Air-kerma strength determination for the BEBIG GmbH model Ir2.A85-2 ¹⁹²Ir source

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Overview

Introduction

- Seven-distance method
- Seven-distance algorithm
- Measurement Results
 - Air-kerma strength (S_{K}) measurements
 - Radiochromic film exposures
- Seven-distance sensitivity study
 - Variable offset model
 - Simulation results
 - Conclusion





Project description

- Introduction
- Measurement Results
- Sensitivity study
- Conclusion

To perform an air-kerma strength (S_{K}) investigation of the BEBIG GmbH model Ir2.A85-2 ¹⁹²Ir brachytherapy source:

- Measure S_{K} using the seven-distance technique
- Compare measured S_K against:
 - Standard transfer well chambers at the UWADCL
 - Source strength reported from Mallinckrodt Medical (Westerduinweg, Germany)
 - Reference air-kerma rate (RAKR) reported from PTB (Berlin, Germany)







Introduction to the seven-distance method

- Initially proposed by Goetsch to determine S_K of a Classic Nucletron source¹
 - U.S. interim standard for ¹⁹²Ir source calibration²
 - NIST-traceability established through inverse interpolation of air-kerma calibration coefficients³



Introduction

Seven-distance method

Measurement Results Sensitivity study Conclusion



- S. Goetsch et al. Medical Physics, 18(3):462-467, 1991
- 2. AAPM, internal document, Appendix A5, 2006
- 3. E. Hing and D. Rogers, *Medical Physics*, 33(9), 3340-3347
- 4. L. DeWerd et al. Dept. of Medical Physics, University of Wisconsin, 1990



Introduction to the seven-distance method

- Initially proposed by Goetsch to determine S_K of a Classic Nucletron source¹
 - Linearly spaced measurements from source
 - Room scatter and distance offsets
 assumed constant
 - S_K calculated from system of nonlinear equations⁴



- 1. S. Goetsch et al. Medical Physics, 18(3):462-467, 1991
- 2. AAPM, internal document, Appendix A5, 2006
- 3. E. Hing and D. Rogers, *Medical Physics*, 33(9), 3340-3347
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Introduction

Seven-distance method

Measurement Results

Sensitivity study Conclusion



Comparison of S_K results

- S_K measurement type A uncertainties:
 - 0.18% Seven-distance
 - 0.09% Well chambers
- 0.13%-0.30% difference at the 95% confidence level (Welch's T-test, p<0.0001)



Introduction

Measurement Results • S_κ measurements

Sensitivity study Conclusion

	$S_{\bf k}~({ m Gym^2hr^{-1}})$	Uncertainty $(\%)$	$\%\Delta$ from Seven-Distance
Seven Distance	4.674×10^{-2}	2.7	_
UWADCL Well Chamber	4.664×10^{-2}	2.8	-0.21
PTB source certificate	4.687×10^{-2}	2.5	+0.28
Mallinckrodt source certificate	4.637×10^{-2}	3.3	-0.79





Comparison of S_K results

- Introduction
- Measurement Results
- S_K measurements
- Sensitivity study
- Conclusion

- Table uncertainties reported at 95% confidence level
- Agreement within 0.3% of the RAKR reported by PTB
- All values of S_K agreed within 1%



	$S_{\bf k}\;({\rm Gym^2hr^{-1}})$	Uncertainty $(\%)$	$\%\Delta$ from Seven-Distance
Seven Distance	4.674×10^{-2}	2.7	-
UWADCL Well Chamber	4.664×10^{-2}	2.8	-0.21
PTB source certificate	4.687×10^{-2}	2.5	+0.28
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Radiochromic film exposures

- Introduction
 Mossurement
 - Measurement Results
 - Radiochromic film exposures
 - Sensitivity study
 - Conclusion

- Autoradiographs acquired on Ashland Gafchromic EBT3 film
- Film exposed at depths of 1, 3 and 5 cm in Virtual Water[™] (Med-Cal, Verona, WI)
 - 2 Gy exposures
- Scanning methods and image analysis based on methods of McCaw et al.¹ and Riley et al.²







T McCaw *et al. Medical Physics*, 38(10), 5771-5777, 2011
 A. Riley *et al. Medical Physics*, 40(7), 71732-1-71732-5, 2013

Seven-distance sensitivity study

- Introduction
- Measurement Results
- Sensitivity study
- Conclusion
- Original algorithm assumes constant offsets for all nominal measurements
- Distance offset integrates uncertainties in:
 - Kondo-Randolph factors
 - Effective point of measurement
 - Physical reproducibility of the measurement
- Aim of this study:
 - Characterized various offset behaviors
 - Investigate their aggregated behavior on S_K









Conclusion

- Introduction
- Measurement Results
- Sensitivity study
- Conclusion

Seven distance

- 0.13%-0.30% (k=2) difference from standard well chambers
- Current consensus standard at UWADCL is valid for the BEBIG GmbH model Ir2.A85-2 ¹⁹²Ir source
- Good agreement (<1%) among Mallinkcrodt Medical and PTB

Sensitivity study

- Seven-distance algorithm over predicted S_K by 0.24% due to variable distance offsets
- Uncertainty budget does not need to be expanded



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