SUBJECT: Determining the $k_{Q,Q_0}$ factor for Exradin ionization chambers not described in IAEA TRS-398 Code of Practice for Photon Beams

The following information is provided as a service to our users and customers:

Determining the $k_{Q,Q_0}$ factor for Exradin ionization chambers (either cylindrical or parallel plate) not described in IAEA TRS-398 Code of Practice for Photon Beams

For ion chambers not characterized in IAEA TRS-398 for use with high-energy photon beams, the values of $k_{Q,Q_0}$ for the unknown chamber can be determined by performing cross-calibration measurements with a characterized chamber with a known $k_{Q,Q_0}$ in the user’s high-energy photon beam. This beam quality correction factor, $k_{Q,Q_0}$, is described in detail in Section 3.2 of IAEA TRS-398.

Currently, the Exradin ion chambers characterized in IAEA TRS-398 for use in photon beams are the A12, A1, T1, A2 and T2. Refer to Table 14 of IAEA TRS-398 for a list of $k_{Q,Q_0}$ values for these chambers as a function of $TPR_{20,10}$.

Throughout this Technical Note, all referenced sections listed in brackets are taken from IAEA TRS-398 Code of Practice, published in December 2000, unless otherwise specified.
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The concept of the cross-calibration method is straightforward: the Absorbed Dose to Water at the reference depth of $z_{ref}$ in a water phantom is the same, regardless of which chamber is being used to measure it. Refer to Section 6.6 for further explanations and details.

This cross-calibration technique should be done as follows:

1. Both chambers should have a PSDL or SSDL or equivalent calibration done for Absorbed Dose to Water at the same reference beam of quality $Q_0$, at a reference depth of $z_{ref}$.
2. It is strongly encouraged that the cylindrical chamber with the known $k_{Q,Q_0}$ factor be a Farmer-type cylindrical chamber – 0.6 cc, due to its historical use as a reference chamber.
3. Only a liquid water phantom should be used, at least 30 cm x 30 cm x 30 cm in size.
4. The Reference Point of the characterized chamber with the known $k_{Q,Q_0}$ factor is set at a depth of $z_{ref}$ and the output is measured with the bias voltage setting as stated in its calibration report in the user’s high-energy photon beam. Then the Reference Point of the chamber with the unknown $k_{Q,Q_0}$ replaces the Reference Point of the characterized chamber, and its output is measured. This must be repeated for both chambers at every beam quality desired. [Refer to Standard Imaging Tech Note 4659 for Thimble ion chambers and 4660 for Parallel Plate ion chambers for Reference Point positioning details.]
5. By setting Equation 20 of TRS-398 for the characterized chamber equal to the Absorbed Dose to Water of the unknown chamber, the $k_{Q,Q_0}$ of the unknown chamber can be determined by the following equation:

$$k_{Q,Q_0}^u = k_{Q,Q_0}^c \times \left( \frac{k_{TP}^c \cdot k_{elec}^c \cdot k_{pol}^c \cdot k_{s}^c \cdot M_{c}^c \cdot N_{D,w,Q_0}^c}{k_{TP}^u \cdot k_{elec}^u \cdot k_{pol}^u \cdot k_{s}^u \cdot M_{u}^u \cdot N_{D,w,Q_0}^u} \right)$$
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where:
- $u$ superscript refers to a parameter of the chamber with the unknown $k_{Q,0}$
- $c$ superscript refers to a parameter of the characterized chamber with known $k_{Q,0}$
- $k_{Q,0}$ is the response correction factor accounting for the difference in chamber response in a reference beam quality, $Q_0$, and in the user beam quality, $Q$
- $k_{TP}$ is the temperature-pressure correction factor [refer to 4.4.3.1]
- $k_{elec}$ is the electrometer calibration factor (if calibrated separately from ion chamber) [refer to 4.4.3.2]
- $k_{pol}$ is the polarity correction factor for the chamber [refer to 4.4.3.3]
- $k_{s}$ is the ion recombination correction factor for the chamber [refer to 4.4.3.4]
- $M$ is the uncorrected ion chamber reading from the electrometer
- $N_{D,w,Q_0}$ is the Absorbed-Dose to Water calibration factor in a reference beam quality $Q_0$

The following precautions apply to $k_s$ and $k_{pol}$:
1. $k_s$ should be measured at positive full voltage ($+V_1$) and then at a lower positive voltage ($+V_2$); it is recommended in TRS-398 that the ratio $V_1/V_2 \geq 3$. Then take a measurement at the negative lower voltage ($-V_2$) and then at negative full voltage ($-V_1$) and then finally back to positive full voltage ($+V_1$) for comparison. The second full reading ($+V_1$) should be close ($\leq 0.5\%$) to the first full reading ($+V_1$). Ensure the system (ion chamber, extension cable, etc) has adequate time to settle between voltage changes. [Refer to Section 4.4.3.4 for more information.]
2. $k_{pol}$ should be measured for each chamber and should be $\leq 0.3\%$. Ensure the system (ion chamber, extension cable, etc) has adequate time to settle between voltage changes. [Refer to Section 4.4.3.3 for more information.]

Note: If there is a significant effect for either $k_s$ or $k_{pol}$, it should be accounted for as addressed in the TRS-398 Code of Practice.
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Below is a chart with an inter-comparison of four critical features for the entire Exradin cylindrical ionization chamber product line. This is intended to help the physicist see the similarities and differences between the chamber models.

<table>
<thead>
<tr>
<th>Collector, Guard &amp; Wall Material</th>
<th>Mod 1</th>
<th>Mod A1SL</th>
<th>Mod 2</th>
<th>Mod A12</th>
<th>Mod A12S</th>
<th>Mod 14</th>
<th>Mod A14SL</th>
<th>Mod A16</th>
<th>Mod A18</th>
<th>Mod A19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>A, T</td>
<td>A, T, P</td>
<td>A</td>
<td>A</td>
<td>A, T</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Radius of air cavity [mm]</td>
<td>2.0</td>
<td>2.0</td>
<td>4.8</td>
<td>3.0</td>
<td>3.0</td>
<td>2.0</td>
<td>2.0</td>
<td>1.2</td>
<td>2.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Aluminum collector present?</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Wall Thickness [mm]</td>
<td>1.0</td>
<td>1.1</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
<td>1.0</td>
<td>1.1</td>
<td>0.5</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Collecting Volume [cc]</td>
<td>0.056</td>
<td>0.056</td>
<td>0.500</td>
<td>0.650</td>
<td>0.250</td>
<td>0.009</td>
<td>0.009</td>
<td>0.007</td>
<td>0.125</td>
<td>0.622</td>
</tr>
</tbody>
</table>

"A" - denotes Air-Equivalent (AE) material (Shonka Conductive C552 plastic)
"T" - denotes Tissue-Equivalent (TE) material (Shonka Conductive A150 plastic)
"P" - denotes Polystyrene-Equivalent (PE) material (Shonka Conductive D400 plastic)

1 the prefix of the chamber’s model number (ie the “A” in the A12), refers to the material of the shell, guard and collector
2 while there is no aluminum collector present, there is a small silver-plated copper-clad steel wire which acts as the chamber’s collector (Ø 0.3mm x 1.3mm)

Relevant Articles: