Absorbed Dose Standards for Brachytherapy

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HDR ^{192}Ir Brachytherapy Dosimetry

NIST/ADCL

- Provides chamber calibration factor

Calibrated well type chamber

- Allows measurement of S_K

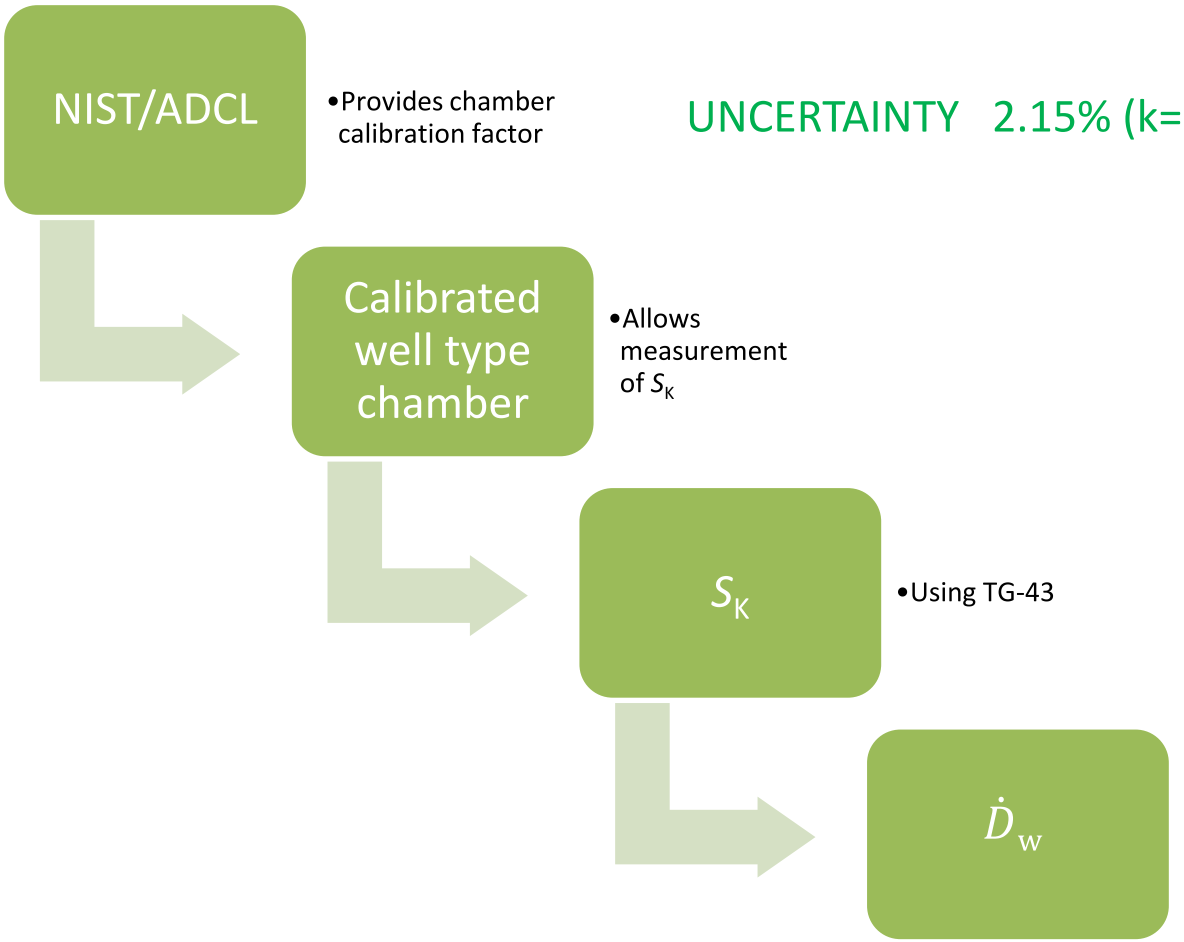
S_K

- Using TG-43

$\dot{D}_w$

HDR ^{192}Ir Brachytherapy Dosimetry

UNCERTAINTY 2.15% (k=2)



