Romanian Reports in Physics, Vol. 67, No. 3, P. 1152–1158, 2015

ABSORBED DOSE TO WATER MEASUREMENTS IN HIGH ENERGY ELECTRON BEAMS USING DIFFERENT PLANE PARALLEL CHAMBERS*

ELENA STANCU[1,2], CATALIN VANCEA[1,2], JIRI VALENTA[3], JOSEF ZEMAN[3], EUGENIA BADITA[1,2], ANCA SCARISOREANU[1]

[1]National Institute for Laser, Plasma and Radiation Physics, 409 Atomistrilor str., Magurele, Ilfov,
E-mail: elena.stancu@inflpr.ro, catalin.vancea@yahoo.com, eugenia_badita@yahoo.com, a_m_mihalache@yahoo.com
[2] Bucharest University, Physics Department, 407 Atomistilor str, Magurele, Ilfov
[3]IBA Dosimetry GmbH, Bahnhofstrasse 5, 90592, Schwarzenbruck, Germany,
E-mail: Jiri.Valenta@iba-group.com, Jozef.Zeman@iba-group.com

Received September 25, 2013

Abstract. Reference value measurement is the most important aspect in calibration coefficient assessment. For high energy electron beams, the absorbed doses to water have been measured using two types of plane parallel chambers: TN 34045 (PTW) and NACP-2 (IBA Dosimetry) owned by the secondary standard laboratories. Measurements have been carried out at the Elekta Synergy linear accelerator of the IBA Dosimetry laboratory according to the IAEA TRS 398 protocol. The differences between the obtained dose values were determined for measurements of electron beams with nominal energies of 6 MeV, 8 MeV, 10 MeV, 12 MeV, 15 MeV and 18 MeV. The En numbers show good agreement for the absorbed dose to water quantity achieved by both laboratories.

Key words: Conventional true value, En numbers, absorbed dose to water, high energy electron beams.

1. INTRODUCTION

The Code of Practice of the International Atomic Energy Agency for the determination of absorbed dose to water in electron beams is based on the use of ionization chambers calibrated in a reference beam quality Q_0 [1]. This reference quality may be either ^{60}Co gamma radiation or an electron beam. In the latter case the dosimeter may be calibrated either directly at the standards laboratory or by cross-calibration in a clinical electron beam. The quality correction factor $k_{Q,Qo}$ corrects for the difference between the response of a ionization chamber in the

---

* Paper presented at the Annual Scientific Session of Faculty of Physics, University of Bucharest, June 21, 2013, Bucharest-Magurele, Romania.

reference beam quality Q_0 and in the actual user beam of quality Q. When the reference quality is ^{60}Co gamma radiation this factor is denoted by k_Q [1, 2].

Aside from having its foundation on standards of absorbed dose, the most significant change from previous practice is the use of a new reference depth. This depth has been shown to significantly reduce the influence of spectral differences between different accelerators as well as that of electron and photon contamination in clinical electron beams. For simplicity, beam qualities and all factors dependent on beam quality (including the new reference depth) are expressed in terms of the half-value depth R_{50} rather than beam energy. This change parallels the longstanding practice in photon dosimetry where beam qualities are expressed in terms of the penetration of the beam [1].

When different ionization chambers are used in the same radiation beam, the values measured for the absorbed dose to water should be the same. In this paper we investigate the possibility of determining the absorbed dose in a reference high energy electron beam when different types of ionization chambers are used. Also the influence of calculated and measured k_Q factors on absorbed dose to water was studied.

