Large-Angle Ionization Chambers for Brachytherapy Air-Kerma-Strength Measurements

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There has been a significant increase in the use of low-energy photon-emitting radionuclides in the past decade to treat cancer with a special form of radiation therapy called brachytherapy. For treating prostate cancer, brachytherapy sources are approximately the size of a grain of rice and are normally radioactive I-125 or Pd-103 sources encapsulated in titanium or plastic. Although these sources have proven effective in the treatment of cancer, the clinical dosimetry is difficult due to the unique varieties available and their typically low activities.

A large-angle free-air chamber at the National Institute of Standards and Technology (NIST) called the Wide-Angle Free-Air Chamber (WAFAC) is the current standard for measuring the strength of low-energy photon-emitting radionuclides for brachytherapy. This chamber has served the clinical medical physics community well and is a significant improvement over previous standards. However, it has some shortcomings.

This thesis describes the development of a new large-angle ionization chamber at the University of Wisconsin called the Variable-Aperture Free-Air Chamber (VAFAC) to measure brachytherapy sources with extended capabilities. This chamber is constructed to explore characteristics in the calibration of brachytherapy seeds by quantifying potential variations caused by anisotropy and the change in response with integration angle. In addition, the characterization of yet another large-angle free-air chamber called the Grossvolumen Extrapolationskammer (GROVEX) in the German national standards institute Physikalisch-Technische Bundesanstalt (PTB) is also presented.

The objective of this thesis is to present improved measurement techniques with free-air ionization chambers that will improve the accuracy of the dose delivered to patients. First, it will be shown that the UW VAFAC is capable of measuring conventional I-125 or Pd-103 seeds as well as longer sources, coiled sources, and miniature x-ray tubes. Additionally, the VAFAC's improved seed holder, a derivative technique and variable apertures are shown to be more accurate methods to determine the desired unit, air-kerma strength.

The results of the measurements presented in this thesis support a new methodology for extrapolating measurements with variable apertures to an infinitely small aperture size. This is more accurate than relying on Monte Carlo calculations, since the measurements are of actual sources, not theoretical models.