Stump et al., Med. Phys. 29 (2002)

Primary absorbed dose standards

- Calorimetry
  - Water
  - Graphite
- Ferrous Sulphate-based (Fricke)
- Ionization chamber based

Water Calorimetry

- Rational for absorbed dose to water calibration:
  - It is the quantity we like in the first place
  - Spectral effects that affect S_K affect $\dot{D}(r_\mathrm{o}, \theta_\mathrm{o})$ much less

Water Calorimetry

- Measuring dose to water directly at a point based on

$$D_w = c_w \cdot \Delta T$$

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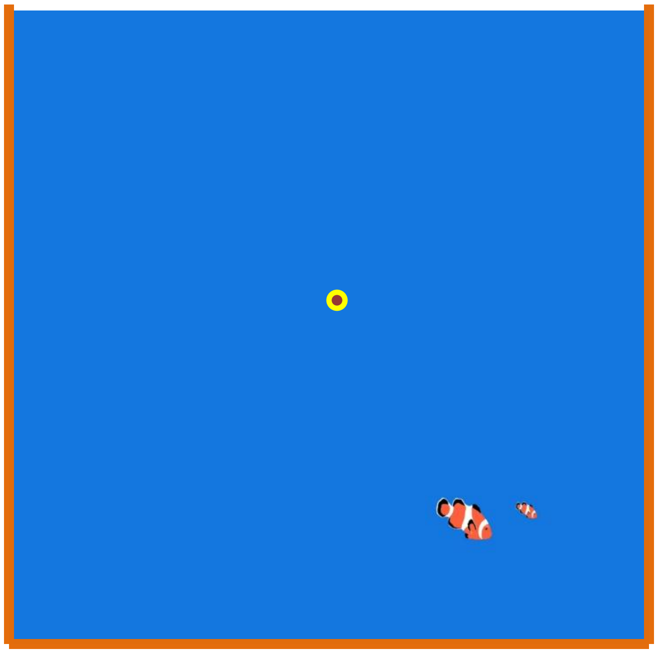

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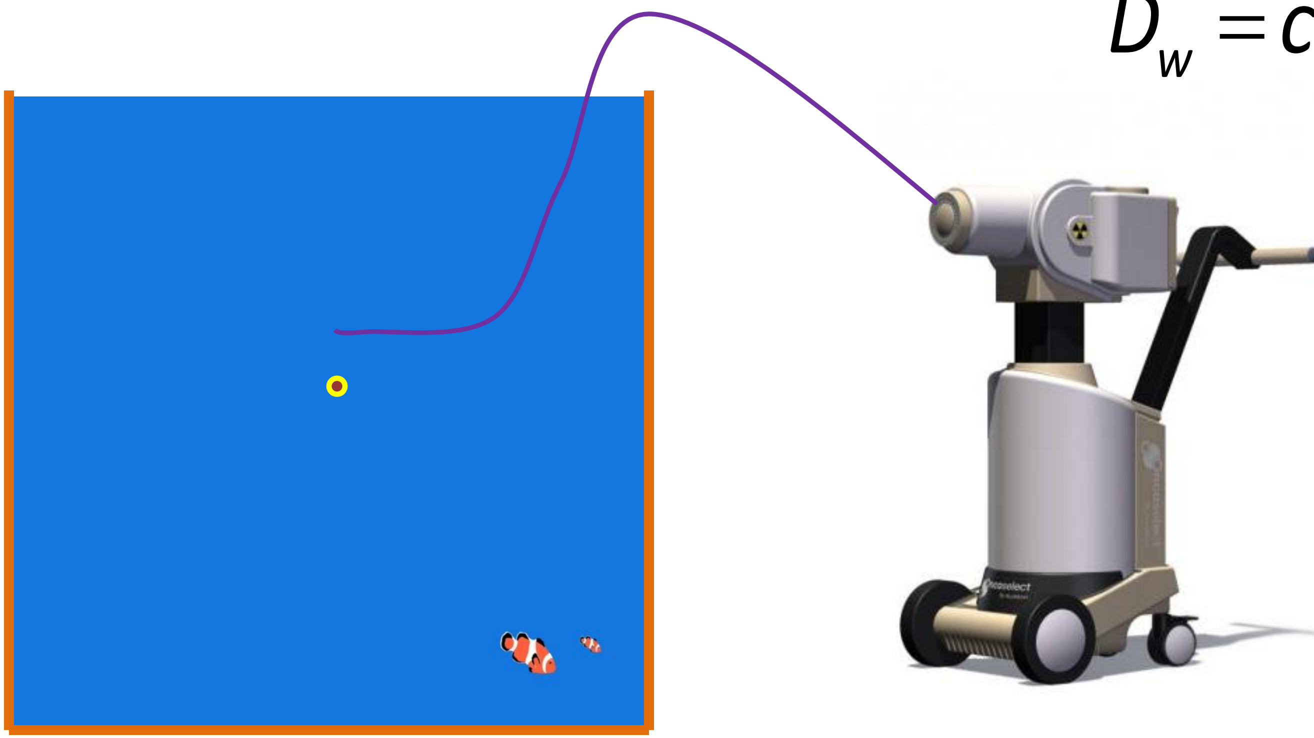