Absorbed dose to water measurements were performed at type Elekta Synergy linear electron accelerator of SSDL IBA Dosimetry. The participating laboratories were the High Energy Secondary Standard Dosimetry Laboratory STARDOOR, INFLPR (National Institute for Laser, Plasma and Radiation Physics) and the Secondary Standard Dosimetry Laboratory of IBA Dosimetry. The ionization chambers used by both laboratories were plane-parallel type; each ionization chamber was connected to the corresponding dosimeter owned by each laboratory. The measurements for the absorbed dose to water in reference point were performed for high energy electron beams with nominal energies of 6 MeV, 8 MeV, 10 MeV, 12 MeV, 15 MeV and 18 MeV. The degree of coincidence of the absorbed dose to water was evaluated through the En numbers determined according to the International Standard ISO 13528 [3].

2. METHOD FOR DETERMINING THE ABSORBED DOSE TO WATER

In this paper, the STARDOOR laboratory and IBA Dosimetry have determined the absorbed dose to water in electron beams at the Elekta Synergy linear accelerator of the IBA Dosimetry laboratory at the reference depths according to the IAEA TRS 398 protocol.

The reference depth z_{ref} in water in an electron beam at the reference depth is determined using the formula below:

$$z_{ref} = 0.6 \cdot R_{50} - 0.1 \text{ g} \cdot \text{cm}^{-2}, \tag{1}$$

where R_{50} is the half-value depth in water, used as the beam quality index for electron beams and is measured in g · cm^{-2} [1, 2]. The half-value depths in water were measured by SSDL IBA Dosimetry for each of the applied energies and are presented in Table 1.

Under this standard, the absorbed dose to water is determined as follows:

$$D_{w,Q} = N_{Dw,Q_0} \cdot M_{cor} \cdot k_{Q,Q_0} \,, \tag{2}$$

where: $N_{Dw,Qo}$ is the chamber calibration coefficient in terms of dose absorbed to water, M_{corr} is the reading of dosimeter corrected for the influence quantities temperature and pressure, electrometer calibration, polarity effect and ion recombination as described in the TRS 398 and $k_{Q,Qo}$ is the beam quality correction factor, defined as a ratio at the qualities Q and Q_0 of the calibration factors in terms of absorbed dose to water of the ionization chamber.

Table 1

The beam qualities of the used energies

Nominal energy	**Beam quality index, R_{50}**
6 MeV	25.0 mm
8 MeV	31.9 mm
10 MeV	40.9 mm
12 MeV	47.9 mm
15 MeV	61.7 mm
18 MeV	72.0 mm

According to TRS 398 absorbed dose determination in photon and high energy electron beams [2], based on standards of absorbed dose to water, M_{corr} is given by:

$$M_{corr} = M_{uncorr} \cdot k_{elec} \cdot k_{TP} \cdot k_{pol} \cdot k_s \cdot k_h \,, \tag{3}$$

where: M_{uncorr} is the uncorrected dosimeter reading, k_{elec} is the correction factor corresponding to the calibration factor of the electrometer in terms of charge or current [1, 2]. If the electrometer and the ionization chamber are calibrated together, a value of unity is to be used for k_{elec}.

k_{TP} is the correction for air density which is given by:

$$k_{TP} = \frac{P_0(273.15+T)}{P(273.15+T_0)} \,, \tag{4}$$

where T and P are the temperature and pressure of the measuring environment having reference values of P_0 = 101.3 kPa and T_0 = 20 °C [1, 2].

k_s is the ion recombination correction factor for pulsed or pulsed-scanned radiation and can be determined from

$$k_s = \frac{M_1 / M_2 - 1}{V_1 / V_2 - 1} + 1, \tag{5}$$

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, 2].

k_{pol} is the correction factor for polarity effect which is given by:

$$k_{pol} = \frac{(|M_+| + |M_-|)/|M_+|}{[(|M_+| + |M_-|)/|M_+|]_{Co}}, \tag{6}$$

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, 2].

k_h is the correction factor for humidity; in this case k_h is taken as 1.000.

