Non-InvasiveTransfer System to Calibrate kVp Meters

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INTRODUCTION

Quality assurance programmes in diagnostic radiology have been increased in the last years due to the fact that the extensive use of X-rays in medicine for diagnosis of injuries and diseases represents the largest man-made source of public exposure to ionizing radiation (1). The assessment and control of the performance characteristics of X-ray generators and tubes is an essential part of a quality assurance programme. The high voltage peak is an important measurable quantity to ensure optimal image quality and thus accurate diagnoses. Consequently the calibration of the kilovoltage peak (kVp) meters is very important.

Since 1980 instruments are being calibrated at the Calibration Laboratory of IPEN at radiotherapy and radiation protection levels and recently a few qualities at the diagnostic radiology level were established to test some instruments (2).

A commercial non-invasive kVp meter, usually, has two diode detectors partially shielded by different filters to provide a ratio that can be used to determine the tube voltage. An additional ionization chamber is necessary to measure air kerma. To calibrate these devices a method using the measurement of the spectrum endpoint has been established with a portable gamma and X-ray spectrometer.

The objective of this work is to use as non-invasive transfer system two identical ionization chambers developed at IPEN. The chambers differ only by the electrode material, one is made of aluminium and the other is made of graphite. The good behaviour of the graphite electrode chamber provides the air kerma rates. The transfer system can be calibrated against a spectrometer and against a standard ionization chamber which is traceable to the German Primary Laboratory (Physikalisch-Technische Bundesanstalt - PTB). Thus it is possible to use only one reference system to determine kVp and air kerma values.

MATERIALS AND METHODS

The X-rays generating system consists of a Medicor Mövek Röntgengyara X-rays generator, model Neo-Diagnomax (125 kV). Measurements were taken from 50 to 90 kV, using the established qualities listed in Table 1. As reference to the air kerma rates determination, a 1.0 cm^3 parallel plate ionization chamber, Physikalisch-Technische Werkstätten (PTW), model 77334, traceable to PTB, Germany, was utilized in this work.

For the maximum tube voltage determination, a portable gamma and X-ray Intertechnique spectrometer system was used. It consists of a planar hyper pure Germanium (HPGe) Σurisys Mesures detector (16 mm diameter, 13 mm thickness) connected to a 5 litre dewar vessel, a spectroscopy amplifier with pile-up rejection, a multichannel analyser with ultra fast ADC power supply and a high voltage supply in a mini rack, and a notebook with the interpc spectrometry software. The spectrometer was calibrated using an ^{241}Am source with emission peaks at 59.537 keV (γ rays) and 17.611 keV (X rays).

Table 1 : Diagnostic radiology qualities established at the Calibration Laboratory of IPEN.

Radiation Quality	Tube Voltage (kV)	Total Filtration (mmAl)	Half-Value Layer (mmAl)	Effective Energy (keV)	Air Kerma Rate (mGy/min)
RQR 3	52	2.5	1.82	32.0	5.06
RQR 5	70	2.5	2.45	39.2	6.59
RQR 7	90	2.5	3.10	46.0	6.92

The proposed system consists of two parallel plate ionization chambers developed at IPEN(3,4,5). The design of the chambers can be seen in Figure 1. They have Lucite walls, and one has the electrode and the guard ring made of graphite, and the other is made of aluminum. The thickness of the electrodes is 4.8 mm and the diameter is 16 mm. The ionization chambers volume is 0.6 cm^3.

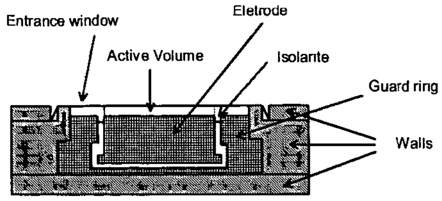

Figure 1 : Parallel plate ionization chamber developed at IPEN[3].

The transfer system (the two ionization chambers together) was placed in the X-ray beam, using a Lucite holder as shown in Figure 2. They were connected to a PTW electrometer, model MULTIDOS, which allows connection to the two ionization chambers simultaneously.