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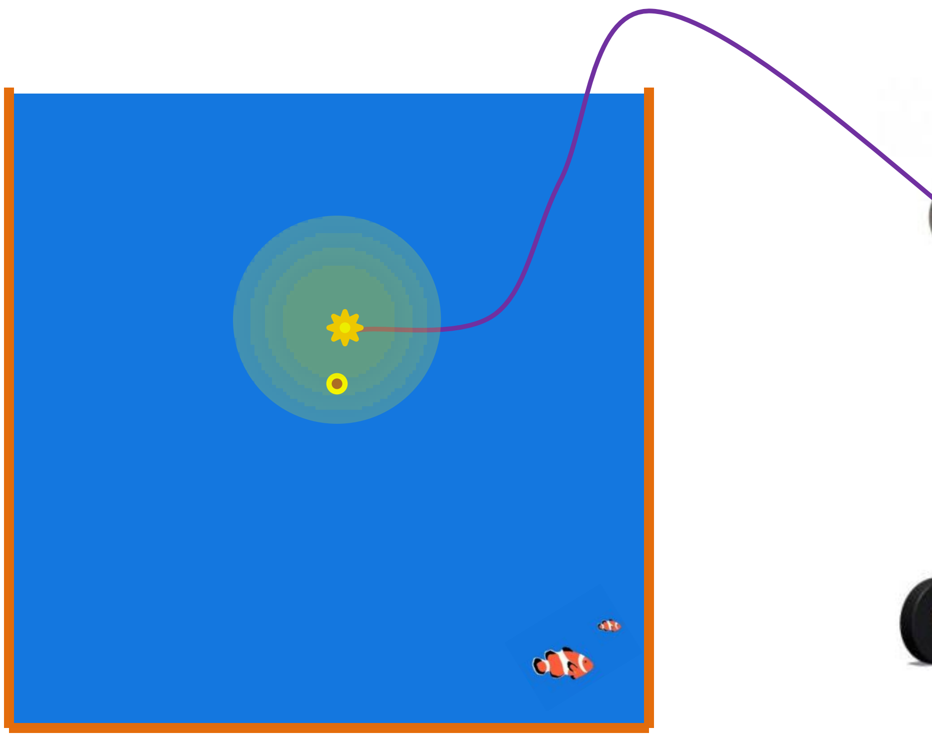

Not as easy as a fish tank

- 0.23 mK per each Gy of absorbed dose
- Large source self-heating
- Sharp dose gradient

