# Primary Calibration of Coiled $^{103}$Pd Brachytherapy Sources

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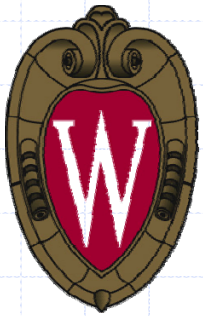

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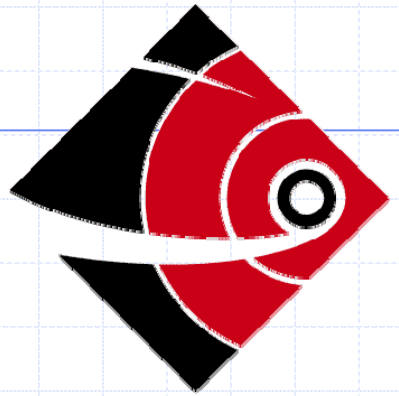


Medical Radiation Research Center

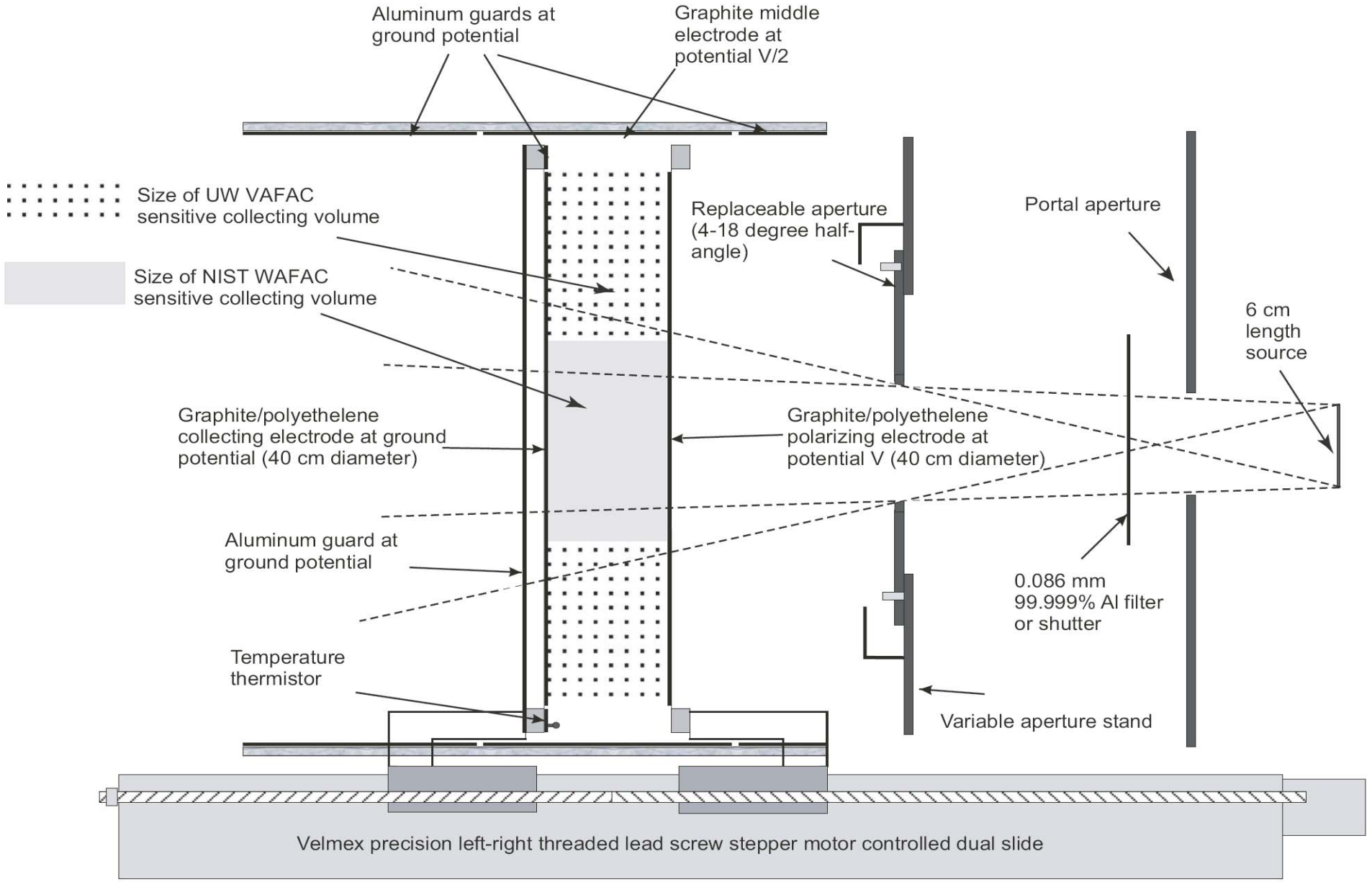
# Coiled $^{103}$Pd Sources

- Developed to be used as permanent prostate implants by RadioMed Corp.
- 0.2mm x 0.05mm rhodium wires activated in a cyclotron to produce $^{103}$Pd
- Activated wire then wound into coils
- Coils cut into integer lengths from 1 to 6cm
- Alleviate the same issues as stranded source while requiring less construction time

# Low Energy Air Kerma Strength ($S_K$) Standard

- National Institute of Standards and Technology Wide-Angle Free-Air Chamber (NIST WAFAC)
- Due to the size of the NIST WAFAC, it is unable to determine $S_K$ of sources longer than 1cm
- University of Wisconsin Variable-Aperture Free-Air Chamber (UW VAFAC) is larger than the NIST WAFAC and does not have the same geometric limitations

# UW VAFAC


Aluminum guards at ground potential
Graphite middle electrode at potential V/2
Size of UW VAFAC sensitive collecting volume
Size of NIST WAFAC sensitive collecting volume
Replaceable aperture (4-18 degree half-angle)
Portal aperture
6 cm length source
Graphite/polyethelene collecting electrode at ground potential (40 cm diameter)
Graphite/polyethelene polarizing electrode at potential V (40 cm diameter)
Aluminum guard at ground potential
0.086 mm 99.999% Al filter or shutter
Temperature thermistor
Variable aperture stand
Velmex precision left-right threaded lead screw stepper motor controlled dual slide