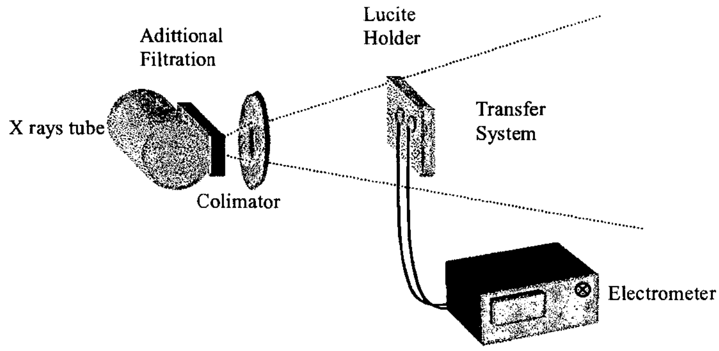

Figure 2 : Transfer system in the radiation beam of a diagnostic radiology system.

Three kVp meters were used to test the transfer system as a reference system. Their characteristics are listed in Table 2.

Table 2 : Characteristics of the kVp meters tested in this work.

Identification	Instrument	Model	Type
A	Victoreen	NERO 6000M	Non-invasive
B	Radcal	Dynalizer III	Invasive
C	Gammex	RMI 242	Non-invasive

RESULTS

As the ionization chambers used in this work have different electrodes providing different energy dependences, the Tandem method is possible to apply. This method consists of the use of the ratio between the different responses or the calibration factors of two dosemeters for energy effective determination in unknown X radiation fields (6). Figure 3 shows the energy dependence of the chambers. The graphite electrode chamber (C1) shows only 0.28% of variation on its calibration factor while the aluminum electrode chamber (A1) shows 19%.

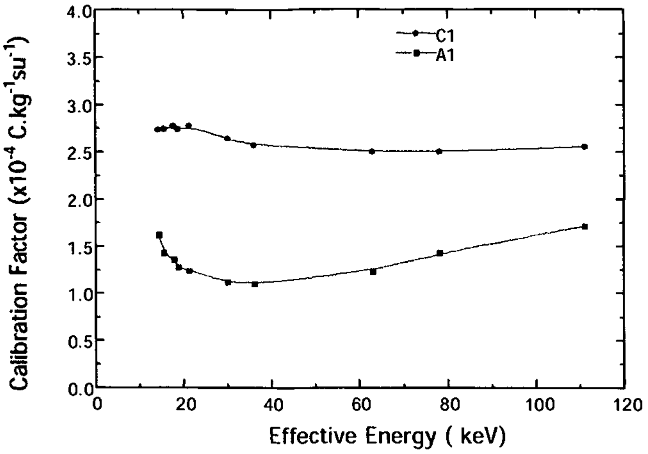

Figure 3 : Energy dependence of the parallel plate ionization chambers (3).
su : scale unit

The ratio between the calibration factors provided the Tandem curve of this system, as shown in Figure 4. The associated uncertainties were always less than 0.4%. This simple method allows the exposure or air kerma rates determination in an unknown X radiation field.

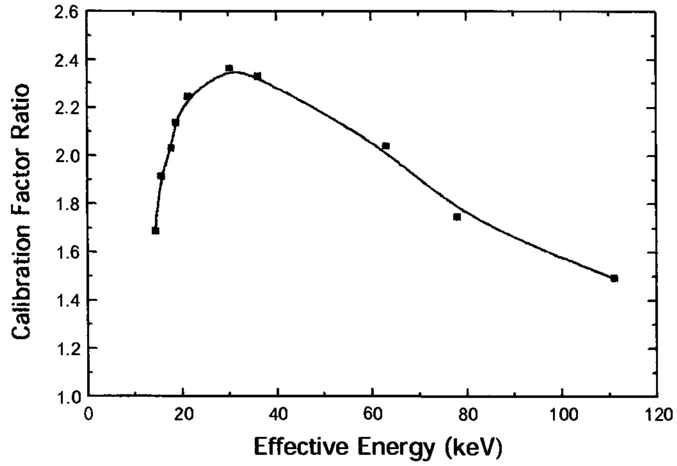

Figure 4 : Tandem curve of the parallel plate ionization chambers developed at IPEN (3).

These chambers have been tested in comparison with other Tandem systems and their behaviour showed a good stability to be used as a reference system (7). To test the pair of chambers as a transfer system in diagnostic radiology fields, as proposed, initially in the spectrometry of the X radiation system in the established qualities was performed. The values obtained are presented in Figure 5 and were used as reference values in this work, considering that spectrometry is a primary method to determine the radiation field characteristics (8).

