2017 International Nuclear Atlantic Conference - INAC 2017
Belo Horizonte, MG, Brazil, October 22-27, 2017
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR – ABEN

Agência Brasileira do ISBN
ISBN 978-85-99141-07-6

APPLICATION OF THE CORRECTION FACTOR FOR RADIATION QUALITY K_q IN DOSIMETRY WITH PENCIL-TYPE IONIZATION CHAMBERS USING A TANDEM SYSTEM

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ABSTRACT

The pencil-type ionization chamber widely used in computed tomography (CT) dosimetry, is a measuring instrument that has a cylindrical shape and provides uniform response independent of the angle of incidence of ionizing radiation. Calibration and measurements performed with the pencil-type ionization chamber are done in terms of Kerma product in air-length ($P_{k,l}$) and values are given in Gy.cm. To obtain the values of ($P_{k,l}$) during clinical measurements, the readings performed with the ionization chamber are multiplied by the calibration coefficient ($N_{k,l}$) and the correction factor C for quality (K_q) which are given in Calibration certificates of the chambers. The application of the correction factor for radiation quality K_q is done as a function of the effective energy of the beam that is determined by the Half Value layer (HVL) calculation. In order to estimate the HVL values in this work, a Tandem system made up of cylindrical aluminum and PMMA absorber layers was used as a low cost and easy to apply method. From the Tandem curve, it was possible to construct the calibration curve and obtain the appropriate K_q to the beam of the computed tomography equipment studied.

1. INTRODUCTION

The pencil-type Ionization chambers have peculiar characteristics of use and geometry and, therefore, the method of calibration of these chambers is also differentiated. There are different calibration methods where the main difference is related to the irradiated area of the ionization chamber [1].

The total irradiation of the chamber is common in several applications of the camera, but it is known that tests of homogeneity of the response along its sensitive length have shown that there is a loss of sensitivity in its extremities [2]. Taking into account the peculiarities of the pencil chamber, the International Atomic Energy Agency (IAEA) practice code TRS 457 [3] established the methodology for calibration in SSDLs where the chamber is partially irradiated.

Calibration and measurements performed with the pencil-type ionization chamber are done in terms of Kerma product in air-length ($P_{k,l}$) and values are given in Gy.cm. In order to obtain the values of ($P_{k,l}$) during clinical measurements, the readings performed with the ionization chamber are multiplied by the calibration coefficient ($N_{k,l}$) and by the correction factor for quality (K_q) Calibration of the chambers. However, there is a gap between the calibration of an ionization chamber in the laboratory and its use in clinical applications, which takes into account the coefficients and factors indicated in the calibration certificate provided by the laboratory in which it is calibrated.

Due to frequent doubts from customers of the Instruments Calibration Laboratory (LCI) of the Institute for Energy and Nuclear Research (IPEN), regarding the use of the factors indicated in the calibration certificates, it was noticed that many users make mistakes when using a camera Calibration in the dosimetry of their CT systems. The geometry of irradiation used in a calibration differs totally from that available in a CT system requiring the application of factors that will relate the Kerma magnitude in the air to those specific for CT. Another fundamental difference is that calibration is done in the air while clinical measurements are usually performed only in simulators.

The use of specific calibration simulators that can more accurately and reliably relate CT-specific quantities is not yet known. To further clarify the application of these factors, methodologies were developed to construct calibration curves as a function of the Half Value Layer (HVL) so that the user can find the correct correction factors for the energy of the clinical beam. By definition, the energy of a beam is determined by the value of HVL [4]. The determination of HVL values in computed tomography was performed using a methodology using a Tandem system composed of cylindrical aluminum and PMMA absorber layers.

2. MATERIALS AND METHODS

Using the radiation qualities established for the range corresponding to a computed tomography beam, RQT 8, RQT 9 and RQT 10, shown in Table 1 and the standard LCI ionization chamber, the calibration procedures were applied according to Code of practice of the international atomic energy agency (IAEA) TRS 457 in accordance with Fig.1.

