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PORTABLE RADIATION METERS EVALUATION IN HIGH RATES OF AIR KERMA

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ABSTRACT

A set of portable meters of ionizing radiation high rates of air kerma (teletectors) commonly used in emergencies in Brazil and sent to the Calibration Laboratory of IPEN were under several tests and analyst is parameters for the detectors behavior were established, specifying their sensitivities and operating characteristics. Applied tests were: reading equipment variation with battery voltage, geotropism effect, energy dependence, the angular dependence and overload. Thus it was possible to determine the most common characteristic found in these equipments (quality control programs). The behavior of 17 portable meters was analyzed and in this study, 10 of them have been tested. It was performed to characterize the gamma irradiating system (radiation dosimetry field) that possesses higher activity in teletectors for testing of larger measuring range. New calibration criteria were established following international recommendations. Therefore, it was made the improvement of the quality control programme of portable meters of ionizing radiation high rates of air kerma calibration laboratory, benefiting the users of such equipment with better consistent calibration measurements.

1. INTRODUCTION

The Instrument Calibration Laboratory (LCI) of Instituto de Pesquisas Energéticas e Nucleares (IPEN) held annually about 1100 calibration tests [1-5] (procedures performed in order to verify the operating conditions of the instruments) and calibration measures radiation monitors, which are used in radiation protection, radiation therapy, diagnostic radiology and nuclear medicine. The gauges used in radioprotection represent the vast majority of tests, about 60% of the instruments routinely tested and the irradiated samples are used in radiation protection measures and ^{137}Cs gamma radiation.[6,7]

The radiologic protection plan must prevent, in an emergency, tracking of the facility with an adequate instrument to those measurements[1-3]. Utilizing an uncalibrated instrument during an emergency can indicate a false result, exposing the worker. If the emergency is about high levels of kerma in the air (more danger) it is extremely necessary quantifying these levels, because establishing the kerma levels, the radioactive element, time of worker's exposure, distance of radioactive element and subject, among others, is possible to determine the dose of kerma in the tissue, as well as in the whole subject. Being possible to analyze the dose and, as a result, the effects caused by the ionizing radiation.[8,9]

Therefore, this paper intends to demonstrate performance tests applied on portable monitors of ionizing radiation to certify their capability of measurement, and also, show the importance of carrying out these procedures on a daily basis, complemented with the calibration of the devices.[9-11]

The objective is the establishment of a methodology performance tests to be applied to portable radiation monitors range which are widely used in services and operational routines radioprotection and improve the methodology of performance tests applied on the calibration of portable meters of radiation that have limit measure intervals of 50mSv/h.

2. METHODOLOGY

They were 17 portable meters was analyzed and in this study, 10 of them have been tested in the LCI-IPEN.

2.1. Materials

A. Irradiation systems

It was used the irradiator system with remote control and irradiation time control with power of ^{60}Co, ^{137}Cs, with different kerma levels in the air, brand STS, model: OB 85/1; in figure 1 is possible to see irradiator.

Figure 1: Radiator system type STS brand, model: B 85/1 with sources of ^{60}Co, ^{137}Cs.

The chosen system was the irradiator Caesa-Gammatron (teletherapy irradiator) with and electric igniter through a control panel made by the LCI-IPEN, and with a controller of the irradiation time, with a single Cesium 137 power. In figure 2 is possible to see the irradiator.

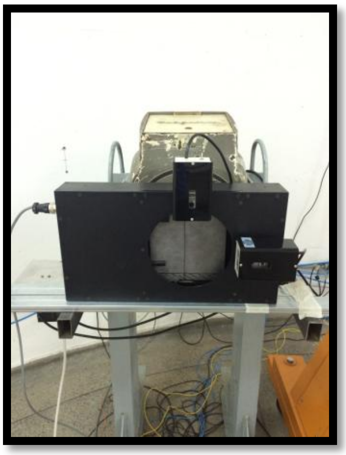

Figure 2: Caesa-Gammatron with source of ^{137}Cs.

We used a gamma irradiator with two power sources of 137Cs (100 mCi and 100 Ci), with shield, collimator and control panel included, brand Hopewell, model G10-2-360-E.

B. Measurement reference system (Radiology protection level)

We used ionization chambers with sensible volume of 1000 cm^3 (model 32002), 30 cm^3 (model 23361), 0,3 cm^3 (model 31013), brand PTW; electrometer brand PTW, model UNIDOS and cable PTW triaxial for connection. Figures 3, 4 e 5 show the equipment.

Figure 3: Electrometer PTW brand, US model.

Figure 4: Ionization chambers with sensitive volume 30 cm^3 (model 23361).

Figure 5: Ionization chambers with sensitive volume of 1000 cm^3 (model 32002).

