Implementing the ISO Reference Radiations at a Brazilian Calibration Laboratory

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Abstract. One important parameter related to the protection of people exposed to ionizing radiation is the accurate dose measurement. In order to guarantee metrological reliability, the International Organization for Standardization (ISO) specifies x and gamma reference radiations for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy. In this work the implementation of the ISO reference radiations (wide and narrow spectrum series) in the Agfa-Seifert x-ray machine was evaluated. Quality control tests were performed and beam parameters like half-value layer, homogeneity coefficient, and inherent filtration were simulated. Results showed that the control tests complied with the standard requirements. It was conclude that the implemented x-ray beams could be considered similar to the ISO reference radiations and they may be used for the purpose of calibrating dosemeters and doserate meters used in radiation protection field.

KEYWORDS: reference radiation; x-ray calibration, ionizing radiation metrology

1. Introduction

The exposure of workers and environment to radiation must be monitored in order to comply with regulatory requirements and to help the radiological protection of the people. Gamma and x-ray reference radiations for calibrating dosimeters and for determining their energy response as a function of photon energy were established by the International Organization for Standardization [1]. The x reference radiations are grouped in four series: the low air-kerma rates, the narrow spectrum, the wide spectrum and the high air-kerma rate series. Detailed information on the beam production and dosimetry are provided in the ISO standards [1,2].

The Nuclear Technology Development Center (CDTN), in Belo Horizonte, Brazil, has maintained a metrology laboratory to provide calibrations of dosemeters in gamma beams. After acquiring a 320 kV Agfa-Seifert x-ray machine, steps were done to offer calibration services of ionizing chambers and area radiation monitors as well as irradiation of personal dosemeters in x-ray ISO beams.

2. Methods and Results

2.1 X-ray equipment

A Isovolt 320 HS Pantak Seifert x-ray machine that was installed at the CDTN Laboratory was used to have the reference radiations implemented. The characteristics of the x-ray machine are given in Tab. 1 [3]. The machine was covered with a 10 mm lead to shield scattered radiation; a 55 mm diameter hole in the exit of the x-ray allows collimating the beam. A shutter is positioned in the center of this hole; an opening and closure pneumatic command makes possible to control the time exposure without turning the machine off.

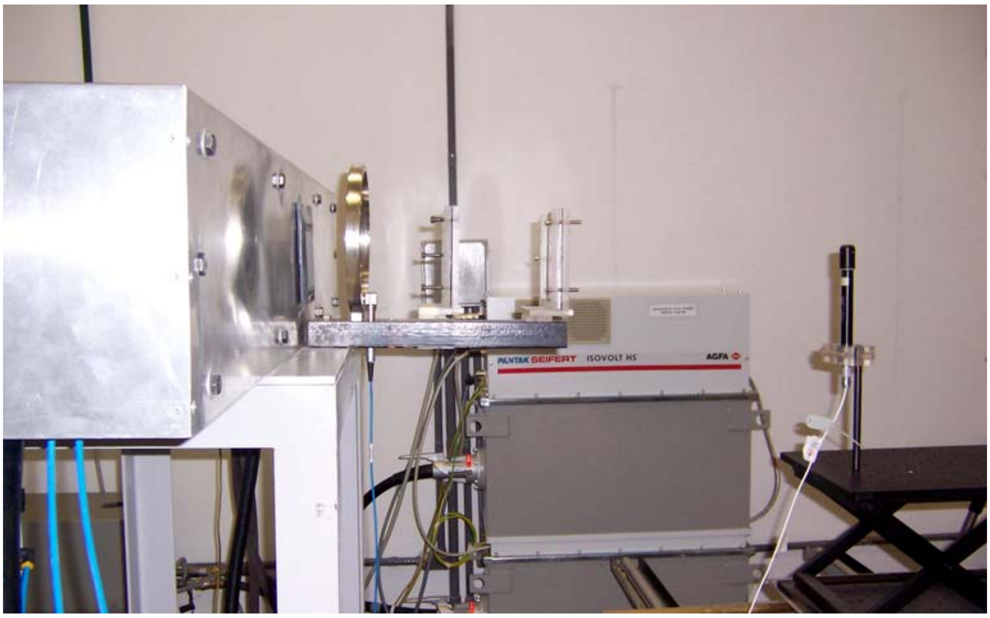
Table 1: Technical characteristics of the Agfa-Seifert x-ray machine.