Table 1. Characterization of radiation quality series RQT established.

Radiation quality	X ray tube voltage (kV)	Added filtration (mm Cu)	Nominal first HVL (mm Al)
RQT 8	100	0.20	6.9
RQT 9	120	0.25	8.4
RQT 10	150	0.30	10.1

The method used was the substitution method where Kerma measurements in air are first made with the standard ionization chamber in the same position of the ionization chamber in calibration and corrected by the ambient conditions and then performed with the ionization chamber a be calibrated.

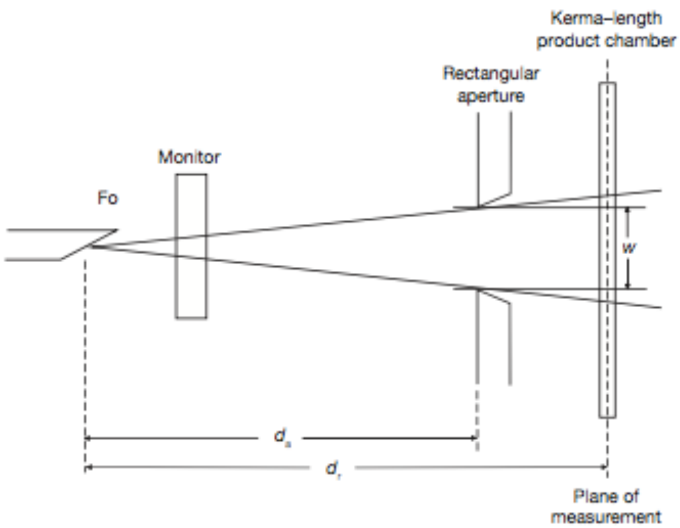

Figure 1. Illustration of the arrangement suggested by the IAEA TRS 457 for calibration of the ionization chambers of the pencil-type.

2.1. Determination of Kerma air rates with the standard chamber

To determine the air Kerma rate (K_{ar}), the correction factors for quality (K_q) and calibration coefficients ($N_{k,l}$) provided by the German primary laboratory PTB were used and multiplied by the readings obtained with the standard chamber as shown in Equation 1.

$$K_{ar} = \mathrm{Nk,l} \times K_q \times M \quad (1)$$

Where M is the reading with the reference instrument.

2.1.1. Determination of calibration coefficients $N_{k,l}$

The calibration coefficient $N_{k,l}$ was determined from the quotient between the Kerma rate reading in the standard chamber air, by the mean of the chamber Kerma rate readings in calibration and corrected by the ambient conditions as in Equation 2:

$$N_{k,l} = \frac{K_{ar}}{M \times F_{T,p}} \quad (2)$$

At where:

K_{ar}: It is the Kerma rate in the air obtained through the standard chamber;

M: is the average of the Kerma rate readings obtained with the camera in calibration;

$F_{T,p}$: It is the correction factor for temperature and pressure.

2.1.2. Determination of correction factor for quality K_q

The correction factor for quality K_q was determined by the calibration coefficient $N_{k,l}$ as shown in Equation 3:

$$K_q = \frac{N_{k,l}}{N_{K,lref}} \qquad (3)$$

At where,

K_q: Is the correction factor for quality.

$N_{k,l}$: is the calibration coefficient in terms of $P_{k,l}$ (Kerma product in air - length) of RQT 8, 9 or 10 quality.

$N_{K,lref}$: Is the calibration factor in terms of $P_{k,l}$ (Kerma product in air - length) of reference quality RQT 9.

With the K_q values of the reference qualities obtained during the calibration it was possible to construct the calibration curve.

2.1.3. Application of K_q in clinical measurements

Using the Tandem system composed of cylindrical absorber layers and pencil-type ionization chamber in the Siemens Somaton Definition AS tomography equipment, the parameters shown in Table 2 were used to carry out the readings and to evaluate the HVL values.

