Using a Tandem Ionization Chamber for Quality Control of X-ray Beams

M.T. Yoshizumi and L.V.E. Caldas

Instituto de Pesquisas Energéticas e Nucleares, Comissão Nacional de Energia Nuclear, IPEN-CNEN/SP, São Paulo, Brazil

Abstract— **X-ray beam qualities are defined by both the mean energies and by the half-value layers. 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.**

I. Introduction

When using ionizing radiation, mainly for medical purposes, the delivered dose must be known very accurately. 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 method [2].

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 fields [3-5].

At Instituto de Pesquisas Energéticas e Nucleares a double-faced ionization chamber was developed to be used as a tandem system [6]. 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.

II. Materials

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 cm^3 each one. Because the inner electrodes are made of different materials: one is made of aluminum (Face A) and the other is made 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 $^{90}Sr+^{90}Y$ 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 BIPM [7]) 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.

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

III. Results

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

A. 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 ^{90}Sr + ^{90}Y 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 Fig. 1, the maximum variation obtained in the medium-term stability test was 0.27% for Face A and 0.30% for Face G. Thus, both cases are within the recommended value of ±0.5% [8].

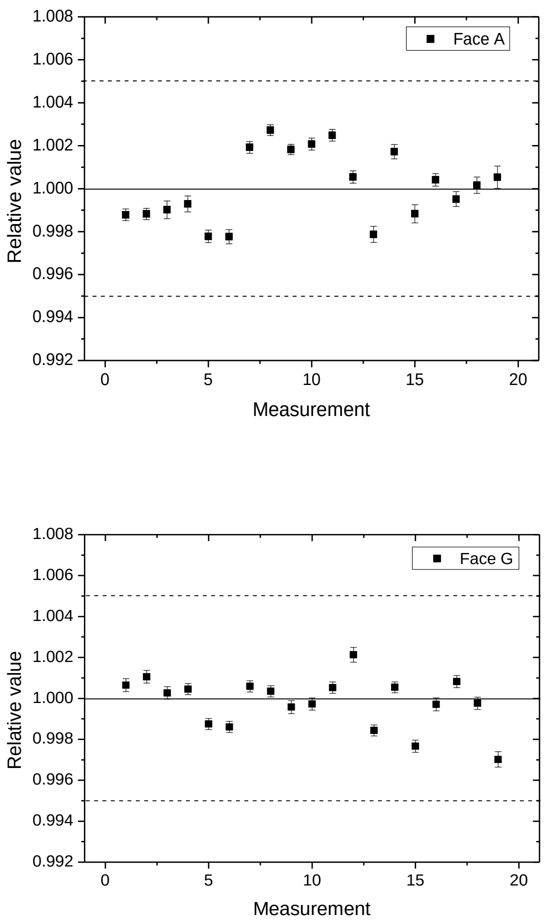

Fig. 1 Medium-term stability test for Face A and Face G of the tandem ionization chamber

B. 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.

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 Fig. 2.

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

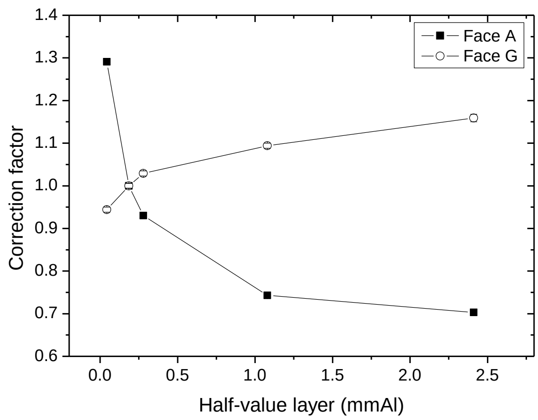

Fig. 2 Energy dependence of the tandem ionization chamber for both Faces A and G

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 Fig. 3.

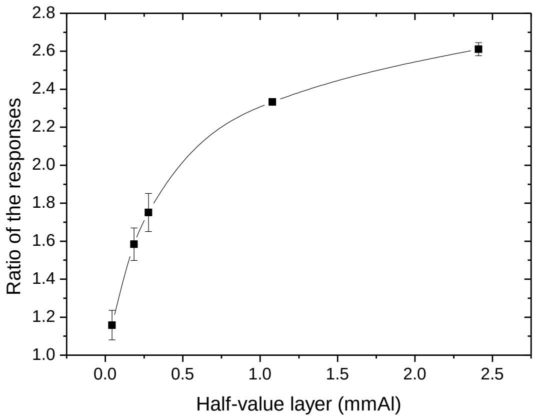

Fig. 3 Tandem curve of the ionization chamber

C. 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 ±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. Fig. 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.

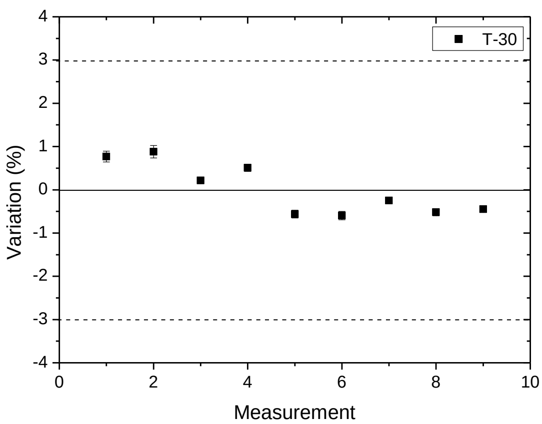

Fig. 4 Constancy check of the beam quality T-30

IV. 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.

ACKNOWLEDGMENTS

The authors would like to thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) and MCT (INCT for Radiation Metrology in Medicine), Brazil, for partial financial support.

REFERENCES

1. International Atomic Energy Agency IAEA (1994) Calibration of dosimeters used in radiotherapy. Technical Reports Series No374, Vienna
2. Maia A F and Caldas L V E (2006) A simple method for evaluation of half-value layer variation in CT equipment. Phys Med Biol 51:1595-1601
3. Gorbics S G and Attix F H (1968) LiF and CaF_2:Mn thermoluminescent dosimeters in tandem. Int J Appl Radiat Isot 19:81-89
4. Da Rosa L a R and Nette H P (1988) Thermoluminescent dosemeters for exposure assessment in gamma or X-radiation field with unknown spectral distribution. Appl Radiat Isot 39:191-197
5. Miljanie S, Vekie B and Martineie R (1999) Determination of X-ray effective energy and absorbed dose using CaF_2:Mn and LiF:Mg,Ti thermoluminescent dosemeters. Radiat Prot Dosim 85:381-384
6. Costa A M and Caldas L V E (2003) Response characteristics of a tandem ionization chamber in standard X-ray beams Appl Radiat Isot 58:495-500
7. Bureau International des Poids et Mesures BIPM (2004) Measuring condition used for the calibration of ionization chambers at the BIPM. Rapport BIPM-04/17, Sèvres
8. International Electrotechnical Commission IEC (1997) Medical electrical equipment - Dosimeters with ionization chambers as used in radiotherapy. IEC 60731, Genève
9. Instituto Nacional do Câncer INCA (2000) Aspectos físicos da garantia da qualidade em radioterapia. TEC DOC-1151, Brazil

CORRESPONDING AUTHOR:

Author: Maíra Tiemi Yoshizumi
Institute: Instituto de Pesquisas Energéticas e Nucleares
Street: Av. Prof. Lineu Prestes 2242
City: São Paulo
Country: Brazil
Email: mairaty@ipen.br