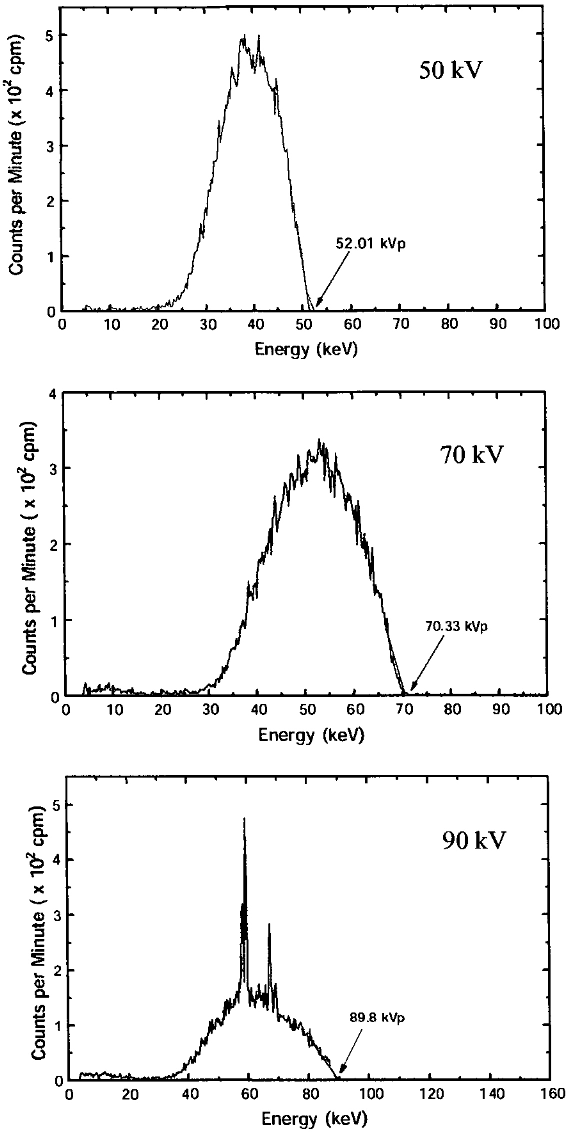

Figure 5 : Spectra for 50 , 70 and 90 kV X-rays obtained in the Neo Diagnomax diagnostic radiology system. The kVp values are : 52.01, 70.33 and 89.8 respectively. The current was 0.5 mA in all cases.

The transfer system (two chambers together) was placed in the beam and calibrated against de reference ionization chamber in relation to the air kerma rates. The calibration factors obtained for the two chambers are listed in Table 3. The chamber C1 has a very good behaviour when compared to the reference chamber. The maximum variation on its response was 6%, while the chamber A1, as expected, showed a variation of 60% in relation to the reference chamber. The maximum uncertainty in the experimental data was 5.5%.

Table 3 :Calibration Factors, N_K, for the C1 and A1 ionization chambers in the diagnostic radiology established qualities at the Calibration Laboratory of IPEN.

Radiation Quality	Tube Voltage (kV)	Half-Value Layer (mmAl)	Effective Energy (keV)	Air Kerma Rate (mGy/min)	N_K (mGy/s.u.)	
					C1	A1
RQR 3	52	1.82	32.0	5.06	1.01	0.402
RQR 5	70	2.45	39.2	6.59	1.04	0.428
RQR 7	90	3.10	46.0	6.92	1.06	0.460

Transference factors were determined for the calibration of the kilovoltage meters, in the range from 52 to 90 kV, relating the values obtained by the two chambers simultaneously. These ratios between the measurements (A1/C1) provided conversion factors to the kVp determinations. Figure 6 shows the behaviour of the system. This is comparable to the behaviour of the chambers separately as a Tandem system. The maximum uncertainty in the experimental data was 1.2%.

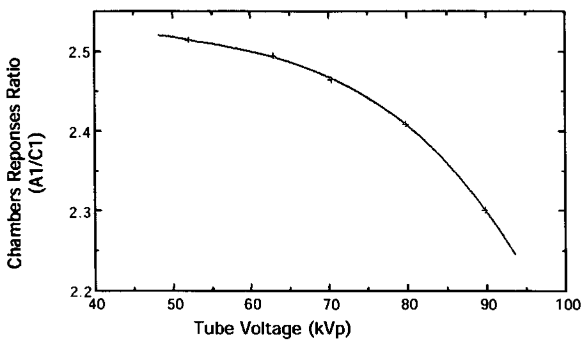

Figure 6 : Conversion curve for the kilovoltage peak determination in a diagnostic radiology system obtained by the ratios between the measurements of chambers A1 and C1.