	Large focal spot	Small focal spot
Maximum tube voltage	320 kV	320 kV
Maximum anode dissipation	4200 W	1680 W
Tube current at maximum tube voltage	13 mA	5 mA
Focal spot size	6.30 mm	3.00 mm
Emergent beam angle	40º	
Target material	tungsten	
Inherent filtration	7 mmBe	
Weight (tube only)	35 kg	

2.2 Irradiation geometry

Geometry conditions and x-ray parameters were verified in order to establish the ISO narrow and wide spectrum reference radiations. Figure 1 shows the positioning set-up that was used for implementing the x-ray qualities. A conical lead collimator with 13 mm thickness and 36.5 mm entrance surface diameter and 42 mm exit surface diameter was placed after the x-ray tube. Two additional plan collimators with 50 and 60 mm diameters were used to define the field size and to reduce the scattered radiation. Aluminum, cooper and tin absorbers with not less than 99,9% purity were used to reproduce the reference radiations and to measure the half-value layers (HVL). The radiation field size was enough to cover uniformly the sensitive volume of the reference ionization chamber that was positioned 100 cm to the focal spot; absorbers were exactly positioned in the middle between the focal spot and the ionization chamber.

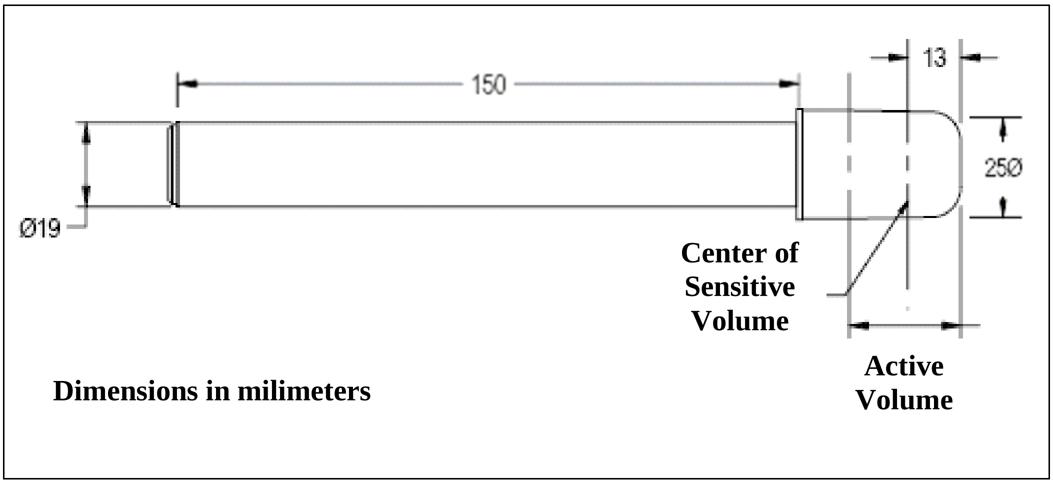
Figure 1: Set-up for implementing the x-ray reference radiations.



A PTW-Freiburg ionization chamber model TN34014 with 155 mm useful diameter was connected to a Keithley electrometer model 6517A; it was positioned after the first lead collimator and used to monitor the fluctuations in the radiation field, assure the stability of the system and make possible the measurements corrections.

An unsealed cylindrical 6 cm^3 Radcal Corporation model RC6 ionization chamber (Fig. 2) with small energy dependence was connected to a Keithley electrometer model 6517A for beam measurements.

Figure 2: The Radcal Corporation model RC6 ionization chamber



2.3 Radiation field size

The radiation field size was visualized with an intensifying screen arranged behind the ionization chamber that was positioned at 1 m distance from the focal spot. The diameter of the field was estimated to be 100 mm for the used geometry. Figure 3 shows a Radcal ionization chamber RC6 in the centre of the radiation field.

Figure 3: Radiation field and the ionization chamber images in the intensifying screen

2.4 Radiation beam uniformity

The uniformity is used for delimiting the beam area to be used for irradiation and calibration of dosemeters. The beam uniformity was verified for all radiation qualities in terms of air kerma under the same geometry mentioned before. The Radcal ionization chamber RC6 was moved in the horizontal and vertical direction, perpendicular to the radiation beam; the intersection of these lines was considered as the center of the radiation beam. The air kerma was verified at distances not larger than 5 mm along the horizontal and vertical lines. In all situations, results assured that 80 mm and 90 mm diameter radiation fields had uniformity inside ± 3% and ± 5%, respectively. Figures 4 to 9 show the beam uniformity of the N40 to N150 narrow reference radiations series.

