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A New Approach on Output Current Calculation for Thimble-type Ionization Chamber with Variation of Gamma-ray Irradiation Angle

Jae Cheon KIM,a Yong Kyun KIM,b Soon Young KIM,a Jong Kyung KIM b
a Innovative Technology Center for Radiation Safety, Haengdang-dong, Seongdong-gu, Seoul 133-791, Korea
b Hanyang Univ., 17 Haengdang-dong, Seongdong-gu, Seoul 133-791, Korea, macpie@nural.hanyang.ac.kr

1. Introduction

The output current of an ionization chamber is directly connected with the size of the active volume and ion-pair distribution in air volume. Their accurate assessments are significantly important in order to analyze the design characteristics of an ionization chamber and interpret the measurements with it.

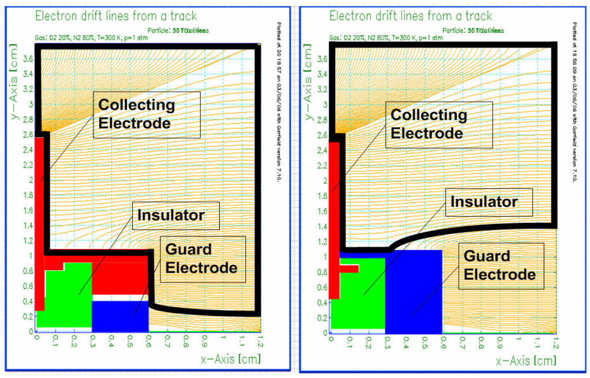
It has been generally assumed that ion-pairs are generated uniformly in air volume for simplicity although they are not uniformly distributed due to various source and geometry conditions. Ion-pair distribution is mainly dependent on the irradiation source conditions, while active volume is deeply related to the ionization chamber design. Therefore, such assumption should be examined if the ion-pair distribution affects real output current of the active volume defined by electric field.

A new analytical approach considering both electric field and ion-pair nonuniformity has been proposed to analyze accurately the design characteristics of an ionization chamber and interpretation of measurements with it. The angular dependence analysis was carried out to validate the new concept for calculation of output current.

2. Methods and Results

2.1 New Analytical Method

The ion-pair generated by interactions with incident radiation are not uniformly generated in air volume of an ionization chamber. Some ions formed in the gas volume can be drawn either to the guard ring or to the collector. The guard ring is usually inserted between the collector and the high voltage electrode to intercept the leakage current. The ions collected to the guard ring do not contribute to the output current of an ionization chamber. Therefore, the guard ring design can influence considerably the total amount of output current. Figure 1 shows the ion drift lines by electric field and the active volume of each ionization chamber with two different guard ring designs, respectively. Based on the ion drift lines drawn to the collector, the size of active volume was determined. Its area is indicated by black solid border as shown in Figure 1. The Type-B ionization chamber has the guard ring prominently inserted into the gas space compared with Type-A.



(a) Type-A (B) Type-B

Figure 1. Active Volume of the Ionization Chambers with Type-A and Type-B Guard Ring

MAXWELL® and Garfield were employed to render the electron/ion drift lines in air volume. Through the assessment of ion drift lines, active volume can be quantitatively calculated by obtaining the area [1]. Monte Carlo codes, MCNP5 and EGSnrc, were used to obtain the ion-pair distribution in gas volume. The gas volume was divided into many small cells and their absorbed doses were calculated. The number of ion-pair in each cell was calculated by dividing the absorbed dose by W-value.

The output currents were classified into three types such as whole current, uniform current, and nonuniform current whether electric field and ion-pair nonuniformity are applied to the output current calculation or not. Whole current means whole ion-pairs in air volume without considering the electric field. Uniform current is the one when ions are generated uniformly in air volume although ion-pairs in active volume are considered as a charge. Nonuniform current supposed by this work considers the active volume by electric field and the ion-pair distribution according to various source conditions.

2.2 Angular Dependence Analysis

Some calculations and measurements were performed to investigate the output current variation according to the change of the incident angle of ^{241}Am as shown in Figure 3 [2].