Moreover, in this case, according to TRS 398 standard, the quality factor $k_{Q,Qo}$ is given by the formula below:

$$k_{Q,Q_0} = \frac{N_{D,w,Q}}{N_{D,w,Q_0}} = \frac{D_{w,Q} / M_Q}{D_{w,Q_0} / M_{Q_0}}, \tag{7}$$

where $N_{Dw,Qo}$ is the calibration coefficient in terms of absorbed dose to water of dosimeter at reference quality Q_o, and $N_{Dw,Q}$ is the calibration coefficient in terms of absorbed dose to water of dosimeter at the electron beam quality Q. For ionization chambers calibrated in high energy electron beams of the same quality as the beam quality measured ($Q = Q_o$), the respective calibration coefficient N_{DwQ} is used and the quality correction factor $k_{Q,Qo}$ is equal to unity.

3. EXPERIMENTAL SETUP

Both participating laboratories have measured absorbed dose to water in electron beams at the Elekta Synergy linear accelerator at the reference depths.

The radiation detectors used in this study are two ionization chambers; one is an Advanced Markus TN 34045 (sensitive volume 0.02 cm^3) connected to UNIDOS dosimeter type T10005 and the other was of type NACP-2 (cavity volume 0.16 cm^3) connected to a Keithley 6517 B digital electrometer. The Advanced Markus TN 34045 ionization chamber and the UNIDOS dosimeter have been calibrated at the Physikalisch-Technische Bundesanstalt, Germany, in a ^{60}Co source radiation field while the NACP-02 ionization chamber has been calibrated at the primary standard dosimetry laboratory of the National Physical Laboratory, UK, in high-energy electron beams.

The radiation dose delivered by the Elekta Synergy accelerator used for the measurements at each energy, 6 MeV, 8 MeV, 10 MeV, 12 MeV, 15 MeV and 18 MeV, was the same for both laboratories. The radiation beam geometry used was vertically incident on a water phantom.

The reference conditions for measurements of the absorbed dose to water in electron beams at the reference depths [1] are presented in Table 2.

Table 2

Reference conditions for the determination of absorbed dose in electron beams

Influence quantity	Reference value or reference characteristic
Phantom material	Water
Chamber type	plane-parallel
Measurement depth z_{ref}	$z_{ref} = 0.6 \cdot R_{50} - 0.1\ \text{g} \cdot \text{cm}^{-2}$
Reference point of chamber	inner surface of the entrance window, at its centre
Position of reference point of chamber	at z_{ref}
Distance source-surface, SSD	100 cm
Field size at phantom surface	10 cm × 10 cm

4. RESULTS

4.1. THE RESULTS FOR THE MEASUREMENT OF ABSORBED DOSE IN WATER

For all applied energies, the absorbed dose to water measurements were performed at reference measurement depth. The reference measurement depths were assessed for each energy using half-value depth R_{50}. The absorbed dose to water in electron beams was measured by each laboratory using a standardized method. Measurement uncertainties were calculated for each value according to specific laboratory standards [4, 5].

The results for the measurements of absorbed dose to water in electron beams are presented in Fig 1.

When analyzing the measurement results of the absorbed dose to water in high-energy electron beams obtained by both participating laboratories, it is apparent that the reported values are the same when considering the measurement uncertainty. The measurement uncertainties of the measured values are reported by each laboratory and are presented in Fig 1.

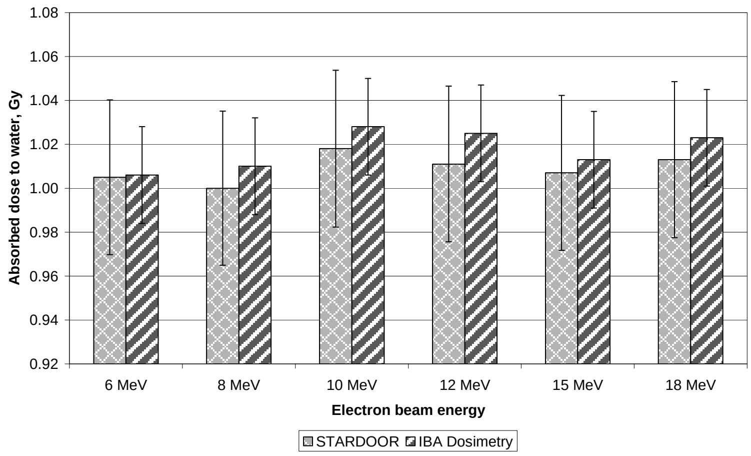

Fig. 1 – Diagram of the measurement results of absorbed dose in water and the expanded uncertainty for the two laboratories.

