# Design and assembly of a simple monitor ionization chamber

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## Abstract
At the Instituto de Pesquisas Energéticas e Nucleares, Brazil, a new monitor ionization chamber was designed, developed and characterized. This monitor is a parallel-plate type ionization chamber, and it has two sensitive volumes formed by three conductive foils. The chamber body is made of PMMA disks that are positioned outside the primary radiation beams. The pre-operational tests and the response stability tests were performed. The pre-operational tests, as saturation curve, ion collection efficiency, polarity effect and response linearity showed very good results. The response stability tests (repeatability and long-term stability) also showed satisfactory results, within international recommendations. Besides the good results, this ionization chamber is very simple to manufacture, and all materials used in this project are of low-cost and commercially available.

## Introduction
Ionization chambers are the most used dosimeters. They are simple and they can be used for many purposes, depending on their material, volume and design.

A special kind of ionization chamber is the transmission chamber that is used as a monitor chamber for X-radiation beams. This kind of ionization chamber has some particular characteristics, such as a large sensitive volume which may cover the entire radiation beam section and is made of materials which are transparent to the X-rays (IAEA 2007).

In a Calibration Laboratory, the transmission ionization chamber can be used as a reference instrument since its response shows good stability and the calibration factor is transferred from a standard device (IAEA 2007). In this case, the transmission chamber may be calibrated periodically.

In the Calibration Laboratory of IPEN, two monitor chambers have recently been constructed (Yoshizumi and Caldas 2010a, 2010b). These ionization chambers have a ring-shaped design, and they measure only the radiation penumbra. They showed usefulness according to international recommendations.

## Materials and methods

A simple transmission ionization chamber was designed and assembled at the Calibration Laboratory of IPEN. This ionization chamber has two sensitive volumes formed by two aluminized polyester foils and a graphite coated polyester foil. The chamber body is made of PMMA and the electrodes are connected to co-axial cables.

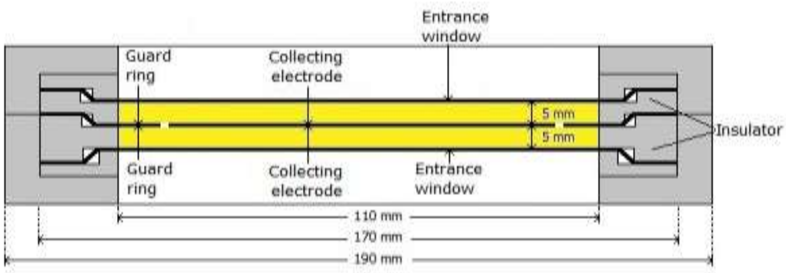
An electrometer, *Physikalisch-Technische Werksttäten* (PTW), model UNIDOS was used as a measuring assembly.

The characterization tests were performed using an X-ray unit, Pantak/Seifert, model ISOVOLT 160HS. Diagnostic radiology beam qualities, defined by IEC 1267 (1994), established in this equipment, were utilized in this work. The air kerma rates were measured using a secondary standard ionization chamber, PTW, model 77334. This standard ionization chamber calibration factors are traceable to the German primary standard laboratory *Physikalisch-Technische Bundesanstalt*, PTB.

The response stability tests were performed using a $Sr^{90}+Y^{90}$ check source, PTW, model 8921.

## Results

The transmission chamber developed at IPEN has two entrance windows of aluminized polyester foils of superficial density of 1.87 mg.cm$^{-2}$. The collecting electrodes and the guard rings are made of a graphite coated polyester foil. The graphite coating was made using a commercial lubricant spray Aerodag G, Acheson. A ring-shaped mask was made to separate the collecting electrode and the guard ring when spraying. A diagram and photography of the transmission chamber can be seen in Figure 1. The total sensitive volume of the chamber is about 63.5 cm$^3$.




(a)

(b)

**Fig. 1. (a) Diagram and (b) photograph of the transmission ionization chamber.**

## Saturation curve, ion collection efficiency and polarity effect

The saturation curve was determined using the radiation beam quality RQA5 at a distance of 30 cm from the tube focal spot. The voltage applied to the sensitive volume of the chamber was increased in steps of ±50 V, covering a range from -400 V to +400 V. The results can be seen in Figure 2. The chosen operating voltage was -300V.

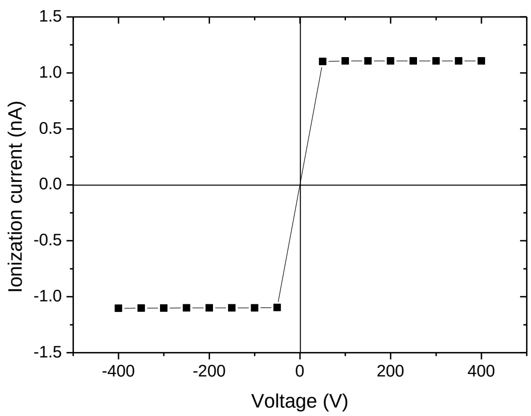



**Fig. 2. Saturation curve of the transmission ionization chamber. The uncertainties associated to the measurements are negligible and they do not appear in the graph.**

From the results obtained in the saturation curve test, the ion collection efficiency and the polarity effect of the chamber could be determined.