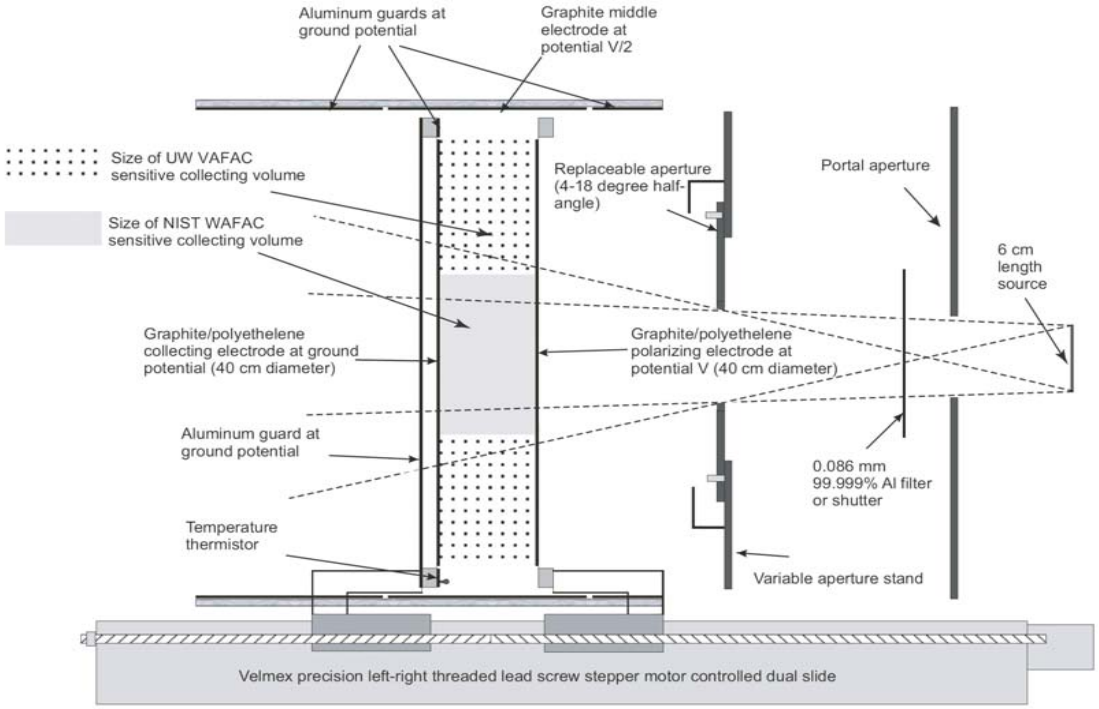
# Measurements with the UW VAFAC

$$S_K = (\overline{W}/e)\frac{d^2}{\rho_{air} A_{eff} (1-g_{air})}\left(\frac{dI_{net}}{ds}\right)\prod k_i$$

- Source is held in place 30cm from the primary aperture and rotated
- Aluminum filter to remove low energy photons

Ionization current measurements taken at 5 electrode separations

Background and leakage measurements taken at each electrode separation



# Measurement of 1cm Coils

- A 1cm coil was measured on both the NIST WAFAC and the UW VAFAC
- Two additional 1cm coils were measured with a UW ADCL well chamber (traceable to NIST WAFAC) and the UW VAFAC

| Coil Reference Date | VAFAC $S_K$ (U) | WAFAC $S_K$ (U) | % difference (WAFAC - VAFAC) | Well Chamber $S_K$ (U) | % difference (Well - VAFAC) |
|---|---|---|---|---|---|
| 12/14/2005 | 2.567 | N/A | N/A | 2.564 | -0.1 |
| 12/14/2005 | 2.541 | N/A | N/A | 2.564 | +0.9 |
| 2/2/2006 | 1.443 | 1.430 | -0.9 | 1.437 | -0.4 |

All UW VAFAC $S_K$ values differ by less than 1% from NIST or NIST-traceable values

# Correction Factors

$$S_K = (\overline{W}/e)\frac{d^2}{\rho_{air} A_{eff}(1-g_{air})}\left(\frac{dI_{net}}{ds}\right)\prod k_i$$

- Both the NIST WAFAC and the UW VAFAC apply corrections factors to the raw measurements that account for attenuation, scatter, source holder effects, aperture effects, etc.
- For traditional sources both Monte Carlo and analytical methods are used assuming a point source
- Point source assumption no longer valid with elongated coiled sources and geometry-dependent corrections must be updated

# Correction Factors for Linear Sources

- MCNP5 transport code used to determine the updated correction factor values for each source length
- All statistical uncertainties on the calculations were less than 0.1% (k=1)
- A new geometry correction factor, $k_{geo}$, is introduced with the coiled sources which accounts for the sources not appearing as point sources to the UW VAFAC at the 30cm measurement distance

