Initial tests for the establishment of standard qualities in an X-rays system

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Abstract. The objective of this work was to collaborate in the establishment of standard qualities of radioprotection, diagnostic radiology, and radiotherapy for the new X-ray equipment of the Instrument Calibration Laboratory of the Institute of Energy and Nuclear Research (LCI-IPEN), following the recommendations of the national and international standards, and to contribute for the expansion of the metrological capacity of the laboratory. To achieve the proposed objective, the alignment of the X-ray tube and stability tests with the transmission chamber were carried out.

1. Introduction

The Brazilian Nuclear Energy Commission (CNEN) establishes that the calibration of equipment used in the monitoring and calibration of beams and sources used in medical exposure be traceable to a standard dosimetry laboratory recognized or authorized by CNEN [1].

The Calibration Laboratory of Instruments of IPEN (LCI – IPEN/CNEN) has carried out, for approximately 40 years, calibrations of radiation detectors (radioprotection, diagnostic radiology, nuclear medicine and radiotherapy levels). This service has been offered to hospitals, industries, clinics and other users located throughout Brazil, following international and national recommendations [2, 3, 4, 5]. In addition to calibration services, irradiation services of samples and materials are also offered in standard fields.

Regarding the calibration of instruments using X radiation, the LCI has currently a Pantak/Seifert brand X-ray equipment, which operates between 5 kV and 160 kV with standardized radiation qualities established for conventional diagnostic radiology, mammography, computed tomography, radioprotection, and radiotherapy beams. They are used both for calibration activities and for the development of research projects. Several of these projects were developed aiming at the quality control of the systems and methods used in the Calibration and Dosimetry Laboratories [6, 7, 8, 9, 10].

From the point of view of regulation and standardization of radiation qualities, it is necessary to establish a well-defined radiation condition that can be used internationally to specify operating standards for X-ray equipment, as well as to provide procedures for describing and verifying the performance of this equipment.

The ISO 4037 standard [5] published by the International Organization for Standardization specifies the characteristics and production methods of reference X and gamma radiations to calibrate dosimeters and dose meters, radiation protection level. Its first version was published in 1979 with the title Radiological protection — X and gamma reference radiation for calibrating dosemeters and dose meters and for determining their response as a function of photon energy dose and to determine its response as a function of photon energy. This standard was updated in 2019 incorporating the improvements in high voltage generators, the spectral measurements in irradiation installations equipped with these generators and all published information, with the aim of adjusting the requirements of the technical parameters of the reference fields.

In 2007, the International Atomic Energy Agency (IAEA) published the TRS 457 Code of Practice (Technical Reports Series nº 457 [11]), for dosimetry in diagnostic radiology, which can be adopted by dosimetry and calibration laboratories and in diagnostic radiology clinics. Regarding the implementation of radiation qualities, the TRS 457 follows the recommendations of the IEC 61267 standard [12]. In the chapter referring to calibration laboratories, it describes in detail the instrumentation necessary for the operation of the laboratory, introduces the possibility of using non-invasive meters to measure the voltage applied to the X-ray tube and makes possible the implantation of mammography qualities in systems of X-radiation with a non-molybdenum anode.

The TRS 398 code of practice [4] aims to promote the international unification of methods for calibrating ionization chambers in terms of absorbed dose in water for beams applied to radiotherapy, presenting methodologies for determining a calibration factor in terms of absorbed dose in water directly, or through a calibration factor in terms of air kerma.

The maximum tube voltage allowed by the existing X-ray tube at that time in the LCI was 160 kV, so the radiotherapy qualities for higher voltages could not be implemented. However, LCI recently installed a Yxlon brand X-ray equipment in its laboratory that operates up to a maximum voltage of 320 kV and no radiation quality has yet been established. Radioprotection, diagnostic radiology and radiotherapy qualities will be implanted in this X-ray equipment, including voltages of up to 320 kV.

2. Materials and methods

The materials used for the experimental tests are presented.

2.1. Radiation systems

The Pantak/Seifert brand X-ray equipment, model ISO-VOLT 160HS, which operates between 5 kV and 160 kV was used for the stability tests of the transmission chamber using the RQR-2M radiation quality described in Table 1.

Table 1. Parameters used for the RQR-2M mammography quality established in the LCI Pantak/Seifert system.

Radiation Quality	Tube Voltage (kV)	Tube Current (mA)	Half-Value Layer (mm)	Additional Filtration (mm)	Air Kerma Rate (mGy/min)
RQR-2M	28	10	0.37	0.07 Mo	13.0

The alignment of the X-ray tube was performed using the Yxlon equipment, model Y.TU 320-D30, which operates between 5 kV and 320 kV.

2.2. Reference Measurement Systems

2.2.1 Ionization chambers

The ionization chambers available at LCI used in this work were:

- Cylindrical graphite-type ionization chamber PTW, with a volume of 0.6 cm^3. Its calibration certificate was issued in 2019 by the National Metrology Laboratory of Ionizing Radiation (LNMRI).
- Transmission chamber PTW, model TN 34014.