Table 2. Parameters used to perform clinical trials with the Tandem system

Nominal thickness	Number of Slices	Pit (mA.s)	kV
2 mm	1	170	130

The assembled arrangement for carrying out the readings with the Tandem system can be seen in Fig.2.

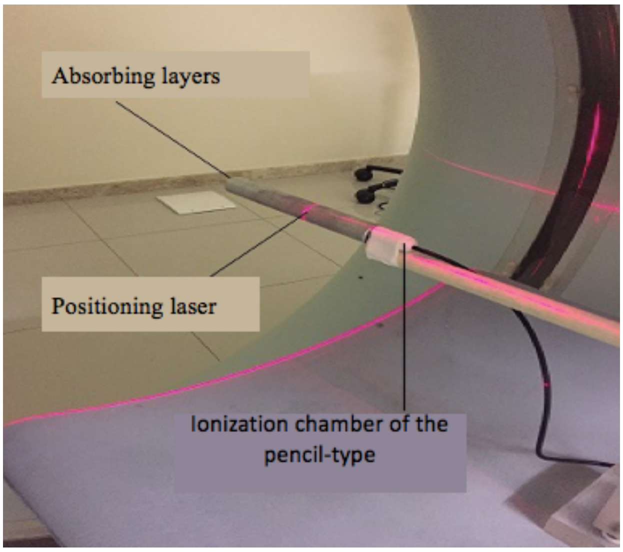

Figure 2. Arrangement assembled to obtain the readings with the Tandem system.

We know the value of HVL corresponding to the energy of the beam under study, by means of the equation of the calibration curve shown previously, it was possible to know the correction factor for quality K_q.

3. RESULTS

The calibration data of the pencil-type ionization chamber can be seen in Table 3.

Table 3. Calibration data o ionization chamber of the pencil-type used in this work.

Radiation quality	X ray tube voltage (kV)	HVL (mm Al)	$N_{k,l}$ (Gy.cm.ue$^{-1)}$)	K_q
RQT 8	100	6.9		1.015
RQT 9	120	8.4	9.158 x 10^{-3}	1.00
RQT 10	150	10.1		0.995

With the correction factors that are provided by the calibration certificate and in this case, can be visualized in the Table 3 shown above, the calibration curve of the ionization chamber of the pencil type used in this work was constructed and can be seen in Fig.3.

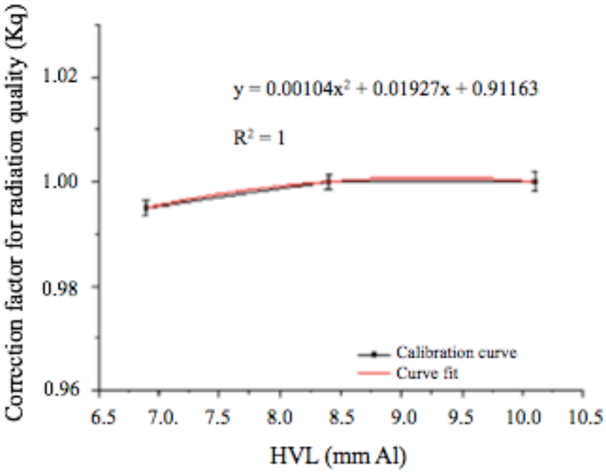

Figure 3. Calibration curve of the ionization chamber of the pencil-type used in this work.

Using the equation of the Tandem curve the estimated value for HVL in the CT scanner was 8.6 mm Al and the value found was 1.00. The estimated HVL value found was close to the expected value for RQT 9 quality, which is 8.4 mm Al.

4. CONCLUSION

The application of the correction factor for radiation quality is important to correct possible variations in the energetics dependence of the pencil-type ionization chambers. It is possible to construct the calibration curve of the measurement system by means of the data provided in the certificates issued by the calibration laboratories.

5. ACKNOWLEDGMENTS

The authors acknowledge the partial financial support of the CAPES, FAPESP, CNPQ and INCT (project: Radiation Metrology in Medicine).

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