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STUDY OF THE RESPONSE OF RADIATION PROTECTION MONITORS IN TERMS OF H*(10) IN X RADIATION

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ABSTRACT

The ambient dose equivalent, H*(10), is an operational quantity recommended by the International Commission of Radiation Units and Measurements Report 39 for measurements in area monitoring. However, most of the monitoring instruments used in radiation protection in Brazil still use the old quantities exposure rate and absorbed dose rate. Therefore, it is necessary to study how to change the operational quantity to H*(10). In this work, the response of radiation protection monitoring detectors was studied in terms of H*(10) for different energies using standard X-rays (narrow beams) at the Calibration Laboratory of IPEN.

1. INTRODUCTION

The diversity of instruments used in medicine and industry for radiation protection is increasing. Therefore it is necessary to invest in safety. For the use of each instrument, it is necessary that it operates according to international recommendations to obtain specific and reliable measures. According to the International Commission on Radiation Units and Measurements Report 47 [1], a set of measurable quantities that estimate the effective dose, for the most commonly external ionizing radiations (photons, neutrons and electrons of energies up to about 20 MeV) was defined in 1985. The ICRU defined the operational dose equivalent quantities for area monitoring and individual monitoring [1-3].

In this work, the radiation monitors were calibrated at the Calibration Laboratory of IPEN which offers instruments calibration services of instruments with gamma, X, beta and alpha radiations. The instrument calibration can ensure if it is working properly and determines the indication of an instrument as a function of the measurement (the quantity intended to be measured). One way to know if the instrument is working correctly is studying its the energy dependence [2].

The objective of this work was to study the energy dependence of radiation monitors for low and medium energy X-rays, using the ambient dose equivalent quantity, $H^*(d)$.

2. MATERIALS AND METHODS

Ionization chambers are mostly utilized as radiation monitors for X radiation. In this work fifteen ionization chambers were tested in standard beams, at the distance of 2.5 m from the tube, to study the energy dependence of their response. The X-rays equipment was utilized: Pantak/Seifert, model MXR-160/22, with mean energies of 48 keV, 65 keV, 83 keV and 118 keV respectively for the N-60, N-80, N-100 and N-150 radiation qualities. The energy dependence was obtained in relation to the qualities in $H^*(d)$. Some ionization chambers were pre-calibrated using gamma radiation (^{137}Cs and ^{60}Co). Table 1 shows the radiation beam characteristics.

Table 1. Characteristics of the radiation beams (narrow spectrum series), radioprotection level

Radiation quality	Mean energy (keV)	Voltage (kV)	Half-value layer (HVL) (mmCu)	Additional filtration (mm)
N-60	48	60	0.25	0.6(Cu)
N-80	65	80	0.61	2.0(Cu)
N-100	83	100	1.14	5.0(Cu)
N-150	118	150	2.40	2.5(Sn)

Initially, the measurement of the exposure rates and air kerma rates were converted to ambient dose equivalent rates. The conversion coefficients from air kerma to ambient dose equivalent are presented in Table 2.

Table 2. Conversion coefficients from air kerma to ambient dose equivalent for the radiation qualities of ISO 4037-3[4], at the reference distance of 2m

Radiation quality	Conversion coefficients (Sv/Gy)
N-60	1.59
N-80	1.73
N-100	1.71
N-150	1.58

The energy dependence of the response of the several radiation monitors was obtained using the calibration factors for the N-60, N-80, N-100 and N-150 radiation qualities (narrow beams). The calibration factor is the ratio between the nominal value (reference) of the ambient dose equivalent rate and the value measured (indicated) by the radiation monitor.

3. RESULTS

Fifteen ionization chambers of different kinds and models were identified with letters and calibrated using standard X radiations. The calibration factors obtained are presented in Table 3 and their energy dependence are presented in Table 4.

Table 3. Calibration factors for the ionization chambers

Ionization chamber	Model	Identification	Calibration factor			
			N-60	N-80	N-100	N-150
Fluke Biomedical	451B-ryr	A1	0.96	0.88	0.85	0.88
		A2	0.99	0.99	0.97	1.05
Victoreen	450P	B1	1.20	1.14	1.15	0.91
	451P	C1	1.09	1.05	1.05	0.91
		C2	1.12	1.07	1.07	0.95
		C3	1,15	1,08	1,06	0.94
	451B	D1	0.96	0.93	0.95	0.99
		D2	1,11	0,99	0,95	0.81
Step	RGD 27091	E1	1.03	1.13	1.10	0.98
Radcal	2026C	F1	1.01	1.04	1.09	1.04
	9015	G1	0.97	1.00	1.07	1.06
	9010	H1	1.00	1.03	1.09	1.05
		H2	0.98	1.01	1.08	1.06
		H3	1.01	1.04	1.11	1.06
		H4	0.98	1.01	1.09	1.06

Eight of the fifteen ionization chambers presented satisfactory calibration factors close to the unit. The ionization chambers A1, B1, C2, C3, D2, E1 and H3 presented energy dependence values higher than 10%. The ionization chamber A1 presented the highest energy dependence of all radiation detectors of this study.

Table 4. Energy dependence of the ionization chambers to ambient dose equivalent $H^*(10)$ (radioprotection level) for X-rays.