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TOO CLOSE

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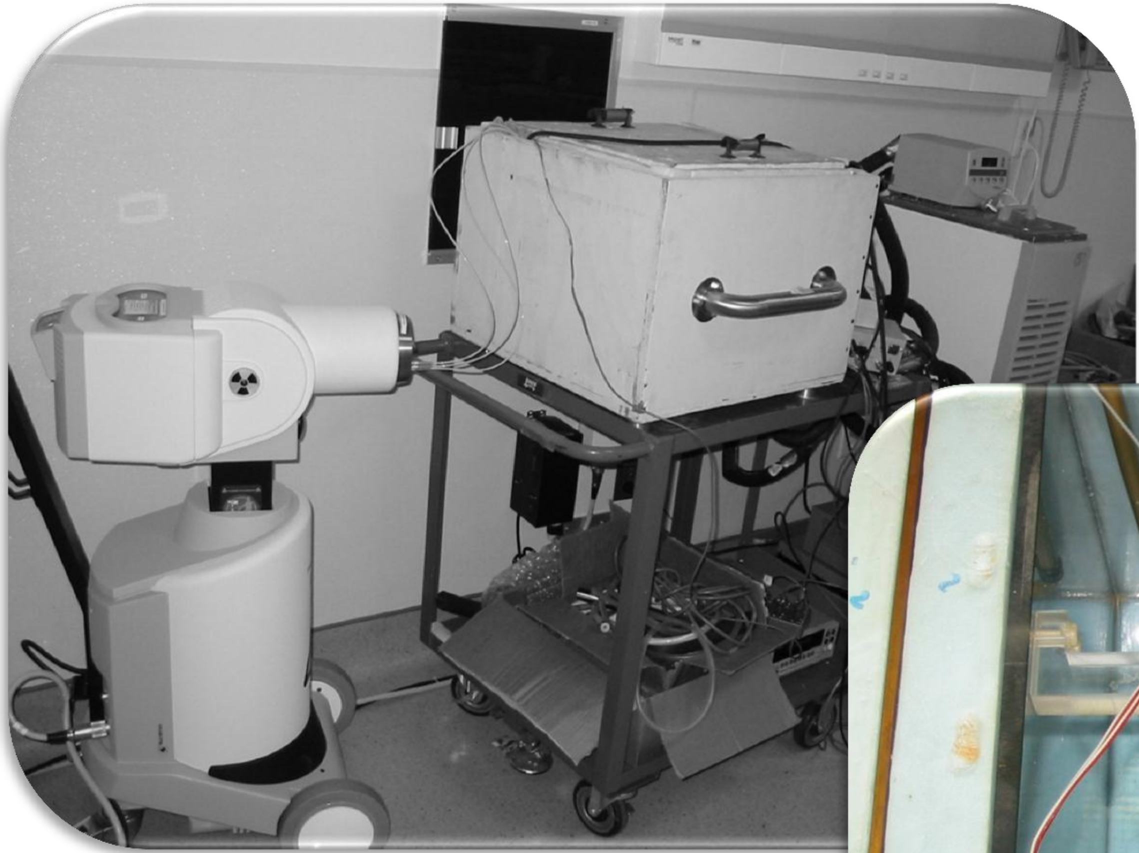
TOO CLOSE

