation angle. A.Katoh et al. measured wall attenuation correction factors and exposure rates for cylindrical cavity chamber at several irradiation angle and they found that there was variation of exposure rate against incident angle of gamma-rays. Wall correction factor depends on irradiation angle, but measured exposure rate should be constant at any angle.

The factor K_{wall} was also determined by Monte Carlo calculations by Bielajew[2] and then Rogers and Bielajew[3]. The results of these calculations deviate appreciably from the K_{wall} values determined according to the above experimental procedure. We also estimated K_{wall} value by simulaitons, and there was not such difference between calculated and experimental value of K_{wall} because of difference of irradiation angles.

So in this study, we measured angular dependence of ionizing current and estimated wall correction factor using Monte Carlo simulation at each angle.

2. Experiments

Experiment set up are shown in Figure 1. The primary air kerma standard at AIST for ^{60}Co and ^{137}Cs gamma rays is based on two different size cylindrical graphite ionization chamber. One has an inner height 50mm and 40mm in diameter, and the other has an inner height 19.3mm and 20mm in diameter. The graphite used had a density of 1.85g/cm^3. A chamber was placed so that the center of it becomes at the reference point of the gamma ray field. The distance from source to center of the chamber is 1m. We set chambers at 0, 22.5, 45, 67.5 and 90 degrees for measurements of angular dependence of ionizing current and wall correction factor by linear extrapolation technique. Ionization current was measured for 3, 4, 5 and 6mm thick-wall for ^{60}Co gamma rays and 2, 3, 4, 5 and 6mm for ^{137}Cs gamma rays at each angle.

3. Simulation

The Monte Carlo calculations was made using the EGS4 code[4] and PRESTA for electron transport algorithm. Electrons and photons were followed down to 1keV (ECUT=0.512MeV, PCUT=0.001MeV). Point source with mono-energy for Co-60 and Cs-137 were simulated and distance of source to center of cavity chamber is also 1m. Source positions were placed at 0, 22.5, 45, 67.5 and 90 degrees against the center of cavity chamber. In this case, 0 degree corresponds to hitting the chamber on the flat face.

The value of K_{wall} is determined by scoring

$$k_{wall} = \frac{\sum_i r_i^0 e^{+\mu d_i}}{\sum_i \left(r_i^0 + r_i^1\right)} \qquad (1)$$

where r^0 is the energy deposited in the air cavity by electrons generated by primary photon interaction, r^1 the energy deposited by electrons generated by second and higher-order scattered photons, μ is the linear attenuation coefficient of wall material for primary photons, and d the pass length of the photon to the first interaction point in the chamber wall . K_{wall} includes wall attenuation(K_{at}), center of electron production (K_{cep}) and scattering correction(K_{sc}) like following equation.

$$K_{wall} = K_{at} \cdot K_{cep} \cdot K_{sc}$$

4. Results and comparison

Figure 2 shows the attenuation curve of large cavity chamber for Co-60 and Cs-137 at several irradiation angles and figure 3 shows the results of small cavity chamber. All measured data are normalized with the value of 3mm wall thickness for Co-60 and 2mm for Cs-137 at the incident angle of 45 degree. The extrapolated value to zero wall thickness means wall attenuation correction. Compared with other angles, K_{at} becomes smaller for 0 and 90 degree, because effective thickness of side wall are longer at other angles compared with 0 and 90 degree.

Figure 4 shows variations of the measured current, corrected value of attenuation by experiments and corrected value using calculations for large chamber and figure 5 shows for small chamber. These data are also normalized with the value of 3mm wall thickness for Co-60 and 2mm for Cs-137 at 45 degree. Only attenuation correction were done in corrected value by experiments (not correct K_{cep}), but K_{wall} by calculations include K_{at}, K_{cep} and K_{sc}. Although measured correction factors are used, it can be seen some variation because of underestimation of attenuation correction by experiments. Corrected values by K_{at} should become constant because air kerma rate is constant at any irradiation angles. At 0 or 90 degree, side walls are parallel to beam angle and path length becomes much larger than other angles. But it is difficult to estimate actual path length from experiment data for cylindrical cavity chamber. On the other hand, corrected values by calculations become almost constant at any angles for large chamber. For small chamber, the corrected value at 90 degree becomes larger than other angles because of stem scattering effect. The ratio of stem volume to cavity volume is larger for small chamber than that for large chamber, so stem scattering effect becomes remarkably. From these results, it could be said that Monte Carlo simulation can estimate actual attenuation correction and calculated K_{wall} correction factor should be used spatially at 90 degree.

