Absorbed dose dependence of the correction factors for ionization chamber cable irradiation effects

1991 Phys. Med. Biol. 36 339

(http://iopscience.iop.org/0031-9155/36/3/003)

Phys. Med. Biol., 1991, Vol. 36, No 3, 339–344. Printed in the UK

Absorbed dose dependence of the correction factors for ionization chamber cable irradiation effects

L L Campos and L V E Caldas

Instituto de Pesquisas Energéticas e Nucleares, Comissão Nacional de Energia Nuclear, Caixa Postal 11049, Pinheiros, CEP 05499, São Paulo, SP, Brazil

Received 7 March 1990, in final form 31 October 1990

Abstract. A simple method was developed, for possible use by hospital physicists, to evaluate the irradiation effects on cables and connectors during large-radiation-field dosimetry with ionization chambers and to determine correction factors for the used system or geometry. This method was based on the absorbed dose dependence of the correction factor.

1. Introduction

Total body irradiation (TBI) has been used for over six decades, since it was first introduced in 1923, in the treatment of disseminated malignancies. Another technique, total skin electron therapy (TSET), has been used for the treatment of mycosis fungoides.

For such whole body treatments the best method would involve using a radiation field large enough to cover the entire body. However, patient comfort, irradiation time and space and equipment availability must be considered. Conventionally, one of the most common techniques to obtain a sufficiently large field has been to increase the treatment distance of an orthovoltage or a ^{60}Co unit. Due to the fact that this treatment method involves the use of large radiation fields and a source–skin distance greater than 110 cm, it is fundamental that the dosimetric aspects for each utilized therapy equipment are analysed very carefully (Khan *et al* 1980, Gonçalves *et al* 1985). Since the entire chamber and a part of the cable are in the beam, the readings should be corrected for possible stem and cable effects (Massey 1970).

Preliminary work (Spokas and Meeker 1980) showed the importance of the photon irradiation effects on cables of ionization chambers. This effect was studied in terms of its dependence on cable length by Caldas *et al* (1989) and its dependence on absorbed dose for photon and electron energies by Campos and Caldas (1990).

A simple method was developed for possible use by hospital physicists to both evaluate the irradiation effects on cables and connectors during large-radiation-field dosimetry with ionization chambers and to determine correction factors for the used system or geometry. This method was based on the absorbed dose dependence of the correction factor, one of the most important parameters of the radiation effects in dielectrics extensively studied by Armistead *et al* (1949), Mayburg and Lawrence

0031-9155/91/030339+06$03.50

(1952), Fowler and Farmer (1954a, b), Gross (1954), Warner *et al* (1954) and Meyer *et al* (1956).

2. Materials and methods

The radiation effects on cables and connectors of ionization chambers were investigated in dosimetric situations of radiotherapy at usual treatment distances for photon and electron beams, by means of measurements of the chamber response to a ^{90}Sr standard check source and the radiation-induced leakage current.

One 0.6 cm^3 thimble chamber, Nuclear Enterprises (NE) model 2505 (chamber 1), and two 0.6 cm^3 thimble chambers, NE model 2505/3 (chambers 2 and 3), were used with a NE electrometer (Baldwin Farmer type) model 2502/3, under normal use conditions of −300 V. A NE ^{90}Sr (0.37 GBq) check source, model 2505/3, was essential in this work. Two NE extension cables, model 2509/3, were denominated cables 1 and 2. The chamber–extension cable junction was denominated the connector.

Four systems were used for the cable irradiations with x-rays, gamma rays and electron beams: a 250 kV x-ray generator Stabilipan, Siemens and two linear accelerators (a Varian, model Clinac-4 and a CGR-10P, model Neptune, with photon beams of 9 MV and electron therapy capability with energies up to about 10 MeV). A ^{137}Cs source (30 TBq), Cesapan-M Generay, was also used.

All irradiations were performed in air and the measurements were corrected for the standard ambient conditions of temperature and pressure.

For x-ray and gamma ray cable irradiations, the usual calibration conditions were used: a field size of 10 cm × 8 cm and a source–surface distance of 50 cm. Different air kerma values were obtained by changing the source–surface distance between 30 and 50 cm.