Ionization chamber	Model	Identification	Energy dependence (%)
Fluke Biomedical	451B-ryr	A1	12.94
		A2	8.24
Victoreen	450P	B1	31.86
	451P	C1	19.78
		C2	17.89
		C3	22.34
	451B	D1	6.45
		D2	37.03
Step	RGD27091	E1	15.30
Radcal	2026C	F1	7.92
	9015	G1	10.30
	9010	H1	9.00
		H2	10.20
		H3	9.90
		H4	11.22

The energy dependence varied between 8.2% and 37.0% for the X-rays qualities, and the uncertainties varied between 1.6% and 6.8%. The radiation protection monitors were divided in different classes according to their use by the standard NBR 100011 [5]. The ionization chambers in this work agree with the requirements of class II, working reference equipment. In this class, the maximum response variation is ± 25% of the nominal value (reference). Only the energy dependence of ionization chambers B1 and D2 do not agree with this standard; the other ionization chambers presented satisfactory results.

The response of the ionization chambers A2, B1, C1, D1, E1, F1, G1 and H4 is represented in Figure 1 in function of the mean energy of the incident radiation beams. The ionization chambers were chosen in this case from the highest energy dependence of each group of same model. As can be observed, the radiation monitors presented very different behaviors in X-rays beams; this fact has to be taken into consideration for the interpretation of measurements from these instruments, when monitoring X-rays.

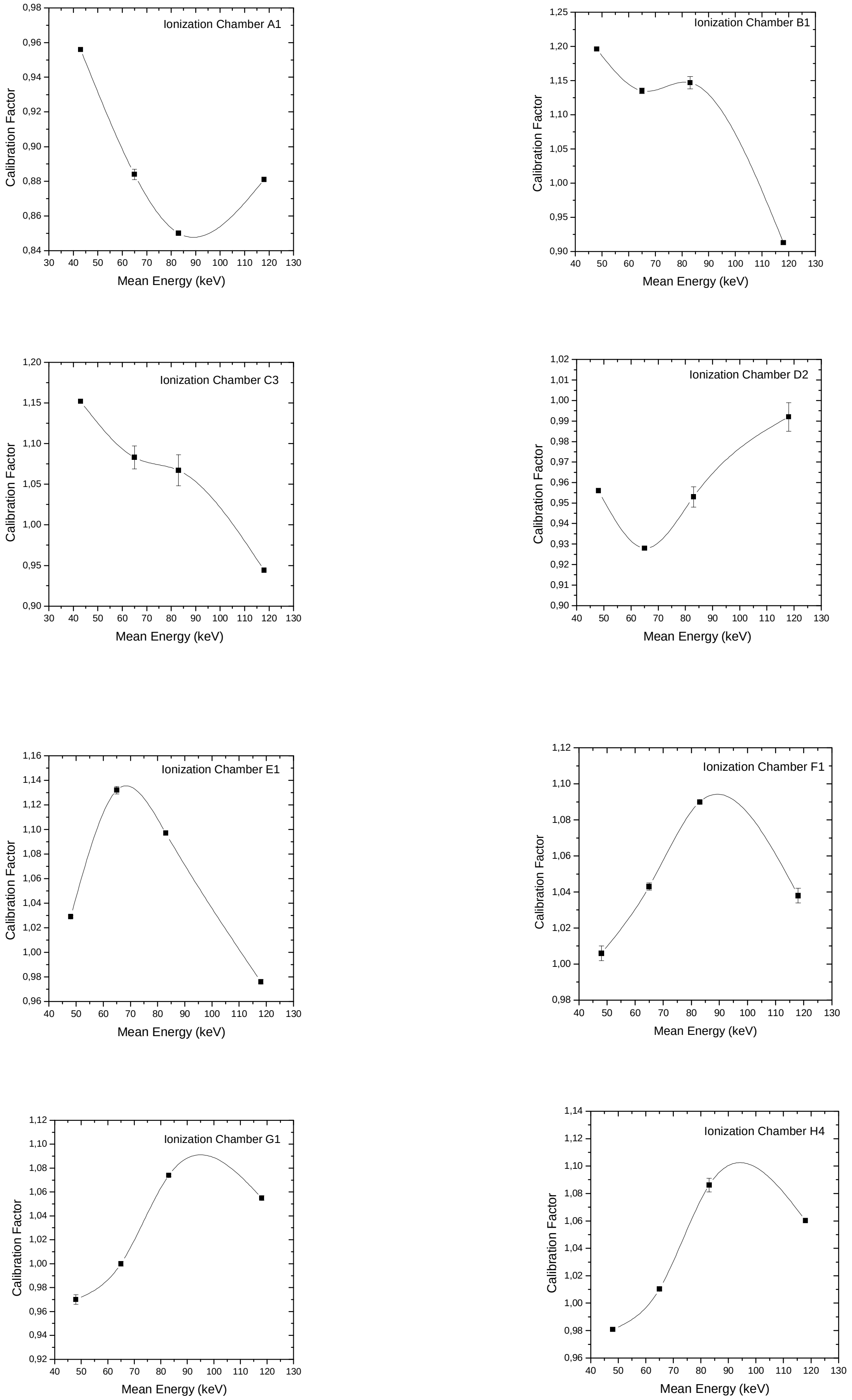

Figure 1. Calibration factors of the ionization chambers A1, B1, C3, D2, E1, F1, G1 and H4.

4. CONCLUSIONS

The results obtained for the ionization chambers were satisfactory, according ISO-4037-2, ISO-4037-3 and SRS-No.16 recommendations. Only two of all fifteen ionization chambers presented a dependence energy higher than 25%.

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