X-Ray Multimeter Performance in Diagnostic Imaging Calibration Beams

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Purpose: X-ray multimeters (XMMs) are commercially available dosimeters designed for measurements in diagnostic radiology and mammography beams. These devices are composed of several solid-state dosimeters, and the manufacturer-provided software uses the readings from each internal dosimeter to estimate beam quantities such as tube potential, air kerma rate, and half-value layer (HVL). Currently, there is not a national standardized process for calibrating these dosimeters, meaning that users must trust the calibration and performance information provided by the manufacturers. Other groups have investigated the performance of these detectors in clinical and calibration beams [1,2]. This study expanded upon the existing body of work by analyzing the performance of two x-ray multimeters in tungsten- and molybdenum-anode beams that have been matched in HVL with beams at the National Institute of Standards and Technology (NIST). This research provides performance information that is valuable for devising a NIST-traceable calibration process.

Methods: The XMMs used in this study were an RTI (Mölndal, Sweden) Piranha and a Radcal (Monrovia, CA) Accu-Gold+ with AGMS-DM+ sensor. The beams chosen for this project were the M-series and MO-series beams at the University of Wisconsin Accredited Dosimetry Calibration Laboratory (UWADCL). These beams have been matched with beams at NIST, in terms of HVL. The UW M-series beams were generated using a tungsten-anode x-ray tube and several different aluminum and aluminum-copper filters. The UW MO-series beams were generated using a molybdenum-anode x-ray tube and a 32-micron thick molybdenum filter. Tube potentials between 60 and 150 kV (UW M-series), and 23 and 35 kV (UW MO-series) were used for this study. The multimeters were positioned using the typical calibration geometry: one meter from the source in a 10 x 10 cm^2 field (Figure 1). The values for tube potential, air kerma rate, and HVL were recorded after each 60 s measurement. All data points in the following plots are the average of five measurements.

