Measurements of $k_Q$ factors, ion recombination, polarity and sleeve effects of Farmer type chambers calibrated in terms of absorbed dose to water at NPL

Introduction

The National Physical Laboratory (NPL) has calibrated ionisation chambers in terms of absorbed dose to water in a range of megavoltage photon beams since 1995. The majority of these chambers have been the NPL-designed secondary standard chamber, type NE 2561 or NE 2571, but a small number of Farmer chambers, type NE 2571, have been calibrated in the same high-energy beams. These measurements, and recent work using two examples of a waterproof Farmer chamber manufactured by Wellhofer, allow us to report results on the corrections for beam quality, kQ, for ion recombination, kR, and for polarity, kP, and on the effect of the waterproof sleeve.

Beam quality-dependence: $k_Q$

The calibration in terms of absorbed dose to water $N_{cw}$ of an ion chamber in a beam of quality Q can be expressed as a product of a beam quality-dependent correction factor, $k_Q$, and the chamber calibration in a reference quality $Q_0$.

$$N_{cw}(Q) = N_{cw}(Q_0) k_Q$$

(1)

This becomes useful when the quality-dependent correction depends only on the chamber type: the may be true for chambers which are well-designed and properly manufactured, but cannot be taken for granted. In 1995, $k_Q$ factors were obtained by analysing absorbed dose measurements made with thirteen chambers of type NE 2571 in eight beam energies. The absorbed dose calibration was averaged over all chambers and $k_Q$ obtained as the average of this ratio in quality $Q_0$ divided by the average calibration in the reference quality $Q_0$.

The factored form (1) was found to represent the 104 individually measured calibration factors with a maximum deviation of 0.3% and an rms deviation of 0.06%. This level of reproducibility is typical of absorbed dose calibrations using the NPL linear accelerator and cannot be taken to indicate real variations from one chamber to another.

Absorbed dose calibrations performed at NPL since 1995 have been based on measurements made in at least four different beam qualities, rather than the full range previously employed, and include six measured calibration factors for a total of nine chambers of type NE 2571. These data cannot be analysed so simply and a least squares analysis found that the recombination correction is best described in more detail in Duane and Simon (2003) for chambers of type NE 2561 or NE 2571, and their results for the NE 2571 chambers are presented here.

Table 2. Mean values of the recombination coefficients in photon and electron beams.

<table>
<thead>
<tr>
<th>Beam type</th>
<th>Photon beams</th>
<th>Electron beams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>DC</td>
<td>DC</td>
</tr>
<tr>
<td>6MV</td>
<td>1.0001</td>
<td>0.9901</td>
</tr>
<tr>
<td></td>
<td>±0.0061</td>
<td>±0.0051</td>
</tr>
<tr>
<td>12MV</td>
<td>0.9786</td>
<td>0.9167</td>
</tr>
<tr>
<td>18MV</td>
<td>0.9076</td>
<td>0.8513</td>
</tr>
</tbody>
</table>

Conclusions

We have found that the NE 2571 Farmer type chambers are consistent in their quality-dependence, and that this quality-dependence differs from that of the waterproof Wellhofer Farmer chamber, whether or not the recombination of chambers is allowed to vary with beam quality. The overall recombination correction in photon and electron beams is found to be comparable in magnitude to the changes in its dose-rate dependence. There is a small difference in the polarity effect between electron and photon beams for the usual protocols, measurements in photon beams are always made with the same (negative) polarity. Although the same approach could be adopted for measurements in an electron beam when the calibration is directly traceable to an electron beam absorbed dose standard (such as the NPL dosimeter), current practice is to make measurements at both polarities and provide a calibration based on the average of positive and negative polarity results.

Acknowledgements

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References

Quelle, S. and Simon, M., Experimental Determination of the Quality-Dependent Correction Factors, kQ, for Ionisation Chambers of Type NE 2561 and NE 2571, Poster 4433, World Congress on Medical Physics and Biomedical Engineering, 2003.