For electron cable irradiations a 10 cm × 10 cm field size was used at a source–surface distance of 103 cm. Different absorbed doses were obtained by varying the monitor units between 300 and 500. These values correspond to absorbed doses in water between 3.0 and 5.0 Gy at the build-up depth for these conditions.

The chamber response was measured by exposing the chamber to a reproducible amount of radiation of a check source. The reading so obtained is constant. Ten readings were taken before and after submitting a certain length of an ionization chamber cable or a connector to the radiation, while the chamber is held in the radioactive check source. During the cable irradiation 10 readings were also taken at regular intervals.

The cable and connector factors, f, are defined as

$$f = R/R_1 \tag{1}$$

where R is the electrometer reading before the cable irradiation and R_1 is the electrometer reading during the cable irradiation.

Leakage current measurements were performed by switching on the electrometer and setting up the dosemeter, previously exposed to radiation, exactly as if a measurement were to be taken, but in fact the chamber was not subjected to any radiation.

The leakage current measurements were taken 10 times before and after the cable or the connector irradiation. During the cable irradiation 10 readings were also taken at regular intervals.

The leakage factor, F, is defined as

$$F = L/L_1 \qquad (2)$$

where L is the electrometer reading before the cable irradiation and L_1 is the electrometer reading during the cable irradiation.

The f and F factors for cables and connectors were investigated as a function of air kerma and the absorbed dose of photon and electron beams respectively.

All control tests recommended by the IAEA (Massey 1970) for clinical dosemeters were performed to verify the dosemeter performance.

The stem leakage was also measured. In this case, the chamber assembly was irradiated by positioning the reference point of the chamber at the centre of an elongated rectangular field, the short dimension just covering the sensitive ionization chamber volume (6 cm). After these measurements the chamber was rotated by 90°. The ratio of the chamber response in the two positions gives the stem leakage factor for the irradiated stem length. This procedure was repeated for sizes of the rectangle's longest side between 6 and 16 cm.

All dosimetric conditions were provided by the users and are normally used in radiotherapy.

3. Results and discussion

3.1. Stem factor

Stem factors for the two thimble chambers 1 and 2 were determined as described, keeping constant all experimental conditions. The results are shown in figure 1 for these chambers in the case of ^{137}Cs gamma irradiation.

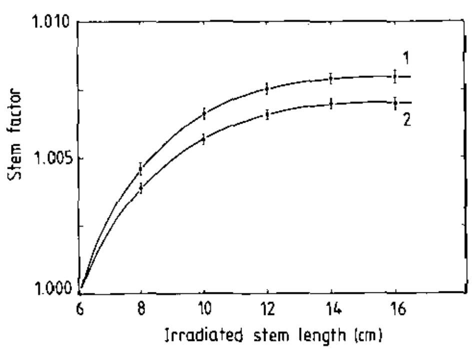

Figure 1. Stem factors of chambers 1 and 2 as a function of the irradiated stem length, due to ^{137}Cs gamma irradiation.

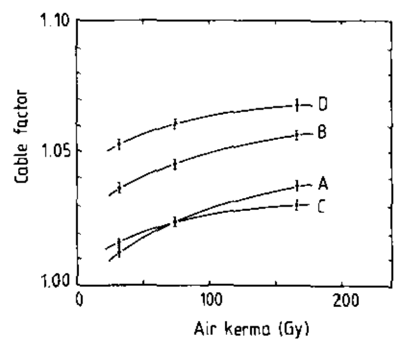

Figure 2. Cable factor of chamber 1 as a function of the air kerma. Irradiated cable length: A, 15 cm; B, 45 cm. Cable factor of chamber 1 coupled to the extension cable of length 10 cm (C) and 30 cm (D).

Each chamber presents a different stem factor; they are significant above 8 cm irradiated stem length.

3.2. Cable and connector factors

The cable and connector factors, f, were extensively studied as a function of the air kerma and the absorbed dose for x-ray and electron irradiations respectively.

The air kerma dependence of the f cable factor in the case of x-radiation of 137 keV for chamber 1 is given in figure 2 for irradiated cable lengths of 15 cm (curve A) and 45 cm (curve B). The same measurements were performed with extension cable 2 coupled to chamber 1 for irradiated extension cable lengths of 10 cm (curve C) and 30 cm (curve D). In figure 3 the air kerma dependence of the f factor is shown in the case of x-radiation of 137 keV for two connectors with chamber 1 coupled to extension cable 1 (curve A) and to extension cable 2 (curve B). In all cases the air kerma was between 39.4 and 170.8 Gy.

The air kerma dependence determined follows the general relation

$$f \propto X^{\Delta} \tag{3}$$

where $\Delta = 0.020 \pm 0.005$ for the cables and connectors of the three chambers and two connectors; $\Delta = 0.015 \pm 0.005$ for the two extension cables coupled to all three chambers. Similar behaviours were obtained using a ^{60}Co gamma source and photon beams of 4 and 9 MV.

The electron cable irradiations were performed varying the monitor units between 300 and 500. The results are shown in figure 4 for chamber 1. Two electron mean energies were tested: 2.0 MeV (curve A) and 2.7 MeV (curve B). In both cases the irradiated cable length was 10 cm.

In this case the general relation is

$$f \propto D^{-\Delta} \tag{4}$$

where $\Delta = 0.035 \pm 0.005$ for all chambers.

The effect for electron irradiation is opposite to the photon irradiation. This behaviour can be explained by the presence of two separate effects: the Compton current, I_C, usually a negative current proportional to the radiation intensity which is induced on the central conductor (Gross 1954), and the component due to the applied electric field, I_σ, the signal of which depends on the direction of irradiation and the applied field polarity.

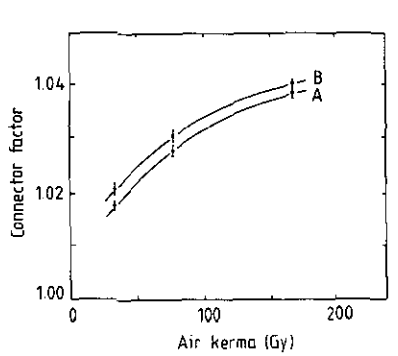

Figure 3. Connector factor of chamber 1 as a function of the air kerma. Irradiated connectors 1 (A) and 2 (B). Radiation field: 15 cm × 10 cm.

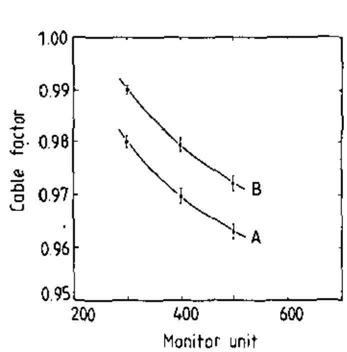

Figure 4. Cable factor of chamber 1 as a function of monitor units. Irradiated cable length: 10 cm. Electron mean energies: 2.0 MeV (A) and 2.7 MeV (B).

The final radiation-induced leakage current is the sum of these two components:

$$I = -I_C \pm I_{\sigma}^{\mp}.$$

These results confirm those obtained by Spokas and Meeker (1980) and Campos and Caldas (1990).

3.3. Leakage factor

For the leakage factor determination, measurements were taken using 94 keV effective energy x-rays and air kerma between 39.4 and 118 Gy. The irradiation time was always 4 min.

A similar behaviour to that of the cable factor, f, was observed for the leakage factor, F. The Δ values for cables and connectors were 0.020 ± 0.005 and 0.015 ± 0.005 for extension cables in the case of photon irradiations. For electron irradiations the determined Δ value was 0.035 ± 0.005.

These results confirm that the only measured effect is a leakage current, positive for electron irradiations and negative for photon irradiations, in this case. For the ionization chambers NE 2571 and 2581 this effect may be somewhat reduced because they are guarded in a different manner than the older models.

Based on these results a simple method for cable factor determination can be proposed.

4. Proposed method

The following cable irradiation effect properties were determined by Campos and Caldas (1990): (i) the chamber response increases proportionally to the irradiated cable length; (ii) the energy dependence is high for both photon and electron irradiations; and (iii) the air kerma dependence follows the general relation given in equation (3), $f \propto X^{\Delta}$, for x-ray or gamma cable irradiations, and equation (4), $f \propto D^{-\Delta}$, in the case of electron cable irradiation.