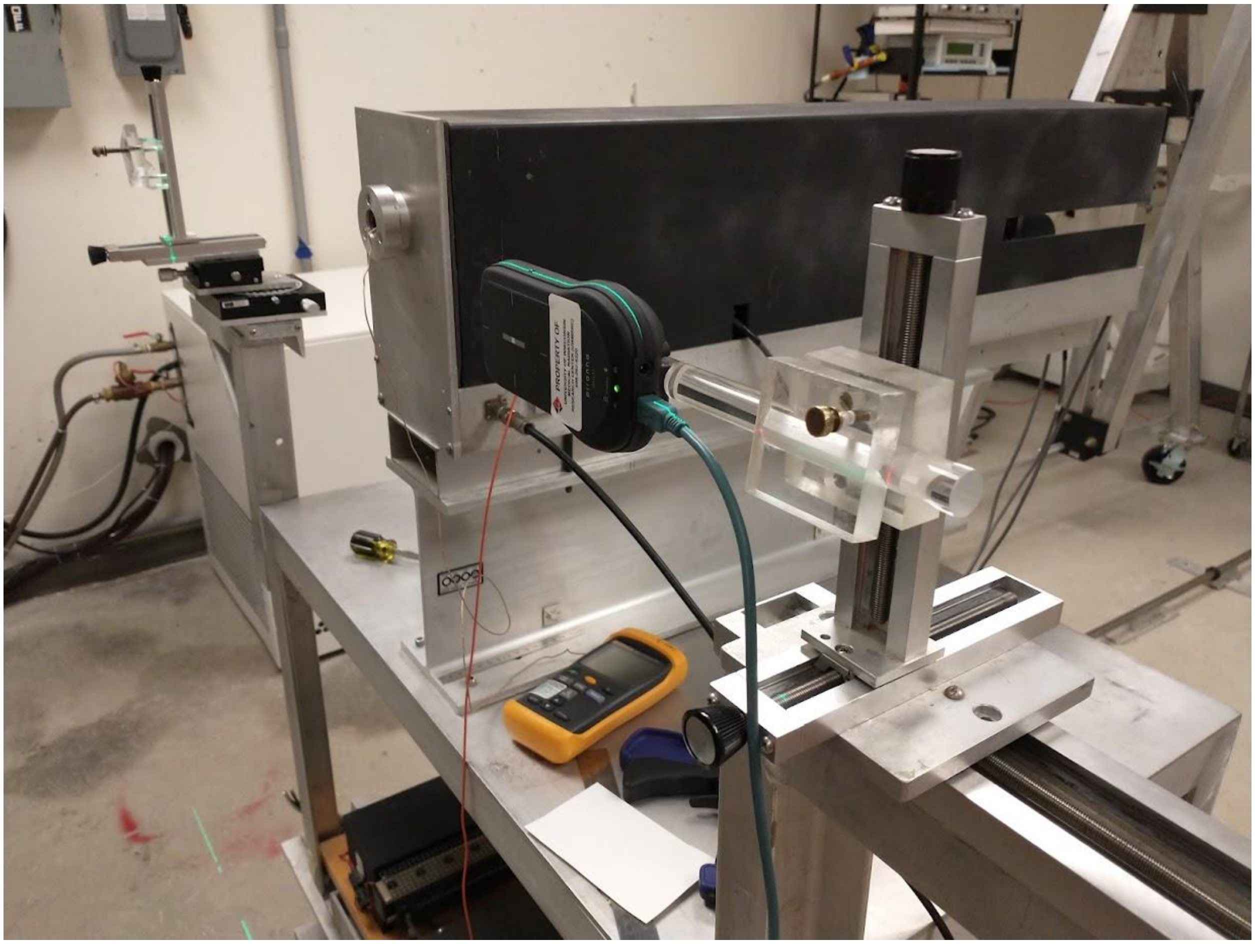

Figure 1. RTI Piranha positioned for measurements.

Results: Plots of measured vs. reference tube potentials, air kerma rates, and HVLs are shown in Figures 2 through 4, respectively. Error bars indicate the manufacturer-stated uncertainties. Both multimeters performed poorly when estimating tube potentials. Measurements with the Piranha did not agree within the manufacturer-stated uncertainty of the set tube potential. The AGMS-DM+ showed similar results for the UW100-M, UW120-M, and UW150-M beams. Air kerma rate measurements were significantly better, with all measurements showing agreement with the reference values. Lastly, all HVL measurements agreed with reference values other than the AGMS-DM+ measurement for the UW60-M beam. This measurement likely had the largest deviation because the selected tube potential was near the minimum tube potential for the selected operating settings.

