

# MEASUREMENTS OF kVp, PPV AND AIR KERMA VALUES IN FUNCTION OF THE ELECTRIC CURRENT QUANTITY AND THE FOCUS-DETECTOR DISTANCE IN ONE X-RAY EQUIPMENT

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## ABSTRACT

The objective of this work was to study the behavior of the X-ray equipment Pantak/Seifert, model MXR-160/22 of the calibration laboratory of IPEN, LCI, operating in the diagnostic radiology radiation quality RQR 5 (70 kV). For this evaluation it was used a noninvasive meter PTW, Diavolt™ model. The measurements of kVp, PPV and Dose (air kerma), were made varying the electric current and distance between the focal point and the meter. This behavior is described in the literature and was expected in the analysis of the measurements for comparison purposes. For the tests where it was only increased the electric current it was waited a linear increase of the dose (air kerma), but not a variation in the kVp and PPV. The measurements had corresponded to the waited behavior, since the Dose (air kerma) measurements presented a linear increase with the increase of the electric current and the kVp and PPV values showed a variation less than 2%. In the corresponding measurements increasing the distance between focal point and meter, it was waited the exponentially decreasing of the Dose (air kerma) and again a small variation or no variation of the PPV and kVp with the increase of the distance. Over again the measurements corresponded to the expected, where the Dose (air kerma) decreased exponentially and the PPV and the kVp had a variation less than 1.5%.

## 1. INTRODUCTION

A quality control program applied to X-rays equipments and X-ray beams is required in instruments calibration laboratories, clinics and hospitals, around the world with the intention of assure a high quality of those services, such us: portable survey meters calibration and procedures used for radioprotection routines[1] and also for calibration procedures of dosimetric systems used in diagnostic radiology. Then, it is very important check periodically the performance of Dose (air kerma), kVp and PPV meters and similar devices to permit a trustworthy verification of the calibration set-up [2].

For this control, it is necessary to obey some specific procedures involving uncertainties, as well as to check with the literature to ensure that the measurements have an appropriate behavior. To do that, some norms are used as reference to observe the errors and uncertainties, as well as specific books of the studied subject that are a guide to study the physical behavior of measurements done. According to the IAEA publication technical reports series 457 (TRS 457) [3], the uncertainties attributed to the quantity of Dose (air kerma), kVp and PPV for a non invasive meter should not exceed 5%, in other words, in the reproducibility of a same measurement, the uncertainty related to the all system plus the standard deviation of the average should not exceed 5%.

For the errors found in each measurement of PPV, the norm IEC 61676 [4] recommends that the obtained values by the non-invasive meters of kVp and PPV must be agreed with the values of invasive meters (considered as true values) and their maximum intrinsic errors by the relations 1 and 2. The maximum relative intrinsic (I) error for voltages above 50kV is expressed by the equation:

$$|I| = \left| \frac{U_{meas} - U_{true}}{U_{true}} \right| \leq 0.02 \quad (1)$$

where  $U_{meas}$  is the measured value of kVp by the non-invasive instruments and  $U_{true}$  is the true value of kVp measured by the invasive instrument.

For voltages below 50kV, the maximum intrinsic error (E) shall not be greater than  $\pm 1$ kV over the effective range of voltages. This is expressed by the equation:

$$|E| = |U_{meas} - U_{true}| \leq 1 \text{ kV} \quad (2)$$

where  $U_{meas}$  is the measured value of kVp by the non-invasive instruments and  $U_{true}$  is the true value of kVp measured by the invasive instrument.

In this work measurements of kVp, PPV and Dose (air kerma) were done varying the electric current and the distance between focal point and meter. By positioning the meter and varying the electric current applied to the x-ray tube it is expected that the flow of radiation varies linearly, however the energy of photons can not increase and nor to diminish. Therefore, it is expected that the Dose (air kerma) increases linearly with the increasing of the electric current and that the PPV and kVp not present variation in their values.

In the case where only the distance between meter and focal point is varied, the flow of radiation decreases with the proportion of  $R^{-2}$  with the increase of the distance, since the field where this flow passes is spherical. However, the energy of the photons is not affected by this parameter, but by the attenuation of the beam in the air that block the photons of low energy, however this does not influence the measurements of kVp and PPV that are quantities related to photons of high energy. Already the Dose (air kerma) values must present a drop with the ratio of  $R^{-2}$  with the increase of R.

