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Extrapolation chamber response in low-energy x radiation standard beams

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Measurements of absorbed dose rates in air and tissue produced by low-energy x radiation are often difficult to obtain with accuracy. The recommended instruments for these applications are extrapolation chambers. The performance of an extrapolation chamber, developed at IPEN, was studied in low energy x radiation standard beams in relation to its response linearity, extrapolation curves and energy dependence. The results obtained indicate that the developed chamber is suitable for x radiation measurements. © *2001 American Institute of Physics.* [DOI: 10.1063/1.1332416]

I. INTRODUCTION

Superficial lesions of the skin have been successfully treated with low energy x radiation. The rapid dose fall-off in tissue indicates the use of this kind of radiation in the treatment of superficial lesions, considering that a high dose can be applied without affecting the deeper layers of the skin. The extrapolation chamber is an instrument utilized for various applications that allows precise and accurate absolute measurements of beta and low-energy x radiation.[1–4]

An extrapolation chamber was designed and constructed at IPEN for the calibration of beta radiation plane applicators[5] and for beta ray protection level measurements.[6] In the present work, this chamber was applied to the dosimetry of low-energy x radiation standard beams. Its performance was studied in relation to its response linearity and energy dependence. Extrapolation curves and transmission factors were obtained under the normally used conditions.

II. MATERIALS AND METHODS

The chamber which has been developed has a collecting electrode (10 mm diam and 4.0 mm thickness) and a guard ring made of graphite. Between the collecting electrode and the guard ring, polymethylmethacrylate (Lucite) was utilized as an insulating material. In the current design, the high voltage electrode is readily removable. For this work aluminized polyethylene terephthalate with different thicknesses of 0.84 $mg\,cm^{-2}$ and 6.42 $mg\,cm^{-2}$ were utilized; the chambers were called, respectively, C1 and C2.

The ionization currents were measured at both polarities using a Keithley 617 electrometer and the mean values determined. The chamber was positioned at 50 cm from the x-ray system, which consists of a Philips tube, model PW 2184/00 (tungsten target and beryllium window) with a Rigaku Denki generator, model Geigerflex, Japan. All measurements were corrected to standard reference conditions (22 °C, 101.3 kPa).

III. RESULTS AND DISCUSSION

A. Response linearity

The ionization currents were measured varying the x-ray tube current between 2 and 30 mA for 25 and 50 kV (radiation qualities shown in Table I), keeping the interelectrode distance and the source-detector distance constant at 1.00 mm and 50 cm, respectively. A linear behavior of the chamber response was obtained (Fig. 1). No significant recombination effect was verified.

B. Extrapolation curves

The extrapolation curves were obtained for x rays of 25 and 50 kV. The ionization current was measured by varying the chamber depth (interelectrode distance in the chamber) between 0.20 and 1.00 mm, keeping the electric field constant at 10 V/mm. For each chamber depth, measurements were taken at each polarity. For this study, five measurements were taken for each chamber depth. The mean value was represented as a function of the chamber depth, and linearity was observed in all cases. In Fig. 2, the typical curves of chamber C1 are presented. Similar results were obtained for chamber C2. The slope of the straight lines is used for the determination of the absorbed dose rate in air.[2]

C. Energy dependence

The ionization current readings were taken by keeping the interelectrode distance and the electric field constant at 1.0 mm and 10 V/mm, respectively, for different standard beam qualities. The calibration factors were determined using the substitution technique. A parallel-plate ionization chamber, Nuclear Enterprises Ltd. (NE) secondary standard, model 2536/3B, was used for the x radiation exposure rate

TABLE I. Energy dependence of the extrapolation chambers for x radiation F_{C1} and F_{C2}. Calibration factors for the chambers C1 and C2 ($C\,kg^{-1}\,min^{-1}\,pA$).

High voltage (kV)	Added filtration (mmAl)	Half-value layer (mmAl)	Average energy (keV)	Exposure rate (10^{-3} $C\,kg^{-1}\,min^{-1}$)	F_{C1}	F_{C2}
25	0.44	0.26	14.3	10.96	2.273	1.764
30	0.54	0.37	15.5	11.65	2.362	1.849
40	0.68	0.56	17.7	16.37	2.395	1.920
45	0.73	0.65	18.7	15.50	2.396	1.940
50	1.02	0.91	21.2	12.84	2.398	1.996

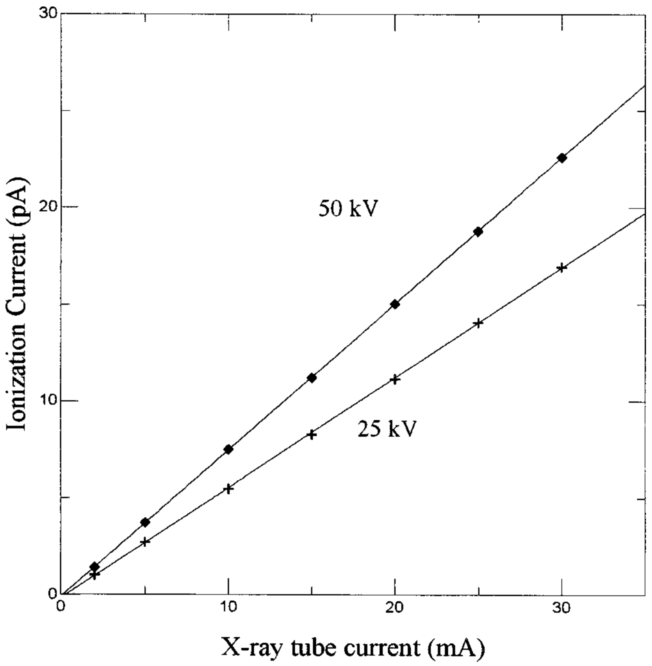

FIG. 1. Linearity response of chamber C1 for x radiation of 25 and 50 kV.

determination. The calibration factors were obtained as the ratio between the exposure rates and the measured ionization currents.

