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Technical Note

Evaluation of the polarity effect of Roos parallel plate ionization chamber in build-up region

Arwa Ahmed AL-AGHBARI [1,ABCDEF,*]

[1]*Physics Department, Sana'a University, Sana'a, Yemen*
[*]*Corresponding author: Arwa Ahmed Al-Aghbari; physics_177@yahoo.com*

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Abstract

Purpose: Despite widespread studying of the polarity effect of Roos parallel plate ion chamber in electron beams as mentioned in several protocols, no investigations have up till now studied this effect in photon beams in the build-up region. It is important to examine its polarity effect in the build-up region for photon beams, so this is the first work that focuses in to evaluate the polarity effect of the Roos chamber in the surface and build-up region and comparing its effect with other chambers.

Methods: In this study, the Roos chamber was irradiated by a Theratron 780E ^{60}Co beam to a known polarity effect. The Polarity effects of 5×5 up to 35×35 cm^2 field sizes at positive and negative polarizing voltages were measured in the build-up region from surface to 0.7 cm in a solid water phantom.

Results: The polarity ratios (PRs) were obtained at 1.020 ± 0.00 and 1.015 ± 0.00 for field sizes 5 × 5 up to 35 × 35 cm^2, respectively. For the same fields, the percentage of polarity effects (%PEs) was obtained at 1.99% ± 0.00% and 1.47% ± 0.02%, respectively. The results found that the %PEs decrease with increased field sizes and depths. Moreover, the %PEs exhibited a decrease with an increased percentage surface dose (%SD). The uncertainty of %PE was estimated as 0.01% for all measurements in this study.

Conclusions: As a result, the average %PE of the Roos chamber described here is equal to 0.756% ± 0.013% for all depths and field sizes for the ^{60}Co γ-ray beam. It has introduced a less percentage of polarity effect than other chambers.

Keywords: Roos chamber; polarity effect; build-up region; cobalt ^{60}Co.

Introduction

Several high-energy beam dosimetry protocols[1-4] recommended that the parallel plate ionization chambers (PPICs) are preferred for electron beam dosimetry. In addition, these chambers utilize to measure dose in the build-up region of high-energy photon beams. So, extrapolation PPIC is the best tool with high accuracy for measuring dose in the build-up region in a high-energy photon beam. However, it is expensive and time-consuming compared with commercial parallel plate ionization chambers, which need corrections such as the polarity effect.

Several types of PPICs have shown a variance in the charge obtained from one polarity and another when used in the build-up region or at depth.[5-6] Gerbi and Khan[7] measured the polarity effect in the build-up region for three PPICs in 6-24 MV x-ray beams. They found a difference in the charge obtained from the two polarities as high as 30%.[7] Several authors studied the polarity effects for parallel plate[5-16,18] and thimble[6,9-11,17-19] chambers as a function of various variables such as energy,[5-7,9-14,19] electrometers,[6] field sizes,[5-11] depths[5-11] and design of chambers for electron beams.[5] On the other hand, previous studies have investigated the polarity effects for some types of PPICs such as Gerbi and Khan[7] used Holt/Memorial, PTW/Markus and Capintec PS-033 chambers, Gerbi[8] used Attix chamber, Kubo[9] used Attix and KH chambers and Butson et al.[15] used Attix chamber in build-up region in photon dosimetry.

The polarity ratio calculation is given as the quotient of the negative charge (Q^-) and the positive charge (Q^+). Therefore, this ratio measurement may always be higher or lower than unity, so the variations of the polarity ratio around unity tend toward the polarity effects. However, if the absolute value of Q^- and Q^+ are the same, it means no polarity effect. Accordingly, this ratio is used to estimate the magnitude of the polarity effect obtained in reversing the bias. Despite studying the polarity effect of Roos in electron beams, no studies have yet investigated this effect in photon beams in the build-up region. So, this study evaluated the polarity effect behavior in ^{60}Co beam, various depths in build-up region, and field sizes, and compared it with other parallel plate ionization chambers.

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Authors' contribution:
A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article.

Materials and Methods

Ionization chamber

The Roos parallel plate ionization chamber (Model TW 34001; PTW, Freiburg, Germany) has a Polymethyl Methacrylate (PMMA) body. It is a waterproof chamber with a 0.35 cm^3 sensitive volume vented through its connecting cable. The entrance window of it composed of a 1 mm thick PMMA with a density of 1.19 g/cm^3, a 0.02 mm thick graphite with a density of 0.82 g/cm^3 and a 0.1 mm thick varnish.[20] The guard ring is of 4 mm width surrounding a 16 mm collecting electrode diameter and 2 mm electrode separation.[4,21] The outside surface of the Roos chamber has a cylindrical air cavity with dimensions; of 24 mm in diameter and 5.8 mm high as shown in **Figure 1**.