Associated with the ionization chambers, a PTW electrometer, model Unidos, was used.

2.3. Auxiliary Systems
Thermometers, barometers, hygrometers, dehumidifiers, and air conditioning systems were used for monitoring and controlling the environmental conditions. In addition, a microcomputer was used for data analysis and computational simulations.

3. Results
The activities carried out are presented.

3.1. X-ray tube alignment
The alignment of the Yxlon X-ray tube, model Y.TU 320-D30, was initially carried out. The cylindrical graphite ionization chamber was used, positioned 1 m away from the focal point of the X-rays system. Measurements were taken by varying the angle of the X-ray tube, ten for each position. The result obtained is presented in Figure 1.

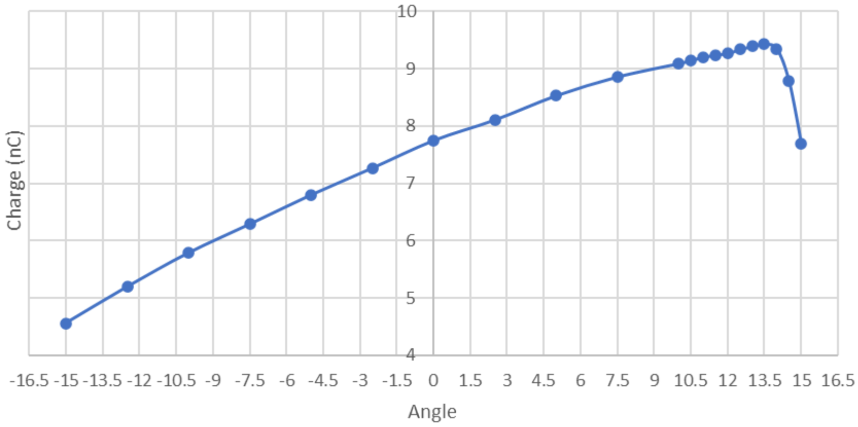

Figure 1. Detector response with the variation of the X-ray tube angle. The maximum uncertainty of the measurements was 0.2%, not visible in the graph.

The position of the X-ray tube was established at 13.5º counterclockwise, where the highest value for the response of the ionization chamber was obtained.

The filter wheel was positioned in front of the tube as shown in Figure 2.

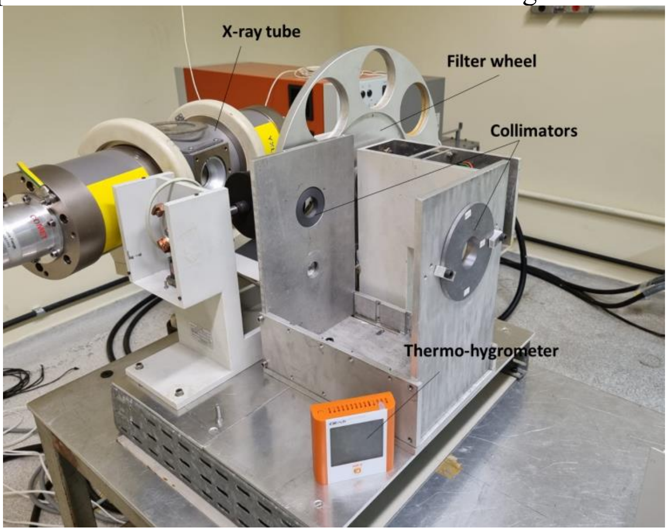

Figure 2. X-ray tube and filter wheel in place.

Thermohygrometers were positioned: one close to the radiation outlet and the other close to the ionization chamber.

4. Stability tests with the transmission chamber

For the stability tests, the IEC 61674 [13] and IEC 60731 [14] standards were used as references.

For the repeatability test, the transmission chamber was positioned 100 cm from the focal point. Ten consecutive measurements were performed after 15 min of irradiation, to observe the degree of agreement between measurements.

The results of the repeatability test were within the limit recommended by the standard IEC 61674 [13] of 1.0% and by the standard IEC 60731 [14] of 0.3%.

To verify the leakage current of the system, the response variation was observed in an interval of 20 min before and after irradiation. The highest leakage current observed before irradiation was 0.15% and after irradiation 0.23%, both values being below the limits recommended by the standards IEC 61674 [13] and IEC 60731 [14] of 5.0 % and 0.5% respectively.

The stabilization time test evaluates how long it takes for the ionization chamber and electrometer set to become electrically stable. According to the IEC 61674 [13] and IEC 60731 [14] standards, the response of the ionization chamber under irradiation conditions, in the time intervals of 15, 30, 45, and 60 min, must not have a variation greater than 2.0 % and 0.5%, respectively. The observed variation was 0.3%, within the recommended limits.

5. Conclusions

It was possible to position the X-ray tube, the filter wheel, and the thermo-hygrometers. In addition, stability tests were carried out with the Transmission chamber PTW, verifying its proper functioning. The completion of this work is of great importance, as it is an initiative to increase the metrological capacity of the LCI, which receives radiation measuring instruments from all regions of the country, including hospitals, industries, and clinics.

6. Acknowledgements

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