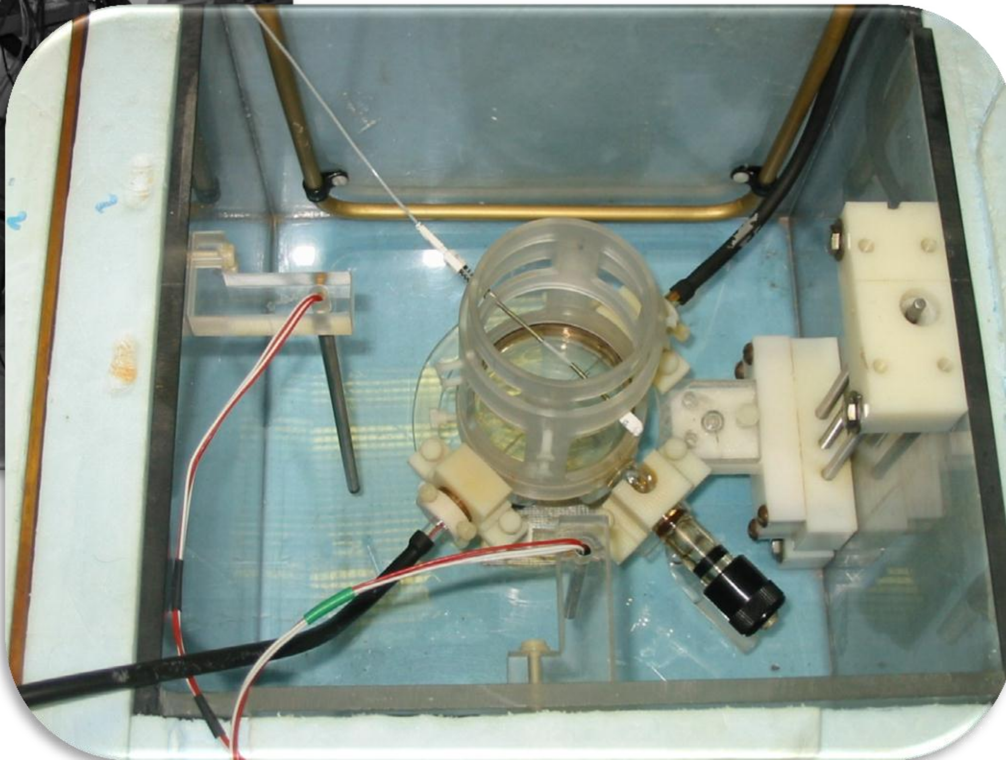
TOO FAR

Water Calorimetry

Sarfehnia et al, Med. Phys. 34 (2007)
Sarfehnia and Seuntjens, Med. Phys. 37 (2010)

Water Calorimetry

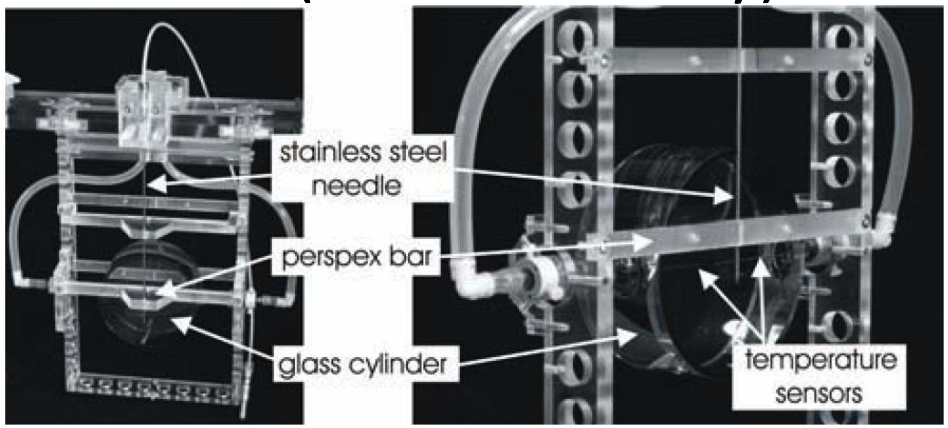




Sarfehnia et al, Med. Phys. 34 (2007)
Sarfehnia and Seuntjens, Med. Phys. 37 (2010)

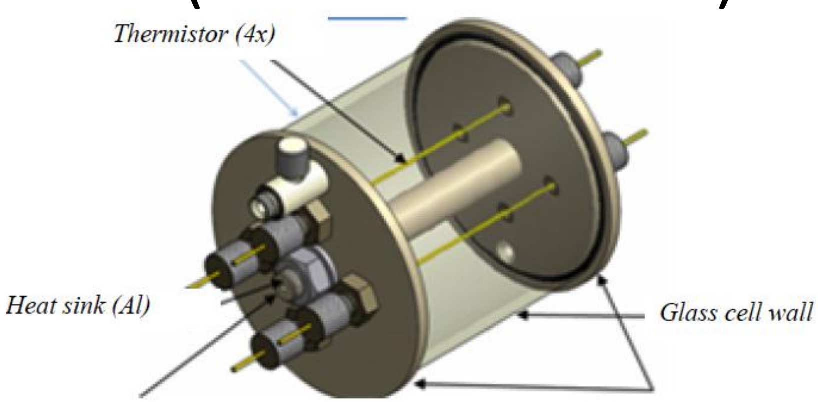
Other Setups

PTB (PSDL Germany)



