Investigation of Low and Medium Energy X-Ray Calibrations for Survey Meters

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INTRODUCTION

- In 2005, additional security controls and regulations were implemented by the United States Nuclear Regulatory Commission (NRC) in order to prevent the misuse of radioactive materials[1].
- Radiation Survey Meters (RSMs) are calibrated at Accredited Dosimetry Calibration Laboratories (ADCLs) using a ^{137}Cs source, with a monoenergic photon energy of 662 keV .
- RSM calibrations are performed using a ^{137}Cs source and varying shielding and distance from the source [2]:
  - Irradiations are performed at each individual operating range of the RSM, specifically at the 50% point.
  - Adjustments are made to each individual operating range potentiometer if results are different than the 50% value.
  - 20% and 80% values of each operating range exposures are conducted to ensure that deviation from the given value does not exceed 5% [3].
- Additionally, New York City passed a law in 2019 that requires RSM calibrations for electronic brachytherapy sources at the source energy, 50 kVp.
- The work investigates the feasibility of using currently available NIST traceable low and medium energy x-ray beam qualities as a surrogate for ^{137}Cs to calibrate RSMs.

METHODS

X-Ray Beams

- COMET MXR-320/26 – kV range (0-320 kV), mA range (0.1-30 mA)
- 9 Moderately Filtered NIST Traceable Beam Qualities (Table 1)

RSMs

- 2 Ionization Type Survey Meters
  - Fluke 451B (Air-Communicating) – Operating Range (0.1 mR/hr – 50 R/hr)
  - Fluke 451P (Pressurized) – Operating Range (0.1 mR/hr – 5 R/hr)
- 1 Geiger Mueller Type Survey Meter
  - Ludlem 14C – Operating Range (0.1 mR/hr – 2 R/hr)

Exposure Rate Calculations

- Air-kerma-rates associated with each beam quality in Table 1 were measured at the UW-ADCL
- Exposure rates were scaled by the inverse square law and the linear relationship between input tube current and air-kerma-rate:

$$X = X_{ref}\frac{Current_{meas}}{Current_{ref}}$$

Beam Quality	Effective Energy (keV)	Tube Current (mA)	Air Kerma, 1m (mGy/sec)	Exposure, 1m (R/hr)	Exposure, 2m, 0.1 mA (R/hr)
UW40-M	19.8	20	1.32	540	0.68
UW50-M	22.4	25	2.02	830	0.83
UW60-M	26.9	25	1.80	738	0.74
UW80-M	33.5	25	1.82	748	0.75
UW100-M	42.1	25	1.82	748	0.75
UW120-M	49.9	25	2.37	971	0.97
UW150-M	67.0	20	2.17	893	1.12
UW200-M	99.8	15	1.93	793	1.32
UW250-M	145	12	1.63	671	1.40

Table 1. NIST Traceable Beam Qualities and Associated UW-ADCL Measured Air-Kerma-Rates

Monitor Chamber Measurements

- Monitor chamber measurements were taken for each beam quality input voltage and corrected for tube output versus the linear relationship between tube current and air-kerma-rate.
- Exposures were done with each RSM at an input tube current of 0.1 and 0.5 mA to investigate the energy response from 19.8 to 145 keV.

RESULTS

- Monitor chamber measurements showed a 25% increase in tube output at 40 kV and 0.1 mA inputs and a 38% decrease at 250 kV and 0.1 mA (Figure 1)
- Correction factors for tube output were applied to calculated exposure rates in Table 1 and an energy response plot was tabulated for each RSM at 0.1 and 0.5 mA tube current inputs (Figure 2).

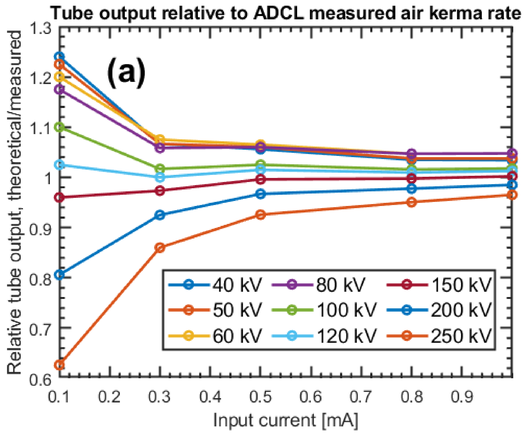

Figure 1. Correction factors associated with each beam quality to correct for actual tube output

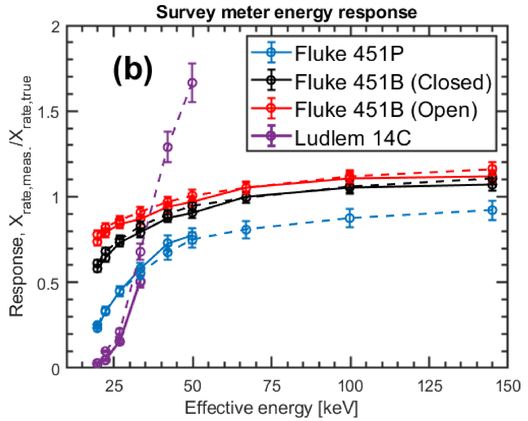

Figure 2. Energy response plots for each RSM with corrected exposure rates

CONCLUSIONS

- Further Monte Carlo work should be done to simulate 320 kV beam qualities with additional filtration to see if the air-kerma-rates can be lowered to meet all RSM operating ranges.
- Additional physical measurements will be required to validate that any beam quality with a 320 kV x-ray tube could overcome the energy dependence of Geiger Mueller type RSMs.

ACKNOWLEDGEMENTS

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REFERENCES

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