technical note

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Ionization Chamber Extension Cables: Radiation Effects

LINDA V. E. CALDAS,* DIETER F. REGULLA and PETER PYCHLAU†

Gesellschaft für Strahlen- und Umweltforschung (GSF) München, Institut für Strahlenschutz, Ingolstädter Landstrasse 1, 8042 Neuherberg, F.R.G.

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The effect emerging when ionization chamber extension cables are in a radiation field is analyzed in terms of energy dependence and linearity of the response. In the region of 100 keV x-rays the effect reaches maximum values and for ^{137}Cs radiation fields, minimum values. Linear behaviour was observed between 5 and 40 cm of irradiated extension cable length.

1. Introduction

Accurate knowledge of the applied dose is a necessary condition for the accurate use of ionizing radiation in radiotherapy. The importance of dosimetry has been realized since the very first applications of ionizing radiation in medicine and biology, and continuing efforts are being devoted to the development of more reliable, effective and safe instruments, and to a further improvement in the accuracy of dosimetry for all the types of ionizing radiation.

Commercial instruments with ionization chambers are commonly used for the dosimetry of radiation fields. Practical dosimetric procedures are well established in international protocols (ICRU, 1969, 1970, 1984).

In large radiation fields the extension cable and the connector are also irradiated. Undesirable effects can appear and influence ionization current measurements. Therefore it is necessary to apply correction factors that depend on the specific case. In this work, the effect emerging when the extension cable is exposed to γ radiation from ^{137}Cs and ^{60}Co sources and to x-radiation with an effective energy between 49 and 142 keV (190 and 300 kV) was studied. The linearity of the effect was also investigated.

*Permanent address: Instituto de Pesquisas Energéticas e Nucleares, C.P. 11049, 05499 São Paulo, Capital, Brazil.
†Permanent address: Physikalisch-Technische Werkstätten (PTW), Lörracher Strasse 7, 7800 Freiburg in Breisgau, Germany.

2. Experimental Procedure

The experiment consists of exposing a certain length of an ionization chamber extension cable to radiation. The chamber is not irradiated in the same beam as the extension cable; otherwise the effect is easily masked. However, an electric signal from the chamber is needed and is obtained by placing the ionization chamber close to, or inside, a radioactive check device, for instance.

Extension cables from two different manufacturers were tested and these were connected to thimble chambers (0.3 cm^3) with their respective electrometers, and radioactive check devices were used. All ionization current measurements were corrected for ambient temperature and pressure, when using unsealed chambers.

The irradiations were all made in air for a 60 s exposure using the facilities (Eckerl and Nahrstedt, 1981) of the Secondary Standard Dosimetry Laboratory of Institut für Strahlenschutz, GSF, Munich, F.R.G.

In the case of γ radiation, the ^{137}Cs and ^{60}Co sources were used with radiation fields of $10 \times 10\,cm^2$, at 38 and 100 cm respectively, and with exposure rates of $2.58 \times 10^{-5}\,C\,kg^{-1}\,s^{-1}$ ($0.100\,R\,s^{-1}$) and $3.66 \times 10^{-5}\,C\,kg^{-1}\,s^{-1}$ ($0.142\,R\,s^{-1}$). The 420 kV x-ray installation was used with the radiation qualities (Selentag *et al.*, 1979) of Physikalisch-Technische Bundesanstalt (PTB), Brunswick, F.R.G.; Table 1. In this table the current and exposure rate values measured can also be observed. The inherent filtration was 4 mm Al in order to obtain x-rays with the calibration qualities for therapy dosimeters. The source-extension cable distance was maintained at 100 cm and the radiation field at $10 \times 10\,cm^2$. For the 300 kV machine the irradiated extension cable length was varied between 5 and 40 cm, in order to investigate a possible length dependence of the observed effect.

Ionization current measurements were taken five times before and after the extension cable exposure to radiation.

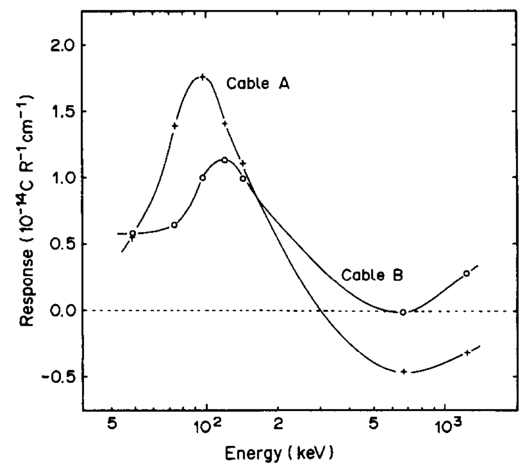

Fig. 1. Energy dependence of the radiation effect on extension cables.