Bambynek et al. World Congress on Medical Physics and Biomedical Engineering, September 7 - 12, 2009, Munich, Germany, IFMBE Proceedings Volume 1, 2009, pp 89-92

VSL (PSDL Netherland)



Uncertainty Budget

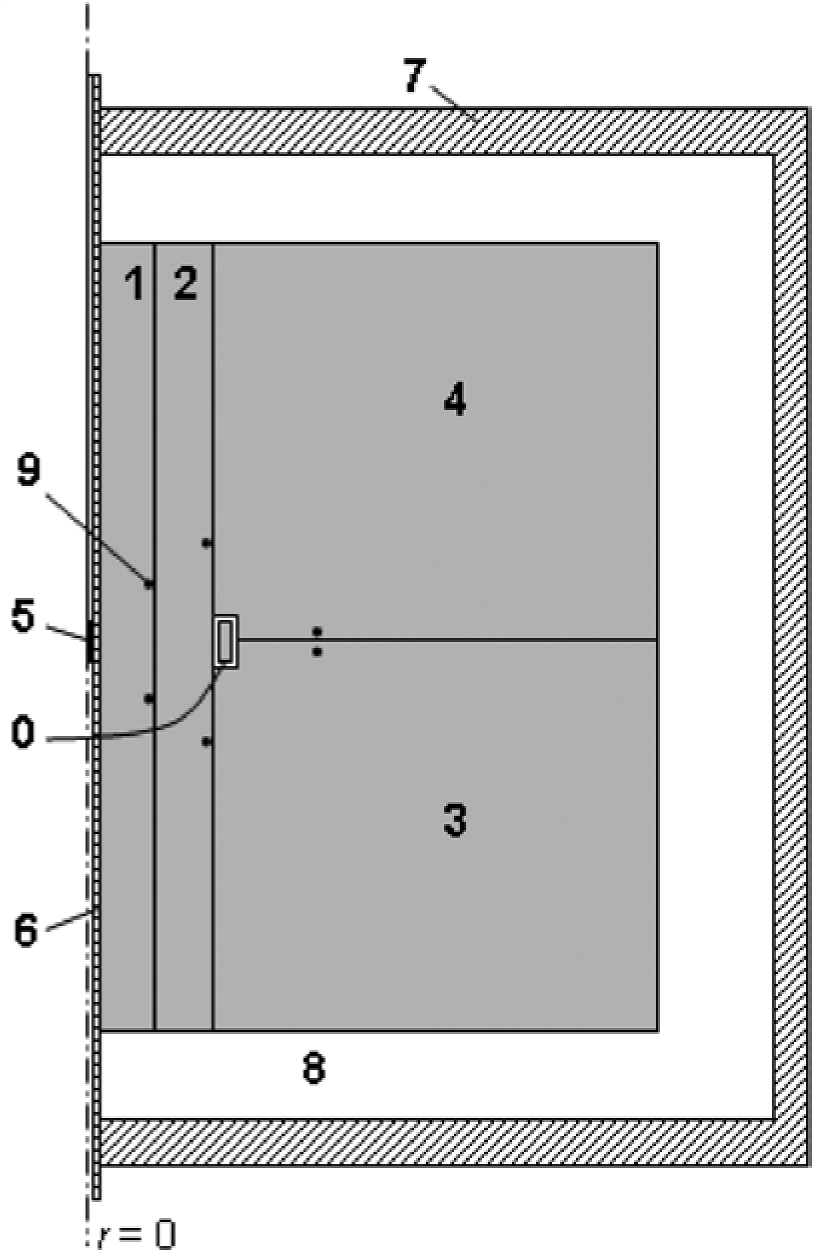
TABLE I. The uncertainty budget for ^{192}Ir water calorimetry.