The conversion factors obtained for the range 52 to 90 kV in this work are in Table 4. Using these factors it is possible to calibrate kVp instruments used for control quality measurements.

Table 4 : Conversion factors for the transfer system to real tube voltages obtained by spectrometry.

Tube Voltage (kVp)	Conversion Factor
52.01	2.51 ± 0.03
62.89	2.49 ± 0.03
70.33	2.42 ± 0.03
80.07	2.40 ± 0.02
89.80	2.30 ± 0.02

To test the established methodology, three kV meters described in Table 2 were utilized. They were positioned at the same distance as the transfer system, 50 cm. The obtained values are in Table 5. The instrument **C** shows sensibility only above 60 kV. The instrument **B** presents the best behaviour, with 2.7% of maximum variation. The other instrument present a variation about 10% when compared to the transfer system. The maximum standard deviation was 1.3% in all cases.

Table 6 : Tube voltages values obtained using the tested instruments in the diagnostic radiology system at the Calibration Laboratory of IPEN, using as a reference the transfer system of the two ionization chambers developed at IPEN.

Transfer System (kV)	A (kV)	B (kV)	C (kV)
52.0	47.4	53.4	---
62.9	59.0	62.2	63.5
70.3	67.1	69.9	66.1
80.1	78.6	80.2	72.9
89.8	89.4	91.0	80.6

CONCLUSIONS

The proposed transfer system using ionization chambers developed at IPEN showed its usefulness through several tests : stability and repetibility, energy dependence, radiation sensibility and the utilization as a Tandem system. As a transfer system, for tube voltage and air kerma determinations, it can be periodically calibrated against the spectrometer and a reference ionization chamber. This will guarantee its traceability to primary and secondary standard systems. The variation obtained with commercial kV meters (10%) showed the need and importance of this kind of instruments calibration.

ACKNOWLEDGEMENTS

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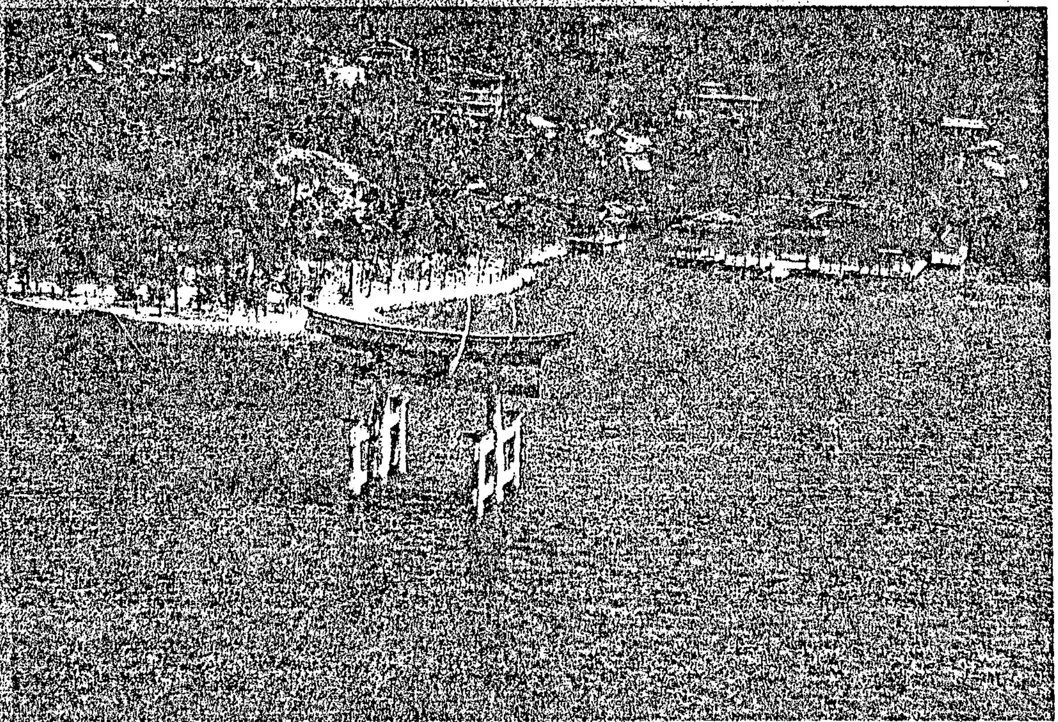

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