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NEW IONIZATION CHAMBERS FOR BETA AND X-RADIATION

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Two new ionization chambers were designed, constructed and tested in beta and X-radiation fields. They have a circular form, a sensitive volume of 0.6 cm^3 and collecting electrodes of graphite and aluminium. The short- and long-term stability checks and the lack of current leakage indicate that the present performance of the chambers is comparable to that expected from secondary standards. The differential energy dependence of both chambers permits effective-energy determination of unknown X-radiation fields. The chambers display applicability for $^{90}Sr + ^{90}Y$ radiation detection.

1. Introduction

Over the past several years interest in developing ionization chambers has increased in Brazil. Thimble-type chambers [1], graphite transmission chambers [2,3] and an extrapolation chamber [4] were constructed and the results indicate their applicability in radiation dosimetry.

The use of plane-parallel ionization chambers in low-energy X-radiation fields is highly recommended for dosimetric purposes, especially so for those radiation centers having comprehensive X-ray detection facilities, as suggested in the guidelines of ref. [5]. Such chambers can also be used for high-energy X-radiation detection as well as for electron beams. In the latter case they are especially recommended [6], as they have a well-defined point of measurement, being the proximal surface of the collecting electrode.

At the Calibration Laboratory of São Paulo new ionization chambers were designed, constructed and tested with the objective of detecting beta and soft X-radiation. They were required to be simple, of low cost and to be capable of use with any type of electrometer.

2. Experimental

Two plane-parallel ionization chambers were constructed. Both have a circular form, fixed sensitive volumes of 0.6 cm^3 and aluminized Mylar entrance windows. The only difference between the two is in the collecting electrode material: one has a graphite electrode and the other an aluminium electrode. The chamber bodies are of Lucite and they are unsealed, providing communication with the atmosphere. Table 1 shows the main technical specifications of these chambers. A schematic diagram of the chambers can be seen in fig. 1. The radioactive check device (C) and its holder (B) are also represented in the same figure. The three components are placed as near as possible (the source does not touch the entrance window) during the measurements of the short-term stability tests of the chambers in order to assure a fixed geometry.

The ^{90}Sr radioactive check source is from Physikalisch-Technische Werkstätten, FRG, S 1253 and has a nominal activity of 8.4 MBq.

The chamber volume of 0.6 cm^3 was chosen to be compatible with standard Baldwin–Farmer-type dosimeters. In the present work the chambers were connected to an electrometer model 2502/3, S 330, of Nuclear Enterprises Ltd., England.

The chambers were submitted, in this investigation, to beta- and low-energy X-ray radiation.

The $^{90}Sr + ^{90}Y$ source (1.85 GBq) of the secondary standard system of Buchler & Co., FRG, with a calibration certificate issued by Physikalisch-Technische Bundesanstalt, FRG, was used at a distance of 11 cm

Table 1
Technical specifications of the ionization chambers

Characteristics	Specifications
Entrance window material	Aluminized Mylar
Entrance window superficial density	0.84 mg/cm^2
Electrode material	Graphite/aluminium
Electrode thickness	2.5 mm
Electrode diameter	16 mm
Electrode graphite purity	99.97%
Sensitive volume	0.6 cm^3
Chamber wall material	Lucite
Insulator material	Teflon
Chamber outer height	22 mm
Chamber outer diameter	55 mm
Chamber inner diameter	21 mm

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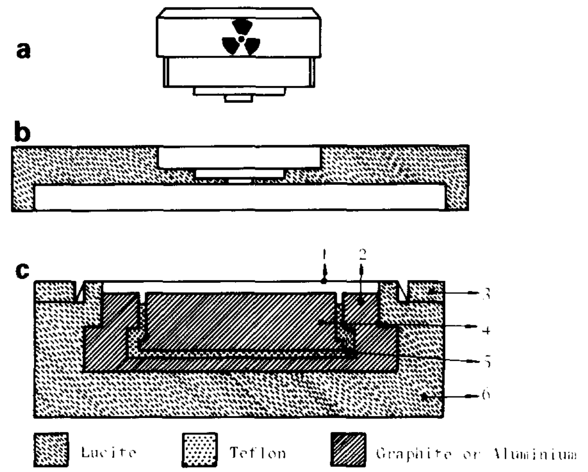

Fig. 1. Schematic diagram of: (a) Plane-parallel ionization chamber: (1) entrance window; (2) guard ring; (3) entrance window fixation ring; (4) collecting electrode; (5) insulator ring; (6) chamber body. (b) Holder for the radioactive check device. (c) ^{90}Sr check source.

from the chambers, with an absorbed dose rate in air of 0.120 μGy/h.

In the case of X-radiation the chambers were positioned at 50 cm from the system, consisting of a Philips tube model PW 2184/00, The Netherlands, (tungsten target and beryllium window) with a Rigaku Denki generator model, Geigerflex, Japan. The main characteristics of this radiation system are shown in table 2. In order to determine possible variations in the X-ray radiation intensity during the measurements, a PTW graphite monitor chamber was used. The secondary standard system with which the chambers were calibrated is composed of a plane-parallel chamber model 2536/3B (sensitive volume of 0.3 cm^3) connected to an electrometer model 2560, both of Nuclear Enterprises Ltd., England, and has a calibration certificate originating from the National Physical Laboratory, England.

3. Results

The chambers were submitted to the following tests, as recommended in ref. [7]: short- and long-term stability, leakage and energy dependence.

Table 2
Characteristics of the low-energy X-radiation system; inherent filtration: 1.0 mm Be

Tension [kV]	Current [mA]	Additional filtration [mm Al]	Half-value layer [mm Al]	Exposure rate [C/(kg h)]
25	30	0.445	0.25	0.672
40	30	0.682	0.50	0.975
50	30	1.021	1.00	0.911

3.1. Short- and long-term stability tests

Ten consecutive readings, corrected for ambient conditions, were taken on each occasion for both chambers using the radioactive check source, this constituting the short-term stability test. The percentage standard deviation values varied between 0.04 and 0.36% for the Al-chamber (with aluminium electrode) and between 0.04 and 0.25% for the C-chamber (with graphite electrode).

For the long-term stability test a series of measurements were performed wherein the radioactive check source was completely removed from the ionization

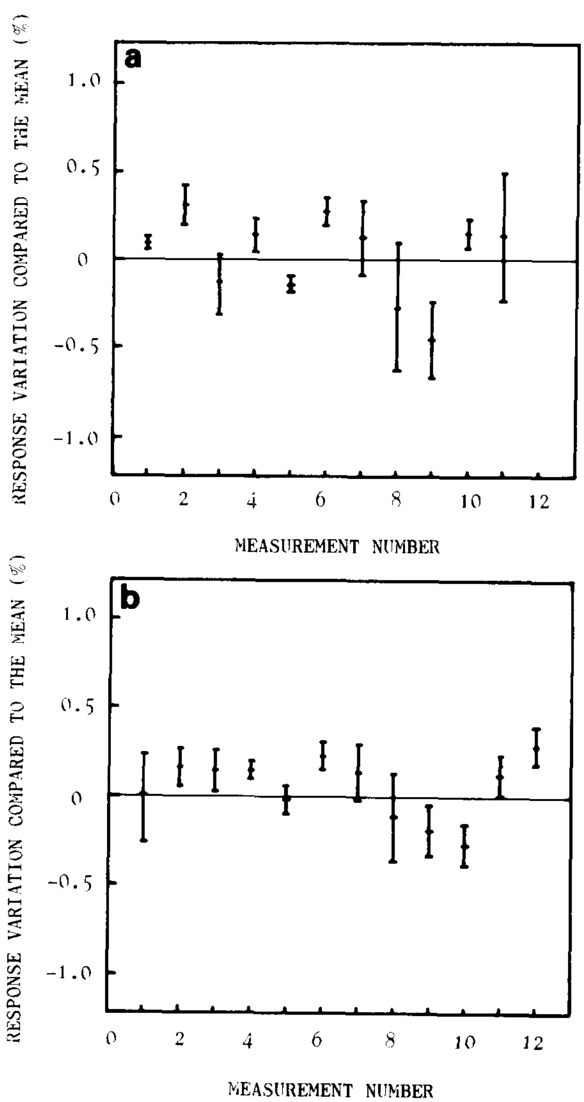

Fig. 2. Long term stability test of the plane parallel ionization chambers: (a) Al-chamber (with aluminium collecting electrode), (b) C-chamber (with graphite collecting electrode) Each data point represents the mean of ten readings.

Table 3
Energy dependence for soft X-radiation of plane-parallel ionization chambers (s.u.: scale unit)

Tension [kV]	Half-value layer [mm Al]	Calibration factor [R/s.u.] [a]		
		Al-chamber	C-chamber	Secondary standard chamber [b]
25	0.25	0.6276 ± 0.0002	1.0585 ± 0.0004	0.935 ± 0.007
40	0.50	0.5281 ± 0.0003	1.0725 ± 0.0004	0.917 ± 0.006
50	1.00	0.4789 ± 0.0003	1.0752 ± 0.0010	0.902 ± 0.006
Source		Calibration [cGy/s.u.]		
$^{90}Sr + ^{90}Y$		0.7137 ± 0.0007	0.8347 ± 0.0009	0.6627 ± 0.0008

[a] The calibration factors are in old units for comparison with those of the secondary standard calibration certificate.
[b] NPL calibration certificate, for X-radiation.

chamber and then replaced again to obtain successive measurements. Fig. 2 shows the variation in relation to the mean value of the chamber response as a function of the measurement number. As can be observed, all mean values presented by the Al-chamber lie within ±0.5% and those by the C-chamber within ±0.3%.

3.2. Leakage

The leakage test was performed by submitting the chambers to radioactive check source irradiation to obtain a reading in the middle of the scale. The source was disconnected and measurements were taken at intervals of 5 min until an elapsed time of one hour post-irradiation was achieved. The determined leakage showed a maximum variation of 0.03% for the Al-chamber and 0.02% for the C-chamber in relation to the ionization current produced by the minimum applied exposure rate of 0.67 C/(kg h). These results are better than the recommended value (0.5%) for secondary standard chambers [7].

3.3. Energy dependence

The calibration factors of both chambers can be seen in table 3 for low-energy X-radiation, comparison being made with factors for the plane-parallel NE secondary standard chamber. For the secondary standard there is a variation of 3.6%, over the studied energy range, whilst for the C-chamber the variation is only 1.6%. In the case of the Al-chamber, the variation exceeds 30%. The results for the energy dependence of the C-chamber in soft X-radiation fields are always within the recommended value [7] of ±3% for the range of half-value layers from 0.05 to 2 mm Al, i.e. approximately 12 to 75 kV X-ray tube potentials.

In the case of beta radiation, the chambers produced a comparative difference in response of 17% (table 3). The secondary standard chamber was also submitted to this radiation field and its obtained calibration factor is also shown in the same table, for purposes of comparison. This chamber is not a reference instrument for beta radiation.

4. Conclusion

The tests performed on the chamber with a graphite collecting electrode showed that is has good metrological characteristics that are comparable to those of plane-parallel ionization chambers used as secondary standards, viz. good short- and long-term stabilities, low leakage current and low energy dependence.

The other chamber, with an aluminium collecting electrode, in spite of having negligible current leakage and good short- and long-term stabilities, has a very high energy dependence. This fact suggests the possibility of using the pair of chambers for determining the effective energy of unknown soft X-radiation fields, using their differential energy response to the same radiation field.

Both chambers demonstrate applicability for $^{90}Sr + ^{90}Y$ radiation detection.

Their development has extended beta- and X-radiation detection ability at one Institute, but these chambers are going to be tested at two other Institutes in the near future.

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