Uncertainty	Type A (%)	Type B (%)
Std error on the mean (meas.)	0.43	
c_w		0.03
Absolute temperature		0.01
$(\Delta R/R)/\Delta V$ calibration		0.04
Thermistor calibration (β)		0.1
k_ρ		0.05
k_{hd}		0.3
k_p		0.1
k_{ht}		
Conv. model (physical data)		0.35
Simulation data		0.05
Interval extrapolation		0.01
Vessel dimension		0.02
k_{dd}		0.45
Source-vessel separation		0.85
Probe position wrt vessel		0.03
Dwell time		0.01
Dummy/real source position		0.00
Predrift linearization		1.5
Total uncertainty (1σ) (%)	**1.90**	

Sarfehnia and Seuntjens, Med. Phys. 37 (2010)

Graphite Calorimetry

- Rational for Graphite Calorimetry?
  - 6X the signal for the same dose
  - BUT, need to convert from dose to graphite to dose to water



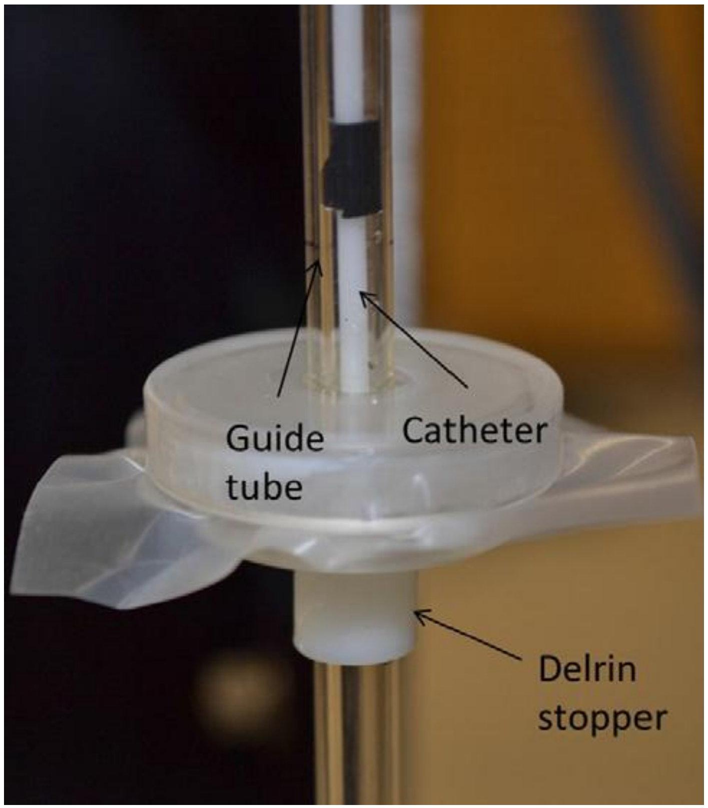
Sander *et al*, Metrologia 49 (2012)

