

Using a tandem ionization chamber for quality control of X-ray beams

Utilizando uma câmara de ionização tandem para controle de qualidade dos feixes de raios X

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Abstract

X-ray beam qualities are defined by both the mean energies and by the half-value layers (HVL). Many international protocols use the half-value layer and the beam voltage to characterize the X-ray beam quality. A quality control program for X-ray equipment includes the constancy check of beam qualities, i.e., the periodical verification of the half-value layer, which can be a time consumable procedure. A tandem ionization chamber, developed at Instituto de Pesquisas Energéticas e Nucleares, was used to determine the HVL and its constancy for five radiotherapy standard beam qualities. This ionization chamber is composed by two sensitive volumes with inner electrodes made of different materials: aluminum and graphite. The beam quality constancy check test was performed during two months and the maximum variation obtained was 1.24% for the radiation beam quality T-10. This result is very satisfactory according to national recommendations.

Keywords: tandem system, X-ray beams, quality control.

Resumo

As qualidades do feixe dos raios X são definidas tanto pelas energias médias quanto pelas camadas semirredutoras. Muitos protocolos internacionais utilizam a camada semirredutora e a tensão do feixe para caracterizar a qualidade do feixe dos raios X. Um programa de controle de qualidade para equipamentos de raios X inclui a verificação constante das qualidades do feixe, ou seja, a verificação periódica da camada semirredutora, que pode ser um procedimento que consome tempo. Uma câmara de ionização tandem, desenvolvida no Instituto de Pesquisas Energéticas e Nucleares, foi utilizada para determinar a camada semirredutora e sua constância para cinco qualidades do feixe-padrão de radioterapia. Essa câmara de ionização é composta por dois volumes sensíveis com eletrodos internos feitos de materiais diferentes: alumínio e grafite. O teste de verificação da constância da qualidade do feixe foi realizado durante dois meses, e a variação máxima obtida foi de 1,24% para a qualidade T-10 do feixe de radiação. Esse resultado é muito satisfatório, de acordo com as recomendações nacionais.

Palavras-chave: sistema tandem, feixes de raios X, controle de qualidade.

Introduction

When using ionizing radiation, mainly for medical purposes, the delivered dose must be very accurately known. One way to achieve the recommended limits of dose accuracy is maintaining a quality control program of radiation beams.

One of the recommended procedures in a quality control program for X-radiation equipment is the verification of the beam qualities constancy in terms of the half-value layer (HVL)¹. The HVL of each beam quality is, conventionally, obtained by adding high purity absorbers of known thickness at midway between the radiation tube and the detector. The use of a tandem system is an alternative for the HVL verification. This method provides

an accurate response and it is easier and faster than the conventional one².

A tandem system is composed by two dosimeters with different characteristics. Thermoluminescent dosimeters in tandem system were studied to determine the effective energy of unknown radiation fields³⁻⁵.

At Instituto de Pesquisas Energéticas e Nucleares, a double-faced ionization chamber was developed to be used as a tandem system⁶. The main objective of this tandem chamber is to verify the HVL value constancy in a quality control program.

In this work, the tandem ionization chamber was used to establish a methodology for checking the beam quality constancy for radiotherapy standard X-ray beams.

Materials and methods

A special double-faced ionization chamber, developed at IPEN, was utilized. This ionization chamber is disc-shaped and contains two sensitive volumes of 0.6 cm³ each one. Because the inner electrodes are made of different materials - one is made of aluminum (Face A) and the other of graphite (Face G), this ionization chamber constitutes a tandem system. This tandem chamber was developed to be used in low-energy X-ray beams.

A ⁹⁰Sr+⁹⁰Y check source, Physikalisch-Technische Werkstätten (PTW), model 8921, with nominal activity of 33.3 MBq (1998), was used to perform the response stability tests of the tandem ionization chamber.

An X-ray unit, Pantak/Seifert, model ISOVOLT 160HS, with standardized beam qualities was used in this work. The radiation qualities (suggested by BIPM⁷) characteristics are presented in Table 1. A secondary standard plane-parallel ionization chamber, PTW, model M23344, was used as a reference system for these beam qualities.

Results

The tandem ionization chamber was submitted to response stability tests and energy dependence for X-radiation.

Response stability tests

The response stability of the tandem ionization chamber was tested for both sides of the ionization chamber (Face A and Face G).

The leakage current was measured during 20 minutes, before and after each irradiation, and it was always negligible during the whole test period.

