Phantom-based Absorbed Dose ($D_w$) Determination in Low Energy kV X-Ray Beams

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PTB provides calibrations, $N_{D,W}(Q,a_0,d_0)$, of plane-parallel ionization chambers mounted on the surface of a rectangular PMMA phantom for therapy radiation qualities $Q$ ranging from 10 kV to 100 kV. Reference conditions are: SSD $a_0$=30 cm; Field size $d_0$=3 cm

The calibration factor depends on $a$ and $d$. A user needs to know the calibration factor at his conditions. This is achieved by the factor $k_g$:

$$N_{D,W}(Q,a,d) = N_{D,W}(Q,a_0,d_0)* k_g(Q,a,d)$$

In this work, $k_g(Q,a,d)$ was determined for two chamber types at $a = 30$ cm and $d = 3$ cm, 5 cm and 10 cm.
$D_w$ in low-energy kV x-ray beams

$Q$: radiation quality (10 kV- 100 kV)
$d$: field diameter
$a$: source surface distance (SSD)

$K_{\text{air}}(Q, d, a)$: measured with FAC
$(\mu_{\text{en}}/\rho)_{\text{w,air}}(Q, d, a)$: calculated
$B_w(Q, d, a)$: calculated

$$D_w(Q, d, a) = K_{\text{air}}(Q, d, a) \ (\mu_{\text{en}}/\rho)_{\text{w,air}}(Q, d, a) \ B_w(Q, d, a)$$
In-phantom calibration factor $N_{D,w}^P(Q, d, a)$

$Q$: radiation quality (10 kV- 100 kV)  
$d$: field diameter  
$a$: source surface distance (SSD)

$K_{\text{air}}(Q, d, a)$: measured with FAC  
$(\mu_{\text{en}}/\rho)_{w,\text{air}}(Q, d, a)$: calculated  
$B_w(Q, d, a)$: calculated  
$M_P(Q, d, a)$: chamber reading

$$D_w(Q, d, a) / M_P(Q, d, a) = K_{\text{air}}(Q, d, a) / M_P(Q, d, a) (\mu_{\text{en}}/\rho)_{w,\text{air}}(Q, d, a) B_w(Q, d, a)$$

$$N_{D,w}^P(Q, d, a) = N_{K}^P(Q, d, a) (\mu_{\text{en}}/\rho)_{w,\text{air}}(Q, d, a) B_w(Q, d, a)$$
Geometry correction $k_{g,\text{type}}^{P}(Q, d, a)$

Calibrations are performed at reference conditions: $d_0 = 3 \text{ cm}$; $a_0 = 30 \text{ cm}$

$$N_{D,w}^{P}(Q, d_0, a_0) = N_{K}^{P}(Q, d_0, a_0) \left(\mu_{\text{en}}/\rho\right)_{w,\text{air}}(Q, d_0, a_0) \ B_{w}(Q, d_0, a_0)$$

User needs $N_{D,w}^{P}(Q, d, a) = N_{D,w}^{P}(Q, d_0, a_0) \ast k_{g,\text{type}}^{P}(Q, d, a)$ for his chamber type.

$$k_{g,\text{type}}^{P}(Q, d, a) = \frac{N_{D,w}^{P}(Q,d,a)}{N_{D,w}^{P}(Q,d_0,a_0)} = \frac{N_{K}^{P}(Q,d,a)\ast(\mu_{\text{en}}/\rho)_{w,\text{air}}(Q,d,a)\ast B_{w}(Q,d,a)}{N_{K}^{P}(Q,d_0,a_0)\ast(\mu_{\text{en}}/\rho)_{w,\text{air}}(Q,d_0,a_0)\ast B_{w}(Q,d_0,a_0)}$$

$$k_{g,\text{type}}^{P}(Q, d, a) = \frac{N_{D,w}^{P}(Q,d,a)}{N_{D,w}^{P}(Q,d_0,a_0)} = \frac{N_{K}^{P}(Q,d,a)\ast B_{w}(Q,d,a)}{N_{K}^{P}(Q,d_0,a_0)\ast B_{w}(Q,d_0,a_0)}$$
Physical explanation of \( k_{g,\text{type}}^P(Q, d, a) \)

\[
\frac{B_w(Q,d,a)}{B_w(Q,d_0,a_0)} \quad \text{From calculations (Großwendt 1990, PMB 35, 9, 1233-1245)}
\]

\[
\frac{N_K^P(Q,d,a)}{N_K^P(Q,d_0,a_0)} \quad \text{From measurements at } a_0 \text{ and field sizes 3, 5 and 10 cm}
\]

Examined chamber types:
PTW M23342 (SN 592,2565,2878)
PTW M23344 (SN 1058, 1059)
Results for chamber type M23342
# Results for M23342 and M23344

> Table 1. Correction factors $k_g$ for PTW M23342 and M23344 at the distance $a=30$ cm and beam diameters $d=5$ cm and $10$ cm.

<table>
<thead>
<tr>
<th>Radiation Quality</th>
<th>Voltage kV</th>
<th>Filter mm Al</th>
<th>HVL mm Al</th>
<th>M23342 5 cm</th>
<th>M23342 10 cm</th>
<th>M23344 5 cm</th>
<th>M23344 10 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>TW 10</td>
<td>10</td>
<td>-</td>
<td>0.030</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>TW 15</td>
<td>15</td>
<td>0.05</td>
<td>0.071</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>TW 20</td>
<td>20</td>
<td>0.15</td>
<td>0.113</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.99</td>
</tr>
<tr>
<td>TW 30</td>
<td>30</td>
<td>0.5</td>
<td>0.359</td>
<td>0.99</td>
<td>0.98</td>
<td>0.99</td>
<td>0.98</td>
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<td>TW 40</td>
<td>40</td>
<td>0.8</td>
<td>0.741</td>
<td>0.98</td>
<td>0.97</td>
<td>0.98</td>
<td>0.96</td>
</tr>
<tr>
<td>TW 50</td>
<td>50</td>
<td>1.0</td>
<td>0.940</td>
<td>0.99</td>
<td>0.97</td>
<td>0.98</td>
<td>0.96</td>
</tr>
<tr>
<td>TW 70</td>
<td>70</td>
<td>4.0</td>
<td>2.94</td>
<td>0.97</td>
<td>0.93</td>
<td>0.96</td>
<td>0.92</td>
</tr>
<tr>
<td>TW100</td>
<td>100</td>
<td>4.5</td>
<td>4.41</td>
<td>0.97</td>
<td>0.94</td>
<td>0.96</td>
<td>0.93</td>
</tr>
</tbody>
</table>
Conclusions

- Corrections $k_g$ determined for PTW M23342 and M23344
- New values agree with those determined 30 years (!) ago
- Values can be explained by differences in the backscatter factors of water and PMMA
- Measurements will be extended to field sizes up to 20 cm
- Tabulated values will be provided in dosimetry protocols (e.g. IAEA TRS 398 updated, DIN 6809-4 revised 2019)
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