SUBJECT: Parameters needed to calculate $N_{gas}$ (AAPM Protocol TG-21) or $N_D$ (IAEA Protocol TRS-277) for Exradin Thimble Ion Chambers

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

Parameters needed to calculate $N_{gas}$ (AAPM Protocol TG-21) or $N_D$ (IAEA Protocol TRS-277) for Exradin Thimble Ion Chambers

Please note the policy of the AAPM is that the local physicist is responsible for this calculation. This document is to review the essentials and to give parameters for Exradin chambers normally used in these protocols.

These protocols are based on the Spencer–Attix formulation of the Bragg–Gray relationship. For further details on any of the quantities discussed below, the protocols should be read. The dose to the medium (water) is determined from the dose to the gas in a calibrated ionization chamber. This involves the calculation of the quantity, $N_{gas}$ in TG-21\textsuperscript{1} or $N_D$ in TRS-277\textsuperscript{2}, equation below. Both of these involve the Air Kerma or exposure calibration coefficient, which needs to be obtained from a calibration laboratory, such as an ADCL traceable to NIST. The equations for each protocol are given below.

AAPM Protocol TG-21
For TG-21 and since the chambers listed here have buildup caps and walls of the same material, C552, the value of $N_{gas}$ is given by Equation 5 of the TG-21 protocol, given below.

$$N_{gas} = N_X \frac{k \left( \frac{W}{e} \right) A_{ion} A_{wall} \beta_{wall}}{ \left( \frac{L}{\rho} \right)_{wall} \left( \frac{\mu_{en}}{\rho} \right)_{air} \left( \frac{\rho_{en}}{\rho_{wall}} \right)_{gas} } \tag{1}$$

There were a number of updates\textsuperscript{3,4} to the quantities listed here and the primary standard became Air Kerma, which eliminated $k$, the conversion from roentgens to mass of air and $W/e$, the quotient of the average energy expended to produce an ion pair. Attix\textsuperscript{4} best summarizes this in his equation for the use of the Air Kerma calibration coefficient.

$$N_{gas} = N_K \left( 1 - g \right) \left( \frac{\mu_{en}}{\rho} \right)_{wall} \left( \frac{L}{\rho} \right)_{gas} A_{ion} A_{wall} \tag{2}$$
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where \( \left( \frac{L}{\rho} \right)_{\text{air}}^{m} \) is the restricted stopping power and \( \left( \frac{\mu_{\text{en}}}{\rho} \right)_{\text{air}}^{m} \) is the mass energy absorption coefficient. TG-21 uses these quantities individually whereas TRS-277 combines these into a factor, \( k_m \). In this case, ratios like \( \left( \frac{\mu_{\text{en}}}{\rho} \right)_{\text{wall}} \) represent the ratio of the energy absorption coefficients of the wall of the chamber to air; \( g \) for cobalt is 0.0032. \( A_{\text{ion}} \) is given in the calibration report as well as the value for \( N_K \). In addition, always remember to include the calibration coefficient for the electrometer when a measurement is made.

IAEA Protocol TRS-277

The equation in TRS-277 that is equivalent to Equation 2 above is

$$N_D = N_K'(1-g)k_{\text{att}}k_m$$

(3)

Notice here that \( N_K' \) includes the quantity \( A_{\text{ion}}=1/p_s \) which is generally assumed to be 1.000. Thus, the relation is

$$N_K' = N_KA_{\text{ion}}$$

(4)

Comparing Equations 2 and 3, note that \( k_{\text{att}}=A_{\text{wall}} \) and \( k_m \) is the product of the absorption coefficient ratios and the stopping power ratios. The value of \( k_m \) is given by the equation

$$k_m = \left( \frac{L}{\rho} \right)_{\text{air}}^{m} \left( \frac{\mu_{\text{en}}}{\rho} \right)_{\text{air}}^{m}$$

(5)

The values for the \( k_m \) and \( k_{\text{att}} \) (or \( A_{\text{wall}} \)) for the Exradin thimble chambers, as listed, are given in the table below. Since they are made from C552 material, \( k_m \) is 1.006 as found in Table XVII of TRS-277. The value of \( k_{\text{att}} \) or \( A_{\text{wall}} \) (TG-21) can be derived from the equation given in Med Phys 10: 741 (1983) and from information given in Reference 49 of TRS-277. This is determined by the construction of the thimble of the given chamber. For some small volume Exradin Thimble chambers, there is a need for extrapolation of values given. The extrapolation process results in a greater uncertainty in the value of \( k_{\text{att}} \). The function is linear up to the point of extrapolation so it is reasonable to do the extrapolation.
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<table>
<thead>
<tr>
<th>Model</th>
<th>$k_m$</th>
<th>$k_{att}$ or $A_{wall}$</th>
<th>$k_m k_{att}$</th>
</tr>
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<tbody>
<tr>
<td>Exradin A1SL</td>
<td>1.006</td>
<td>0.992</td>
<td>0.998</td>
</tr>
<tr>
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<td>Exradin A12</td>
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<tr>
<td>Exradin A19</td>
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<td>0.991</td>
<td>0.997</td>
</tr>
</tbody>
</table>

Therefore from the table above and the ADCL calibration report, where $N_K$ and $A_{ion}$ are given, the parameters for the calculation of $N_{gas}$ are available. Again do not forget to apply the multiplicative electrometer calibration coefficient (given in another ADCL calibration report) to the measurement value.

References: