EXTRAPOLATION CHAMBER RESPONSE IN BETA RADIATION STANDARD FIELDS

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ABSTRACT

Two extrapolation chambers were designed, constructed and their performance was studied at the Calibration Laboratory of São Paulo. These chambers are simple, easily made and of low cost. Both have the collecting electrode and the guard-ring made of graphite. The only difference between the two chambers is the superficial density of the entrance window materials. These chambers were tested at the calibration conditions of a beta secondary standard system. The short and medium-term stabilities were studied. The tissue superficial dose rates and the transmission factors were obtained at 11 and 30cm source-detector distances. The obtained results were compared with those of the calibration certificate of the beta secondary standard source, showing very good agreement.

INTRODUCTION

Extrapolation chambers have been used successfully for the measurement of dose rates from beta sources. They have been chosen as standard measuring devices. Standardized beta-particle fields have been established in Primary Standard Laboratories. These laboratories utilize an extrapolation chamber for the calibration of protection-level beta-particle sources and instrumentation [1]. The extrapolation chamber is a plane parallel ionization chamber with variable cavity volume. Since its introduction by Failla in 1937, it has taken many forms, and some modifications have been reported [2,3,4].

Extrapolation chambers have been also recommended for calibration of clinical applicators [5,6]. These applicators are sealed radioactive sources that have been used for the treatment of superficial eye disorders and skin superficial lesions.

The main problems concerning beta rays are their limited penetration power, strong gradient of energy and angular distribution as function of spatial position [1]. The dose-rate calibration is difficult because of the rapid fall-off dose with distance, and in the case of calibration of an ophthalmic applicator it is further complicate due to its curvature [7,8].

Two extrapolation chambers were developed and studied in the present work at the calibration conditions of a beta secondary standard system.

MATERIALS AND METHODS

The developed chambers have the collecting electrode (10mm diameter and 4.0mm thickness) and the guard-ring (6.0mm diameter) made of graphite. The only difference between the two chambers is the entrance window material: the chamber C1 is made of aluminized Mylar (0.84mg.cm^{-2} of superficial density), and the other, chamber C2, of aluminized Hostaphan (6.40mg.cm^{-2} of superficial density). Lucite was used as insulating material between the electrode and the guard-ring.

The $^{90}Sr + ^{90}Y$ (1850 MBq) of the beta secondary standard system, with a calibration certificate of Physikalisch-Technische Bundesanstalt (PTB), Germany, was used for these experiments. A Keithley 617 electrometer was used as measurement assembly.

RESULTS

a. Short and Medium Term Stabilities

The chambers were positioned in a reproducible manner in relation to the radioactive source and ten measurements were taken for the short term stability determination. Both chambers showed a variation coefficient lower than 0.5%. For the medium term stability test 12 daily measurements series were realized. A maximum variation coefficient of 0.25% was obtained.

b. Transmission Factors

The transmission factors were obtained covering the chamber with polyethylene therephthalate (Hostaphan) foils and Plexigles plates with different thickness. For these experiments the chamber depth was maintained constant at 1.0mm and the detector was positioned at 11cm from the $^{90}Sr + ^{90}Y$ (1850MBq) source. The maximum relative standard deviation in the measurements was 1%. The transmission factors determined for typical values of the tissue equivalent material are present in Table I.

The transmission factors obtained with the chambers showed a difference lower than 1% between the experimental results and the calibration certificate values (except for 1.0mm tissue thickness).

Table I. Transmission factors for beta radiation
$^{90}Sr + ^{90}Y$ (1850MBq), chamber-source distance: 11cm

Tissue Thickness mm	Superficial Density $mg.cm^{-2}$	PTB Certificate	Chamber C1	Chamber C2
0	0	1.000	1.000	1.000
0.02	2	1.028	1.034	1.025
0.04	4	1.049	1.054	1.045
0.05	5	1.058	1.062	1.055
0.07	7	1.070	1.080	1.075
0.10	10	1.095	1.098	1.095
0.20	20	1.158	1.148	1.150
0.50	50	1.201	1.200	1.200
1.00	100	1.157	1.134	1.150

c. Absorbed Dose Rates to Tissue

The absorbed-dose rates to tissue were determined from current measurements at a range of air gaps. In this study, the measurements were realized at 11 and 30cm distances from the detector. The extrapolation curves were obtained measuring the ionization current for both potential polarities applied to the chambers electrodes and plotting the average of this values as a function of the chamber depth from 0.5 to 2.5mm. It was utilized a constant gradient of 10V/mm.

The absorbed-dose rate to tissue in Gy/s is given by [1,5]:

$$\dot{D}_Z = \frac{(\overline{W}/e).S_{air}^{tissue}}{\rho_0 . A}(\frac{\Delta I_c}{\Delta d}) \qquad (1)$$

where $\dot{D}_Z$ is the absorbed-dose rate to tissue at depth z, $\overline{W}/e$ is average energy required to produce an ion pair in dry air (33.97 J/C), S_{air}^{tissue} is the ratio of the average mass stopping power of tissue to air (1.12), ρ_o is the density of dry air at reference conditions of 22 °C and 101.3kPa (1.197 kg/m^3), A is the area of the collection electrode and $(\frac{\Delta I_c}{\Delta d})$ is the fitted slope of the corrected current versus air gap function. For the determination of the absorbed-dose rate at $7 mg.cm^{-2}$, the transmission factors were employed. Table II presents the obtained results of the chambers C1 and C2 and the values of the PTB certificate corrected for decay to the time of the measurement and for the recent values of $\overline{W}/e$ and S_{air}^{tissue}.

The uncertainties in this procedure include measured ${\Delta I_c}/{\Delta d}$ ratio as well as uncertainties in the chosen values for average energy per ion pair, stopping power ratios, and other correction factors. The overall uncertainties of the absorbed dose rates are estimated to be approximately 5%.

TABLE II. Absorbed dose rate to tissue at $7 mg.cm^{-2}$
$^{90}Sr + ^{90}Y$ (1850MBq)

Chamber	$\dot{D}_m$ ($\mu Gy.s^{-1}$) (11cm)	$\dot{D}_c$ ($\mu Gy.s^{-1}$) (11cm)	Δ_{11} (%)	$\dot{D}_m$ ($\mu Gy.s^{-1}$) (30cm)	$\dot{D}_c$ ($\mu Gy.s^{-1}$) (30cm)	Δ_{30} (%)
C 1	441.4	448.2	1.5	60.45	60.91	0.75
C 2	436.3	448.2	2.7	60.29	60.91	1.0

where

$\dot{D}_m$: absorbed dose rate to tissue at $7 mg.cm^{-2}$ obtained experimentally;

$\dot{D}_c$: absorbed dose rate to tissue at $7 mg.cm^{-2}$ of the PTB certificate;

Δ_{11}: percentual difference between $\dot{D}_m$ and $\dot{D}_c$ at the 11cm source-detector distance;

Δ_{30}: percentual difference between $\dot{D}_m$ and $\dot{D}_c$ at the 30cm source-detector distance.

Comparing the absorbed dose rates to tissue, determined using the C1 and C2 chambers, a maximum percentual difference of aproximately 1.0% was observed. The results, compared with those of the source calibration certificate, showed a percentual difference of 2.7% in the most unfavorable case. The agreement between the chambers is within the obtained 5% uncertainty.

Conclusion

The chambers developed and tested in this work demonstrate that they are useful for beta radiation dosimetry. The obtained results showed very good agreement with those of the calibration certificate of the beta secondary standard source.

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