For the short-term stability test, ten consecutive measurements were taken using the ⁹⁰Sr+⁹⁰Y check source. The standard deviation of the set of measurements presented a maximum value of 0.14% for Face A and 0.05% for Face G. For both faces, the standard deviation is within the recommended of 0.3%⁸.

Comparing the mean values of each set of ten measurements, the medium-term stability test was evaluated. The short-term stability test was performed 10 times and, as can be seen in Figure 1, the maximum variation obtained in the medium-term stability test was 0.27% for

Table 1. Radiotherapy standard beam qualities of the Pantak/Seifert X-ray equipment.

Radiation quality	Tube potential (kV)	Additional filtration (mmAl)	Half-value layer (mmAl)	Air kerma rate (mGy.s ⁻¹)
T-10	10	---	0.043	3.229±0.003
T-25	25	0.4	0.279	2.753±0.002
T-30	30	0.2	0.185	9.492±0.005
T-50 (a)	50	4.0	2.411	0.833±0.002
T-50 (b)	50	1.0	1.079	3.878±0.003

Face A and 0.30% for Face G. Thus, both cases are within the recommended value of ±0.5%⁸.

Energy dependence for X-rays and tandem curve

Both faces of the tandem ionization chamber were calibrated against the secondary standard ionization chamber using the radiotherapy beam qualities described in Table 1. The reference system for these radiation beam qualities is a parallel-plate ionization chamber, PTW, model M23344.

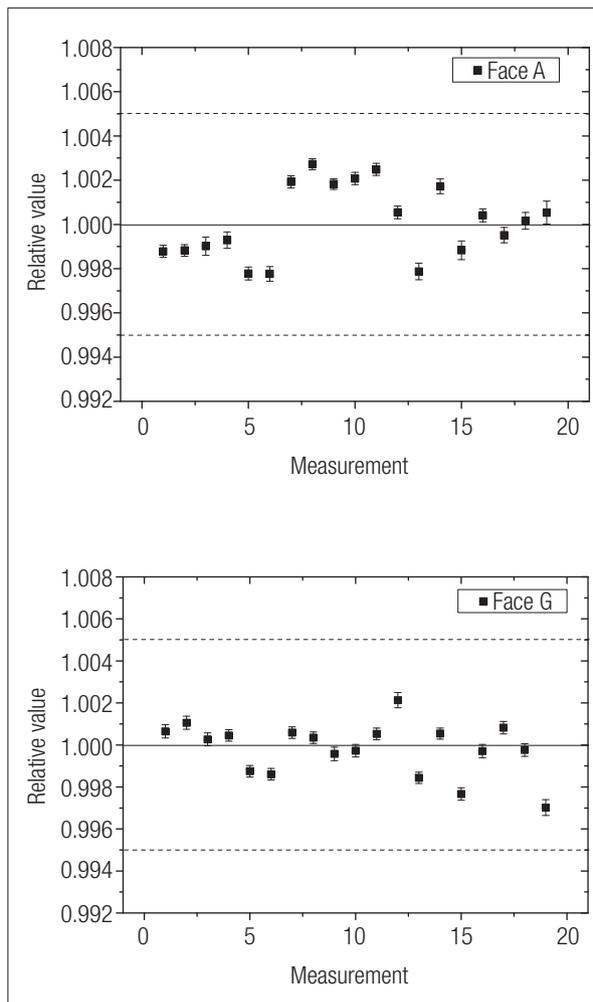


Figure 1. Medium-term stability test for Face A and Face G of the tandem ionization chamber.

Table 2. Calibration coefficients and correction factors of the tandem ionization chamber using X-radiation, radiotherapy beam qualities.

Radiation quality	Calibration coefficients (mGy/nC)		Correction factors	
	Face A	Face G	Face A	Face G
T-10	30.88±0.16	35.75±0.17	1.291±0.008	0.944±0.006
T-25	22.26±0.13	38.98±0.17	0.930±0.007	1.029±0.006
T-30	23.92±0.11	37.89±0.15	1.000±0.006	1.000±0.006
T-50 (a)	16.83±0.19	43.95±0.32	0.703±0.008	1.159±0.009
T-50 (b)	17.77±0.11	41.47±0.17	0.743±0.006	1.094±0.006

The calibration coefficients obtained for each radiation beam quality were normalized to the T-30 beam quality, obtaining correction factors. In Table 2, the calibration coefficients and correction factors are shown. The energy dependence of the tandem ionization chamber can be seen in Figure 2.