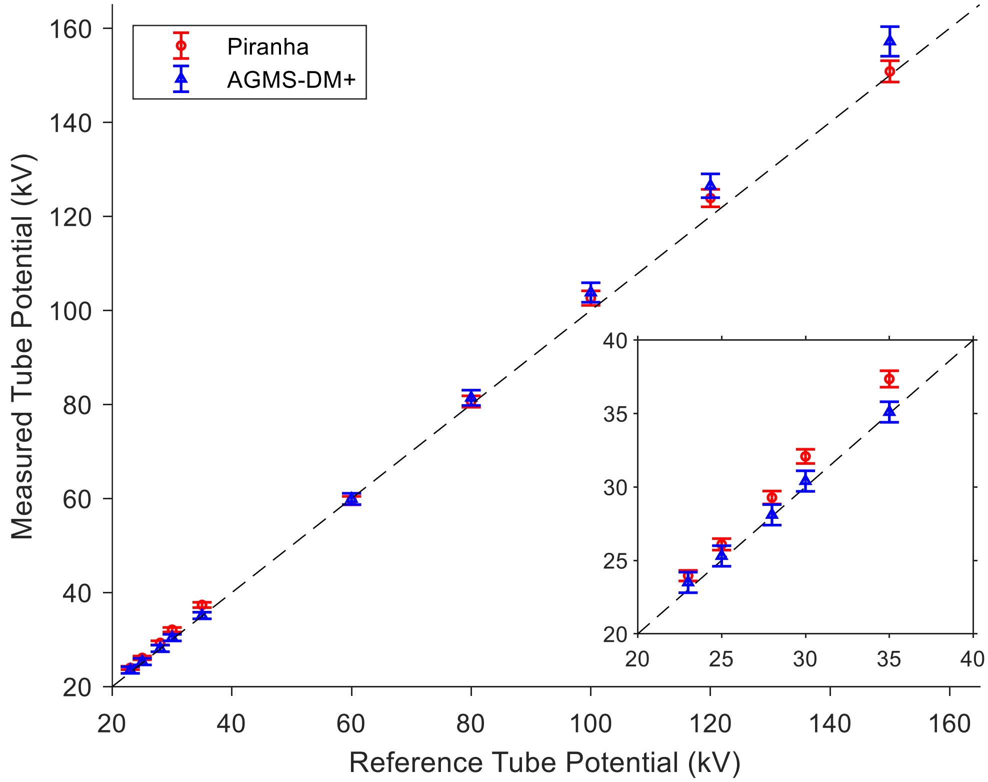

Figure 2. Measured tube potentials vs. reference tube potentials. The inset figure shows the range from 20 to 40 kV.

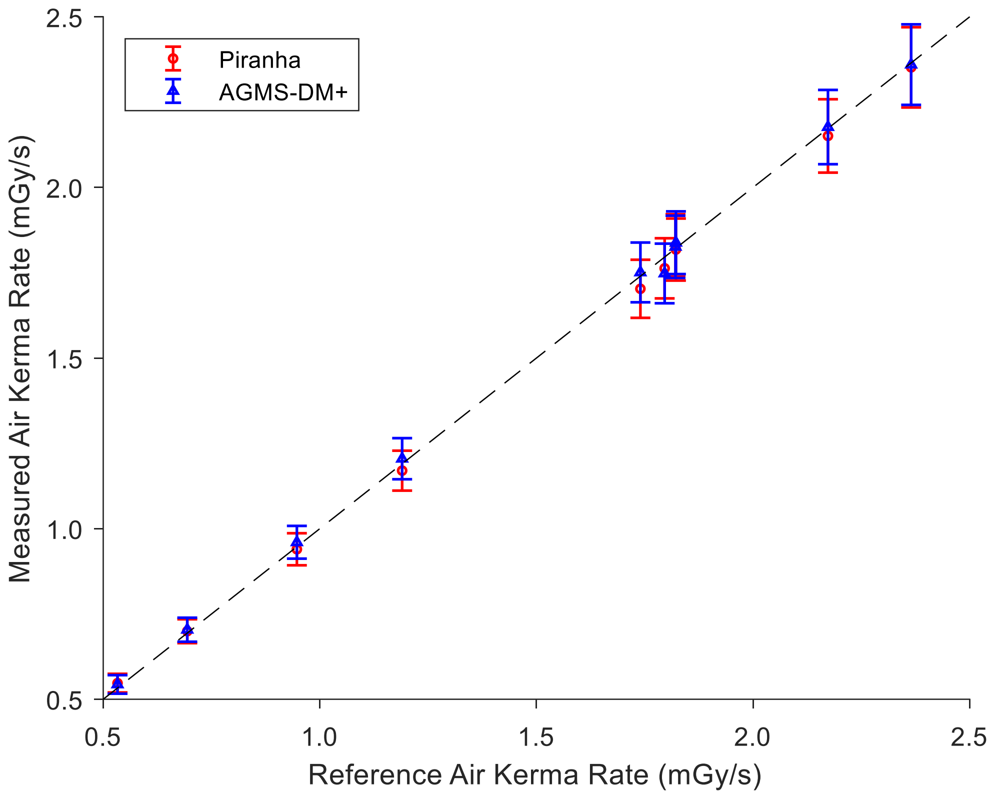

Figure 3. Measured air kerma rates vs. reference air kerma rates.