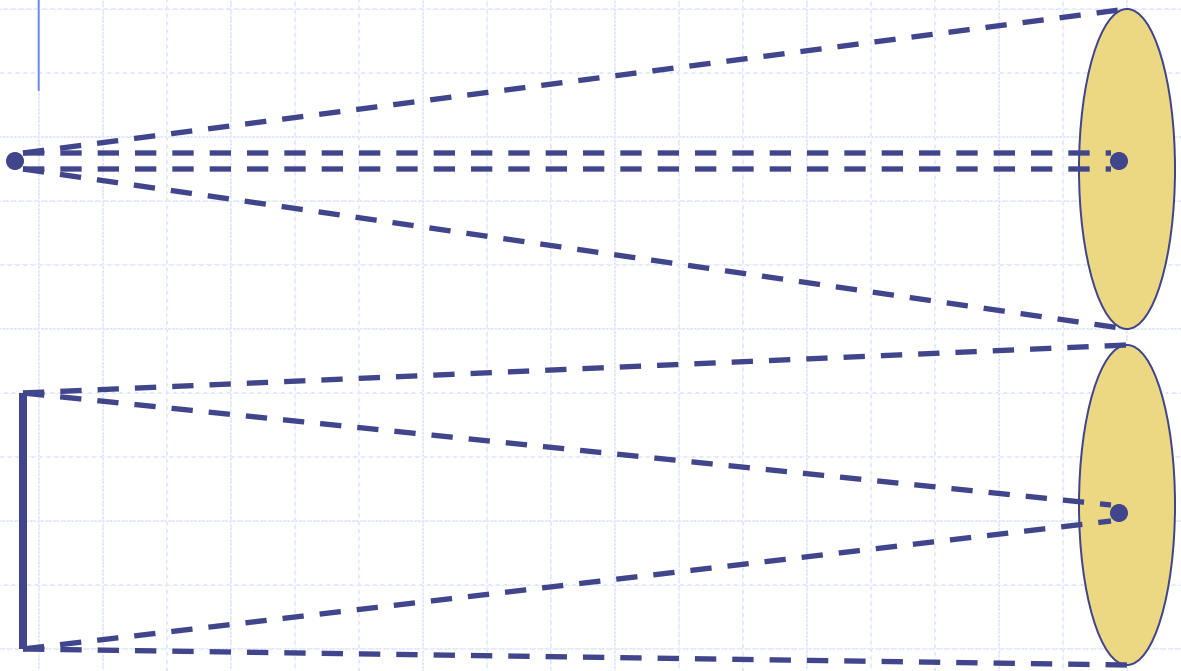
# Geometry Correction ($k_{geo}$)

$$G_P(r,\theta) = \frac{1}{r^2}$$

$$G_L(r,\theta) = \frac{\beta}{Lr\sin(\theta)}$$

$$k_{geo} = \frac{G_P(30cm,90^\circ)}{G_L(30cm,90^\circ)}$$

... if the UW VAFAC were an ideal point detector



Chose to use MCNP5

Ratio of fluence from a point source and fluence from a line source across the aperture plane (F2 tallies)

# Measurement of 3 and 6cm Sources

- Three 3cm coils were measured with the UW VAFAC
- Pairs of 3cm stacked to make 6cm sources and then measured with the UW VAFAC
- 3cm and 6cm sources measured in Standard Imaging (SI) IVB 1000 well chamber and calibration coefficients were determined

# Measurement of 3 and 6cm Sources

- Comparing the point- and line-corrected values

| Length | Coil ID | Point-corrected $S_K$ (U) | Line-corrected $S_K$ (U) | Point-corrected Avg U / cm | Line-corrected Avg U / cm |
|---|---|---|---|---|---|
| 3 cm: | A | 4.588 | 4.595 | 1.532 | 1.534 |
| | B | 4.562 | 4.569 | | |
| | C | 4.635 | 4.641 | | |
| 6 cm: | A+B | 9.148 | 9.179 | 1.529 | 1.535 |
| | B+C | 9.200 | 9.231 | | |
| | C+A | 9.180 | 9.211 | | |
| | | | % difference (3cm-6cm): | +0.16 | -0.03 |

Better agreement when line-source corrections are applied

# Measurement of 3 and 6cm Sources

- SI IVB 1000 calibration coefficients with point and line source corrections

| Length (cm) | Point-corrected Cal. Coeff. (U/pA) | Line-corrected Cal. Coeff. (U/pA) |
|---|---|---|
| 3 | 1.020 | 1.021 |
| 6 | 1.016 | 1.020 |

Again the reduction in the difference shows the removal of the source length dependence when the line-source correction factors are applied

# Conclusions

- The UW VAFAC shows excellent agreement with the NIST WAFAC for 1cm coils
- Correction factors have been determined that remove the source-length dependence from measurements of longer coiled sources
- Experimentally validates the calibration methods proposed by DeWerd *et al.*[1] and Meigooni *et al.*[2]
- First primary measurement of coiled source longer than 1cm has been completed, and now these techniques and corrections can be extended to any future elongated or stranded low-energy LDR brachytherapy sources up to 7cm

[1] L.A. DeWerd *et al.* "Calibration of multiple LDR brachytherapy sources," Med. Phys. **33**, 3804-3813 (2006).
[2] A.S. Meigooni *et al.* "Feasibility of calibrating elongated brachytherapy sources using a well-type ionization chamber," Med Phys. **33**, 4184-4189 (2006).

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