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ASSESSMENT OF ABSORBED DOSE TO WATER IN HIGH ENERGY PHOTON BEAMS USING DIFFERENT CYLINDRICAL CHAMBERS*

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Abstract. Absorbed dose to water is the most important unit for radiation therapy. In this report, we present the values of the absorbed dose to water in high energy photon beams delivered by the Elekta Synergy linear accelerator of the IBA Dosimetry measured by two secondary standard laboratories. The measurements have been performed for photon beams qualities ($TPR_{20,10}$) of 0.69, 0.75 and 0.77 according to the IAEA TRS 398 protocol. The absorbed dose to water has been measured using cylindrical chambers, types PTW TN31010 and IBA Dosimetry FC65-G. Performance of each reference ionization chamber is assessed through En numbers, which are in good agreement with ISO 13528 requirements.

Key words: high energy photon beam, absorbed dose to water.

1. INTRODUCTION

The Code of Practice of International Atomic Energy Agency (TRS 398) for reference dosimetry in clinical high-energy photon beams is based upon a calibration coefficient in terms of absorbed dose to water $N_{Dw,Qo}$ for a dosimeter calibrated in a reference beam of quality Q_o. The code of practice applies to photon beams generated by electrons with energies in the range from 1 MeV to 50 MeV. For photon beams, the most common reference beam quality Q_o is ^{60}Co gamma rays. Some primary standard dosimetry laboratories are providing calibration coefficients $N_{Dw,Qo}$ in other photon beam qualities Q_o.

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When different ionization chambers are used in the same radiation beam, the absorbed dose values measured should correspond. In this paper we investigate the consistence of the absorbed dose to water assessment in high energy photon beams when ionization chambers of different types are used.

Absorbed dose to water measurements were performed at the Elekta Synergy type linear accelerator of IBA Dosimetry. Measurements were performed by two standard laboratories: Secondary Standard Dosimetry Laboratory at High Energies – STARDOOR of INFLPR, Romania, and Secondary Standard Dosimetry Laboratory of IBA Dosimetry, Germany. The ionization chambers used by both laboratories were cylindrical. The absorbed dose to water was determined at the reference point in high energy photon beams with nominal energies of 6 MV, 10 MV and 15 MV.

To evaluate the correspondence between measured values of the absorbed dose to water performed by both laboratories, it was chosen to use En numbers. In this case the reported expanded measurement uncertainty was used. The accepted interval for En numbers is given in International Standard ISO 13528 and lies in the range of [–1; 1] for coverage factor $k = 2$.

2. ABSORBED DOSE TO WATER IN HIGH ENERGY PHOTON BEAMS

In this paper, the STARDOOR and IBA Dosimetry laboratories determined absorbed dose to water in photon beams at the Elekta Synergy linear accelerator of IBA Dosimetry at the reference depth according to the IAEA TRS 398 protocol. The reference depth in photons beams according to the Code of Practice of TRS 398 is 10 $g\cdot cm^{-2}$. $TPR_{20,10}$ represents absorbed dose ratios at depths of 20 and 10 $g\cdot cm^{-2}$ in a water phantom, measured at a constant source-detector distance of 100 cm and a field size of 10 cm × 10 cm and is used as the beam quality index for high-energy photon beams [1].

The absorbed dose to water at the reference depth z_{ref} in water, in a photon beam of quality Q is given by:

$$D_{w,Q} = N_{Dw,Q_o} \cdot M_{corr} \cdot k_{Q,Q_o}\,, \tag{1}$$

where: $N_{Dw,Qo}$ is the chamber calibration coefficient in terms of absorbed dose to water, M_{corr} is the reading of the dosimeter with the reference point of the chamber positioned at z_{ref} and corrected for the influence quantities temperature and pressure, electrometer calibration, polarity effect and ion recombination as described in TRS 398 and $k_{Q,Qo}$ is the beam quality correction factor, defined as a ratio at the qualities Q and Q_o of the chamber calibration coefficients in terms of absorbed dose to water. If the ionization chamber has been calibrated in a beam quality Q_0 equal to the beam quality measured ($Q = Q_0$), the respective calibration coefficient $N_{Dw,Q}$ is used instead of $N_{Dw,Qo}$ and the quality correction factor $k_{Q,Qo}$ is equal to unity.

The response of the ionization chamber corrected to the influence quantities, M_{corr}, is given by:

$$M_{corr} = M_{uncorr} \cdot k_{elec} \cdot k_{TP} \cdot k_{pol} \cdot k_s \cdot k_h \,, \tag{2}$$

where M_{uncorr} is the uncorrected dosimeter reading, k_{elec} is the correction factor corresponding to the calibration factor of the electrometer readout in terms of charge. If the electrometer and the ionization chamber are calibrated together and the readout is in terms of Gy or Gy/s, a value of unity is to be used for k_{elec}.

