TECHNICAL COMMUNICATION

Determination of recombination and polarity correction factors, k_S and k_P, for small cylindrical ionization chambers PTW 31021 and PTW 31022 in pulsed filtered and unfiltered beams

Gregor Bruggmoser[a,*], **Rainer Saum**[a], **Rafael Kranzer**[b]

[a] Universitätsklinikum Freiburg, Klinik für Strahlenheilkunde, Robert Koch Str. 3, 79106 Freiburg, Germany
[b] PTW-Freiburg, Lörracher Str. 7, 79115 Freiburg, Germany

Received 5 May 2017; accepted 20 September 2017

Abstract

The aim of this technical communication is to provide correction factors for recombination and polarity effect for two new ionization chambers PTW PinPoint 3D (type 31022) and PTW Semiflex 3D (type 31021). The correction factors provided are for the (based on the) German DIN 6800-2 dosimetry protocol and the AAPM TG51 protocol. The measurements were made in filtered and unfiltered high-energy photon beams in a water equivalent phantom at maximum depth of the PDD and a field size on the surface of 10 cm × 10 cm. The design of the new chamber types leads to an ion collection efficiency and a polarity effect that are well within the specifications requested by pertinent dosimetry protocols including the addendum of TG-51. It was confirmed that the recombination effect of both chambers mainly depends on dose per pulse and is independent of the filtration of the photon beam.

Bestimmung von Korrektionsfaktoren k_S zur Berücksichtigung der unvollständigen Sättigung durch Rekombination sowie Korrektionsfaktoren k_P zur Berücksichtigung der Polarität der Kammerspannung bei gepulster gefilterter und ungefilterter Strahlung

Zusammenfassung

Das Ziel dieser technischen Kommunikation ist, Korrektionsfaktoren für den Sättigungsverlust und Polaritätseffekt für zwei neue Ionisationskammern PTW PinPoint 3D (Typ 31022) und PTW Semiflex 3D (Typ 31021) zu bekommen. Die Korrektionsfaktoren wurden für die Dosimetrie-Norm DIN 6800-2 und die TG51 der AAPM ermittelt. Die Messungen wurden in gefilterter und ungefilterter Photonenstrahlung in einem wasseräquivalenten Phantom im Dosismaximum der Tiefendosis bei einer Feldgröße auf der Oberfläche von 10 cm x 10 cm durchgeführt. Das Design der neuen Kammer-Typen wurde so optimiert, dass der Sättigungsverlust und der Polaritätseffekt innerhalb der Spezifikationen liegen, die von Dosimetrieprotokolle, incl. des Addendums von TG-51, verlangt werden. Durch die Messungen konnte verifiziert werden, dass der Rekombinationseffekt für beide Kammern hauptsächlich von der Dosis pro Puls abhängt und unabhängig von der Filterung der Strahlung ist.

* Corresponding author: Gregor Bruggmoser, Universitätsklinikum Freiburg, Klinik für Strahlenheilkunde, Robert Koch Str. 3, 79106 Freiburg, Germany.
E-mail: gregor.bruggmoser@uniklinik-freiburg.de (G. Bruggmoser).

Keywords: Ionization chamber, Saturation loss, Recombination, Polarity effect

Schlüsselwörter: Ionisationskammer, Sättigungsverlust, Rekombination, Polaritätseffekt

1 Introduction

The measurement of absorbed dose with ionization chambers in pulsed beams from medical accelerators necessitates the application of correction factors for incomplete ion collection and for polarity effect. The predominant process for ion recombination is the volume recombination which is heavily dependent on the dose per pulse, the geometry of the ionization chamber and the applied chamber voltage [2,3]. With the introduction of accelerators without flattening filters (FFF) which are able to deliver doses per pulse up to several mGy, especially the correction factor for ion collection efficiency, k_S, becomes more important.

Current dosimetry protocols and authors such as DIN 6800-2 [1], TRS No. 398 [4], McEwen [15], Almond [16] describe the determination of the recombination correction factor k_S either by numerical or by experimental methods. IAEA TRS-398 [4] prefers an experimental two-voltage method. DIN 6800-2 [1] suggests a procedure based on a formula, using tabulated coefficients for each type of ionization chamber. For chambers which are not listed in DIN 6800-2 [1], an experimental determination of the recombination factor by measuring the dosemeter readings (M) at different polarizing voltages (U) is recommended. From theory, one expects a linear relation between the inverse reading of the dosemeter (M) and the inverse of the polarizing voltage (U) (Jaffé plot). Several authors [5,6] showed that the behaviors of ionization chambers with small volumes (<0.1 cm^3) not always correspond to what is expected from theory. Some chambers show no significant variation in k_S with dose per pulse (D_P) but relatively large intercepts in the correction factor for the recombination k_S (or P_{ion}) versus D_P plots. Other authors [5] show an increasing signal as the polarizing voltage is reduced or intercepts at zero D_P less than unity. This was the reason, why we looked closely to the linearity of the correction factor for the recombination vs the increasing dose per pulse and the value of the intercept at D_P zero.

In this technical communication we report on the determination of the coefficients used in the formula for the correction factor for ion collection efficiency as described in DIN 6800-2 [1] and the polarity effect for two ionization chambers recently introduced in the market.

2 Materials and methods

2.1 Types of ionization chambers

The PTW PinPoint 3D chamber (type 31022) was optimized for measurement in small fields and is intended to replace its predecessor type 31016. The PTW Semiflex 3D chamber (type 31021) has a larger volume and serves as a reference class chamber according to IEC 60731 [17]. Two units of both chamber types were investigated for this work. Table 1 shows the relevant physical dimensions of the measuring volume.

2.2 Pulse frequency of the accelerator

The effect of recombination is dominated neither by the radiation type nor by the beam energy, but only by the dose per pulse D_P [7,8].

Therefore, we used for the measurements photon beams from a medical accelerator (Varian TrueBeam) with (WFF) and without flattening filter (FFF) mode in order to have access to a wider range of doses per pulse. The pulse frequencies varied between 50 Hz and 240 Hz for the different dose per pulse rates.

The Varian TrueBeam has two different methods for the control of the dose rate. One method is called “pulse drop method” which is used in the FFF mode. By elimination of pulses, the dose rate is adjusted at each nominal accelerating voltage. The dose rate in WFF mode is stabilized by the “pulse length method”. The variation of the pulse length of the linear accelerator used was approximately between 3.5 µs and 5 µs.

For all measurements it was ensured that the pulse frequency did not exceed the inverse of the ion collection time of the ionization chambers in use. The ion collection time was calculated according to a formula in DIN 6800-2 [1].

2.3 Dose per pulse (D_P)

In order to detect the D_P for each test condition, the absorbed dose rate was measured in Gy/min. The protocol taken for dosimetry was DIN 6800-2 [1]. The dose rate was measured simultaneously for each chamber, at the point of measurement. For this approach the beam quality