5. Conclusion

In this study, we measured angular dependence of attenuation correction factor for cavity chamber and calculate wall correction factor for each angle by simulation. Attenuation correction value by extrapolation technique have angular dependence and there are variation of the values after wall attenuation was corrected by measured data. From these data, it can be mention that extrapolation technique could not correct for wall attenuation correction actually for cylindrical cavity chamber and should be taken carefully. The other side, corrected value by calculations becomes constant at any angles. It is supported that the monte carlo simulation is good technique for estimation of wall correction compared with extrapolation by experiments.

Reference

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[2] A.F. Bielajew “Correction factors for thick-walled ionization chambers in point source photon beam”, Phys. Med. Biol. 35 501-516 (1990)

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[4] Nelson W R, Hirayama H and Rogers D W O "The EGS4 Code System", Stanford Linear Accelerator Center Report SLAC-265(1985)

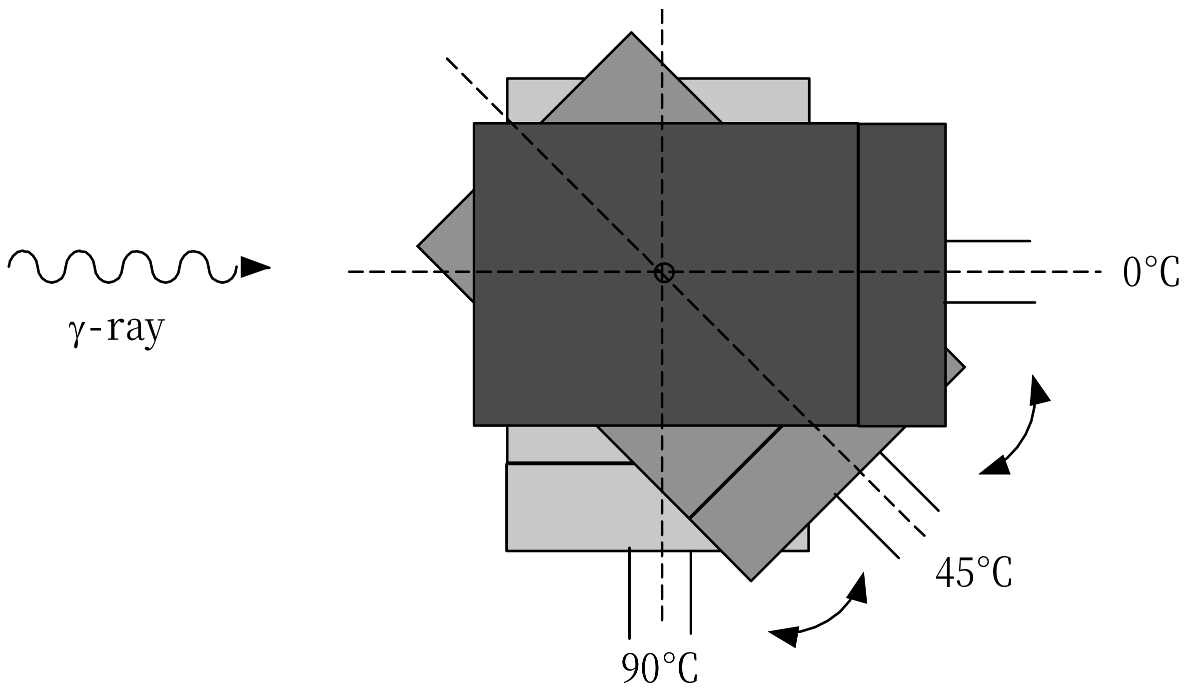

Figure 1. Set up of the cavity chamber for gamma ray irradiation. Incident angle of gamma rays on the chamber is taken as that shown in the figure. The chamber is turned in horizontal plane around the vertical axis through the center of the chamber ionizing volume.