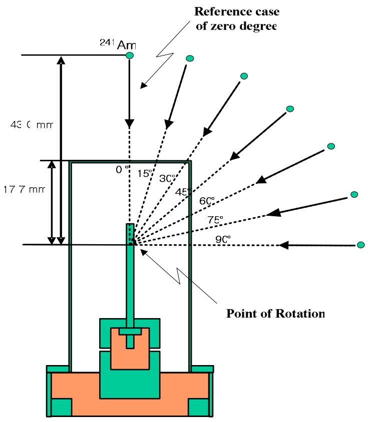


Figure 3. Schematic for Angular Dependence Analysis of the Ionization Chamber According to Change of Irradiation Angle

The current fraction, which is a ratio of current from active volume to whole current, was employed to show clearly the influence of ion-pair distribution. The current fraction for uniform and nonuniform current were defined as $F_{uni} = Q_{uni}/Q_{whole}$ and $F_{non} = Q_{non}/Q_{whole}$, respectively. Figure 4 shows the variation of current fraction at the ionization chamber according to irradiation angle of ^{241}Am gamma-ray.

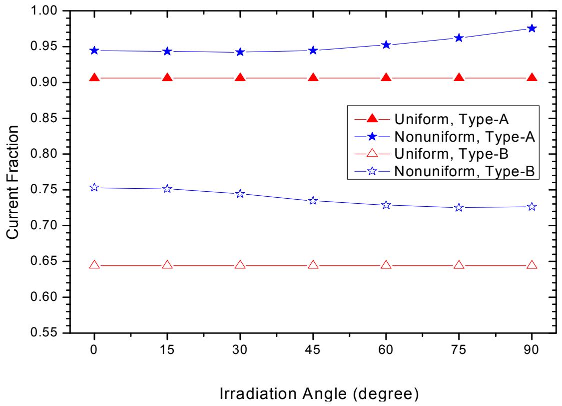


Figure 4. Variation of Current Fraction According to Change of Irradiation Angle

From the results, it is found that the current fraction calculated for nonuniform current increased or decreased with the irradiation angle while uniform current gave a fixed value throughout the entire irradiation angle.

Using the output current generated from the ionization chambers with the two different guard rings, the current ratios $R^{A/B} = Q^A/Q^B$ were calculated for uniform, nonuniform, and measured current, respectively. Figure 5 shows the variation of the current ratios according to the change of irradiation angel of ^{241}Am.

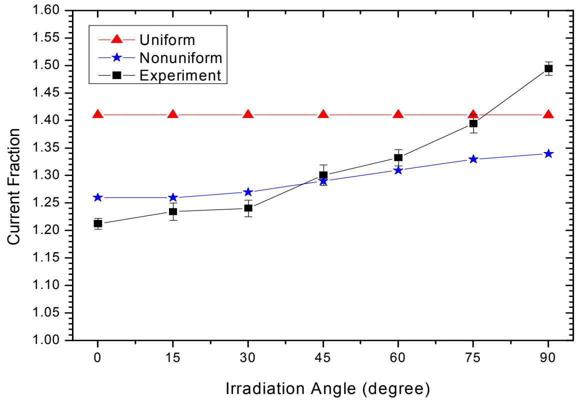


Figure 5. Variation of Current Fraction According to Change of Irradiation Angle

From the results, it is found that nonuniform current was more similar with the measured output current than uniform current.

3. Conclusion

For accurate calculation of the ionization chamber output current, a new analytic method considering electric field and ion-pair nonuniformity was proposed. To validate the new concept for calculation of nonuniform current, the angular dependence analysis of an ionization chamber were carried out. Through the analysis, it is found that the calculation of output currents based on previous assumption have a serious limitation not to reflect appropriately the variation of ion-pair distribution according to the change of irradiation angle. Not only should the precise active volume be considered as an important factor to calculate the output current, but also the variation of ion-pair distribution as well.

Acknowledgement

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