Calibration coefficients in terms of absorbed dose to water for two ionization chambers Standard Imaging A12 and A19 exposed to low-energy x-rays from 20 kV – 150 kV

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Introduction

The current codes of practices for low-energy photon dosimetry [1,2] are based on calibration coefficients for ionization chambers in terms of air kerma while for high-energy photon, they are centered on calibration coefficients in terms of absorbed dose to water. One of the difficulties to determine absorbed dose to water in low-energy photon beams is the rapid attenuation of the photon fluence as a function of the distance caused by the photoelectric effect. This work aims at determining the calibration coefficients in terms of absorbed dose to water, through a combination of Monte Carlo simulations and measurements of two ionization chambers exposed in water and in air to low-energy x-rays from 20 kV to 150 kV (effective energy: 13.5 keV – 65.3 keV).

Theory

Reference dosimetry of kilovoltage x-ray beams is performed with ionization chambers. The AAPM protocol for 40-300 kV x-ray beam dosimetry [2] (TG61) suggests that the parallel-plate chambers are suitable for low-energy x-rays generated with tube potentials below 70 kV, while the cylindrical chambers are the most appropriate for x-rays generated with potentials of 70 kV or higher.

Air kerma calibration factor for a chamber at a specified beam quality is defined as:

$$N_K = \frac{K_{air}}{M}$$

where K_{air} is the air kerma at a reference point for a given beam quality and M is the corrected reading of an ionization chamber for temperature, pressure, ion recombination, polarity effect and electrometer accuracy.

TG61 protocol stablishes the in-phantom method as a formalism for the reference dosimetry at a depth in water of 2 cm. The absorbed dose to water at this reference point can be determined also by means of N_K according to:

$$D_{w,2\,cm} = M N_K P_{Q,cham} P_{sheath} [(\overline{\mu_{en}}/\rho)^{w}_{air}]_w$$

where M is the corrected reading of an ionization chamber with its effective point of measurement placed at 2 cm depth in water, $P_{Q,cham}$ and P_{sheath} are correction factors that accounts for the displacement of water by the ionization chamber, the presence of the stem, the presence of the waterproofing sleeve and $[(\overline{\mu_{en}}/\rho)^{w}_{air}]_w$ is the ratio of the mean mass energy-absorption coefficients.

Method

The measurements were performed using an YXLON x-ray tube and the farmer-type ionization chambers Standard Imaging A12 and A19. The chambers were situated at 2 cm liquid water depth and 61 cm source to detector distance (SDD) and in air, at 63 cm SDD, and were exposed to nine different beam qualities previously characterized in our lab. The charges were collected in water and in air by each chamber. The experimental geometry was reproduced in the EGSnrc Monte Carlo simulation [3] to calculate the absorbed dose to water and the air kerma in the absence of ionization chamber, using the unfiltered x-ray spectra reported by the Physikalisch-Technische Bundesanstalt [4].

Under charged particle equilibrium we established the following relationships:

$$\left(\frac{D_w}{K_{air}}\right)_{exp} = \left(\frac{D_w}{K_{air}}\right)_{MC}$$

$$\frac{M_w N_{D,w}}{M_{air} N_{D,air}} = \left(\frac{D_w}{K_{air}}\right)_{MC}$$

$$N_{D,w} = \frac{M_{air} N_{D,air}}{M_w}\left(\frac{D_w}{K_{air}}\right)_{MC}$$

where M_w and M_{air} are the responses corrected for pressure and temperature of the chamber situated in water and in air, respectively, $N_{D,air}$ is the calibration coefficient in terms of air kerma obtained from NIST and $N_{D,w}$ is the calibration coefficient in terms of absorbed dose to water and $(D_w/K_{air})_{MC}$ is the ratio of absorbed dose to water to air kerma, calculated by MC.

Results

Figure 1 shows the variation of $N_{D,w}$ as a function of the effective energy for the two ionization chambers A12 and A19. These results indicate that $N_{D,w}$ increases with the photon energy and reaches a maximum at 40 keV (associated to a generating potential of 100 kV) and then decreases to a constant value at energies greater than 47 keV (associated to a 120 kV generating potential).

