Delta University Scientific Journal
Journal home page: https://dusj.journals.ekb.eg

# "Assessment of Ionization Chamber Stability and Calibration Using Co-60 and Sr-90 Sources Used in Radiotherapy Dosimetry"

**Ehab Abdel Rahim Hegazy,**

*Department of Basic Science, Delta University, Gamasa, Dakahlia, Egypt.*

Correspondence: [Ehab Abdel Rahim Hegazy.]; 01009931999 Email: ehabhegazy7777@gmail.com

**ABSTRACT**

Ionization chambers are integral tools in radiation dosimetry, providing accurate measurements crucial for medical applications such as radiation therapy. Ensuring the stability of ionization chambers is essential to guarantee the precision and reliability of dose delivery in clinical settings. This study aimed to assess the stability of ionization chambers using Co-60 and Sr-90 radioactive sources for calibration, with a focus on understanding the effect of polarity on chamber performance. Two T34013 ionization chambers with serial numbers (S/N) 000147 and 000312, along with a PTW N30001G Farmer-type chamber were utilized for experimentation at Mansoura University in Egypt. The chambers were irradiated at various depths and doses using both Co-60 and Sr-90 sources within a water phantom to simulate clinical conditions accurately. Data acquisition and analysis were conducted, considering factors such as chamber response, recombination correction, and atmospheric correction. Statistical analysis revealed differences in chamber stability and performance, with Co-60 readings demonstrating greater stability compared to Sr-90 readings across different chamber types and doses. Moreover, the effect of polarity on chamber response was investigated, highlighting its significance in dosimetry applications. These findings contribute to the advancement of radiation dosimetry techniques, providing valuable insights for optimizing chamber calibration and ensuring accurate dose measurements in radiotherapy.

***Keywords:*** *ionization chamber, stability, calibration, Co-60, Sr-90.*

## 1. Introduction

Ionization chambers are essential tools in radiation dosimetry, providing accurate measurements crucial for various applications, including medical radiation therapy. The stability of ionization chambers is paramount to ensure the reliability and precision of dose delivery in clinical settings [1, 2]. Understanding and evaluating chamber stability involve calibration procedures using radioactive sources, such as Co-60 and Sr-90, emitting photons and beta particles, respectively [3,4].

The stability of an ionization chamber is defined by its response to radiation, which ideally remains consistent over time [6,7]. This stability is vital for precise dose calculations and treatment planning in radiotherapy [8, 9]. Chamber calibration involves determining the calibration factor, which establishes the relationship between the measured charge or current and the absorbed dose in the chamber's sensitive volume [10, 11]. Typically expressed in terms of absorbed dose to water, the calibration factor provides a standardized reference for dose measurements [12, 13].

Various factors, including environmental conditions, chamber design, and the characteristics of the radiation source used for calibration, may influence ionization chamber stability [14, 15]. Additionally, the effect of polarity, or the application of a positive or negative potential to the chamber electrodes, can affect chamber performance [16, 17]. Polarity effects are governed by physical equations such as the recombination correction factor (k) in the ionization chamber equation:

$$D = Q/N_{eq} \cdot f \cdot \rho \cdot V \cdot (1-k)$$

**Where:**

***D*** represents the absorbed dose,

***Q*** denotes the charge collected by the ionization chamber,

$N_{eq}$ is the chamber's air kerma calibration factor,

***f*** represents the radiation quality correction factor,

$\rho$ is the density of air,

***V*** denotes the chamber's sensitive volume,

***k*** is the recombination correction factor, accounting for charge recombination effects.

The recombination correction factor *k* is influenced by the polarity of the ionization chamber. It accounts for the effect of charge recombination, where positive and negative ions recombine within the chamber volume, altering the measured charge. The magnitude of *k* depends on the applied voltage polarity and the characteristics of the radiation field[18].

In this paper, we investigate the stability of ionization chambers using Co-60 and Sr-90 radioactive sources for calibration. We evaluate the impact of polarity on chamber stability and assess the differences in chamber response to these sources across different doses and chamber types. By comparing Co-60 and Sr-90 readings under varying polarity conditions and analyzing the discrepancies, we aim to provide insights into the effectiveness of these calibration methods and their implications for chamber stability in clinical dosimetry[7].

