

## **A study to assess the long-term stability of the ionization chamber reference system in the LNMRI**

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**Abstract:** Ionization chambers are used as secondary standard in order to maintain the calibration factors of radionuclides in the activity measurements in metrology laboratories. Used as radionuclide calibrator in nuclear medicine clinics to control dose in patients, its long-term performance is not evaluated systematically. A methodology for long-term evaluation for its stability is monitored and checked. Historical data were analyzed via control chart, produced between 2012-2017 by an ionization chamber, electrometer and  $^{226}\text{Ra}$ , aiming to follow the long-term performance. The results for monitoring systematic errors were consistent within the limits of control, demonstrating the quality of measurements in compliance with ISO17025.

**Keywords:** Ionization chamber, long-term stability, control chart, activity measurement.

### **1. INTRODUCTION**

National Metrology Laboratory on Ionizing Radiation LNMRI/IRD guard, maintain, and disseminate Brazilian standards of radionuclide activity. To keep traceability of these measurement from the primary standardization until several subsequent applications, a well-type ionization chamber in geometry  $4\pi\gamma$  was used [1]. This chamber is an integral part of the secondary reference system of measurements in LNMRI. However, to ensure the accuracy of the measurements obtained, must be carried out quality control tests to check the performance of the measurement system over time, evaluated by means of a control chart [2]. Quality assurance of measurements of activity is also a requirement of the Norm CNEN 3.05, from the point of view of radiation protection and quality control of radiopharmaceuticals used in nuclear medicine services [3]. Quality assurance is also a requirement of the Norm ABNT NBR ISO/IEC 17025, for calibration and essay laboratories [4]. The LNMRI, while reference laboratory for calibration of the radioactive sources, develops, coordinates and performs the interlaboratorial comparison programs of the radionuclide

calibrators used not only in nuclear medicine clinics as well as for the certification of the producer centers of radiopharmaceuticals in different institutions in the country. Radionuclide metrology laboratory monitors the statistical fluctuations in the reference system through source of  $^{226}\text{Ra}$ , but does not use the control chart. In 2017, at the meeting of the Consultative Committee for ionizing radiation, radionuclide area, of the BIPM, was forwarded a proposal demanding that each system of ionization chamber that has been calibrated for a period more than 2 years, to validate their calibrations, keep a control chart in order to demonstrate that there is no trend or systematic error.

### **2. OBJECTIVE**

Apply the method of statistical control chart showing the variation of the activity of a reference source of  $^{226}\text{Ra}$ , long-term, to assess the stability of the measurement system of the secondary standard ionization chamber. In this case, it is proposed to monitor whether the values of the reference source activity are kept within the limits of the control as a stable system.

### 3. MATERIALS AND METHODS

To determine the activity of radionuclides in the ionization chamber (CENTRONIC IG11) with electrometer coupled, it were here performed measurements of the background and of a reference source of  $^{226}\text{Ra}$ , as can be seen in figure 1 [5]. For more than 5 years, the activity of different radionuclides had been measured in the LNMRI by an ionization chamber type  $4\pi\gamma$ . The stability of the chamber has been systematically verified by measurement of the reference source of  $^{226}\text{Ra}$  of long half-life ( $T_{1/2} = 1600(7) \text{ a}$ ) and the results of the measurements were obtained with their uncertainties [6]. This reference source was measured in regular interval of at least once per month, and each measurement has been corrected for background radiation. Thus, 71 values were generated over the period between 2012-2017, and each value is an average of 10 measurements. The activities of historical measurements stored in a database were all corrected to a reference date.

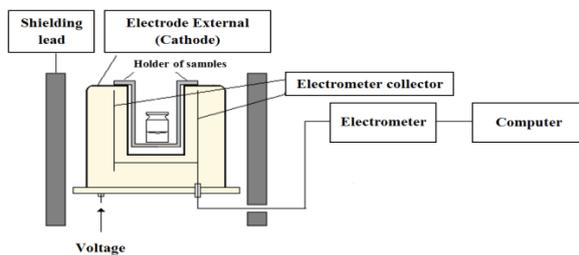


Figure 1 – Ionization Chamber CENTRONIC IG11 with electrometer KEITHLEY 6517A of LNMRI.

In this way, were here adopted the methods of Control Chart for Individual Values (I) and Control Chart of Mobile Amplitudes (MR), used for continuous data, individual, without references, considering only their own measurements and the date chosen, including individual value graphs and amplitude mobile graphs, as follow [2].

