DOSIMETRIC BASIS FOR A CALIBRATION PROTOCOL OF SURVEY METERS FOR DIAGNOSTIC RADIOLOGY

Potiens , M.P. A.[1], Caldas, L.V.E.[1] and Panzer, W.[2]

[1] Instituto de Pesquisas Energéticas e Nucleares
Comissão Nacional de Energia Nuclear
C.P. 11049 - CEP 05422-970 - São Paulo – Brazil

[2] Institut für Strahlenschutz,
GSF-Forschungszentrum für Umwelt und Gesundheit, GmbH.
Ingolstädter Landstraße 1
D-85758 Neuerberg - Germany

ABSTRACT

A calibration protocol of survey meters for diagnostic radiology was developed, initially at the Secondary Standard Dosimetry Laboratory (SSDL) of GSF, Germany, and established at the Calibration Laboratory of IPEN, Brazil. A secondary standard ($30cm^3$) cylinder ionization chamber of the same type available at IPEN (PTW type M23361) was used to provide calibration factors normalized to ^{60}Co for all radiation qualities which might become necessary in the protocol. These calibration factors were transferred to IPEN considering that the GSF chamber has a calibration factor for ^{60}Co from the German Primary Standard Dosimetry Laboratory (PTB) and at IPEN there is a chamber with a calibration factor for ^{60}Co from the British Primary Dosimetry Laboratory (NPL). Measurements were made for A-series (Radiation qualities N in ISO 4037-3), with mean energies between 33 and 65 keV and C-spectra (similar to radiation scattered by a patient), with mean energies between 15 and 40 keV).

INTRODUCTION

The main sources of radiation dose for members of the public are natural radiation and medical applications. The contribution from all medical uses to annual per capita dose varies from a few percent of the dose from natural background in developing countries to substantially higher percentages in developed countries. The largest part of this contribution comes from diagnostic radiology[(1)].

Since 1980 instruments are being calibrated at the Calibration Laboratory of IPEN at radiotherapy and radiation protection levels. Considering the needs of quality control in diagnostic radiology systems as described above, studies have been undertaken in order to improve the calibration service with tests at the diagnostic radiology level for in-beam measurements[(2)].

The objective of this work was to elaborate the dosimetric basis for a protocol for the calibration of survey meters (radiation protection purposes) for diagnostic radiology. The need to calibrate survey meters for use in diagnostic X-ray facilities became more important in Brazil after the publication of the Brazilian Health Ministry Regulation 2043 from 1994, which established the Quality Control Programs to Diagnostic Radiology Services. At IPEN no calibrated ionization chamber was available as a secondary standard for this purpose, but there is a 30 cm^3 cylindric ionization chamber (PTW type M23361) without calibration factors traceable to a Primary Standard in the range of the interest (30 to 150 keV).

The basic idea was to use a cylindric chamber of the same type available at the Secondary Standard Dosimetry Laboratory (SSDL) of the Institut für Strahlenschutz, GSF - Forschungszentrum für Umwelt und Gesundheit, GmbH, German, to provide calibration factors normalized to the calibration factor for ^{60}Co for all radiation qualities which might become necessary in the protocol and to transfer these calibration factors to IPEN. This is possible because the GSF ionization chamber has a calibration factor for ^{60}Co from the German Primary Standard Dosimetry Laboratory (PTB) and at IPEN also there is a similar chamber with a calibration factor for ^{60}Co from the British Primary Standard Dosimetry Laboratory (NPL).

MATERIALS AND METHODS

GSF Measurements

A 160 kV X-ray unit (MG 160, Philips) was used with a transmission chamber and a electrometer IQ4 (both PTW, Freiburg) serving as a monitor. It was calibrated in terms of air kerma at a fixed distance to the focus. The calibration factor is traceable to PTB and provides dose values with an accuracy better than 3%. The utilized ionization chamber was a PTW type M23361 and a electrometer PTW UNIDOS type 10001. The calibration in the A-series, Table 1, was performed to study the energy dependence of this chamber and to conduct type tests (with regard to energy dependence) of survey meters sent to IPEN for calibration. The C-series, Table 2, were decided to be the most suitable ones for the calibration of survey meters in diagnostic radiology because they are very similar to the radiation scattered by a patient[4].

Table 1. A-series as established at GSF

(Radiation qualities N in ISO 4037-3)[3]

Quality	Tube Voltage (kV)	Additional Filtration			Half Value Layer	Mean Energy
		(mmAl)	(mmCu)	(mmSn)	(mmCu)	(keV)
A 40	40	4	0.21	-	0.09	33.0
A 60	60	4	0.60	-	0.24	48.0
A 80	80	4	2.00	-	0.59	65.0
A 100	100	4	5.00	-	1.10	83.0
A 120	120	4	5.00	1.00	1.70	100.0
A 150	150	4	-	2.50	2.40	118.0

Table 2. C-series as established at GSF

Quality	Tube Voltage (kV)	Additional Filtration		Half Value Layer		Mean Energy
		(mmAl)	(mmCu)	(mmAl)	(mmCu)	(keV)
C 30	30	0.5	--	0.35	--	15.0
C 40	40	1.0	--	0.80	--	20.0
C 60	60	3.9	--	2.40	--	30.0
C 70	70	5.4	--	4.00	--	35.0
C 80	80	7.2	--	5.00	--	40.0
C 100	100	4.0	0.15	--	0.29	49.0
C150	150	4.0	0.50	--	0.82	74.0

Determination of the maximum energy of the spectra with a high purity Germanium spectrometer (EG&G ORTEC) showed that the real tube voltages were in very good agreement with the nominal values indicated at the control panel.