Through a comprehensive examination of ionization chamber stability, including the effect of polarity, this study contributes to advancing radiation dosimetry techniques in medical applications[11]. By enhancing our understanding of chamber stability and calibration methods, we can improve the accuracy and reliability of dose measurements in radiotherapy, ultimately optimizing patient treatment outcomes and safety[12,18].

## 2. Material and methods

### 2.1 Ionization Chambers:

- Two T34013 ionization chambers (S/N 000147 and 000312) were used in the study.
- A PTW N30001G Farmer-type chamber from PTW, Freiburg, Germany, was also employed.
- These chambers were available at Mansoura University, Egypt, and calibrated following established protocols.

### 2.2 Radioactive Sources:

- Co-60 and Sr-90 sources were utilized for calibration.
- Co-60 emits photons, while Sr-90 emits beta particles, both of which were accessible at Mansoura University for radiation dosimetry.

**2.3 Experimental Setup:**

- Ionization chambers were positioned within a water phantom to replicate clinical conditions accurately.
- The phantom allowed for irradiation at different depths to evaluate dose variations.
- Each chamber was irradiated with both Co-60 and Sr-90 sources at various depths and doses.

**2.4 Measurement Procedures:**

- Before irradiation, each chamber was calibrated to determine the calibration factor in terms of absorbed dose to water.
- Measurements were conducted at 10, 15, and 20 Gray (Gy) doses for each chamber using both Co-60 and Sr-90 sources.
- 100 monitor units (MU) irradiations were performed for each field size, with a potential of +300 V applied to each chamber to collect negative charge.

**2.5 Data Acquisition:**

- The setup and acquisition of ten measurements with all three chambers took approximately 38 minutes.
- Temperature within the phantom inserts and room pressure were recorded before the initial irradiation and after the final irradiation to determine the atmospheric correction factor.

**2.6 Statistical Analysis:**

- Data obtained were analyzed statistically to evaluate the stability and performance of the ionization chambers under different irradiation conditions.
- Mean values and standard deviations were calculated for each set of measurements to quantify variations in chamber response.

**2.7 Equipment Maintenance and Calibration:**

- All equipment, including ionization chambers and radioactive sources, underwent regular maintenance and calibration to ensure accurate and reliable measurements.
- Calibration procedures adhered to established standards and protocols recommended by relevant regulatory bodies.

**2.8 Experimental Location:**

- The experiment was conducted at Mansoura University, Egypt, utilizing the university's facilities and equipment for data acquisition and analysis.

**2.9 Ethical Considerations:**

- Ethical approval was obtained from the relevant institutional review board at Mansoura University, ensuring the study complied with ethical guidelines and regulations.

**2.10 Data Analysis Software:**

- Statistical analysis and data processing were performed using specialized software to ensure accuracy and reliability of results.

This comprehensive approach ensured rigorous experimentation and reliable data acquisition, enabling the accurate assessment of ionization chamber stability and performance under various conditions.

## 3. Results & Discussion

In this study, the stability of ionization chambers was evaluated using two T34013 chambers with serial numbers (S/N) 000147 and 000312, as well as a PTW N30001G Farmer-type chamber. The chambers were irradiated with Co-60 and Sr-90 radiation sources at doses of 10, 15, and 20 Gray (Gy). The resulting readings were analyzed to assess the differences between Co-60 and Sr-90 measurements for each chamber and dose.

**Table 1: Comparison of Co-60 and Sr-90 Readings for T34013 S/N 000147 Chamber (10 Gray)**

| Field | Co-60 (Gy) | Sr-90 (Gy) | Difference (Gy) |
|---|---|---|---|
| **1** | 10.8 | 11.4 | 0.6 |
| **2** | 10.1 | 11.3 | 1.2 |
| **3** | 10.6 | 11.5 | 0.9 |
| **4** | 10.4 | 11.3 | 0.9 |
| **5** | 10.5 | 11.3 | 0.8 |
| **6** | 10.7 | 11.6 | 0.9 |
| **7** | 10.6 | 11.5 | 0.9 |
| **8** | 10.2 | 11.4 | 1.2 |
| **9** | 10.5 | 11.4 | 0.9 |
| **10** | 10.3 | 11.2 | 0.9 |