As can be observed in Table I, the chambers C1 and C2 show an energy dependence of 5.5% and 13.2%, respectively, for x radiation between 14.3 and 21.2 keV. Considering the energy interval between 15.5 and 21.2 keV (HVL =0.37 mmAl and 0.91 mmAl, respectively) the energy dependence of chamber C1 drops to 1.5%. This value is within the recommended value of 2% for half value layers between 0.05 and 2 mmAl,[7] showing that the developed chamber may be useful for the considered energy interval.

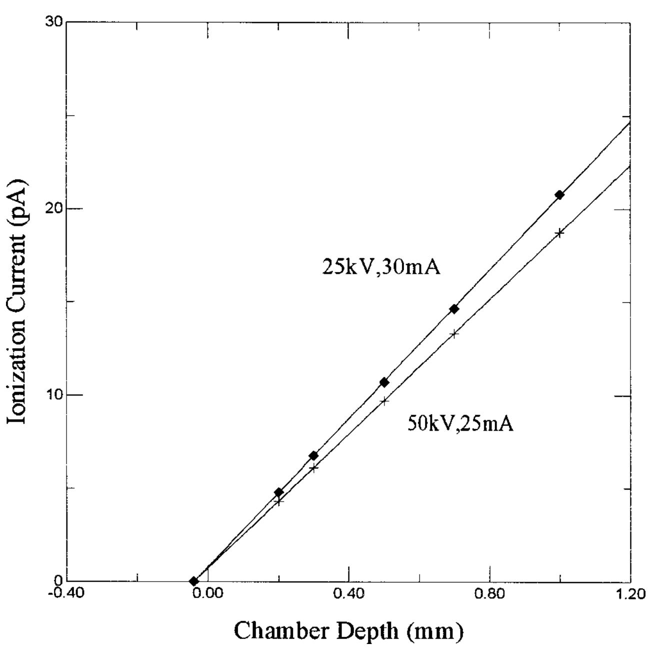

FIG. 2. Extrapolation curves of chamber C1 for x radiation of 25 and 50 kV.

TABLE II. Transmission factors for x radiation using chamber C1.

Tissue thickness (mm)	Transmission factor				
	25 kV	30 kV	40 kV	45 kV	50 kV
0	1.000	1.000	1.000	1.000	1.000
0.02	0.996	0.997	0.998	0.996	0.998
0.04	0.992	0.995	0.996	0.994	0.996
0.05	0.990	0.993	0.994	0.992	0.995
0.07	0.986	0.991	0.992	0.990	0.994
0.10	0.982	0.987	0.988	0.985	0.991
0.20	0.962	0.974	0.978	0.971	0.983
0.50	0.922	0.940	0.977	0.964	0.966
1.00	0.865	0.895	0.925	0.931	0.948
1.50	0.812	0.859	0.892	0.902	0.930
2.00	0.760	0.819	0.868	0.876	0.912
2.50	0.708	0.780	0.840	0.852	0.893
3.00	0.657	0.740	0.812	0.824	0.874
3.50	0.606	0.700	0.784	0.798	0.855

D. Transmission factors

To get more reliable clinical information on depth dose distributions in tissue, transmission factors were determined for different x-ray energies. The transmission factors were obtained by increasing the entrance window thickness by using additional polyethylene terephthalate (Hostaphan) and polymethylmethacrylate (Lucite) foils of known areal density. The absorbed dose rates in tissue at certain limited depths can be obtained applying the transmission factors to the absorbed dose rates in air. In Tables II and III are presented the transmission factors determined for typical tissue equivalent material values, using chambers C1 and C2. The transmission factors are strictly applicable only for these x rays qualities and at the specified source-chamber distance of 50 cm.

As expected, it can be seen in Tables II and III that the decrease effect in the transmission factors, and consequently in the absorbed doses in tissue, is more significant for the lowest energies.

TABLE III. Transmission factors for x radiation using chamber C2.

Tissue thickness (mm)	Transmission factor				
	25 kV	30 kV	40 kV	45 kV	50 kV
0	1.000	1.000	1.000	1.000	1.000
0.02	0.995	0.999	1.000	1.000	1.000
0.04	0.994	0.998	1.000	1.000	0.998
0.05	0.994	0.995	0.995	0.999	0.995
0.07	0.990	0.995	0.990	0.998	0.995
0.10	0.990	0.990	0.995	0.995	0.995
0.20	0.978	0.985	0.993	0.990	0.993
0.50	0.941	0.960	0.975	0.975	0.983
1.00	0.883	0.920	0.950	0.948	0.965
1.50	0.820	0.883	0.915	0.923	0.950
2.00	0.765	0.840	0.888	0.895	0.933
2.50	0.715	0.800	0.860	0.870	0.915
3.00	0.660	0.760	0.830	0.845	0.900
3.50	0.610	0.715	0.800	0.820	0.880

For all beam qualities, a decrease lower than 1.5% in the transmission factors was verified for 0.07 mm tissue thickness (7 $mg\,cm^{-2}$). A comparison between the results obtained of transmission factors using chambers C1 and C2 indicates an agreement within 1.0%.

IV. CONCLUSION

The results on the metrological characteristics of the extrapolation chamber as response linearity and energy dependence show that the chamber is useful for x radiation detection. The transmission factors determined with both chambers presented good agreement.

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