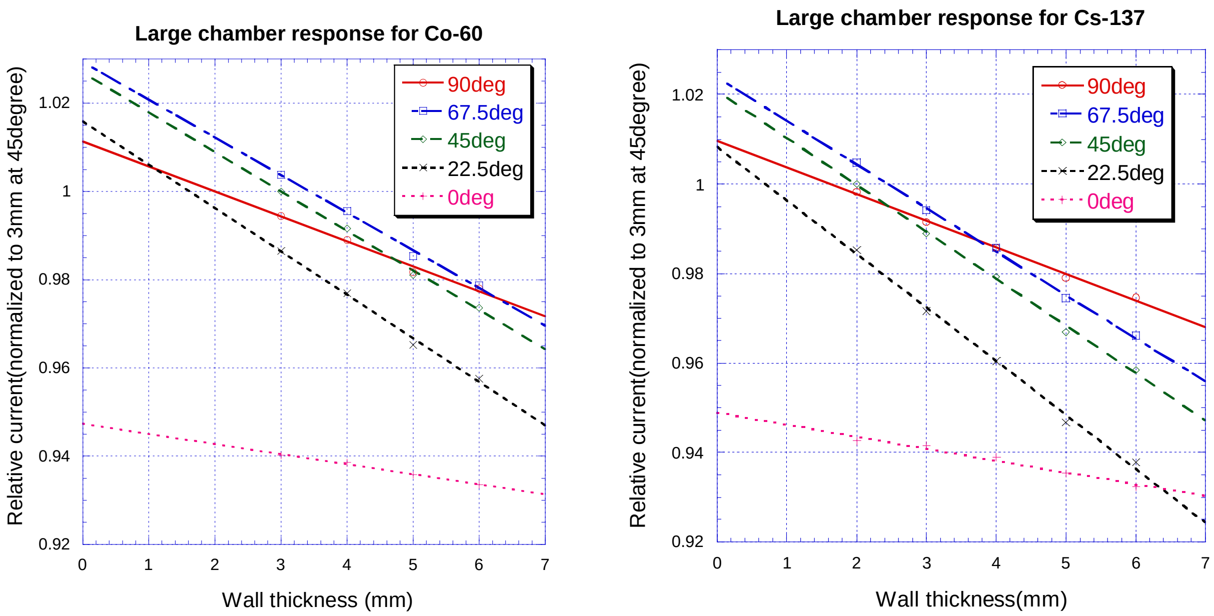

Figure 2. Relative ionization current produced in the chamber plotted against wall thickness with incident angle of gamma rays for large chamber.

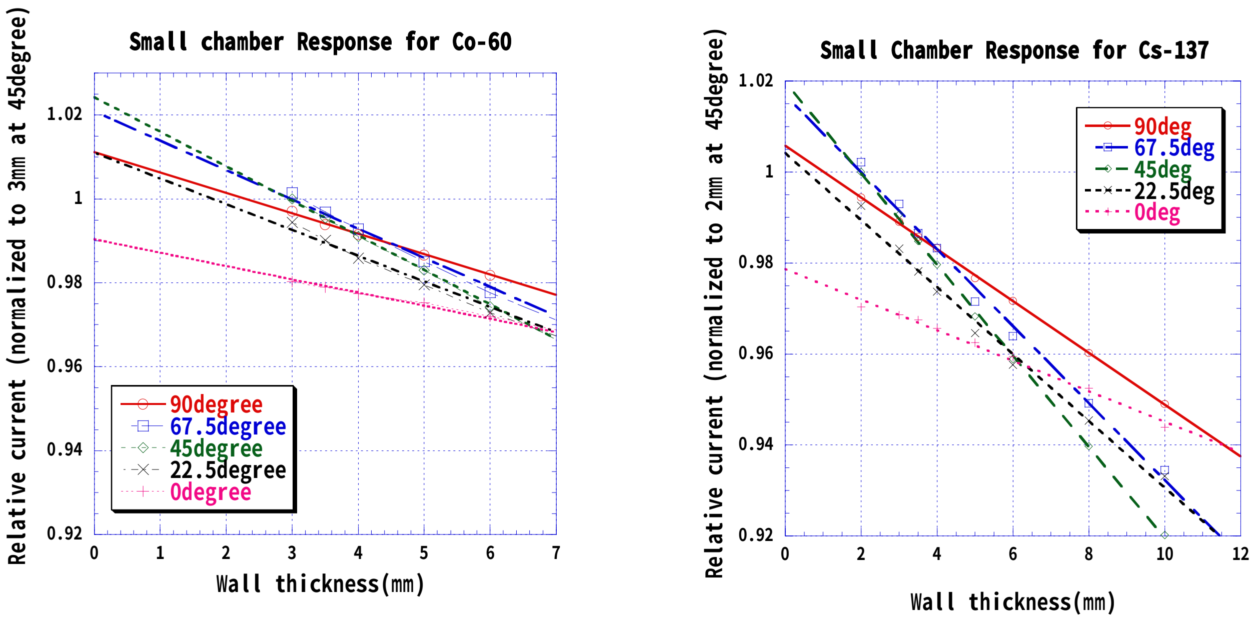

Figure 3. Relative ionization current produced in the chamber plotted against wall thickness with incident angle of gamma rays for small chamber.

