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

Sean Jollota[1], Nicholas Nelson[1], Larry DeWerd[1]

[1]Department of Medical Physics, University of Wisconsin, Madison, WI, 53718

Purpose: Recent policy changes by the Nuclear Regulatory Commission (NRC) have encouraged the replacement of Cs-137 irradiators with X-ray irradiators. Considering Cs-137 is used for exposure rate calibrations of radiation survey meters (RSMs), this work investigates the feasibility using NIST traceable X-ray beam qualities for RSM exposure rate calibrations.

Methods: Nine moderately filtered NIST traceable x-ray beam qualities with effective energies ranging from 19.8 to 145 keV were used to investigate x-ray tube output and measure the energy response of three RSMs (Fluke 451B, Fluke 451P, and Ludlum 14C). For all the beam qualities considered, the air kerma/exposure rates at the reference tube currents greatly exceeded the highest operating ranges of most RSMs (<5 R/hr). Therefore, the x-ray tube output was characterized as a function of tube current down to 0.1 mA using a built-in monitor chamber to produce exposure rates within the operating ranges of the RSMs. These monitor chamber readings were then compared to a theoretical model that assumes a direct linear relationship between tube current and the NIST traceable exposure rates to calculate the exposure rates as a function of tube current. Measurements were then performed using RSMs at 0.1 mA and 0.5 mA for all beam qualities to investigate the energy response.

Results: Monitor chamber measurements of the x-ray tube output revealed 25% increase in tube output at 40 kV and 38% decrease at 250 kV. The air communicating RSM (451B) exhibited the lowest energy dependence (<20% at 50 keV) under the closed and open window configurations. The pressurized RSM (451P) exhibited a greater energy dependence of around 30% at 50 keV followed by the Geiger-Mueller-based Ludlum 14C, which over-responded by 60% at 50 keV.

Conclusions: X-ray-based RSM calibrations are possible through careful considerations of the tube output and energy response of the specific RSM. In the future, exposure rate modulation methods outside of current modulation will be developed to facilitate RSM calibrations. The development of higher energy X-ray beams will be needed to overcome the energy response of GM-based RSMs.

Beam Quality	Effective Energy (keV)	Tube Current (mA)	Air Kerma, 1m (mGy/sec)	Exposure, 1m (R/hr)
UW40-M	19.8	20	1.32	540.15
UW50-M	22.4	25	2.02	829.73
UW60-M	26.9	25	1.80	737.72
UW80-M	33.5	25	1.82	747.99
UW100-M	42.1	25	1.82	748.40
UW120-M	49.9	25	2.37	971.45
UW150-M	67.0	20	2.17	892.58
UW200-M	99.8	15	1.93	792.77
UW250-M	145	12	1.63	670.77

Table 1. Air kerma rate converted to exposure rate at NIST traceable beam qualities nominal currents. The exposure rate needs to be drastically decreased even to reach the highest operating range of most RSMs (1 – 5 R/hr).

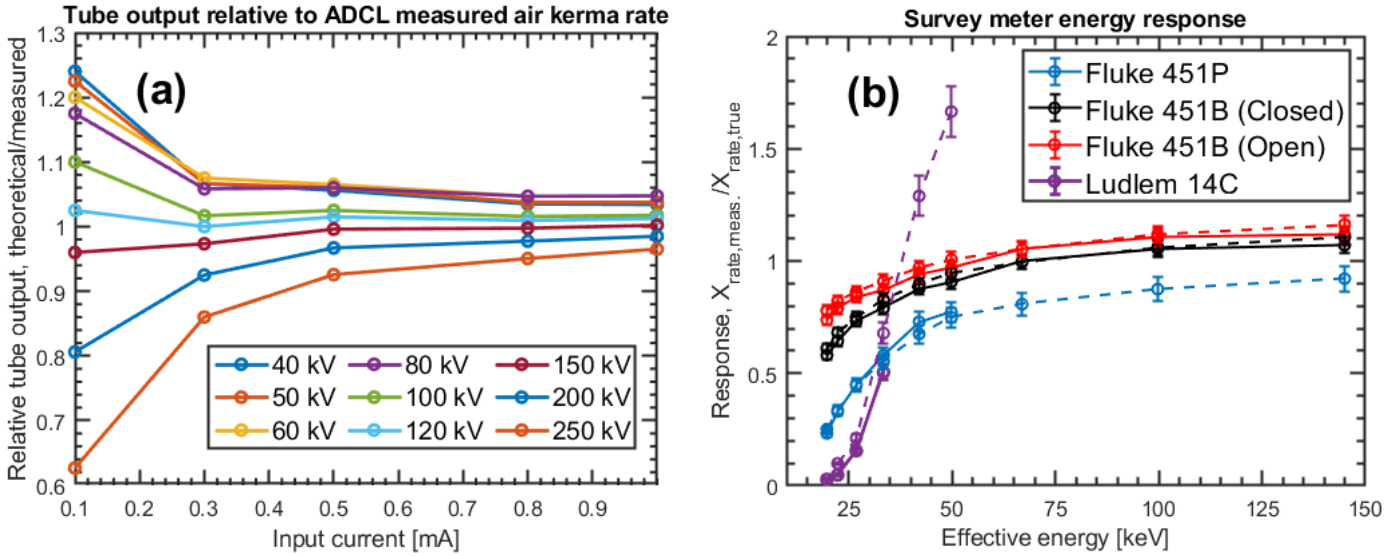

Figure 1. (a) Correction factors to account for actual x-ray tube output versus a direct linear relationship at varying current and voltage inputs. (b) Energy response plots for each survey meter measured after corrected exposure rates. Dashed lines represent 0.1 mA input and solid lines represent 0.5 mA input. Differences in the responses at different current readings are due to off-scale uncertainties for each survey meter.