Correction for loss of collected charge in the cavity ionization chamber

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1. Introduction

In order to properly use various radiation detectors monitored for radiation protection in actual sites using radioactive isotopes, etc., calibrated measuring devices should be used. In order to accurately measure the radiation dose of the reference device used for calibration, an ion chamber with precision is used. Ion charges generated by radiation in the ion chamber cause loss of charge due to recombination of ion pairs during the collection process. The loss of this collected charge is classified into initial recombination, spatial recombination, and loss due to back diffusion to the electrode. According to research by J. Böhm, N. Takata, etc., initial recombination loss and back diffusion loss are inversely proportional to the voltage applied to the ion chamber and independent of air kerma. The spatial recombination loss is inversely proportional to the square of the applied voltage of the ion chamber, and air It is known to be proportional to kerma (1-3).

2. Methods and Results

1) Calculation formula for signal current

The signal current and saturation current measure the applied voltage are expressed as follows when signal current loss due to recombination and diffusion is small.

$$I_s / I_V = 1 + A/V + m^2 (g/V^2) I_s \quad (1)$$

$$m^2 = \alpha / (e K_+ K_-)$$

Where A is a constant dependent on the chamber type used, α is the recombination coefficient, e is the fundamental charge, K_+, K_- is the conductance of positive and negative ions, and g is a factor dependent on the geometry of the chamber.
The second term on the right of Equation (1) represents initial recombination and diffusion, and the third term represents spatial recombination.
From equation (1), it can be expressed as an equation for the signal current $I_{V/n}$ at a lower applied voltage V/n, where n is an arbitrary number greater than 1

$$\frac{I_V}{I_{V/n}} = 1 + (n-1)\frac{A}{V} + (n^2-1)\, m^2 \left(\frac{g}{V^2}\right) I_V \quad (2)$$

Current I_V and $I_{V/n}$ are measured for various air kerma rates, and the ratio $I_V / I_{V/n}$ is expressed as a function of I_V and the value A can be obtained from the y-axis intercept by graphing the measured data and using a linear regression equation, and the spatial recombination factor $m^2 g$ can be obtained by the slope of the straight line.

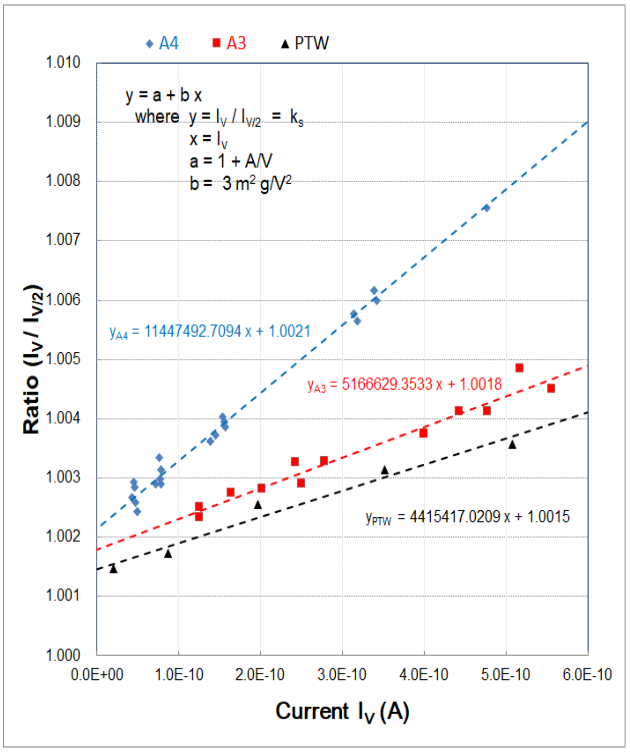

Figure 1. Recombination loss of spherical ion chambers.