Measurements of polarity

In this study, a Roos chamber and a Unidos®E electrometer were used. It was connected via low noise triaxial cable to a Unidos® E electrometer with an applied bias voltage of 200 V. It was embedded in 30×30 cm^2 perspex slabs phantom with a 1.137 relative electron density and was used to measure ionization charge on the central axis in the build-up region. To increase measuring depth, slabs phantom with various thicknesses were taken from below the chamber and placed above the chamber. A minimum backscatter thickness of 17.8 cm was used to ensure full phantom scatter equilibrium. Measurements were carried out using a ^{60}Co beam with field sizes of 5×5 up to 35×35 cm^2 at 80 cm source to surface distance (SSD), at various depths from surface to 0.7 cm. Beam time on was 1 min for each measurement. A total of six readings by electrometer for two bias voltages (+200 and -200 V) were taken with two significant decimals. They were recorded and averaged for each depth and field size configuration.

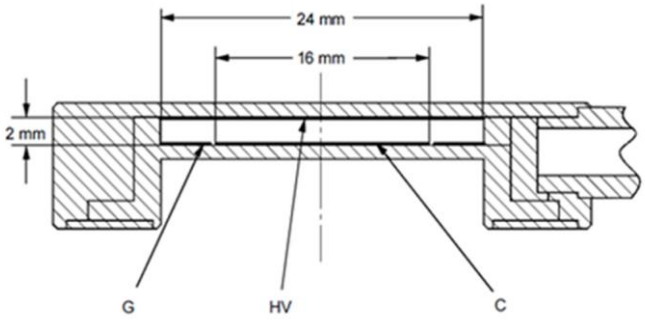


Figure 1. A Roos chamber manufacturer's drawing.[21]

To determine the polarity effect, measurements were performed for charge collections utilizing positive 200 Volts on a Roos dosimeter. After all, measurements were taken, the polarity was reversed to negative 200 Volts at one time. Each time the bias was reversed, the chamber was irradiated to saturate the chamber, and waited certain time between the positive and negative polarity measurements to allow the chamber to stabilize.

Results

Polarity Readings

Figures 2a-d show the charge readings at positive and negative polarization voltages, average readings, polarity differences (PDs), and polarity ratios (PRs) as a function of depth for 5×5 cm^2, 10×10 cm^2, 20×20 cm^2, and 30×30 cm^2 field sizes. The charge readings increase with increased depths and field sizes. The lowest and highest PD and PR are observed at the surface of the phantom and depth of maximum dose (d_{max}), respectively, for all fields, whereas the polarity ratios are reversed. In general, the PD and PR decrease with increased field size, as can be seen in **Figure 2**.

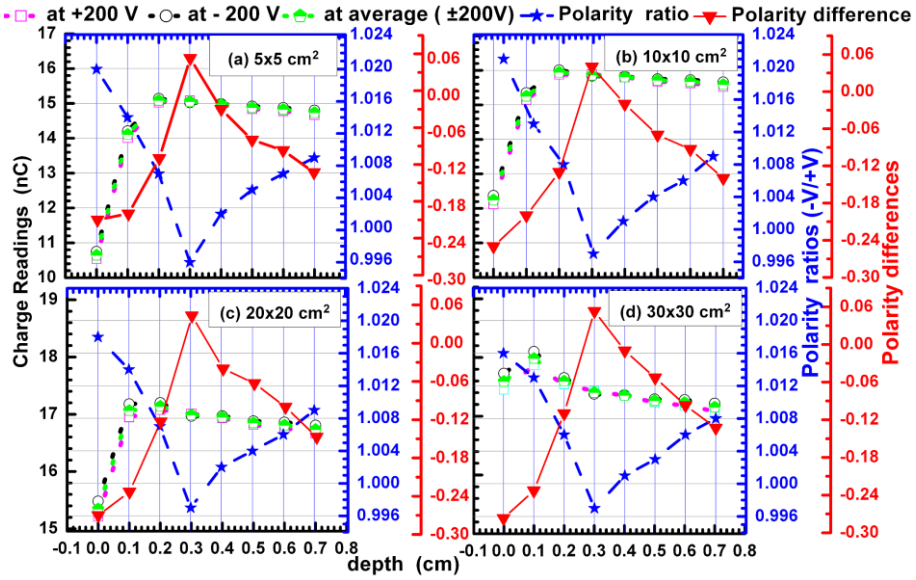


Figure 2. Absolute positive and negative charge readings, average readings, PDs, and PRs of the Roos chamber using ^{60}Co beam (Theratron 780E) as a function of depth.