## 2. MATERIALS AND METHODS

For the tests of performance of the Dose (air kerma), kVp and PPV quantities was used a X-ray system Pantak/Seifert, model MXR-160/22 (constant potential) of the LCI laboratory of IPEN operated in the diagnostic radiology radiation quality RQR 5 (70 kV) with total filtration of 2.8 mmAl. The non-invasive meter of the PTW, model Diavolt<sup>TM</sup> was used for all measurements.

In the first test, the meter was positioned at 1 m of the focal point of the X-ray system and measurements of 3, 5, 8, 10, 15, 20 and 25 mA were made. For each selected electric current were made 10 measurements of 60s each.

To the second test, the meter was positioned at distances of 0.5, 1, 1.5, 2 and 2.5 m, and all the other parameters remained fixed, as well as the electric current fixed in 10mA. In this test also were made 10 measurements of 60s at each distance.

For the 10 sequential measurements were calculated the averages values and their associated average standard deviations. With the calculations of the averages values of all measurements and of the maximum intrinsic errors were plotted graphics (Origin 8 Software) of kVp, PPV and Dose (air kerma) by electric current in the first test and of kVp, PPV and Dose (air kerma) by distance between focal point and meter in the second test. Then these values were compared with the values found in literature.

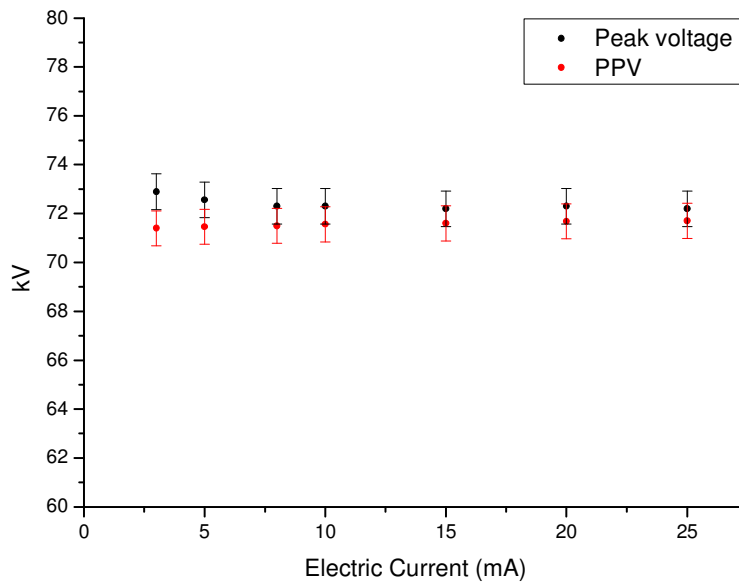
### 3. RESULTS AND DISCUSSION

The Table 1 and the graphics of the figures 1, 2, 3 and 4 show the results obtained in the first test, where the electric current was varied.

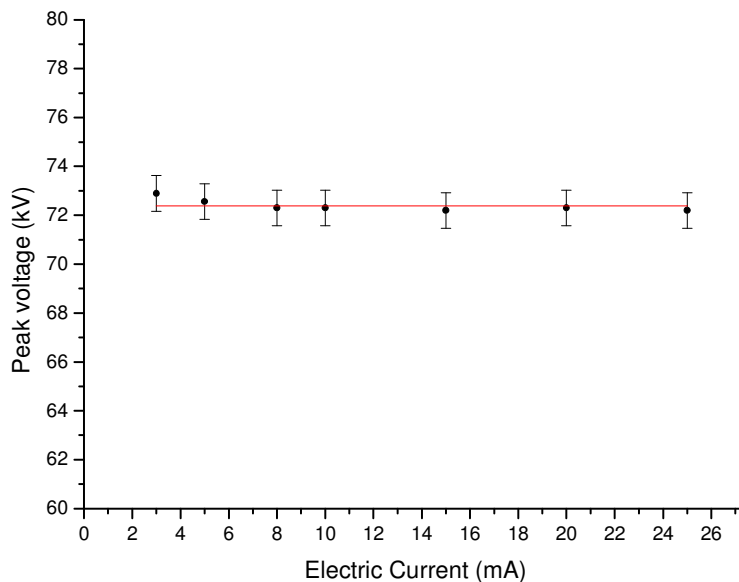
**Table 1. Average values of the measurements of the maximum kVp, PPV and Dose (air kerma) and its uncertainty.**

