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Evaluation of the behavior of a 180cc ionization chamber under different environmental conditions

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Abstract. The use of ionizing radiation for medical purposes has been a major advance for society due to the numerous possibilities of use for the treatment and diagnosis of diseases. On the other hand, knowledge about the damage caused by the biological effects of ionizing radiation requires continuous improvement of diagnostic radiology quality control. Radiation detector equipment is used to measure radiation levels emitted from natural or artificial sources. For convenience and accuracy, among the most widely used detectors are ionization chambers. Especially outdoors, weather factors can affect the behavior of these detectors at the time of measurement, but Brazilian law recommends only calibrating these measuring instruments in a traceable laboratory every two years to ensure their reliability. The objective of this work was to evaluate the performance of an ionization chamber used in radioprotection measurements in diagnostic radiology equipment, considering climatic variations in different regions of Brazil. For this, a system was developed to simulate the environmental conditions found for the temperature and humidity parameters at the moment of the clinical measurements, allowing to estimate the influence of these factors on the obtained values.

Keywords. Ionization chamber; performance test; quality control.

1. Introduction

The use of ionizing radiation in diagnostic radiology is a powerfull tool used in medical and dentistry procedures. Among the artificial sources, most of these contributions come from their use in medicine, especially diagnostic radiology accounting for 90% in developed countries [1].

Radiological equipments in operation throughout the national territory should be evaluated periodically [2,3] reaffirming the need for reliability of measurements, measurement errors, and performance of the ionization chambers (IC) can affect the entire radioprotection system operational chain of the diagnostic radiology center.

Therefore, quantifying the use of ionizing radiations and operating within acceptable and/or controllable limits, for occupationally exposed individuals, patients undergoing procedures and for the general public is critical. Performance tests should be applied to the CI to verify the accuracy of the instrument responses in the measurement and its behavior over time.

Calibration procedures are established in a metrology laboratory with well-defined physical parameters, such as x-ray beam qualities and environmental conditions recommended by international standards, (ISO 4037) Radiological protection X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon [4] the International Atomic Energy Agency (IAEA).

However, these controlled conditions are not maintained when using ICs in routine measurements when they are exposed to adverse environmental conditions. Brazil's continental dimensions provide humidity and temperature factors that vary widely from state to state. In the state of Pará, in the northern part of the country, the relative humidity is naturally above 80% during the day, a critical condition for the use of radioprotection ionization cameras.

Determine the influence of these external factors on field ICs anywhere in Brazil, considering that humidity and ambient temperature conditions are prerequisites for operating within acceptable limits established by current standards, ensuring the reliability and quality of ICs. easured data.

2. Materials and Methods

To make the evaluation of the behavior of a radioprotection IC as proposed in this study, it is necessary to initially calibrate the system in the reference radiation qualities showed at Table 1. The setup used to calibrate the IC is shown in the Figure 1. Thereafter, the IC should be subjected to stability tests to ensure that its performance is adequate. Therefore, IC can be used in the climate system designed to vary environmental conditions. The flowchart of Figure 2 shows these applied items.

Table 1. Characteristics of the radiation protection qualities (ISO, serie N)

Radiation quality	X ray tube voltage (kV)	Total filtration	Nominal first HVL (mm Al)
N-60	60	4 mm Al + 0,6 mm Cu	0.25
N-80	80	4 mm Al + 2 mm Cu	0.612
N-100	100	4 mm Al + 5 mm Cu	1.14
N-150	150	4 mm Al + 2,5 mm Sn	2.4