Air density correction, k_{TP}, is given by:

$$k_{TP} = \frac{P_0(273.15+T)}{P(273.15+T_0)} \,, \tag{3}$$

where T and P are the temperature and pressure during the measurements. The reference values for ambient conditions are P_0 = 101.3 kPa and T_0 = 20 ^{o}C [1, 4].

For pulsed or pulsed-scanned radiation, the ion recombination correction factor k_s can be determined as

$$k_s = \frac{M_1/M_2 - 1}{V_1/V_2 - 1} + 1 \,, \tag{4}$$

where M_1 and M_2 are the readings at two voltages V_1 and V_2. V_1 is the normally used voltage, and V_2 is a voltage reduced by a factor of at least 3 [1, 4].

Polarity effect correction factor k_{pol} is given by:

$$k_{pol} = \frac{(|M_+| + |M_-|)/|M_+|}{[(|M_+| + |M_-|)/|M_+|]_{Co}} \,, \tag{5}$$

where M_+ and M_- are the electrometer readings obtained at positive and negative polarity, the index *Co* refers to the readings obtained in a ^{60}Co beam during calibration [1, 4].

Correction factor for humidity, k_h, in this case is taken as 1.000.

The beam quality correction factor $k_{Q,Qo}$ is, in accordance with the TRS 398 protocol, defined as the ratio, at the qualities Q and Q_o, of the chamber calibration coefficients in terms of absorbed dose to water and is given by the formula below:

$$k_{Q,Qo} = \frac{N_{D,w,Q}}{N_{D,w,Qo}} = \frac{D_{w,Q} / M_Q}{D_{w,Qo} / M_{Qo}} \,. \qquad (6)$$

$N_{Dw,Qo}$ is the chamber calibration coefficient in terms of absorbed dose to water at the reference beam quality Q_o, and $N_{Dw,Q}$ is the chamber calibration coefficient in terms of absorbed dose to water at the beam of quality Q. If the reference quality Q_o used at the calibration is ^{60}Co, the symbol k_Q is often used instead of $k_{Q,Qo}$.

3. EXPERIMENTAL SETUP

Both laboratories have determined the absorbed dose to water in three photon beam energies (nominal accelerating potentials 6 MV, 10 MV and 15 MV, $TPR_{20,10}$ values 0.69, 0.75 and 0.77). SSDL STARDOOR laboratory participated in the comparison with a cylindrical ionization chamber type TN31010 (cavity volume 0.125 cm^3) connected to the UNIDOS electrometer type T10005 calibrated by the primary standard dosimetry laboratory of PTB (Physikalisch-Technische Bundesanstalt), Germany, in a ^{60}Co beam.

The SSDL of IBA Dosimetry participated with a Farmer-type ionization chamber FC65-G (cavity volume 0.65 cm^3) connected to a Digital Electrometer Keithley 6517B. The chamber has been calibrated by the primary standard dosimetry laboratory of NPL (National Physical Laboratory), UK, in high energy X-ray beams.

Both laboratories STARDOOR and IBA Dosimetry used their own method for assessment of the absorbed dose to water quantity based on TRS 398.

The reference conditions for absorbed dose to water measurements at photon beams in the reference depth follow the TRS 398 code of practice. In this way all measurements have been performed in a water phantom type WP1D (IBA Dosimetry) 40 cm × 34 cm × 35 cm. The chamber reference point is on its central axis at the centre of the cavity. The reference depth z_{ref} was 10 g·cm^{-2} for all beam qualities. The field size at the phantom surface was 10 cm × 10 cm and the distance from the source to the phantom surface (SSD) was 100 cm, with a vertical incidence of the beam.

4. RESULTS

4.1. ABSORBED DOSE TO WATER

Absorbed dose to water, at the reference depth z_{ref} 10 g·cm^{-2} has been determined in high energy photon beams of the nominal accelerating potentials of 6 MV, 10 MV, and 15 MV. The beam qualities expressed as $TPR_{20,10}$ (tissue-phantom ratio) are 0.69, 0.75, and 0.77, respectively.

The absorbed dose to water in the reference depth has been measured according to the above specified method by each laboratory. The measurement uncertainties have been assessed by each laboratory.

The measurement results of the absorbed dose to water in high energy photon beams are presented in Fig. 1. They show a good agreement for all beam qualities used.

4.2. EN NUMBERS

The correspondence of the measured values performed by SSDL STARDOOR and IBA Dosimetry laboratories was evaluated using *En numbers*. The *En numbers* were determined in accordance with ISO 13528:2005 [9]. For the *En number* assessment, the expanded uncertainty reported by each laboratory separately was taken into account.