<b>Electric Current (mA)</b>	<b>kVp (kV)</b>	<b>PPV (kV)</b>	<b>Dose (air kerma) (air kerma) (Gy)</b>
3	72.90±0.73	71.40±0.71	0.01141±0.00011
5	72.56±0.73	71.46±0.72	0.01902±0.00019
8	72.30±0.72	71.50±0.72	0.03037±0.00031
10	72.30±0.72	71.56±0.72	0.03793±0.00038
15	72.20±0.72	71.60±0.72	0.05681±0.00057
20	72.30±0.72	71.68±0.72	0.07569±0.00077
25	72.20±0.72	71.70±0.72	0.09455±0.00098

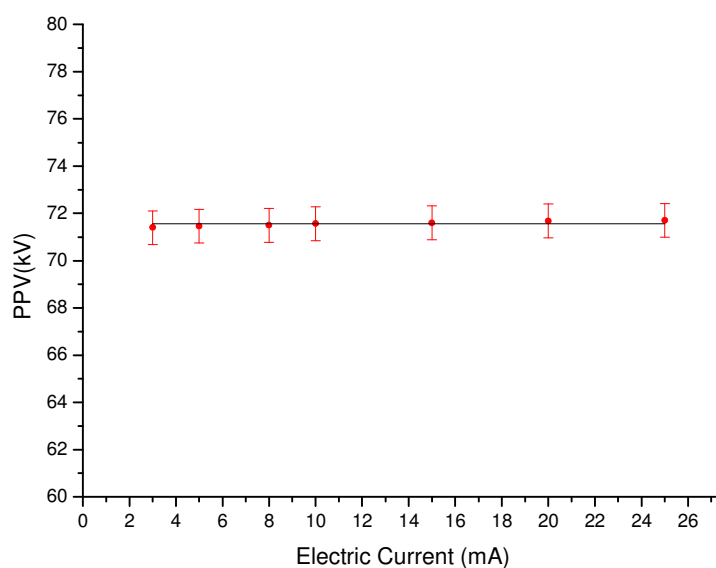
The values of the maximum intrinsic errors did not exceed 0.02 for the PPV, as recommended by IEC 61676 and the values of uncertainties were always less than 2%, showing a good reproducibility of the measurements.



**Figure 1. Graph of kVp and PPV in function of the variation of the electric current. The values of kVp and PPV had been very close (Figure 1), where the values of kVp had been slightly higher than the values of PPV. This behavior occurs because the X-ray system has the characteristic of a generator of constant potential and the difference between the measurements of both quantities should be small.**

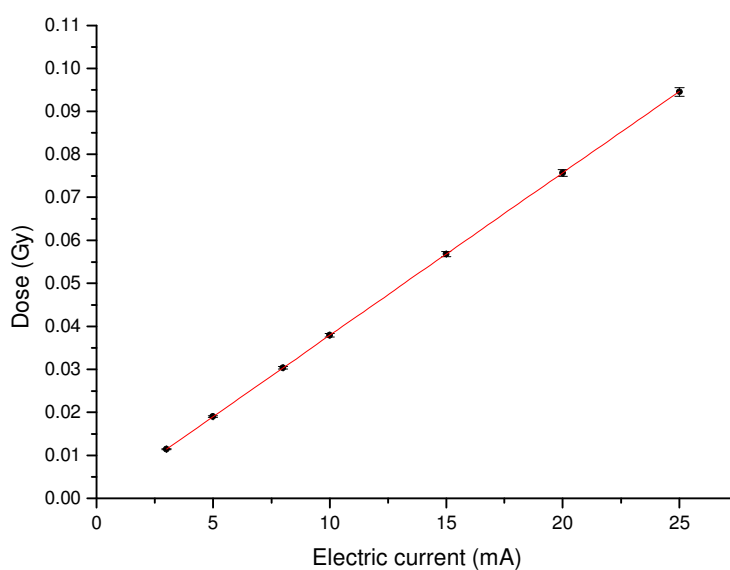


**Figure 2. Graph of kVp in function of the variation of the electric current**



**Figure 3. Graph of PPV in function of the variation of the electric current**

The graphs of the Figures 2 and 3 show the values of kVp e PPV in function of the variation of the electric current. The red and black straight lines represent the straight line with slope equal to 0 that fit better the points of the graphs. Note that the uncertainty of the measurements cover all the referring values to the straight line showing a low variation of kV with the variation of the electric current applied to the X-ray tube.