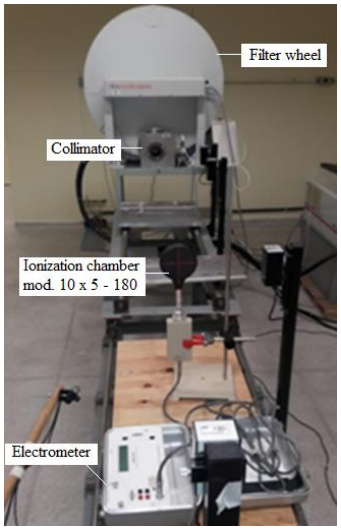

Figure 1. Schematic assembled for calibrate dosimeter

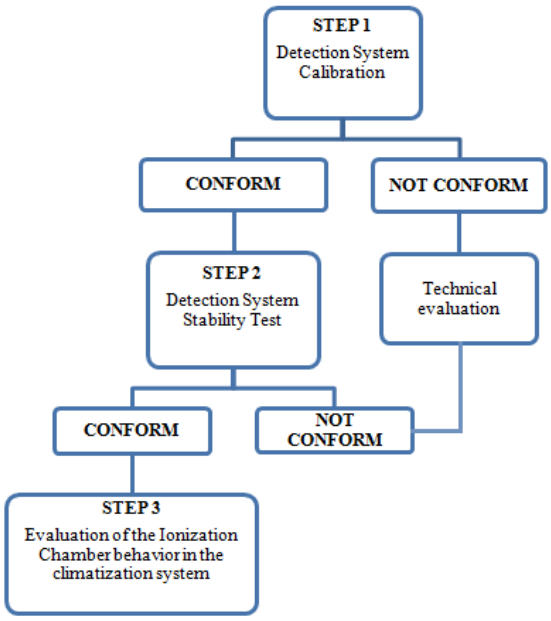

Figure 2. sequence flowchart performed to assess IC behavior under different environmental conditions

The radiation system used is a Radical ionization chamber, model 10 x 5-180 couples at a radical electrometer, model 9015.

The radiation Emitting Systems is a Pantak / Seifert X-ray system, Isovolt160 HS model, in the clinical diagnostic radiology operating range (50 kV-150 kV), located at the Instrument Calibration Laboratory (LCI) of the Institute for Energy and Nuclear Research (IPEN).

To do the stability tests and the measurements inside the climate system it was used the check source of $^{90}Sr + ^{90}Y$, PTW, mod. 8921 S / N 1294 with activity of 33MBq (1994)

To perform the tests proposed in this work, it was necessary to build a climate system for temperature and humidity parameters, consisting of a ventilation system, a heating system with temperature controller and an acrylic box with adequate dimensions for the test. The accessory instruments used were:

- GTech Air Humidifier - Mod. Alergy Free 35W
- VentiSol Heater - Mod. AQ 01 800W
- Fans - Mod. Mini Fan 4.5W
- Western analog external thermometer - Celsius Fahrenheit graduation
- Ageon Mod. G101 Digital Color Temperature Controller
- Lufft Mod. Opus 20 temperature, humidity and pressure measuring station
- Polymethyl methacrylate (PPMA) enclosure with dimensions of 0.60mx 0.65mx 0.60m Aluminum foil
- Styrofoam plates (2 cm thick)

Initially, with a calibrated dosimetric system, quality control was performed from a series of 10 measurements taken with the control source and another series of 10 measurements without the control source with a time of 1 minute for each measurement, determining the initial condition.

In accordance with current regulations [4], the coefficient of variation between cumulative dose rates with the verification source and without the verification source shall be less than 5%.

For the simulated weather condition, the IC must remain in the acclimatization chamber for 15 minutes to establish thermal equilibrium according to the manufacturer's manual instructions.

For this simulation, temperature and humidity data were selected over a period of one year using the National Institute of Meteorology (INMET) database [5].

In this work, the simulated climatic conditions were from the city of Belém, the selected data were presented in four series with the average temperature and humidity parameters of three hours as shown in Table 2.

For each simulated series, 10 measurements with the control source and 10 measurements without the control source were performed with a time of 1 minute for each measurement, checking the behavior of the IC response.

Table 2. Brazil – North Region – Pará State – Belém - Period of data capture: March 29, 2017 until March 25, 2018

Simullated period	Average temperature In the period (ºC)	Average humidity the period (%)
7h – 8h – 9h	24.24 ± 0.02	91.31 ± 0.08
10h – 11h – 12h	25.41 ± 0.04	91.64 ± 0.10
13h – 14h – 15h	26.98 ± 0.22	89.35 ± 0.50
16h – 17h – 18h	28.86 ± 0.21	89.65 ± 0.30

The mounted acclimatization system with the heating, humidity and ventilation control accessories coupled can be seen in Figure 3.