The percentage of polarity effect (%PE)

Figures 3a and **b** exhibit the percentage of polarity effect (%PE) versus depth and field sizes, respectively. The variations of the %PE at surface of phantom for 5 × 5, 10 × 10, 15 × 15, 20 × 20, 25 × 25, 30 × 30, and 35 × 35 cm^2 field sizes were 1.99% ± 0.00%, 2.06% ± 0.00%, 1.85% ± 0.02%, 1.78% ±0.04%, 1.60% ± 0.02%, 1.59% ± 0.02%, and 1.47% ± 0.02%. However, the %PE is the highest at the surface of the phantom and lowest at the depth of maximum dose (d_{max} = 0.3 cm), for all fields. Beyond d_{max}, it increases with increased depth. As can be seen in **Figure 3b**, the %PE decreases with increased field size. The error bars denote the standard deviation of the mean for the %PE.

The percentage of polarity effect with percentage surface dose

The measured values of %PE, PR, and percentage of surface dose (%SD) versus the side of square field sizes are plotted in **Figure 4**. The %PE was decreased from 1.99% ± 0.00% up to 1.47% ± 0.02% by increasing the field sizes from 5×5 up to 35×35 cm^2 and increasing %SD from 66.93% ± 0.20% up to 96.33% ± 0.21%, respectively, whilst the PR was decreased from 1.020 ± 0.00 up to 1.015 ± 0.00 with increases the field sizes from 5×5 up to 35×35 cm^2. So, the PRs and %PEs decrease nonlinearly with field sizes, whereas %SD increases approximately linearly with field sizes. It may be concluded that the PRs and %PEs decreased with increasing the %SD, with increasing field sizes. The graph in **Figure 4** depicts this trend.

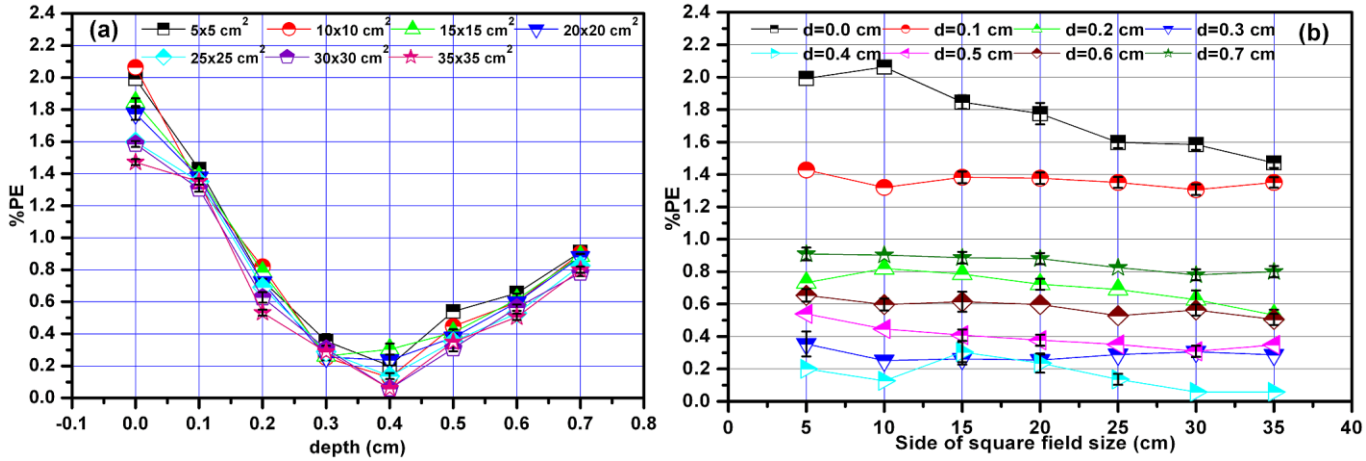


Figure 3. The percentage of polarity effect of Roos chamber using ^{60}Co beam (Theratron 780E) versus (a) depths and (b) field sizes.