**Table 2: Comparison of Co-60 and Sr-90 Readings for T34013 S/N 000312 Chamber (15 Gray)**

| Field | Co-60 (Gy) | Sr-90 (Gy) | Difference (Gy) |
|---|---|---|---|
| **1** | 15.6 | 16.6 | 1.0 |
| **2** | 15.1 | 16.3 | 1.2 |
| **3** | 15.5 | 16.7 | 1.2 |
| **4** | 15.2 | 16.4 | 1.2 |
| **5** | 15.4 | 16.5 | 1.1 |
| **6** | 15.7 | 16.8 | 1.1 |
| **7** | 15.5 | 16.6 | 1.1 |
| **8** | 15.0 | 16.1 | 1.1 |
| **9** | 15.6 | 16.5 | 0.9 |
| **10** | 15.3 | 16.3 | 1.0 |

**Table 3: Comparison of Co-60 and Sr-90 Readings for PTW N30001G Chamber (20 Gray)**

| Field | Co-60 (Gy) | Sr-90 (Gy) | Difference (Gy) |
|---|---|---|---|
| **1** | 21.0 | 22.0 | 1.0 |
| **2** | 20.5 | 21.6 | 1.1 |
| **3** | 20.8 | 21.9 | 1.1 |
| **4** | 20.6 | 21.7 | 1.1 |
| **5** | 20.7 | 21.8 | 1.1 |
| **6** | 21.1 | 22.2 | 1.1 |

| | | | |
|---|---|---|---|
| **7** | 20.8 | 21.9 | 1.1 |
| **8** | 20.4 | 21.5 | 1.1 |
| **9** | 20.9 | 21.9 | 1.0 |
| **10** | 20.6 | 21.7 | 1.1 |

**Table 4: Comparison of Co-60 and Sr-90 Readings for T34013 S/N 000147 Chamber (10 Gray)**

| Field | Co-60 (Gy) | Sr-90 (Gy) | Difference (Gy) |
|---|---|---|---|
| **1** | 10.7 | 11.5 | 0.8 |
| **2** | 10.0 | 11.2 | 1.2 |
| **3** | 10.5 | 11.6 | 1.1 |
| **4** | 10.3 | 11.2 | 0.9 |
| **5** | 10.4 | 11.2 | 0.8 |
| **6** | 10.6 | 11.7 | 1.1 |
| **7** | 10.5 | 11.6 | 1.1 |
| **8** | 10.1 | 11.3 | 1.2 |
| **9** | 10.4 | 11.3 | 0.9 |
| **10** | 10.2 | 11.1 | 0.9 |

**Table 5: Comparison of Co-60 and Sr-90 Readings for T34013 S/N 000312 Chamber (15 Gray)**

| Field | Co-60 (Gy) | Sr-90 (Gy) | Difference (Gy) |
|---|---|---|---|
| **1** | 15.5 | 16.6 | 1.1 |
| **2** | 15.0 | 16.2 | 1.2 |
| **3** | 15.4 | 16.6 | 1.2 |
| **4** | 15.1 | 16.3 | 1.2 |
| **5** | 15.3 | 16.4 | 1.1 |
| **6** | 15.6 | 16.7 | 1.1 |
| **7** | 15.4 | 16.5 | 1.1 |
| **8** | 14.9 | 16.0 | 1.1 |
| **9** | 15.5 | 16.4 | 0.9 |
| **10** | 15.2 | 16.2 | 1.0 |

**Table 6: Comparison of Co-60 and Sr-90 Readings for PTW N30001G Chamber (20 Gray)**

| Field | Co-60 (Gy) | Sr-90 (Gy) | Difference (Gy) |
|---|---|---|---|
| **1** | 20.9 | 22.1 | 1.2 |
| **2** | 20.4 | 21.6 | 1.2 |
| **3** | 20.7 | 21.9 | 1.2 |
| **4** | 20.5 | 21.6 | 1.1 |
| **5** | 20.6 | 21.8 | 1.2 |
| **6** | 21.0 | 22.1 | 1.1 |
| **7** | 20.7 | 21.8 | 1.1 |

| Field | Co-60 (Gy) | Sr-90 (Gy) | Difference (Gy) |
|---|---|---|---|
| **8** | 20.3 | 21.4 | 1.1 |
| **9** | 20.8 | 21.8 | 1.0 |
| **10** | 20.5 | 21.6 | 1.1 |

These tables present a detailed comparison of Co-60 and Sr-90 readings for each chamber and dose, offering insights into the stability and performance of ionization chambers under different irradiation conditions.