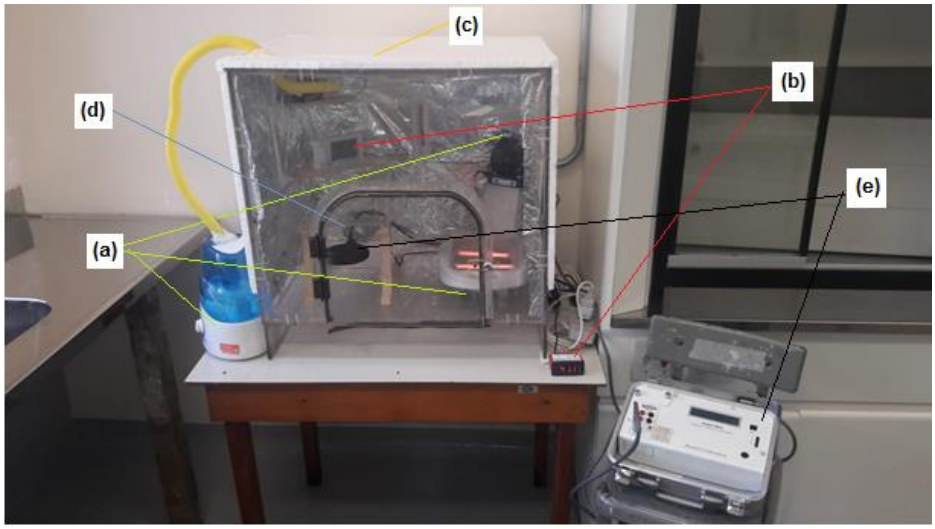

Figure 3. a) Heating, humidity and ventilation systems, b) Temperature control systems, c) Thermal insulation, d) Radiation system, e) Detection system

In Figure 4, we schematically detail the item (d) highlighted in Figure 3, concerning the positioning of the control source that makes up the irradiation system.

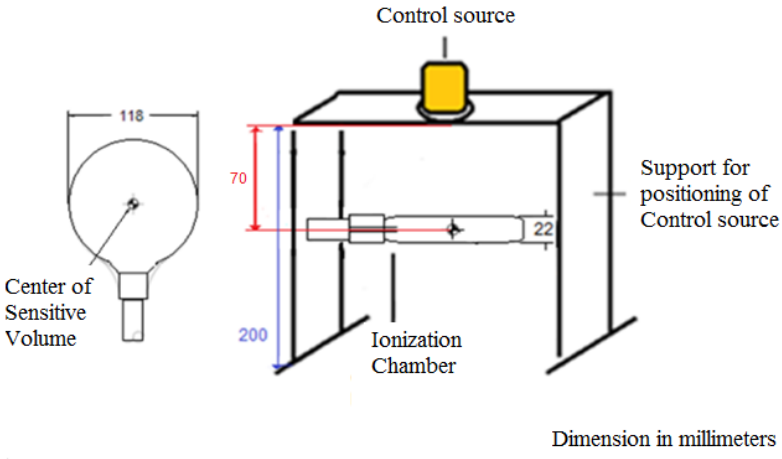

Figure 4. Scheme of the irradiation system

3. Results

Table 3 shows the results obtained for the measurement system in a climate simulation, using the annual averages of temperature and humidity in the four selected time intervals. Measurements were made with and without the verification source.

Table 3. Average temperatures and time obtained for recycled materials

	Temperature (ºC)	humidity (%)	M1 (µGy/min)	M2 (µGy/min)	M3 (%)
Condition Initial	20.4	66	299.19 ± 0.02	1.31 ± 0.02	0.44
Simullated period	Average temperature In the period (ºC)	Average humidity the period (%)	M1 (µGy/min)	M2 (µGy/min)	M3 (%)
7h – 8h – 9h	24.24 ± 0.02	91.31 ± 0.08	304.04 ± 0.05	1.74 ± 0.02	0.57
10h – 11h – 12h	25.41 ± 0.04	91.64 ± 0.10	304.96 ± 0.07	1.78 ± 0.03	0.58
13h – 14h – 15h	26.98 ± 0.22	89.35 ± 0.50	319.90 ± 0.23	14.73 ± 2.45	4.61
16h – 17h – 18h	28.86 ± 0.21	89.65 ± 0.30	321.61 ± 0.49	20.98 ± 0.18	6.52

M1 - Measurement with check source
M2 - Measurement without check source
M3 - Leakage variation coefficient in relation to rates (%)

From the values obtained during the climate simulation test, it was observed that in each acclimatization of the measurement system for the temperature and humidity parameters there was varia-

tion in the IC behavior. For the first simulated period, there was an increase of 0,13% in relation to the coefficient of variation of the initial conditions (M3). In the second period, 0,14%, in the third period, 4,17% and in the fourth and last simulated period, 6.08%. Only the last simulated period presented a coefficient of variation (M3) above 5%, tolerance recommended by the current standard.

4. Conclusions

Preliminary results point to an increase in the accumulated measurements obtained with the ionization chamber due to simulated climatic conditions, being more significant in the measurements made without the verification source (table 3 - M2).

The humidity parameter directly interfered with the background value measured by the ionization chamber, it was observed that the ionization chamber continued to present a significant leakage of current after the test.

Indicating that the dosimetric system must go through a de humidification process before the next use.

Selecting and using appropriate detection equipment for radiometric measurement anywhere in Brazil is a challenge. Although determining the influence of external environmental factors is not an easy task. It is critical to measurement reliability, the establishment of radioprotection systems and the improvement of quality control.

ACKNOWLEDGEMENTS

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5. References

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