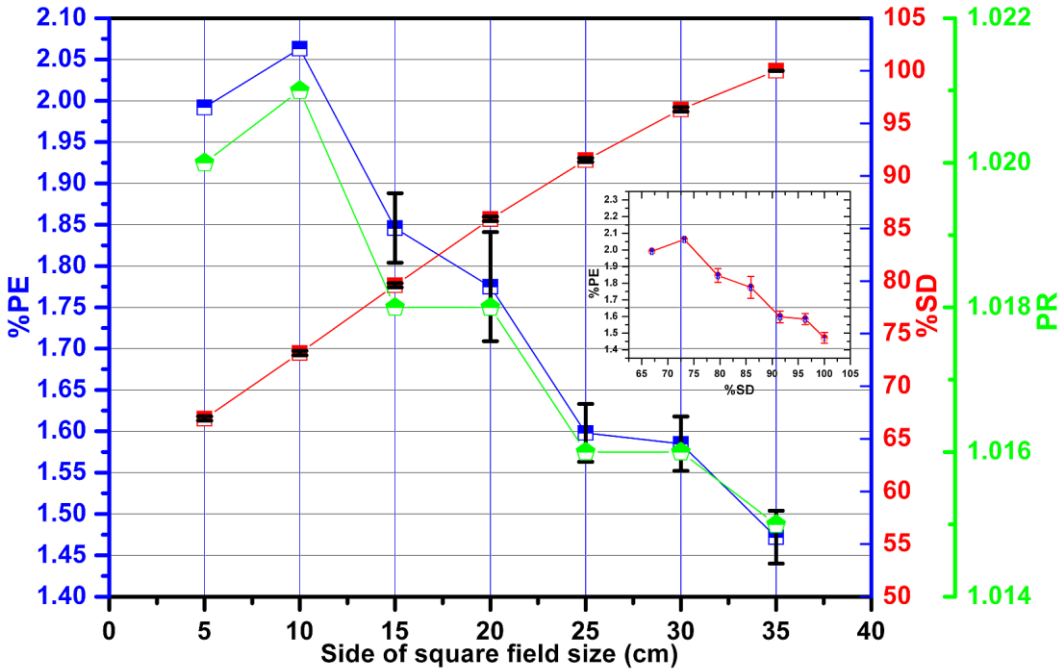


Figure 4. The %PE, %SD, and PR of the Roos chamber using ^{60}Co beam (Theratron 780E) as a function of fields.

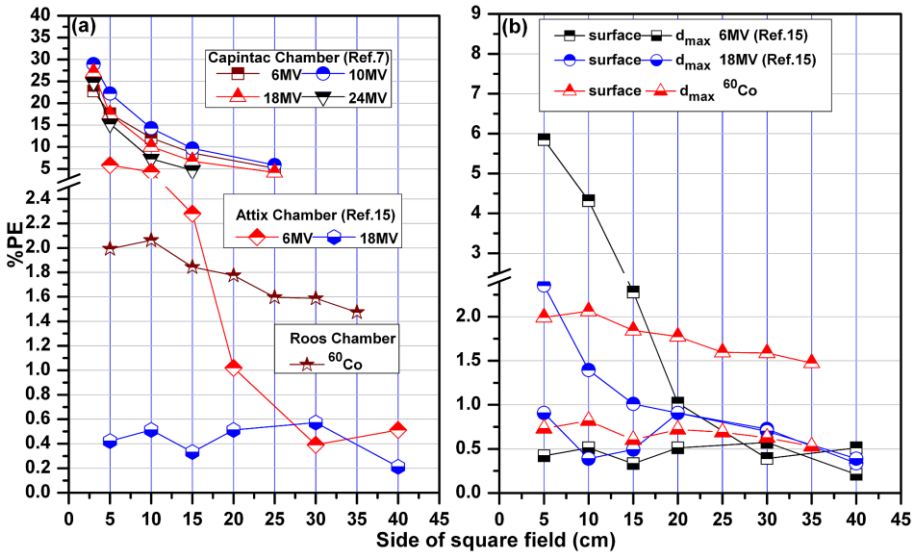


Figure 5. Comparison of the %PEs at (a) phantom surface and (b) surface and d_{max} in this study (using Roos chamber for ^{60}Co beam (Theratron 780E)) and previous studies (using Capintac chamber for 6, 10, 18, 24 MV, and using Attix chamber for 6 and 18 MV).[7,15]

Discussion

According to the results of the present study that found the charge readings using negative polarity are greater than that using positive polarity for all field sizes in the build-up region. So, the polarity ratio was taken by the ratio of negative to positive charge (Q^- / Q^+). If there is any difference in this ratio with the depth, it will give different curves,[7,8] as can be seen clearly in **Figure 2**. These curves are very important in radiotherapy, which represents the percentage depth dose curves in the build-up region. So, the correction of charge readings was given by the average of negative and positive charge readings, which are plotted to indicate the variation in readings.