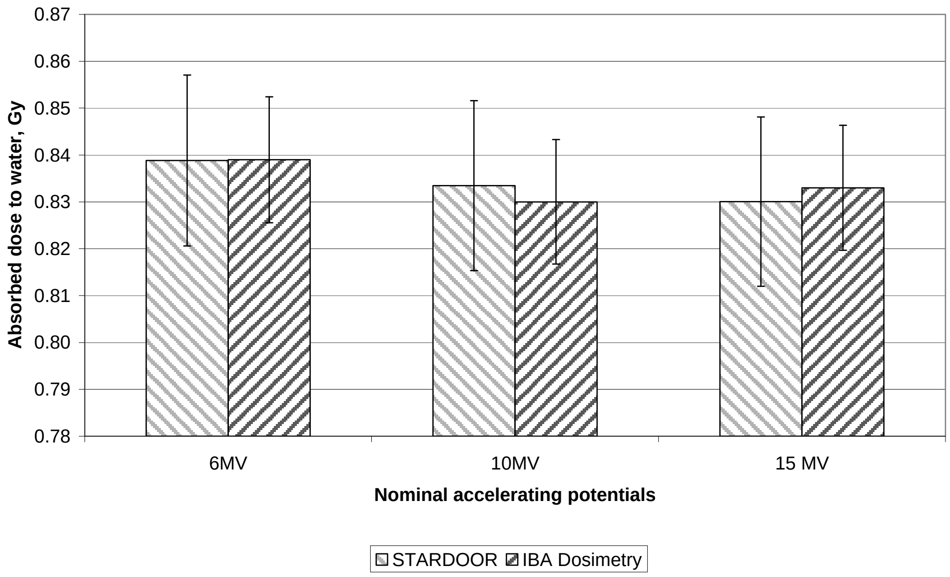

Fig. 1 – Absorbed dose to water in high energy photon beams for beam qualities 0.69, 0.75 and 0.77 measured by both laboratories.

En numbers, calculated for each beam quality, are presented in Fig. 2:

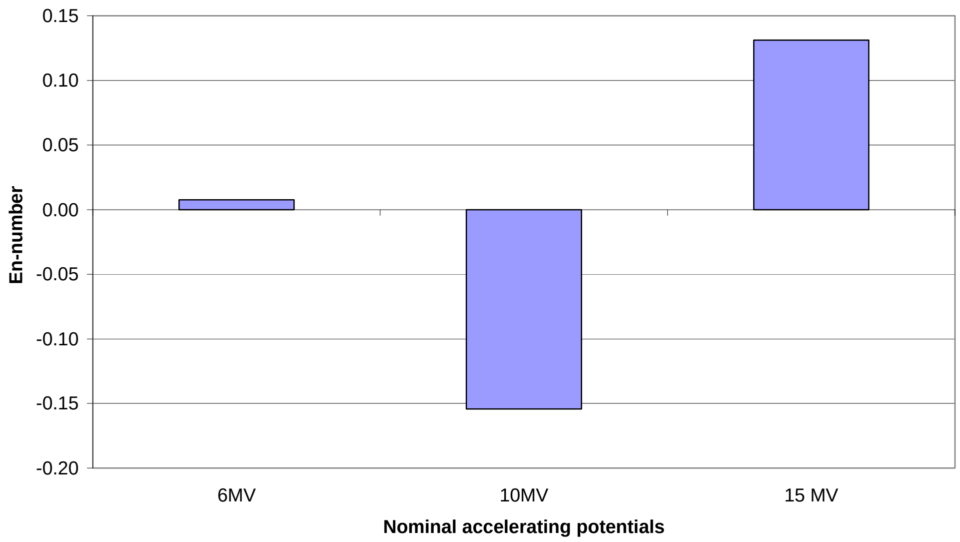

Fig. 2 – En numbers calculated for performance assessment for the participating laboratories.

From the graph we can see that the En number values calculated for absorbed dose to water meet the required limit within the interval of [–1, 1] according to ISO 13528:2005 [9]. Both participating laboratories demonstrated a good practice in absorbed dose to water measurements.

5. CONCLUSION

The results of absorbed dose to water measurements in high energy photon beams delivered by the linear accelerator Elekta Synergy have been presented in this paper. The results obtained with two dosimetry systems (STARDOOR and IBA Dosimetry) meet the requirements for secondary standard dosimetry laboratories. The values of absorbed dose to water in high-energy photon beams lie within the range of measurement uncertainty, calculated according to specific standards. En numbers calculated for absorbed dose to water values for all beam qualities comply with the required range [–1, 1].

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