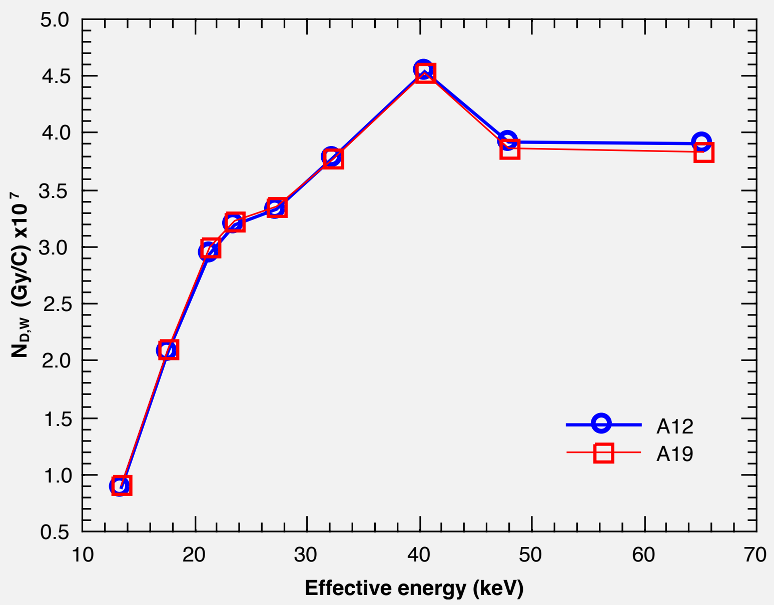

Figure 1. Calibration coefficient in terms of absorbed dose to water for the ionization chambers A12 and A19.

This behaviour is also observed in **Figure 2** that shows the ratio of $N_{D,w}$ to $N_{D,air}$, as a function of the effective energy of the x-ray beam for both ionization chambers. The ratio increases, reaches a maximum about an effective energy of 40 keV and thereafter, seems to be constant at higher energies. This behavior suggests that independent of the chamber, the ratio depends on the energy at photon energies below 40 keV, where the lower is the energy, the lower is the ratio.

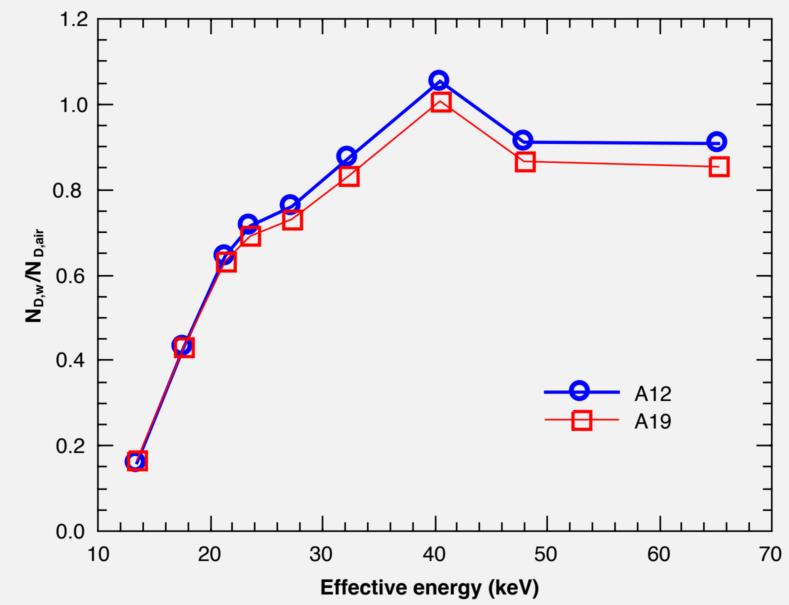

Figure 2. Ratio of the calibration coefficient in terms of absorbed dose to water, $N_{D,w}$, and that in terms of air kerma, $N_{D,air}$, for the ionization chambers A12 and A19.

Conclusion

With this method is possible to obtain calibration coefficients for ionization chambers in terms of absorbed dose to water, offering an alternative to direct calibration against absorbed dose to water primary standards, which are scarce for radiation qualities associated with low-energy photons.

The absorbed dose to water, calculated by using ionization chambers with calibration factor in terms of air kerma, needs to be compared with the dose obtained from the calibration coefficients in terms of absorbed dose to water in order to evaluate the agreement and the uncertainties of the method.

References

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