C. Equipment tested:

We used the teletectors to conduct the tests. These detectors were Geiger Müller and are have two Geiger detectors of different range. Picture 6 shows the teletector detector.

Figure 6: Model Detector teletector.

D. Auxiliary systems and important accessories

The following equipment were used during the tests conducted for this paper: dehumidifiers and climate controllers, HP computer, model PC Pentium 4, Incotherm mercury thermometer, with measurement intervals of –10 e +40^{o}C and precision of ±5%, Veränderlich barometer, model Domatic, Germany, with measurement intervals of 96 and 104 kPa and precision of 0,1 kPa, hygrometer Präzision-Faden, Germany, with measurement intervals of 0 and 100% and with precision of 1% air relative humidity, automatic table for support and positioning the equipment and lasers model Lumina-L2.

E. Calibration laboratory of portable monitors

Figure 7: Control room of portable monitors calibration laboratory. Being able to see the control caesa radiator, control of automated table with their cameras to detect the reader's display and its source detector position.

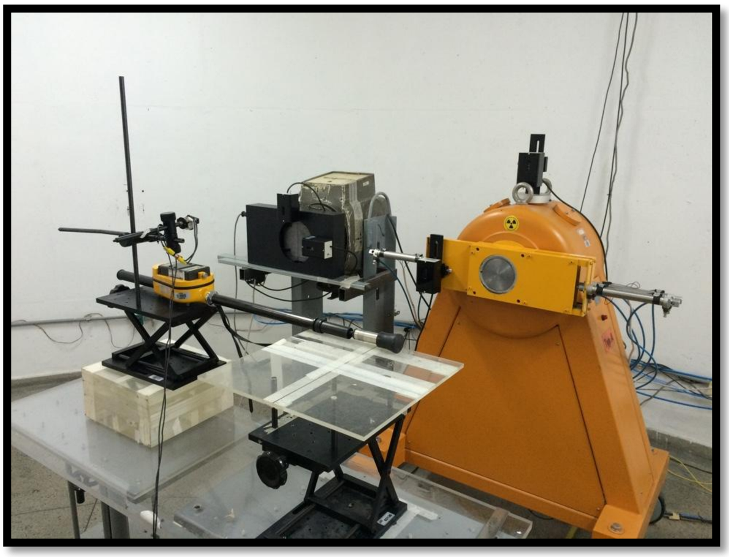

Figure 8: Irradiation Room of portable monitors calibration laboratory. It is able to view the radiators B 85/1 and Caesa, positioning table and a teletector detector.

2.2. Study of the systems that detect the high levels of kerma in the air

The portable monitors of radiation are widely used when monitoring controlled areas, being of great value for the chores and routines of those fields. The trust ability of these measurements is essential for the safety of users of the instruments as well as for the environment.

Having said that, it is of Paramount importance that these portable monitors are used through a routine verifying procedure of the instruments, in order to guarantee the quality of measurements done the equipment.

Verifying the operational characteristics of portable monitors of radiation is done through performance tests. They can be seen as a unit of procedures (trial and test) that allow the evaluation of the equipment.

The performance test can include the evaluation of some or all characteristic of the monitors. The operational characteristics are divides in radiological and non-radiological. The main non radiological characteristic that were tested are:

- Variation on how the equipment works with battery tension;
- Geotropism effect;
- Electrical zero drift;

The main radiological characteristics that were tested:

- Energetic dependence;
- Angular dependence;
- Response to other ionizing radiations;
- Innate Reading mistake of the device;
- Saturation or scale burst (also known as security trial).

The first non-radiological tests and the two first radiological ones were conducted, in this paper, with the main ionizing radiation detector of high kerma level, the automess teletector 6150. [11-16]

3. RESULTS

3.1. Reading variation of the equipment with tension

The automess teletector are portable instruments and require special care with the batteries that provide energy to its full use. Therefore, if the tension of the batteries is below what it considered ideal to your proper function, we will have problems with measurement accuracy.
The test of Reading variation was done trading just one tension from one of the batteries for a tension below the recommended one by the maker of the component. It was not possible to obtain values described by the ABNT NBR 10011, since most part of these detectors were going through the calibration process of LCI.

Table 1 shows the teletector represented by a T, the kerma value in the air measured with batteries functioning perfectly, the value of kerma in the air measured with batteries working with half tension and the percentage difference between both. The measures were carried out with a 100 cm from the radiation ionizing source of ^{137}Cs, with kerma value in the air of 30,4 mR/h and all the detectors were calibrated before performing the test.

Table 1: kerma rate measurements in air with different detectors teletector model with different voltages applied (batteries with usual tension, and tension lower than usual).

