Development of a primary standard for beta-particles

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A primary standard to determine the absorbed dose to water at 1 or 2 mm depth in a water(equivalent) phantom, due to beta particles is under development. The beta particles to be measured originate from capsulated radioactive sources. The capsulated radioactive sources aimed at in this project are ophthalmic applicators and catheter based line (train) sources used in intravascular brachytherapy The sources have to be characterized by dose and dose-distribution over the full surface of the (flat) source in case of ophthalmic applicators and over the flat area of interest of a phantom in case of line sources. The primary standard is based on the principle of a parallel plate extrapolation chamber with a very thin entrance window and is schematically drawn in figure 1.

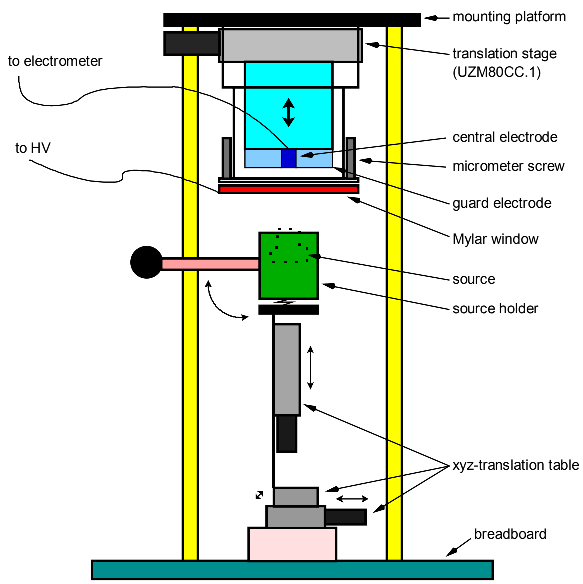

Figure 1. Schematical view of the extrapolation chamber of the NMi.

The extrapolation chamber is mounted in a frame above a computer-controlled motorized *xyz*-translation table by means of which the sources under investigation can be scanned to determine the required dose and dose-distribution. The ionization current, generated into the air volume between the entrance window and the body of the extrapolation chamber, the electrode system, is representative for the absorbed dose to air. The electrode system is formed by a central (measurement) electrode and is surrounded by a guard electrode. The diameter of this central electrode has to be small, compared to the range in air of the beta particles and the diameter of the guard electrode has to be so large, that an enlargement of this diameter does not influence the measured ionization current. The electrode system is mounted on an accurate vertical translation stage, which has been calibrated to an accuracy of 0.1 μm at the NMi section of Length with the help of a laser-interferometer. The large, flat, removable entrance window can be adjusted with the help of micrometer screws to make it parallel to the electrode. With the help of an autocollimator device the angular deviation of the window with respect to the electrode can be adjusted to less than 10 arcsec.

Up till now aluminium electrodes with diameters of 2 and 4 mm for the central electrode have been tested on a flat ^{90}Sr-^{90}Y and a ^{32}P line source, placed in a PMMA phantom at a depth of 0.8 mm. The measured ionization currents (I) at different plate distances (Δd), between the entrance window and the central electrode, show good stability and reproducibility. The response curve (I/Δd) shows a good linear behaviour between plate distances ranging from 20 μm to 50 μm. The extrapolation of this linear behaviour seems to be characteristic for the absorbed dose in the air volume limited by the central electrode. To determine the absorbed dose to water instead of the dose to air a conversion of the measured ionization current can be made, using the stopping power ratios of water to air, averaged over the beta spectrum. The backscatter of beta particles by the material of the central and guard electrode has to be corrected for the difference in backscatter in the material of the central electrode and water. Also differences in behaviour of the bèta particles in the phantom material, compared to water have to be corrected.

The configuration of aluminium electrode and PMMA phantom has been simulated by using the Monte-Carlo codes PENELOPE and EGSnrc. The results obtained with both codes for the combination of backscatter- and phantom correction factors show a behaviour that is not constant over the whole area of interest for the dose distribution, but depend on the geometry of the source and material combination of the central electrode and the phantom material. To minimize these correction factors and the related uncertainties, the process of backscatter and phantom scatter and attenuation will be investigated in more detail. Therefore a new electrode has been manufactured from D400 water equivalent plastic. Different combinations of electrode and phantom materials will be simulated using the PENELOPE Monte-Carlo code. Measurements will be carried out to corroborate the results of the calculations.