Figure 4: Beam uniformity of N40 beam quality

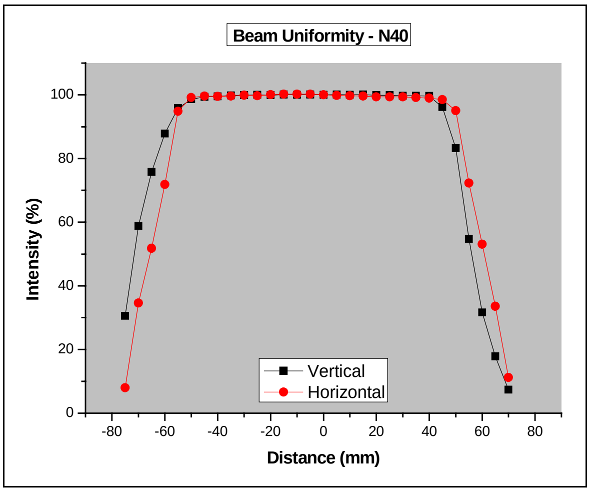


Figure 5: Beam uniformity of N60 beam quality

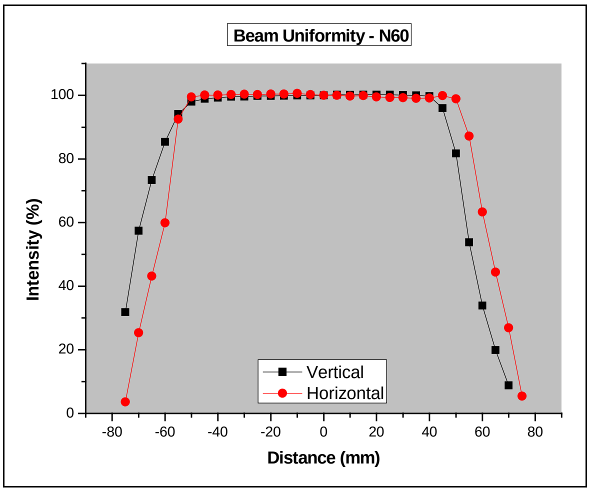


Figure 6: Beam uniformity of N80 beam quality

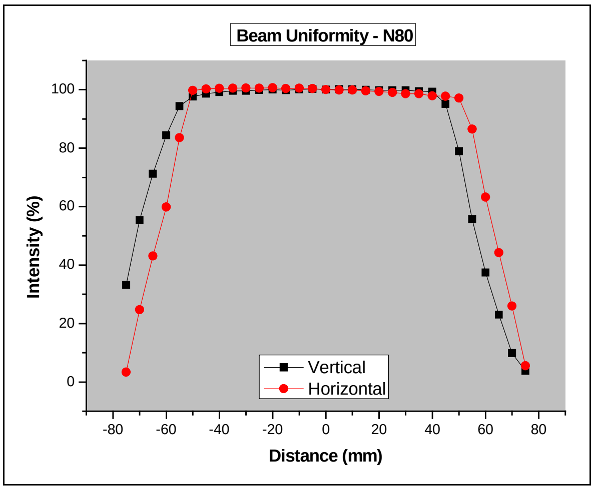


Figure 7: Beam uniformity of N100 beam quality

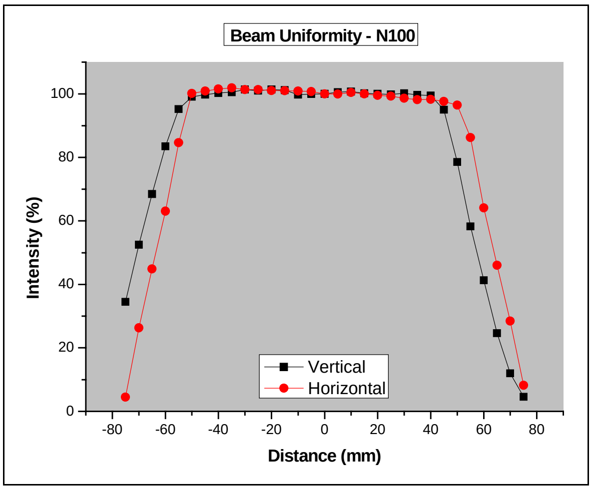


Figure 8: Beam uniformity of N120 beam quality

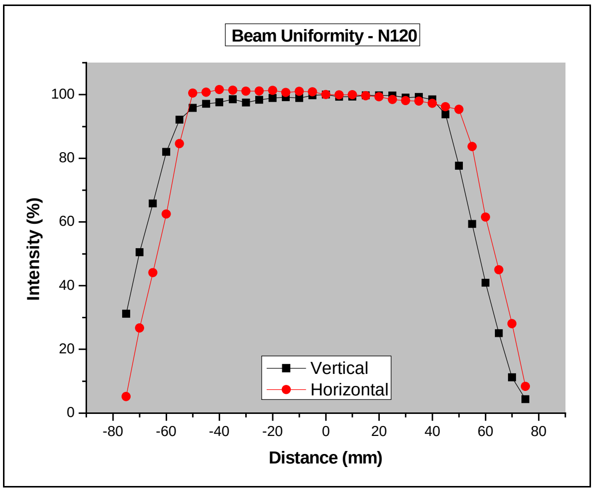
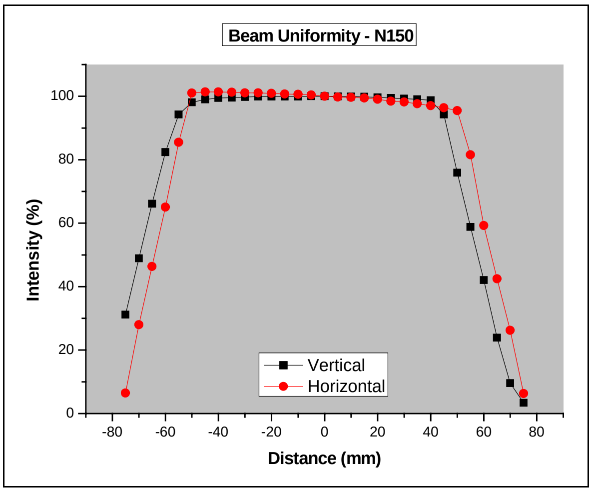


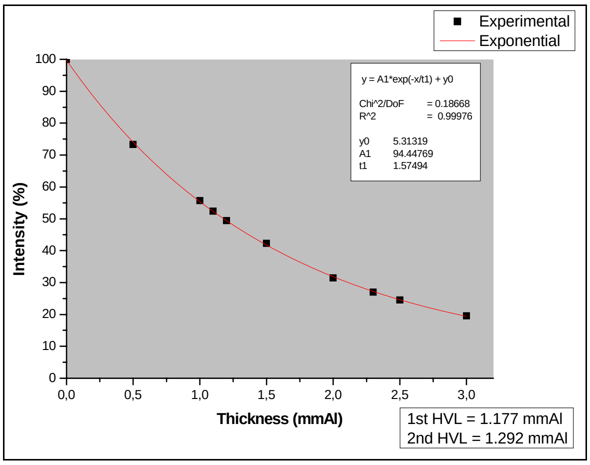
Figure 9: Beam uniformity of N150 beam quality



The tube potential and the inherent filtration at 60 kV were previously measured [4]; the scattered radiation conditions were verified to all reference radiations and they showed to comply with the ISO requirements.

2.5 Implementation of the reference radiation

Figure 10: Attenuation curve –N30 beam quality



The verification of the x-ray spectra was made by experimental measurements of the 1st and 2nd HVLs in the atenuation curve in term of aluminum only for the 30 kV beam quality. For all others series the cooper was used to establish the atenuation curve. It was posible to compare the beams implanted in CDTN and the reference beams specified by the ISO standard [1].

Figures 10 to 18 show the atenuation cuve for all series.Table 2 presents the comparison of parameters of the reference radiations. In all cases, the 1st and 2nd HVLs agreed within ± 5%.