For individual values:

$$LSC = \bar{X} + E_2 \overline{MR}$$

$$LC = \bar{X}$$

$$LIC = \bar{X} - E_2 \overline{MR}$$

For individual mobile:

$$LSC = D_4 \overline{MR}$$

$$LC = \overline{MR}$$

$$LIC = D_3 \overline{MR}$$

Where:

LSC: Upper Control Limit;

LC: Control Limit;

LIC: Lower Control Limit;

$\bar{X}$ : Average of the Activities;

$\overline{MR}$ : Average Amplitude Mobile (difference of consecutive absolute values);

$d_2, D_3, D_4$ : Values of Tabulated Constant;

$E_2 = \frac{3}{d_2}$ , in that 3 is the number of standard deviation for the outer rows, the Upper Control (LSC) and Lower (LIC) Limits, and  $d_2$  is a given value [7].

The points that remain between LSC and LIC shall be considered to be "under control".

However, if one or more points are outside these limits, there is a need for appropriate corrective actions.

### 4. RESULTS AND DISCUSSION

For this study were used the data obtained by the laboratory of radionuclides in June 2012 until June 2017, given a total of 71 current values, converted into net activity, produced by  $^{226}\text{Ra}$  source. All data were referenced to June 6, 2017. Measurements results and the calculated MR values, both in kBq unit had narrow difference. Figure 2 shows the results of the individual values of the control chart, with standard uncertainty of 0.04%. Figure 3 shows the mobile amplitude control chart. It can be checked in these control charts that no point was outside the

limits of control (outlier), that is, not showing trends or special causes despite of the narrow difference between the upper and lower limits, of 0.19% of the average (Chart I). Therefore, in general, is not necessary to apply corrective actions, because the secondary standard measurement system which uses ionization chamber is under statistical control for the evaluated period, demonstrating the high long-term stability, which is a characteristic of ionization chambers.

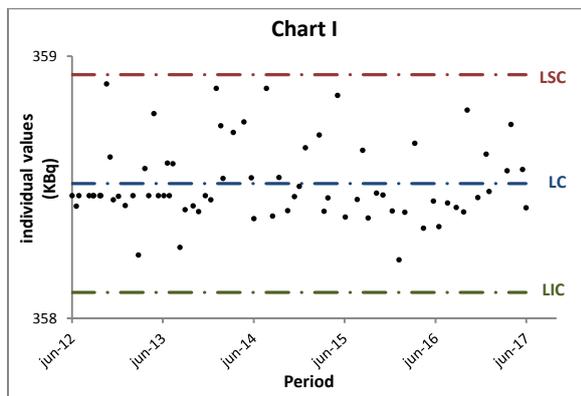


Figure 2 - Individual value control chart, with standard uncertainty of 0.04%.

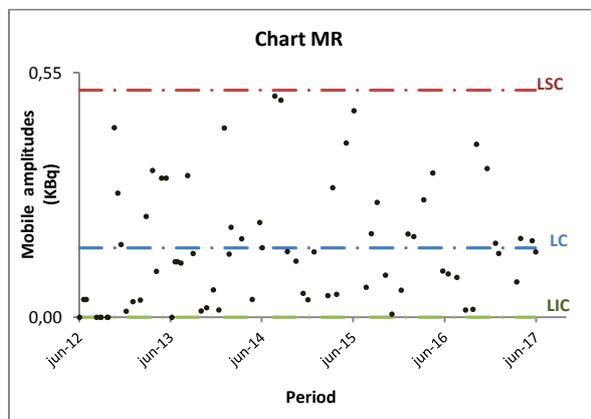


Figure 3- Mobile amplitude control chart.

## 5. CONCLUSION

The performance of the CENTRONIC IG11 ionization chamber, in accordance with the method adopted here remains within the limits that the showing as a stable system, despite the

stability evaluation criteria have been limited (not using replica of each measurement). Additionally, this stability comes to demonstrate the quality of the measurements carried out in compliance with the requirements of the Norm ABNT NBR ISO/IEC 17025 and in compliance with the recent recommendations of the Consultative Committee for Ionizing Radiation of BIPM, CCRI (II), which requires the adoption of control charts for measurement systems with ionization chambers calibrated for over two years.

On the other hand, according to the Norm CNEN (NN 3.05), all the radionuclide calibrators used in Nuclear Medicine Services (SMN) in the country should have their results produced in ionization chamber. This suggests that control chart-based methods can be applied to SMN, taking advantage of that already use standardized sources of intermediary half-lives, for example,  $^{133}\text{Ba}$  or  $^{137}\text{Cs}$ , for assaying of equipment. It should be emphasized that there are other methods of control chart in literature which may fit better in stability evaluation, according to the case.

## 6. REFERENCES

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