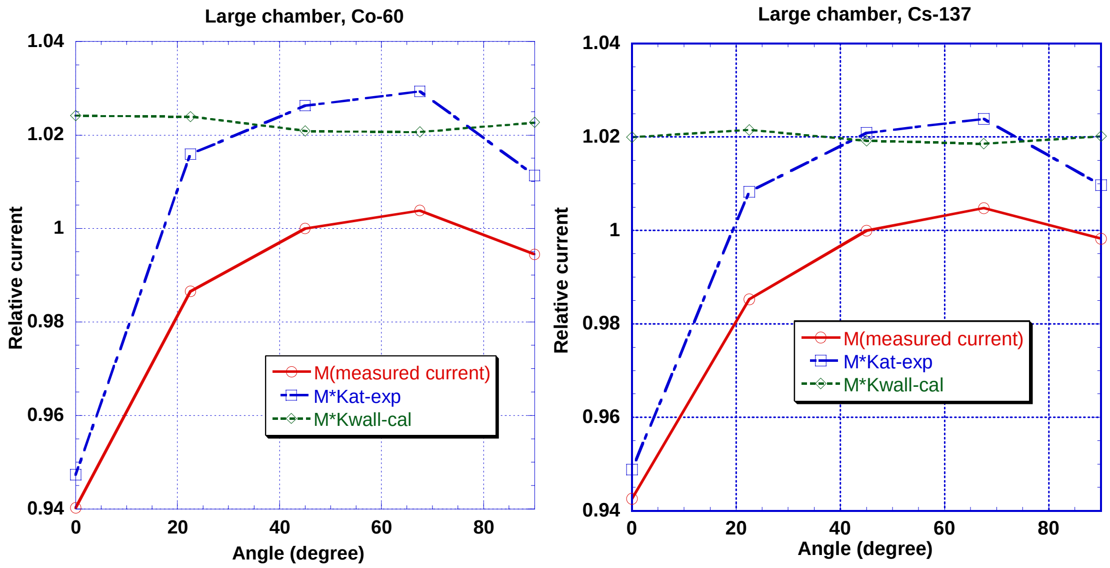

Figure 4. Variation of the measured currents, corrected value by extrapolation and corrected value by calculation against incident angle of gamma rays for large chamber. Each is normalized with the value at the incident angle of 45 degree.

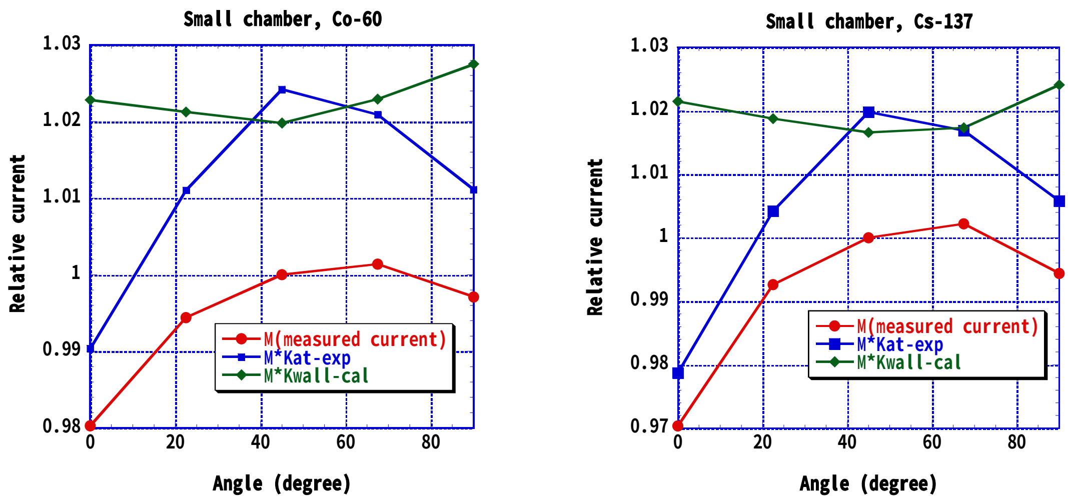

Figure 5. Variation of the measured currents, corrected value by extrapolation and corrected value by calculation against incident angle of gamma rays for small chamber. Each is normalized with the value at the incident angle of 45 degree.