The present study found that the %PE is the greatest at the surface of the phantom and decreases with increasing depths up to $d_{max,}$ and beyond d_{max} the %PE increases with increased depth (0.86% for all fields). These results agree with previous work by Gerbi and Khan,[7] and Butson et al.[15] Gerbi and Khan,[7] found that beyond d_{max} the %PE is less than 1%. In this study, the average of the %PEs for all fields at the surface, $d_{max,}$ and at 0.7 cm were 1.762% ± 0.017%, 0.286% ± 0.015%, and 0.855% ± 0.015%.

The %PE values were plotted against the side of square field sizes, as shown in **Figure 5**. Previous results by Gerbi and Khan,[7] and Butson et al.[15] were also plotted for comparison. Fig. 5(a) illustrated the measured of the %PE data using the Capintec chamber,[7] Attix chamber[15,] and Roos chamber at the surface of the phantom with different energies by various therapeutic machines. General agreement was noted. Since the studies of the previously published reports were for different models of beam delivery machines and different types of chambers (design), some differences in the %PE were expected for many different types of chambers (design) and slightly different models of beam delivery machines. A steep %PE gradient was noted in **Figure 5b**. The gradient was steeper at the surface than that d_{max}. The largest variation of the %PE was observed for small field sizes and at the surface of the phantom.

According to results in this study, the %PEs decrease with increasing the percentage of surface dose (**Figure 4**), which accept with results by Gerbi and Khan[7] and Butson et al.[15] (see **Figure 6**). Also, they found that the polarity ratio has an inverse relationship with the surface dose, which is influenced by chamber design.[7] That agreed with the finding of Nilsson and Montelius,[20] who found that the chamber sidewall material and the chamber internal design influence the chamber response due to electrons scattering into collecting volume.

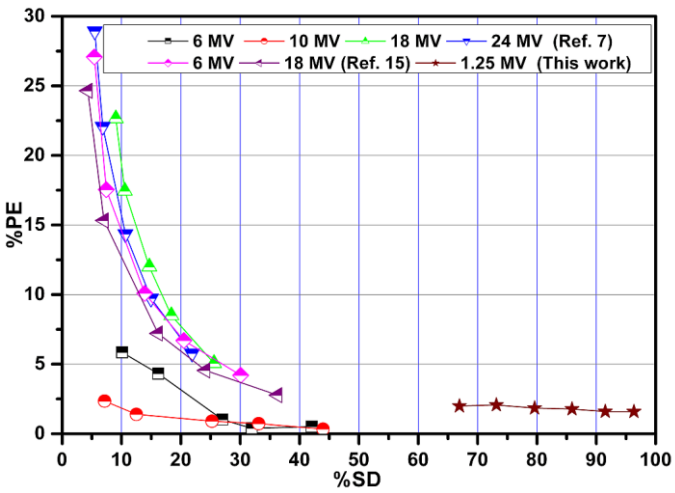


Figure 6. The %PE values against the % surface dose using Roos chamber for ^{60}Co beam (Theratron 780E) in this study and from previous studies[7,15] (using Capintec chamber for 6, 10, 18, 24 MV, and using Attix chamber for 6 and 18 MV) were also plotted for comparison.

The average %PE of the Roos chamber is 1.113% ± 0.00% at all depths from the surface to d_{max} for the 10 ×10 cm^2 for ^{60}Co γ-ray beams. Whereby, the %PE of the Attix chamber is less than 3.5% at all depths from the surface to d_{max} for the 10 ×10 cm^2 for 6 and 24 MV x-ray beams.[8]

Conclusions

Measurements have been completed to characterize the response of the Roos ionization chamber. These measurements have revealed some interesting effects. There appears to be a large difference between the %PE measured in the gamma-ray. For Roos parallel-plate chamber, the %PE was found to exceed unity by approximately 2.0% at the surface of the phantom for 5×5 cm^2; there is a change in chamber reading when changing from positive to negative polarity. It may depend on the measuring depth and the field size. Any polarity effect should be small, so, the polarity effect of the Roos chamber may be considered less acceptable. Thus, at smaller field sizes and surface of the phantom, the %PE is prominent. As a result, the average %PE of the Roos chamber described here is equal to 0.756% ± 0.013% for all depths and field sizes. It has introduced a less percentage of polarity effect, which decreases with increased field sizes and depths. Moreover, the %PEs exhibited a decrease with an increased %SD. The average magnitudes of the %PE were typically 1.65% ± 0.09% and 0.63% ± 0.09% at the surface of the phantom and all depths beyond the surface for all measurements with field sizes, respectively. The large differences in the %PE were expected from different designs of ionization chambers and slightly from different models of beam delivery machines.

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