2) Ion chamber and calibration room

The cavity ionization chamber used in this study is spherical, air-equivalent plastic, and was used to measure the air kerma of the gamma-ray field formed by the Cs-137 and Co-60 irradiators. A spherical chamber with different sizes according to the kerma rate of the gamma field, that is, Exradin A3 with a space of 3.6 cm^3 in a gamma field with a kerma rate ~ 10 Gy/h, and an Exradin A4 with a space of 30 cm^3 in a gamma field with a kerma rate ~ 2 Gy/h, a PTW 1L chamber with a space of 1000 cm3 was used in a gamma ray field with a kerma rate of ~ 30 mGy/h. In addition, in order to obtain various kerma rates(dose rates) in each gamma field, the dose rates were measured at four or more points in each distance of the ion chamber. In order to measure the electric charge collected in the chamber, the collected current was measured using the ammeters of Keithley 617 and 6517B in external feedback mode. The gamma-ray irradiation device used for the measurement is the Co-60 and Cs-137 irradiation device of the Korea Research Institute of Standards and Science.

3) Measurement method

In this study, in order to correct the loss of the collected charge due to ion recombination, n in Equation (2) was set to n = 2, and the following correction was used.

Table 1. The initial loss and volume loss by ion pair recombination for ion chamber A3, A4 and PTW type.

Type	Applied Voltage (V)	1 + A/V	initial loss		volume loss
			A/V (%)	A	$3m^2(g/V^2)$
A3	300	1.00168	0.168 ± 0.0081	0.504 ± 0.024	$(5.6 \pm 0.37) \times 10^6$
A4	300	1.00222	0.222 ± 0.0183	0.666 ± 0.055	$(11.2 \pm 0.44) \times 10^6$
PTW 1L	400	1.00141	0.141	0.565	4.5×10^6

$$I_V / I_{V/2} = 1 + A/V + 3m^2(g/V^2)I_1 \qquad (3)$$

The applied voltage of the ion chambers A3 and A4 was 300 V, the applied voltage of PTW 1L was 400 V, and V/2 was 150 V and 200 V, respectively. To transform equation (3) as follows

$$k_s = I_s/I_V \simeq I_V/I_{V/2} = 1 + A/V + 3m^2(g/V^2)\ I_1 \qquad (4)$$

It is expressed as a linear equation.

3. Results and Discussion

Experiments were conducted on 3 A3 chambers, 4 A4 chambers, and 1 PTW chamber. The collection currents in each of the A3 chambers were collected at four points ranging from 126 pA to 560 pA, the A4 chamber at four points ranging from 40 pA to 480 pA, and the PTW chamber at five points ranging from 20 pA to 500 pA. Table 1 shows the currents collected in each ion chamber according to the dose rate of gamma rays, and the second term (initial recombination loss) and the third term (spatial recombination loss) of Equation (4). Ion chamber A3 had an average initial recombination loss of 1.00168 (0.168 ± 0.0081)% and a term contributing to spatial recombination loss was an average of 5.6 × 106, and ion chamber A4 had an average initial recombination loss of 1.00222 (0.222 ± 0.0183)% And the term contributing to the spatial recombination loss was 1.1 × 107 on average. In the ion chamber PTW, the initial recombination loss part was 1.00141, 0.141%, and the term contributing to the spatial recombination loss was calculated as 4.5 × 106. Figure 1 shows the ion recombination loss according to the collection current. When the collection current is kept below 600 pA, the ion chamber A3 can reduce the loss due to ion recombination within 0.5%, and the ion chamber A4 maintains the collection current at 500 pA In case, the recombination loss was measured to be about 0.8%. The ion chamber PTW can keep the loss due to ion recombination within 0.4% when he collection current is less than 600 pA.

4. Conclusions

In order to accurately measure the radiation field of the reference device, the loss of collected charge due to recombination of ion pairs was corrected when using a spherical ion chamber. In order to keep the loss rate of the collected charge below 1%, the collection current of the ion chamber is measured to be less than 600 pA, and the loss of the collected charge due to spatial recombination according to the size of the ion chamber will require additional research.

5. References

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