**Figure 4. Graph of Dose (air kerma) in function of the electric current variation**

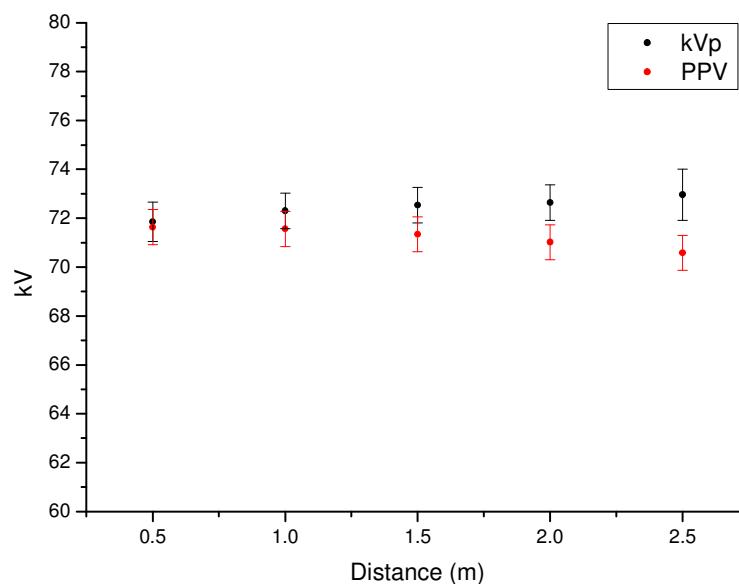
The graph of the Figure 4 shows the values of Dose (air kerma) in function of the variation of the electric current. The values had been adjusted by a straight line that passes for all the points and in its respective uncertainties, showing agreement with the waited theoretical values.

The Table 2 and the graphics of the figures 5, 6, 7 and 8 show the results obtained in the second test, where the distance between focal point and meter was varied.

**Table 2. Average values of the measurements of the maximum kVp, PPV and Dose (air kerma) by distance between focal point and meter and its uncertainty.**

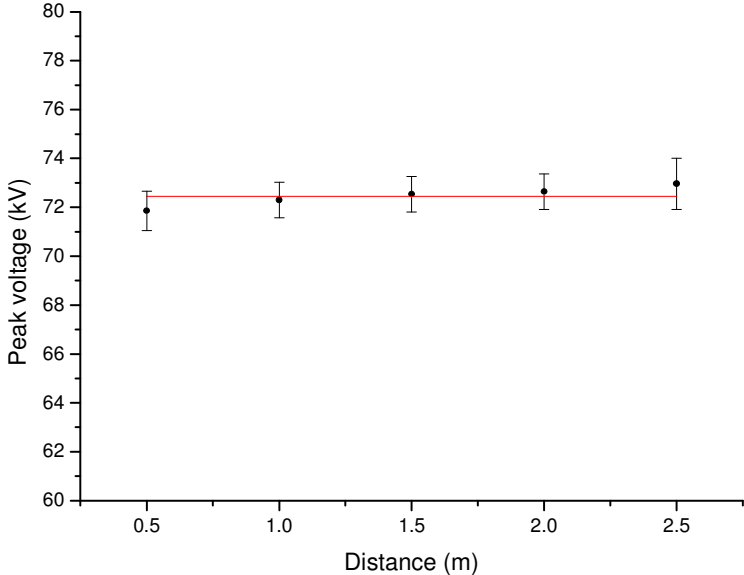
Distance (m)	kVp (kV)	PPV (kV)	Dose (air kerma) (Gy)
0.5	71.86±0.81	71.64±0.72	0.1532±0.0015
1	72.30±0.72	71.56±0.72	0.0379±0.0004
1.5	72.54±0.73	71.35±0.72	0.0166±0.0002
2	72.64±0.73	71.02±0.71	0.0092±0.0001
2.5	72.96±1.05	70.58±0.72	0.0058±0.0001

The values of the maximum intrinsic errors did not exceed 0.02 for the PPV, as recommended by IEC 61676 and the values of uncertainties were always less than 1.5%, showing a good reproducibility of the measurements.