IPEN Measurements

A Medicor Mövek Röntgengyara X rays generator, model Neo-Diagnomax (125 kV) was used in the fluoroscopy mode. The spectrometry of this system showed a difference of 10 kV from the panel and the real tube voltage[2]. Because of this problem, it was not possible to establish the qualities with tube voltages above 100 kV, considering that in the fluoroscopy mode the X rays system reach only l 100 kV. The other qualities are the same as established at GSF. The utilized ionization chamber was a PTW type M23361 and an electrometer PTW UNIDOS type 10001, calibrated against a secondary standard ionization dosemeter traceable to the National Physical Laboratory, England, with an accuracy better than 2% using an ^{60}Co radiation source.

RESULTS

GSF Measurements

The GSF ionization chamber was calibrated by the Primary Standard Dosimetry Laboratory PTB for ^{60}Co, so this calibration factor was used as a reference to the energy dependence. Check source measurements were performed in order to show the chamber stability. The tests were made with the X ray qualities listed in Table 1. The determined calibration factors are listed in Table 3.

Table 3. Calibration factors for a 30 cm^3 chamber for the A-series

Kq = Calibration factor normalized to ^{60}Co

Quality	Tube voltage (kV)	Mean Energy (keV)	Calibration Factor (Gy/C)	Kq
A 40	40	33	9.48×10^5	1.03
A 60	60	48	9.04×10^5	0.98
A 80	80	65	9.19×10^5	1.00
A 100	100	83	9.00×10^5	0.98
A 120	120	100	9.28×10^5	1.01
A 150	150	118	9.33×10^5	1.02
^{137}Cs	-	660	9.44×10^5	1.03
^{60}Co*	-	1250	9.19×10^5	1.00

* Calibrated at PTB

The results demonstrate that this type of chamber is suitable to be used as a reference chamber for the calibration of survey meters for X-ray diagnosis down to energies of 33 keV and for determining the energy dependence of survey meters.

The Table 4 shows the measurements made at the C series. The procedure was the same as for the A-series.

Table 4. Calibration factors for a 30 cm^3 chamber for the C-series

Kq = Radiation quality factor, normalized to ^{60}Co

Quality	Tube voltage (kV)	Mean Energy (keV)	Calib. Factor (Gy/C)	Kq
C 30	30	15.0	1.08×10^6	1.18
C 40	40	20.0	1.01×10^6	1.10
C 60	60	30.0	9.40×10^5	1.02
C 70	70	35.0	9.10×10^5	0.99
C 80	80	40.0	9.17×10^5	1.00
C 100	100	49.0	9.26×10^5	1.01
C 150	150	74.0	9.22×10^5	1.00
^{137}Cs	-	660	9.44×10^5	1.03
^{60}Co*	-	1250	9.19×10^5	1.00

* Calibrated at PTB

The increase of the calibration factors for tube voltages lower then 60 kV is due to the absorption of low energy X-rays which contribute to the spectra of these beams.

Transfer of Calibration Factors to the Calibration Laboratory of IPEN

By normalization to the calibration factor for ^{60}Co, it was possible to transfer the determined calibration factors to IPEN. After that, the A series qualities were established to perform type tests and the C series qualities for the survey meter calibration. All equipment is available at IPEN to perform the survey meter calibration on large scale. The calibration factor to the IPEN 30cm^3 ionization chamber to ^{60}Co was 9.137×10^5 Gy/C. The results for X rays qualities are described in the Table 5. A check source holder was developed and check source measurements were performed to show the chamber stability.

Table 5. Calibration factors for a 30 cm^3 IPEN chamber for the A and C-series

Kq = Radiation quality factor, normalized to ^{60}Co, transferred from GSF

$\dot{K}_{air}$ = Air kerma rate

Quality	Tube voltage (kV)	Mean Energy (keV)	Kq	$\dot{K}_{air}$ (mGy/min)
A-40	40	33	1.03	0.402
A-60	60	48	0.984	0.295
A-80	80	65	1.00	0.106
C 30	30	15.0	1.18	3.61
C 40	40	20.0	1.10	3.47
C 60	60	30.0	1.02	3.01
C 70	70	35.0	0.99	2.96
C 80	80	40.0	1.00	3.29

CONCLUSIONS

The results show that this type of chamber is fully suitable for calibrating survey meters. Since the spectral distribution of the radiation fields of routine conditions at the hospitals cannot be determined in the course of radiation protection survey measurements, the quality C80 is proposed to be used as a reference for the calibration of the survey meters.

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