The ion collection efficiency was calculated using the two-voltage method (IAEA 2000):

$$k_s = \frac{(V_1/V_2)^2 - 1}{(V_1/V_2)^2 - (M_1/M_2)},$$

where $V_1 = \pm 300$ V and $V_2 = \pm 150$ V and $M_i$ is the chamber response obtained when $V_i$ is applied. For both voltages, the ion collection efficiency was higher than 99%, i.e., no ion recombination occurs in the sensitive volume.

The polarity effect measures the variation between the responses obtained for the same voltage but of opposite signals. For all tested voltages, the maximum variation was 0.66%, which is within the recommended limit of 1% (IEC 1997).

## Response linearity

The chamber response linearity test was evaluated using the X-ray unit Pantak/Seifert and the diagnostic radiology quality RQA3. In this test, the ionization current applied to the tube was varied from 0.5 mA to 40.0 mA, covering a range of air kerma rate from 1 $\text{mGy.min}^{-1}$ to 88 $\text{mGy.min}^{-1}$. As can be seen in Figure 3, the transmission chamber presents a linear response for the air kerma rate range studied. A linear regression was obtained that resulted in a correlation factor R of 0.99997.

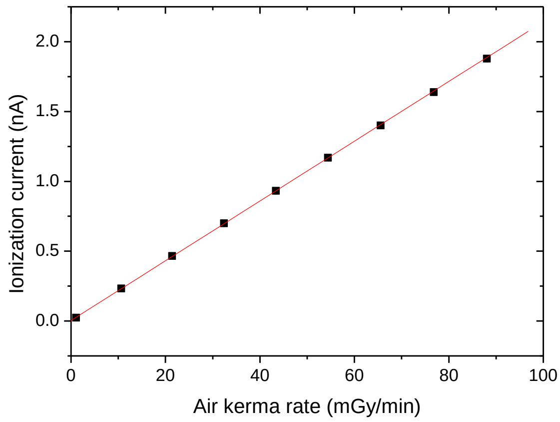



**Fig. 3. Response linearity of the transmission ionization chamber. The uncertainties associated to the measurements are negligible and they do not appear in the graph.**

## Response stability tests

To evaluate the stability of the chamber response, four tests were performed: stabilization time, leakage current, repeatability and long-term stability. A PMMA holder was used to position the check source in front of the entrance window of the chamber.

For the stabilization time test, the check source was positioned in front of the transmission chamber, and then the chamber was connected to the electrometer, in the operating voltage of -300 V. The ionization current was measured ten times, 15 min, 30 min, 45 min and 1 h after the chamber connecting. The mean values obtained for each measurement time are shown in Table 1.

**Table 1. Mean values of the ionization current obtained at different times from the application of the operating voltage to the transmission chamber.**

| Time (minutes) | Mean value of the ionization current (pA) |
|---|---|
| 15 | -100.9 ± 0.8 |
| 30 | -101.2 ± 1.6 |
| 45 | -101.1 ± 2.8 |
| 60 | -101.2 ± 0.8 |

The ionization current obtained 15 minutes after switching on the chamber is 99.7% of the 1 h stabilization current. This result is within the recommended limits of ±2% of response variation (IEC 1997).

The leakage current was measured before and after irradiation. The charge was collected during 20 minutes with no radiation source present. The maximum leakage current was lower than 1.0% of the ionization current obtained with the minimum air kerma rate studied (using the beta check source), therefore within the recommended limit of 5.0% (IEC 1997).

For the repeatability test, ten consecutive measurements of the collected charge accumulated during 15 s were performed. The standard deviation of these measurements shall not be greater than 3% of the mean value according to the IEC 61674 publication (IEC 1997). This test was performed seven times in different days and the maximum variation obtained was 0.2%, therefore within the recommended limit.

From the mean values determined in the repeatability test, the long-term stability of the transmission chamber can be evaluated. Figure 4 shows the result of the seven tests performed.

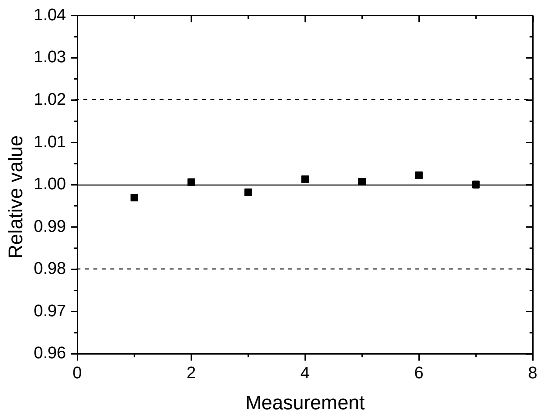



**Fig. 4. Long-term stability of the transmission ionization chamber. The dashed lines represent the recommended limits. The uncertainties associated to the measurements are negligible and they do not appear in the graph.**

From the results shown in Figure 4, the maximum variation of the chamber response in a period of 10 days was 0.3%. The IEC publication recommends a maximum variation of ±2% for the long-term stability test (IEC 1997), so the chamber response is stable according to this recommendation.

## Conclusions

A simple transmission ionization chamber, using commercially available materials, was assembled. The characteristics and the response stability of the home-made transmission ionization chamber were evaluated. All performed tests resulted in good agreement to international recommendations. This chamber represents a good alternative since it is simple, easy to construct, and uses low-cost materials.

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