Teletector	Kerma rate in the air (mR/h)		Difference (%)
	Usual voltage	**Low voltage**	
T_1	30,0	25,9	14%
T_2	30,7	28,1	8%
T_3	29,9	24,1	19%
T_4	30,1	26,9	11%
T_5	31,0	28,3	9%
T_6	29,7	25,2	15%
T_7	30,1	26,6	12%
T_8	30,6	22,9	25%
T_9	29,8	27,0	9%
T_{10}	30,7	25,8	16%

We can see in Table 1 there is a percentage difference of 9% to 25% of the value measured with a battery working with full tension and the one bellow the recommended. The average tension value was bellow 0,5 V in one of the batteries, while the others were working with full tension. Hence, we can conclude the utter importance in verifying constantly the batteries tension, since if one single battery is working with less power, it can cause a difference of 25% during the measurement.

3.2. Angular dependance

The indication of incurred radiation can alter if there is a change in the angle of direction formed between the detector and the beam of radiation. Tests must be taken and regular verifications must be done on the angular dependence of portable detectors.

The portable monitor teletector was positioned on a calibration stool, at calibration position, meaning, the stream of gamma rays were all over the detector probe, reaching the geometric center of the detector element; in this situation, the equipment were horizontally over a calibration desk (parallel at desk surface), with the angle of 0°. The measurements were taken at a distance of 100 ±0,05 cm, from the detector, with a range of 50 mR/h from the ionizing radiation source of ^{137}Cs.

Table 2: We may observe detectors teletector represented by T, the kerma rate of the air values (mR / hr) in the 0 ° position (adopted for calibration), right and left 45 ° (inclined for that field) and perpendicular to the source of ionizing radiation ("pointing" to radiation source) 90 °.

Teletector	Kerma rate in the air (mR/h)								Unlike the measures 0° e 90° (%)
	position 0°	**± σ**	**right 45°**	**± σ**	**left 45°**	**± σ**	**Perpendicular 90°**	**± σ**	
T_1	49,8	0,8	41,0	0,7	42,0	0,6	11,3	0,2	77%
T_2	49,4	0,8	42,0	0,8	42,2	0,6	12,5	0,2	75%
T_3	49,5	0,8	41,5	0,8	41,1	0,6	15,1	0,3	69%
T_4	49,2	0,7	43,7	0,8	43,9	0,7	13,2	0,2	73%
T_5	49,3	0,7	43,2	0,8	41,2	0,6	14,3	0,3	71%
T_6	49,9	0,8	43,8	0,8	41,8	0,6	8,2	0,2	84%
T_7	49,2	0,7	41,9	0,8	43,9	0,7	12,5	0,2	75%
T_8	49,3	0,7	41,1	0,7	41,8	0,6	17,9	0,3	64%
T_9	50,0	0,8	42,3	0,8	43,3	0,7	16,2	0,3	68%
T_{10}	49,3	0,7	41,5	0,8	41,0	0,6	5,1	0,1	90%

The values got it on the angular dependency test for perpendicular position 90° was from 64% to 90% of ideal value of use 0°. According the IEC 395 [6] the indication to incident radiation, by a not superior angle for 45° with relation a calibration direction, do not be under 80%.

So the teletector model detectors obtain satisfactory values for measurements at 45°, because the variations did not reach 20%, and measures 90° values were not satisfactory for any of the tested detectors, all equipment had a higher variation 50%. Thus demonstrating the importance of caring the measurements of this equipment in their routines, having to perform measurements in different directions to obtain the closest measure of reality.

In operating manuals and instructions of the equipment, do not have any information about their response to this type of test.

3.3. Energy dependence

The energy dependence of a portable radiation monitor may be understood as the change in instrument response as a function of the radiation energy, for the same kind of radiation and absorbed dose rate referenced to the tissue or in the air, in principle, for all energy range in which the equipment is designed to measure. Should keep the value of the constant exposure rate [16]. The detectors teletector`s were subjected to gamma radiation and ^{137}Cs ^{60}Co sources from the irradiator, duly aligned with the positioning system of the machine the distance between the radiation source and the equipment, keeping the center of the sensor element always aligned with the radiation beam. The air kerma rate used to perform the energy dependence test was 50 mR / hr for both ^{60}Co source and ^{137}Cs.

Table 3 shows the detectors teletector represented by T, the kerma rate values measured by the air teletector of ionizing radiation sources ^{60}Co and ^{137}Cs, and kerma rate values provided in the air by dosimetry calibration system of the sources of ionizing radiation ^{60}Co and ^{137}Cs with their uncertainties and analysis it was determined the percentage difference between the respective measures.

Table 3: kerma rate measurements in air with different detectors teletector model with sources ^{60}Co e ^{137}Cs.