4.2. THE En NUMBERS ASSESSMENT

En numbers reflect the coincidence of independent measurements between the participating laboratories.

For the measurement analysis, the values of the absorbed dose to water in reference point as true values was considered for the STARDOOR laboratory measurements. For En number assessment the measurement uncertainty reported by each laboratory was used. Using ISO 13528:2005 standard, the En numbers were calculated for each energy value. The obtained results are presented in Fig. 2.

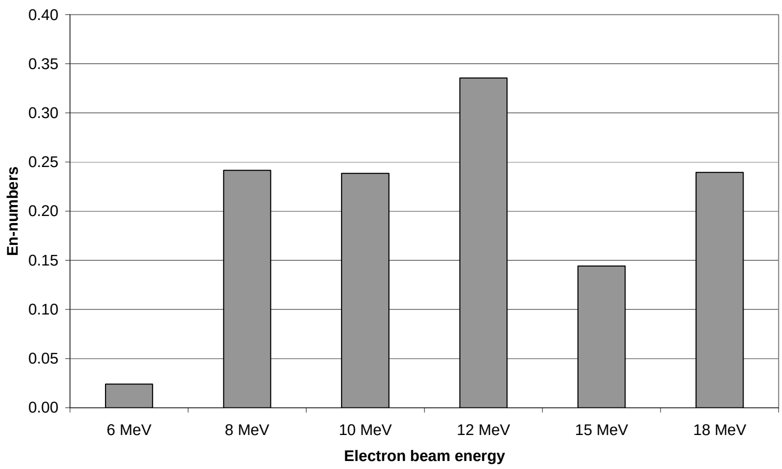

Fig. 2 – En number values calculated for each electron energy.

5. CONCLUSION

This paper presents the results of the absorbed dose to water measurements in the high energy electron beams delivered by the Elekta Synergy linear accelerator. The differences between the obtained dose values were determined for measurements of electron beams with nominal energies of 6 MeV, 8 MeV, 10 MeV, 12 MeV, 15 MeV, and 18 MeV. The obtained values of absorbed dose to water in high-energy electron beams lies within the range of the measurement uncertainty. The uncertainty was calculated according to specific standards by each participating laboratory. The calculated En numbers for absorbed dose to water comply with the range [–1, 1] for each used energy. The En numbers show good agreement for the absorbed dose to water quantity achieved by both laboratories.

REFERENCES

1. IAEA TRS 398, *Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water*, 2004.
2. *Absorbed dose determination in photon and high energy electron beams*, D560.210.1/2, 2006-05.
3. *Statistical methods for use in proficiency testing by interlaboratory comparisons*, International standard ISO 13528:2005.
4. IAEA TECDOC-1585, *Measurement Uncertainty. A Practical Guide for Secondary Standards Dosimetry Laboratories*, 2008.
5. EA 4/02 (1999), *Expression of the Uncertainty of the Measurement in Calibration*.
6. F. Scarlat, A. Scarisoreanu, M. Oane, E. Mitru, C. Avadanei, *On the absorbed dose determination method in high energy electron beams*, 6th Conference on Nuclear and Particle Physics, 17–21 Nov. 2007, Luxor, Egypt.
7. R.-P. Kapsch, K. Derikum, *Dose determination in electron beams in accordance with TRS 398 using different ionization chambers*, IAEA-CN-96124.