Considering these properties, a two-step method can be proposed for cable factor determination in the case of large-radiation-field dosimetry. The method consists of (1) determination of the stem factor, using the rectangular field technique; and (2) determination of the absorbed dose or air kerma dependence of the cable factor or the leakage factor in order to determine the Δ value of the general relations.

These two determinations can be performed with the usual radiotherapy distances, field sizes and air kerma values.

The obtained values can easily be extrapolated for TBI or TSET geometries if the measurements are taken at the adequate energy; otherwise they have to be corrected for the energy dependence, which has to be previously determined.

Acknowledgments

The authors are grateful to the following medical institutions in São Paulo, Brazil: Hospital AC Camargo, Hospital das Clínicas and Hospital Sírio-Libanês for the use of the x-ray systems and accelerators.

Résumé

Dépendance vis à vis de la dose absorbée des facteurs de correction relatifs aux effets de l'irradiation du câble des chambres d'ionisation.

Les auteurs ont développé une méthode simple à l'usage des physiciens d'hôpital pour évaluer les effets de l'irradiation sur les câbles et connecteurs intervenant lors de la dosimétrie des grands champs d'irradiation effectuée avec des chambres d'ionisation. La méthode proposée est applicable à la détermination des facteurs de correction pour la géométrie et le système utilisés et est basée sur la dépendance du facteur de correction vis à vis la dose absorbée.

Zusammenfassung

Energiedosisabhängigkeit von Korrektionsfaktoren bei Bestrahlung des Ionisationskammerkabels.

Eine einfache Methode wurde entwickelt, die Medizin-Physikern helfen soll, die Auswirkung der Bestrahlung auf Kabel und Verbindungen während der Großfelddosimetrie mit Ionisationskammern zu bewerten und Korrektionsfaktoren für das verwendete System und die benutzte Geometrie zu bestimmen. Diese Methode basiert auf der Energiedosisabhängigkeit der Korrektionsfatoren.

References

Armistead F C, Pennock J C and Mead L W 1949 Conductivity changes in dielectrics during 2.5 MeV X-radiation *Phys. Rev.* **76** 860

Caldas L V E, Regulla D F and Pychlau P 1989 Ionization chamber extension cables: radiation effects *Appl. Radiat. Isot.* **40** 93-4

Campos L L and Caldas L V E 1991 Induced effects in ionization chamber cables by photon and electron irradiation *Med Phys.* at press

Fowler J F and Farmer F T 1954a Conductivity induced in polytetrafluoethylene by X-rays *Nature* **173** 317-8

—— 1954b Conductivity induced in insulating materials by X-rays *Nature* **174** 136-7

Gonçalves J F, Souhami L, Pereira Jr P, Cecatti S G P, Pereira E N, Silva M P and Rodrigues A T 1985 Aspectos dosimétricos de irradiação de meio corpo *Radiol. Bras.* **18** 96-9

Gross B 1954 The Compton current *Z. Phys.* **155** 479-87

Khan F M, Willianson J F, Sew Chand W and Kim T H 1980 Basic data for dosage calculation and compensation *Int. J. Radiat. Oncol. Biol. Phys.* **6** 745-51

Massey J B 1970 Manual of dosimetry in radiotherapy *IAEA Technical Report Series* 110 (Vienna: International Atomic Energy Agency)

Mayburg S and Lawrence W L 1952 The conductivity change in polyethylene during γ-irradiation *J. Appl. Phys.* **23** 1006-11

Meyer R A, Bouquet F L and Alger R S 1956 Radiation induced conductivity in polyethylene and Teflon *J. Appl. Phys.* **7** 1012-8

Spokas J J and Meeker R D 1980 Investigation of cables for ionization chambers *Med. Phys.* **7** 135-40

Warner A J, Müller F A and Nordlin H G 1954 Electrical conductivity induced by ionizing radiation in some polymeric materials *J. Appl. Phys.* **25** 131