Table 1. The 420 kV installation. Inherent filtration: 4 mm Al

Voltage (kV)	Additional filtration (mm Cu)	Half value layer (mm Cu)	Effective energy (keV)	Current (mA)	Exposure rate $10^{-5}\,C\,kg^{-1}\,s^{-1}$	Exposure rate $10^{-1}\,R\,s^{-1}$
100	0.15	0.29	49	15.3	1.85	0.718
150	0.5	0.92	74	15.6	3.25	1.26
200	1.0	1.7	97	15.6	4.93	1.91
250	1.6	2.6	121	15.6	7.35	2.85
300	2.2	3.4	142	14.3	9.80	3.80

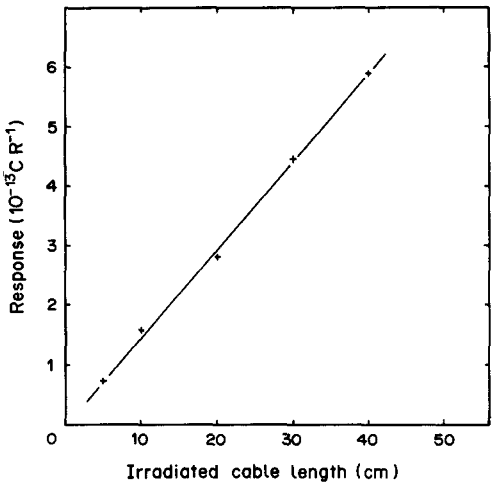

Fig. 2. Linearity of the radiation effect on cable A, with 142 keV x-radiation.

The average of these values (base current i_0) was compared for each situation with the obtained average value (i) from five measurements taken during the cable irradiation. The difference (i–i_0) was divided by the exposure rate ($\dot{X}$) to the cable and by the irradiated cable length (L). The results are presented therefore in C $R^{-1}cm^{-1}$. To avoid a misunderstanding, the results are presented using the Roentgen as the unit for exposure. For this case (C $R^{-1}cm^{-1}$), the SI units would lead to a very strange combination of units (kg cm^{-1}), that do not express the situation at all. For comparison reasons, the currents were normalized to a base current of 1×10^{-12}A.

3. Results and Conclusions

Both cables tested showed similar effects to radiation. Figure 1 presents the ionization chamber response per unit exposure rate and irradiated cable length as a function of the incident radiation energy. This is the energy dependence of the effect. It is particularly prominent near 100 keV. For cable A, a peak appears in the curve at 98 keV and for cable B, at 121 keV. One of the authors (P.P.) had taken measurements at PTW laboratories and observed a similar behaviour in the same energy region as in the present work with a peak also arising around 100 keV. Cable A presents negative responses for ^{137}Cs and ^{60}Co radiation while cable B, only for ^{137}Cs radiation.

Table 2. Linearity of the effect for cable A. x-Radiation: 142 keV; exposure rate: $\dot{X} = 9.80 \times 10^{-5}$C kg^{-1} s^{-1} (0.38 R s^{-1}); V_n: normalized response to a base current of 1×10^{-12} A

Cable length, L (cm)	Response, V_n (10^{-13}C R^{-1})	V_n/L (10^{-14}C R^{-1}cm^{-1})
5	0.727	1.454
10	1.579	1.579
20	2.812	1.406
30	4.456	1.485
40	5.895	1.474

Linear behaviour can be observed in Fig. 2 for the effect in question between 5 and 40 cm of irradiated extension cable length. In this case the response was obviously not divided by the cable length. For this experiment cable A was used (Table 2).

The reproducibility of all measurements was better than 0.70% (1σ) for both cables.

The observed effect should be taken into account every time an extension cable is exposed in a radiation field. The curves from Figs 1 and 2 cannot be used directly as they are characteristic only of the particular cable used. Each clinical dosimeter user should therefore determine the effect for his particular system. The main objective of the present work was to draw attention to the observed effect.

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