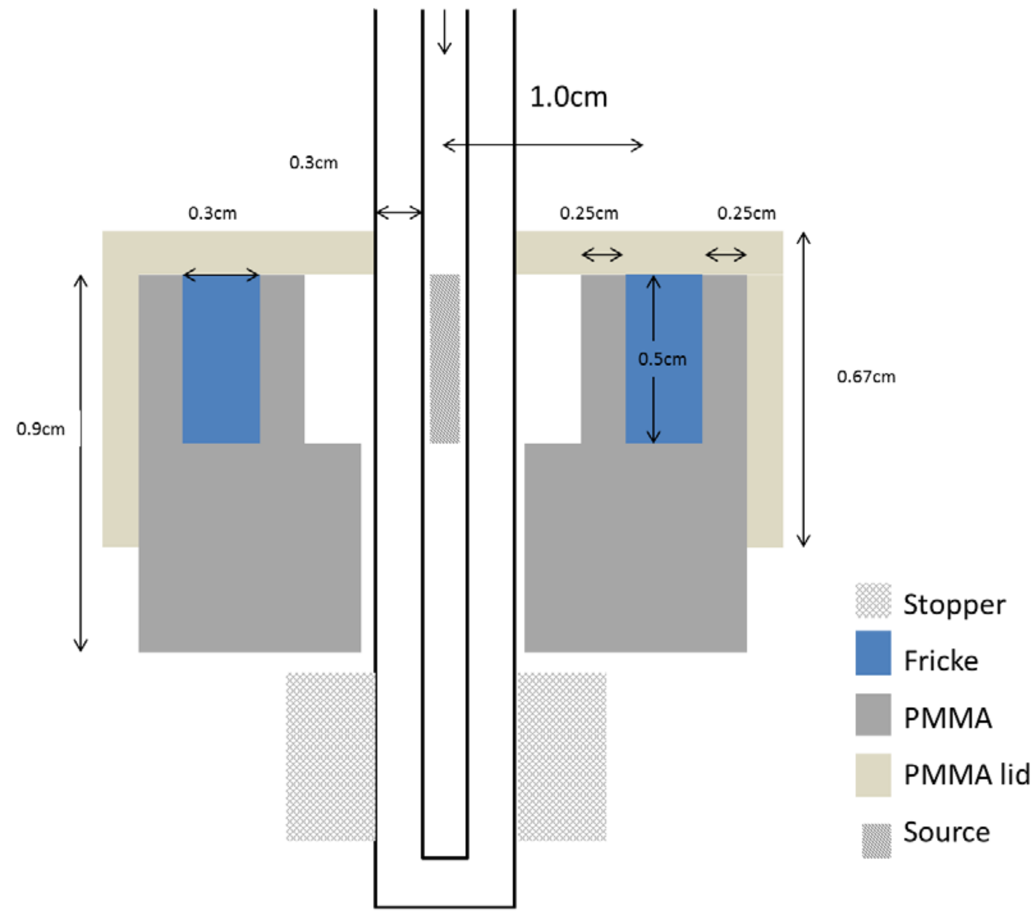
Fricke Dosimetry

- Theory:

$$[Fe^{+2}] \xrightarrow{\gamma} [Fe^{+3}]$$

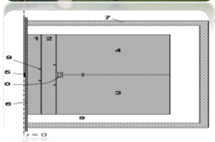
- So, as long as you know the relationship describing number of Fe^{+3} / 100eV (i.e. chemical yield)
- Rational: Not sensitive to source self-heating

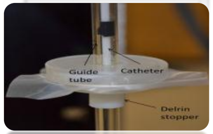


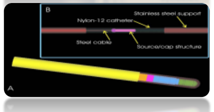


El Gamal *et al*, Phys. Med. Biol. 60 (2015)

Uncertainties

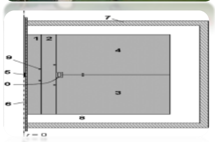
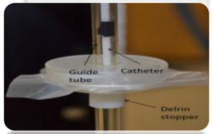


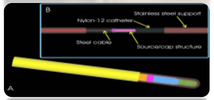
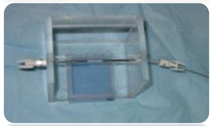




TECHNIQUE	2-sigma Uncertainty
Water Calorimetry	3.8 % (<2 % feasible)
Graphite Calorimetry	1.4 %
Fricke	1.8 %
Ion Chamber	2.9 %

Uncertainties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Water Calorimetry	3.8 % (<2 % feasible)
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Fricke	1.8 %
Ion Chamber	2.9 %
Gafchromic Film	3.5 %
TG-43	**4-5 %**

Conclusion

- Calorimetry, Fricke and Ionization based absorbed dose standards in HDR Ir-192 brachytherapy are feasible.
- Hopefully, once refined, these techniques will be brought to a standard lab near you
- The uncertainty on dose measurements may be improved in brachytherapy based on absorbed dose primary standards.