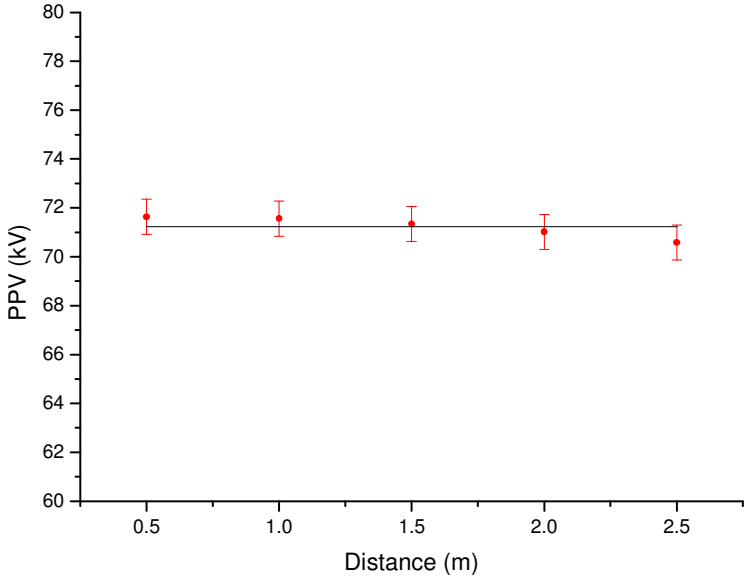


**Figure 5. Graph of kVp and PPV in function of the variation of the distance between focal point and meter**

As well as in the first test, the values of kVp and PPV were very close (Figure 5), and the values of kVp had been slightly higher than the PPV as was expected.

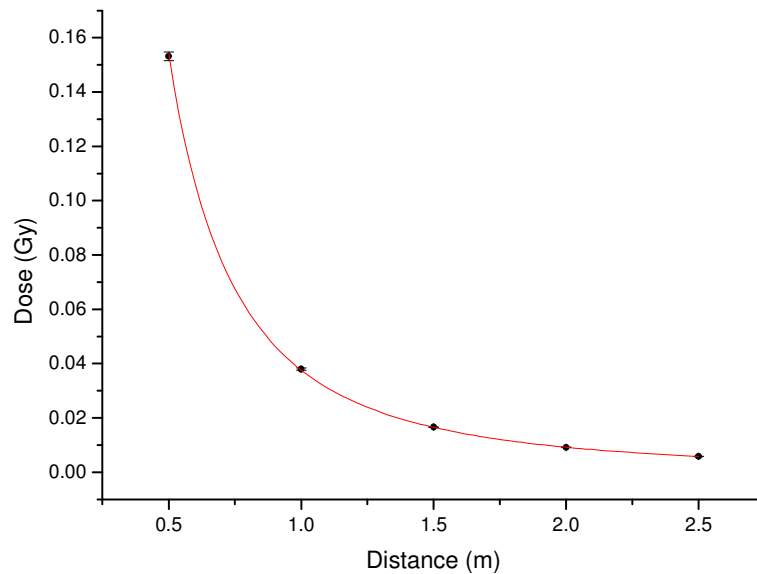


**Figure 6. Graph of kVp in function of the variation of the distance between focal point and meter**



**Figure 7. Graph of PPV in function of the variation of the distance between focal point and meter**

The graphs of figures 6 and 7 show the values of kVp e PPV in function of the variation of the distance between focal point and meter. The black and red straight lines represent the line with slope equal to 0 that fit better the points of the graphs. It is possible to note that the uncertainty of the measurements cover all the referring values to the straight line showing a low variation of kV with the variation of the distance between focal point and meter.



**Figure 8. Graph of Dose (air kerma) in function of the variation of the distance between focal point and meter**

The graph of figure 6 shows the values of Dose (air kerma) in function of the variation of the distance between focal point and meter. The values were adjusted by a waited theoretically curve and that passed for all measured points, showing agreement with the waited theoretical values. The referring uncertainties to the Dose (air kerma)s do not appear on the graph due to low values.

#### 4. CONCLUSIONS

This quality control was important to verify the good reliability of the X-ray equipment and non-invasive meter of the PTW, model Diavolt<sup>TM</sup>, when used with different configurations of electric current and distance between the focal point and meter allowing in this way a better quality in the data acquired in the calibration of the meters devices of X-rays.

Whole the behavior of the measured values were in agreement with the literature, what it demonstrated that the devices used in the tests are functioning satisfactorily and that they can be used in one reliable way.



## ACKNOWLEDGMENTS

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