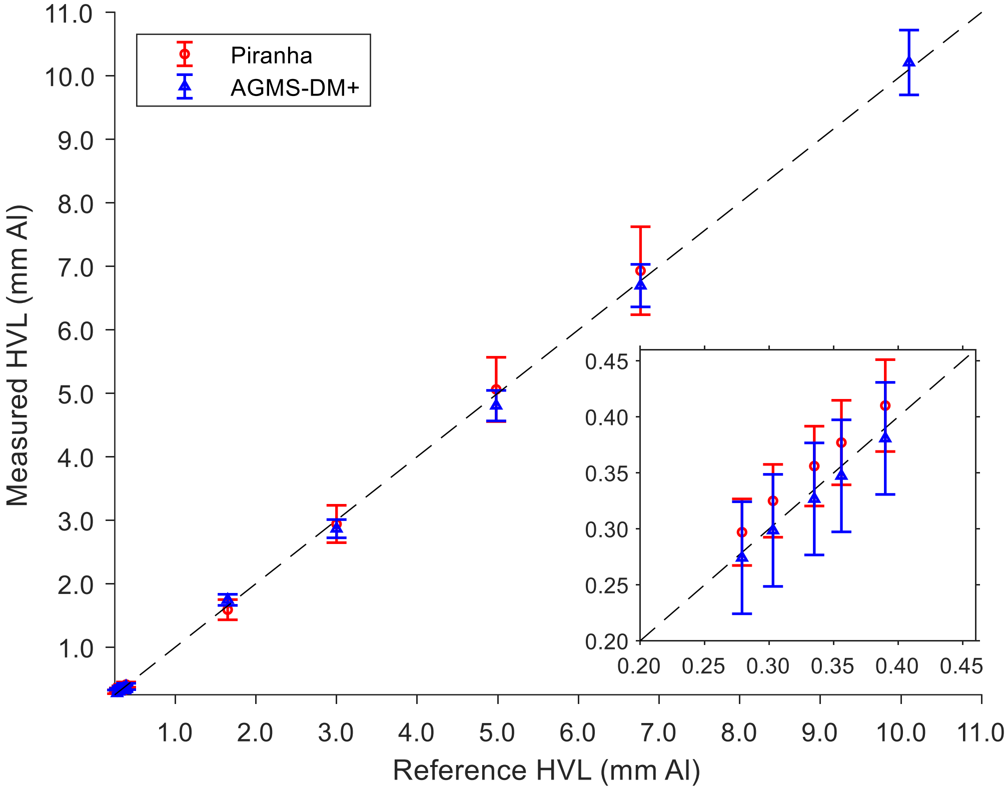

Figure 4. Measured HVLs vs. reference HVLs. The inset figure shows the range from 0.20 to 0.46 mm Al.

The data displayed in Figures 2-4 was collected in December 2022. The same measurements were also performed in September 2022. Table 1 lists the maximum percent change between measurements taken at those times. A NIST-standard ion chamber was used to verify that air kerma rates did not change significantly between measurement dates. All changes are less than the uncertainty of the measurements, as specified by the manufacturer or assumed from the natural variation of the tube output.

Table 1. Maximum percent change of measurements from data collected between September and December 2022.

XMM	**Tube Potential**	**Air Kerma Rate**	**HVL**
Piranha (UW M-Series)	0.50%	0.28%	0.14%
Piranha (UW MO-Series)	0.06%	0.87%	0%
AGMS-DM+ (UW M-Series)	0.08%	0.09%	0.04%
AGMS-DM+ (UW MO-Series)	0.33%	1.08%	0.36%

Conclusions: This study generated the first performance data of these XMMs in NIST-matched calibration beams. Measurements generally agreed with the reference values, except for measurements of tube potential. The multimeters tended to display a systematic over or under response for measurements in the UW MO-series beams, indicating that applying a calibration factor would improve the accuracy of measurements using these devices. Future work will involve repeated measurements to have more long-term data, as well as measurements in other matched beams. Suggested calibration protocols will be devised, and the effect of applying calibration factors to measurements using these multimeters will be evaluated.

Relevance to CIRMS: This work is relevant to CIRMS, as establishing NIST-traceable calibrations for XMMs is important to ensuring long-term dosimeter performance. Increased trust in the accuracy of XMM measurements will lead to more confident dose estimates for diagnostic imaging, which is important for patient safety. This research is part of the doctoral work of the first author which focuses on solid-state dosimetry in mammographic x-ray beams. The first author is a student of the University of Wisconsin Medical Radiation Research Center, investigating radiation metrology. The first author is working towards becoming a clinical medical physicist.

References:

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2. E. Salomon, P. Homolka, I. Csete, P. Toroi “Performance of semiconductor dosimeters with a range of radiation qualities used for mammography: A calibration laboratory study,” *Med. Phys.* 47, 1372-1378 (2020).