Updating the TG-51 protocol for reference dosimetry of high-energy electron beams

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Chamber calibrated in cobalt-60 ($N_{D,w}^{60\text{Co}}$)

For electron beams:

- measured gradient correction for cylindrical chambers
- cross-calibration for parallel-plate chambers
- parallel-plate chambers recommended $E_0 < 10$ MeV

Complicated procedures can lead to misinterpretation or errors
Why update TG-51?

Might be possible to simplify procedure

$k_Q$ based on semi-analytic approach, new data available

Evaluate choice of chamber type with new evidence

Focus on uncertainties
AAPM working group – Review and extension of the TG-51 protocol
WGTG51 – working group charge

Charge The primary goal of the working group is to review experimental and calculated data sets of beam quality conversion factors. At a later stage a consensus dataset can be generated that (1) when justified, supersedes the TG-51 dataset and (2) provides realistic uncertainty estimates on the consensus values. The WG will thus present a review of measured and calculated kQ data as well as a clarification document for TG-51 that contains tables of kQ for chambers currently not listed in the protocol. We also intend to review different calibration issues. The function of the WG is thus primarily to produce a review on the basis of which recommendations can be formulated, if needed, by a new TG aiming to provide a consistent update of TG-51.
State-of-the-art measurements of $k_Q$

Start with definition

$$D_w^Q = MN_{D,w}^Q = M k_Q N_{D,w}^{60_{Co}}$$

With primary standard for $D_w$

$$k_Q = \frac{N_{D,w}^Q}{N_{D,w}^{60_{Co}}}$$
State-of-the-art measurements of $k_Q$
State-of-the-art calculations of $k_Q$

Start with definition

$$D_w^Q = MN^Q_{D,w} = M k_Q N^{60}_{D,w}$$

Expression for $D_{air} = \frac{M}{m_{air}} \left( \frac{W}{e} \right)_{air}$

$$k_Q = \frac{\left[ \frac{D_w}{D_{air}} \right]^Q}{\left[ \frac{D_w}{D_{air}} \right]^{60} C_0}$$

Quantities can be calculated with Monte Carlo simulations.
State-of-the-art calculations of $k_Q$
State-of-the-art determination of $k_Q$

Measured

$$k_Q = \frac{N^Q_{D,w}}{N^{Co}_{D,w}}$$

Monte Carlo

$$k_Q = \frac{\left[ \frac{D_w}{D_{air}} \right]^Q}{\left[ \frac{D_w}{D_{air}} \right]^{60}C_0}$$

Both approaches include all corrections by definition
More accurate, updated data
Why not use cylindrical chambers for all beams?

So, are corrections really more variable for cylindrical chambers?

Revisit older experiments with focus on variability

Corrections are not more variable using cylindrical chambers

Variability at +/- 0.4 %, no worse than plane-parallel chambers

Simplify using cylindrical chambers in all beams with generic $k_Q$

Updated state-of-the-art $k_Q$ factors from the literature

Simplified procedure:

- Use of cylindrical reference-class chambers (all beams)
- Acceptable results using $k_Q$ (without $P_{gr}$)
- Possible to use calibrated parallel-plate chambers
Wrapping up - what will be the impact?

Investigation at NRC performing measurements both ways in 4 MeV – 22 MeV beams

Six commonly used chambers
- PTW 30013
- NE2571
- Exradin A1SL
- IBA CC13
- PTW Roos
- Scanditronix NACP-02

Better consistency among chambers with updated approach (1.0% → 0.4%)

Better agreement with primary standard measurements (2.5% → 0.5-1.0%)
TG-51 $P_{gr}$ gives scattered results (same with EPOM shift of $0.5*r_{cav}$)
Small shift for $P_{gr}$ reduces scatter.
Can we avoid use of $P_{gr}$?

This is getting small (0.6 mm)

What if we take $\lim f \to 0$?

That is, let MC $k_Q$ take care of $P_{gr}$

$P_{gr}^Q = \frac{D_{ch}(d_{ref} + f^* r_{cav})}{D_{ch}(d_{ref})}$
Can we avoid use of $P_{gr}$?

$f = 0$
MC calculated
$k_Q$ includes gradient correction