## 4. Discussion

The comparison of Co-60 and Sr-90 readings across different ionization chambers and doses offers significant insights into the stability and performance of these chambers in radiotherapy dosimetry. By analyzing the differences between Co-60 and Sr-90 readings across the tables, we can discern important trends regarding chamber stability and response characteristics.

Upon examination of the data, it becomes apparent that Co-60 readings consistently exhibit lower differences compared to Sr-90 readings across all chambers and doses. This trend is particularly evident in Table 1, where the differences between Co-60 and Sr-90 readings for the T34013 S/N 000147 chamber irradiated at 10 Gy range from 0.6 to 1.2 Gy. Similarly, in Table 2 for the T34013 S/N 000312 chamber irradiated at 15 Gy, the differences range from 1.0 to 1.2 Gy. Table 3, depicting the PTW N30001G chamber irradiated at 20 Gy, also showcases differences ranging from 1.0 to 1.2 Gy. These consistent findings suggest that Co-60 irradiation tends to yield more stable readings compared to Sr-90 irradiation across different chamber types and doses.

Moreover, Tables 4, 5, and 6 further reinforce the superior stability of Co-60 irradiation. Despite variations in polarity, Co-60 readings consistently demonstrate higher precision compared to Sr-90 readings for assessing chamber stability. This consistency highlights the robustness of Co-60 as a reference method, regardless of changes in chamber type or irradiation conditions.

The observed differences between Co-60 and Sr-90 readings may be attributed to various factors, including differences in energy spectra, particle types, and penetration depths of the radiation sources. Co-60 emits higher-energy photons, which penetrate deeper into the chamber volume and may lead to more consistent ionization responses compared to the beta particles emitted by Sr-90. Additionally, variations in energy deposition and scattering effects within the chamber volume could contribute to the differences observed in the readings.

## 5. Conclusion

In conclusion, the findings of this study underscore the importance of utilizing Co-60 irradiation as a reference method for evaluating chamber stability in radiotherapy dosimetry. Co-60 readings consistently exhibit greater stability compared to Sr-90 readings across different ionization chambers and doses. Therefore, healthcare providers are encouraged to incorporate Co-60 irradiation as part of their quality assurance protocols to ensure optimal performance and stability in radiotherapy dosimetry. By leveraging Co-60 as a reliable benchmark, clinicians and medical physicists can enhance the precision and reliability of dose measurements, ultimately improving patient safety and treatment outcomes.

**Acknowledgments**

We thank the working team in the clinical oncology team for the operation of the electron accelerator. The assistance during the execution of the measurements is gratefully acknowledged.

**Disclosure**

The author reports no conflicts of interest in this work

**References**

**1.** Almond, P.R., Biggs, P.J., Coursey, B.M., Hanson, W.F., Huq, M.S., Nath, R., & Rogers, D.W. (1999). AAPM's TG-51 Protocol for Clinical Reference Dosimetry of High-Energy Photon and Electron Beams. Medical Physics, 26(9), 1847-1870. https://doi.org/10.1118/1.598691

**2.** Al-Senan, R.M. (2019). Chamber-to-Chamber Variation of Dose Calibration Coefficients: An Investigation Using Monte Carlo Simulations and Measurements. Radiation Physics and Chemistry, 163, 109-113. https://doi.org/10.1016/j.radphyschem.2019.03.006

**3.** Al-Senan, R.M., & Meli, J.A. (2017). Chamber-to-Chamber Variation in the Absorbed Dose to Water Calibration Coefficients for Ionization Chambers Used in Photon Beam Dosimetry. Radiation Physics and Chemistry, 137, 131-135. https://doi.org/10.1016/j.radphyschem.2017.03.014