As the energy dependence of Faces A and G are different, a tandem curve can be obtained by the ratio of the responses. For each beam quality, the chamber response obtained for Face G was divided by the response obtained for Face A. The tandem curve presented a good curvature and it is shown in Figure 3.

Constancy check of X-radiation beam qualities

The ratio of the responses was used to determine the constancy of the beam qualities. According to national recommendations, the maximum variation of the HVL is $\pm 3\%$ ⁹. Nine measurements were performed using the five beam qualities studied, and the maximum variation

obtained was 1.24%, thus within the recommended value. Figure 4 shows the constancy of beam quality T-30 using the ratio of the responses. The same behavior was obtained for the other beam qualities.

Conclusions

Both sides of the tandem ionization chamber presented good stability response, within internationally recommended limits. The ratio of responses gave rise to a good tandem curve, enabling the ionization chamber to be used in radiotherapy beam quality constancy checks. The results of nine measurements showed a stable response of the tandem chamber for X-ray beams. The simplicity in the use of this tandem ionization chamber in the verification of HVL values and its satisfactory results showed that this ionization chamber is a good alternative for the conventional method.

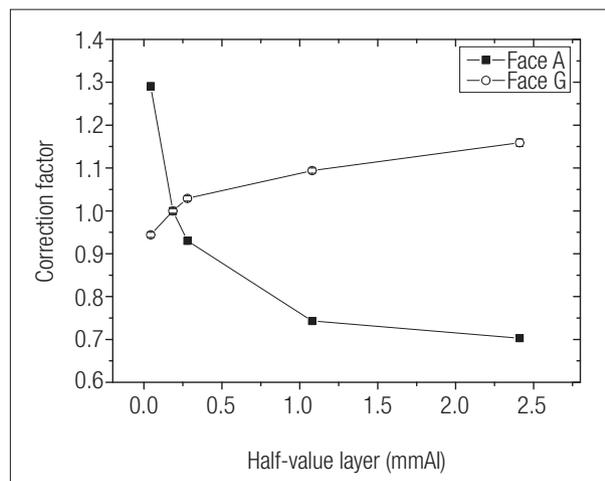


Figure 2. Energy dependence of the tandem ionization chamber for both Faces A and G.

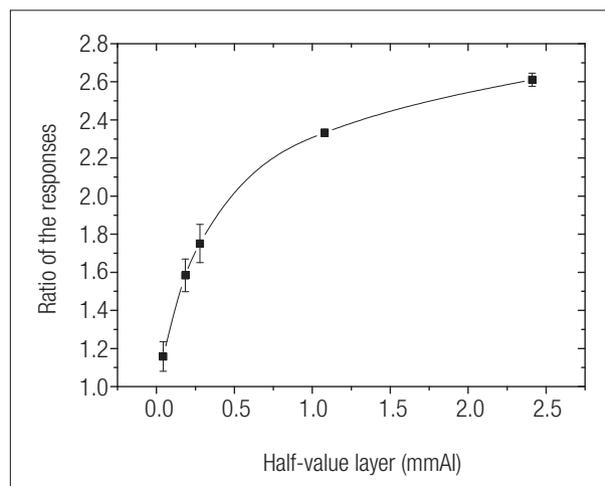


Figure 3. Tandem curve of the ionization chamber.

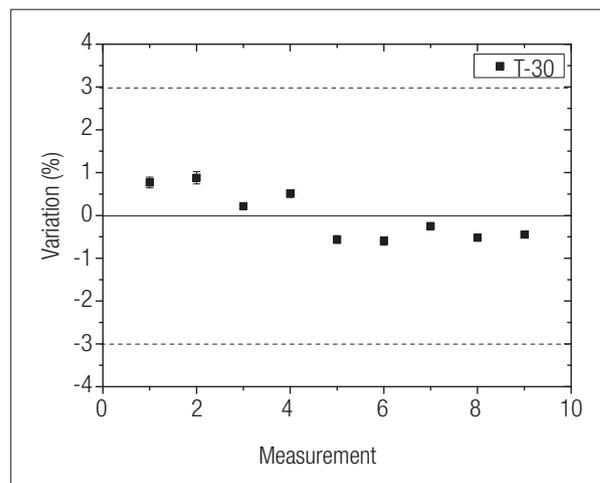


Figure 4. Constancy check of the beam quality T-30.

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