Teletector	Kerma rate in air (mR/h)								Unlike the measures (%)
	^{137}Cs "real"	± σ	^{137}Cs measure	± σ	^{60}Co "real"	± σ	^{60}Co measure	± σ	
T_1	50,0	0,8	49,1	0,9	50,0	0,8	68,9	1,3	40%
T_2	50,0	0,8	49,5	0,9	50,0	0,8	69,0	1,3	39%
T_3	50,0	0,8	49,4	0,9	50,0	0,8	71,5	1,3	45%
T_4	50,0	0,8	49,5	0,9	50,0	0,8	65,2	1,2	32%
T_5	50,0	0,8	49,8	0,9	50,0	0,8	66,2	1,2	33%
T_6	50,0	0,8	49,9	0,9	50,0	0,8	68,4	1,3	37%
T_7	50,0	0,8	49,4	0,9	50,0	0,8	69,4	1,3	40%
T_8	50,0	0,8	50,0	0,9	50,0	0,8	67,8	1,3	36%
T_9	50,0	0,8	49,3	0,9	50,0	0,8	69,2	1,3	40%
T_{10}	50,0	0,8	49,2	0,9	50,0	0,8	68,6	1,3	39%

So you can see that the model teletector ionizing radiation detector has energy dependence, because there were variations in the difference of the measures of ^{60}Co and ^{137}Cs between 33% to 45%. So you can see that with ^{137}Cs readings measures were closer to the real value (dosimetry), are within the uncertainty. And the measures with ^{60}Co were out of the real value (dosimetry), being outside of the value and the associated uncertainty.

According to the NBR 10011 [16] the indication of the instrument to radiation with energies between 50 keV and 3 MeV should not differ by more than ± 25% within this energy range. Soon all equipment is outside the recommended by the standard, however the equipment is within specifications described by the manufacturer, as described in its energy dependence manual is ± 50%.

3.4. Saturation or Overload

The scale burst test is part of the tests called "Safety Conditions". For exposure rates corresponding to directions above the upper limit of any nominal range, the display of the instrument shall acknowledge burst of scale.

This assay was used with the radiator ^{137}Cs source, where the instruments were subjected to 10-fold higher exposure rates than the respective scale of funds for about 5 minutes, thus a display rate greater than 10 Sv/h.

Table 4 shows the results of the burst tests scale portable radiation detectors.

Table 4: Scale overload tests of portable type monitor Geiger- Müller (Teletectors).

Teletector	Results
T_1	approved
T_2	approved
T_3	approved
T_4	approved

All equipment tested in Table 4 was considered approved. The uncertainty in the exposure rate was not higher than 5%.

4. CONCLUSIONS

The study of international and national norms and protocols is very important to carry out measures reliably in the field of ionizing radiation. The update and the improvement still is needed by the complexity of the field. Therefore, not only tertiary laboratory calibration, which is the case LCI-IPEN, but users of these devices in their work routines, it is necessary to study, testing and quality control of the ionizing radiation detectors equipment for performing measurements reliably. So, as it was observed that the LCI reference did not have measuring equipment reliability and alternative study was conducted to perform the dosimetry of ionizing radiation fields used for calibration of portable monitors. So getting a dosimetry for quality control of their calibration instruments.

Performance tests showed results which are very important to characterize the equipment, which in this case is the model detector Automess teletector. The objective is to show that it possesses energy dependence, since there were variations in the difference between measurements of ^{60}Co ^{137}Cs between 33% and 45%, revealing that with ^{137}Cs readings were measures but close to the real value (dosimetry), are within the uncertainty. And the measures with 60Co were out of the real value (dosimetry), being outside of the value and the associated uncertainty energies. Soon all the equipment is out of the recommended standard [16], however the equipment is within specifications described by the manufacturer in his manual.

The angular dependence of its performance test was satisfactory for angle not exceeding 45° and unsatisfactory for angle of 90° as the calibration reference position because its values were 50% larger than that described in the standard. Therefore, one should be careful when carrying out measurements of these devices in their routines having to perform measurements in different directions to obtain the closest measure of reality and reliable measurements.

In the apparatus reading the variation of the voltage test, all equipment obtained a difference between 9% to 25% of the value measured with the usual battery voltage, and voltage lower than usual value. Soon the periodic check of the battery voltage, because only one of this with the usual lower voltage can already present a difference of up to 25% the result of measurement is very important.

Saturation studies are needed to verify the safety conditions of the equipment. They to judge whether the equipment responds to high rates of instantly display, allowing the equipment indicates an abnormal situation, such as the situation of accidental user exposure to excessive exposure rates, or above the unit's reading limits alerting the user for a personal and property risk situation. It is essential to periodically conducting this test. The results of tests to answer other ionizing radiations show the importance of using the most appropriate equipment for the intensity and type of radiation field to be measured.

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