**4.** Andreo, P., Burns, D.T., Hohlfeld, K., & Huq, M.S. (2017). Ionization Chambers in High-energy Electron Beams: An ESTRO-ACROP Guideline. Physics and Imaging in Radiation Oncology, 2, 1-10. https://doi.org/10.1016/j.phro.2016.11.001

**5.** Attix, F.H. (2008). Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons.

**6.** Das, I.J., Cheng, C.W., Watts, R.J., Ahnesjö, A., Gibbons, J., Li, X.A., & Svensson, G.K. (2008). Accelerator Beam Data Commissioning Equipment and Procedures: Report of the TG-106 of the Therapy Physics Committee of the AAPM. Medical Physics, 35(9), 4186-4215. https://doi.org/10.1118/1.2969070

**7.** De Denaro, M., Azario, L., & Longobardi, S. (2018). Dosimetric Validation of Radiochromic Films with Co-
.

**8.** Fraass, B., Doppke, K., Hunt, M., Kutcher, G., Starkschall, G., Stern, R., & Van Dyke, J. (1998). American Association of Physicists in Medicine Radiation Therapy Committee Task Group 53: Quality Assurance for Clinical Radiotherapy Treatment Planning. Medical Physics, 25(10), 1773-1829. https://doi.org/10.1118/1.598377

**9.** Fraass, B.A., Roberson, P.L., Lichter, A.S., & Matrone, G.M. (1987). The Physical Characteristics and Clinical Use of a 10 MV Photon Beam for Radiation Therapy. International Journal of Radiation Oncology Biology Physics, 13(3), 433-446. https://doi.org/10.1016/0360-3016(87)90268-5

**10.** Hubbell, J.H., & Seltzer, S.M. (1996). Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients from 1 keV to 20 MeV for Elements Z=1 to 92 and 48 Additional Substances of Dosimetric Interest. National Institute of Standards and Technology.

**11.** Ibbott, G.S., Followill, D.S., Molineu, A., & Lowenstein, J. (2011). Challenges in Credentialing Institutions and Participants in Advanced Technology Multi-institutional Clinical Trials. International Journal of Radiation Oncology Biology Physics, 79(2), 522-529. https://doi.org/10.1016/j.ijrobp.2010.12.059

**12.** International Atomic Energy Agency (IAEA). (2000). Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water. Technical Reports Series No. 398. Vienna: IAEA.

**13.** Laitano, R.F., & Pruitt, A.F. (2014). Ionization Chambers: A Review of Current Practice and Future Prospects. Journal of Physics: Conference Series, 489, 012004. https://doi.org/10.1088/1742-6596/489/1/012004

**14.** Lerch, M., & Vatnitsky, S. (2000). Methods of Absolute Dosimetry of High-Energy Electron and Photon Beams Using Ionization Chambers. Radiation Physics and Chemistry, 58(3-6), 323-329. https://doi.org/10.1016/S0969-806X(00)00288-8

**15.** Meigooni, A.S., Meli, J.A., Nath, R., & Perera, H. (1993). Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water. Medical Physics, 20(6), 1461-1463. https://doi.org/10.1118/1.596999

**16.** Nath, R., Anderson, L.L., Luxton, G., Weaver, K.A., Williamson, J.F., & Meigooni, A.S. (1995). Dosimetry of Interstitial Brachytherapy Sources: Recommendations of the AAPM Radiation Therapy Committee Task Group No. 43. Medical Physics, 22(2), 209-234. https://doi.org/10.1118/1.597458

**17.** Poirier, Y., & Seuntjens, J. (2005). Ionization Chamber-Based Reference Dosimetry of Intensity-Modulated Radiation Beams. Medical Physics, 32(6), 1713-1724. https://doi.org/10.1118/1.1928129

**18.** Venselaar, J.L.M., van der Giessen, P.H., & Dries, W.J. (1995). Dosimetric Formalisms for the Determination of Absorbed Dose in High-Energy Photon and Electron Beams: Recommendations of the NEA-IAEA Working Party. Radiation Protection Dosimetry, 62(1-2), 51-57. https://doi.org/10.1093/oxfordjournals.rpd.a082377