Figure 11: Attenuation curve – N40 beam quality

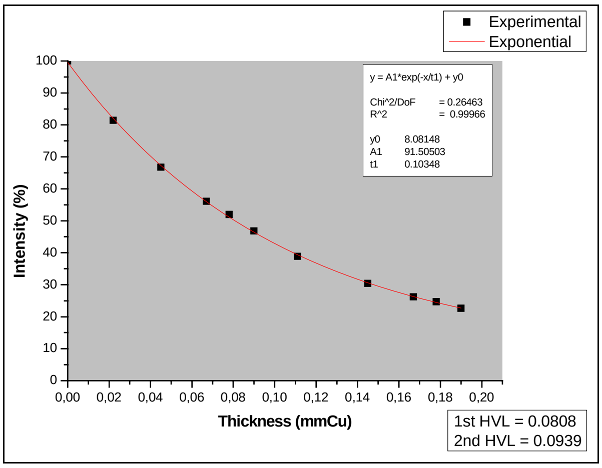


Figure 12: Attenuation curve – N60 beam quality

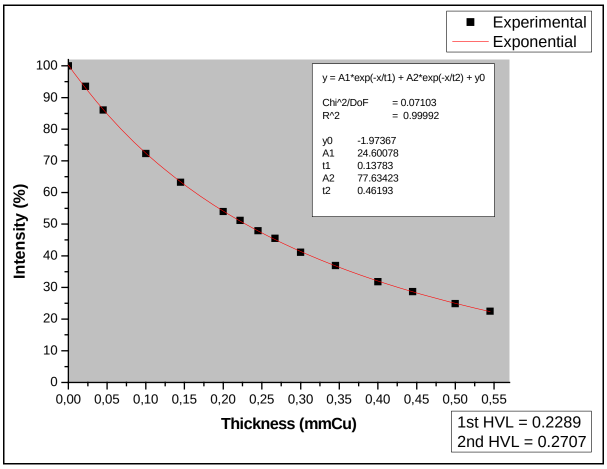


Figure 13: Attenuation curve – N80 beam quality

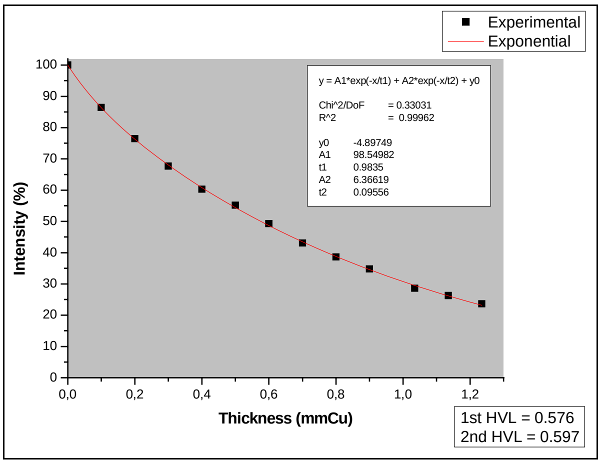


Figure 14: Attenuation curve –N100 beam quality

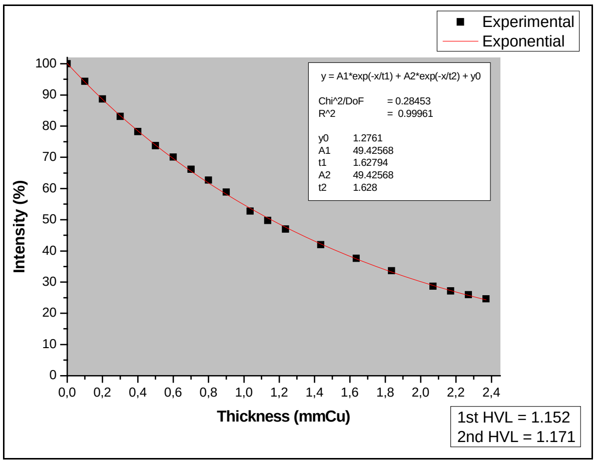


Figure 15: Attenuation curve–N120 beam quality

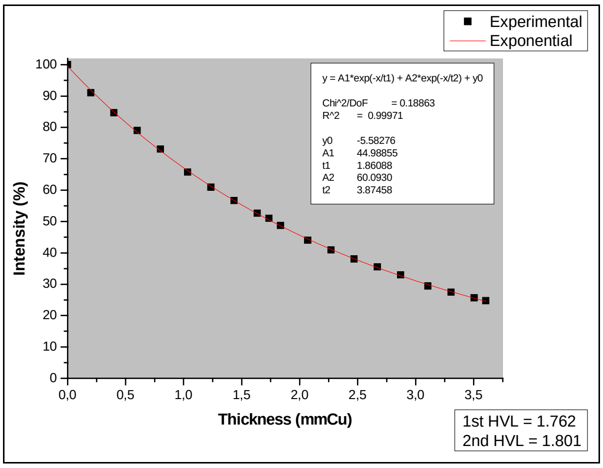


Figure 16: Attenuation curve– N150 beam quality

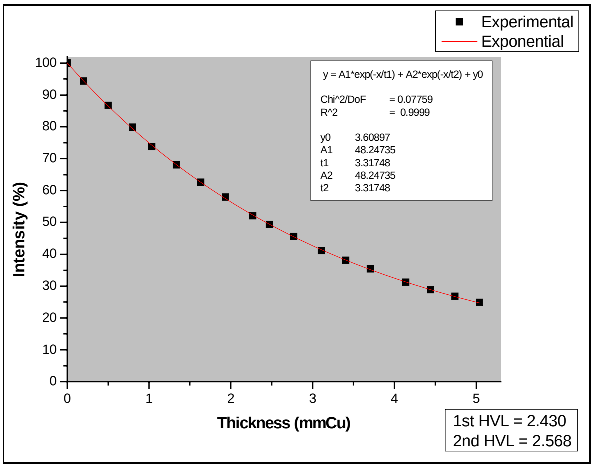


Figure 17: Attenuation curve–W200 beam quality

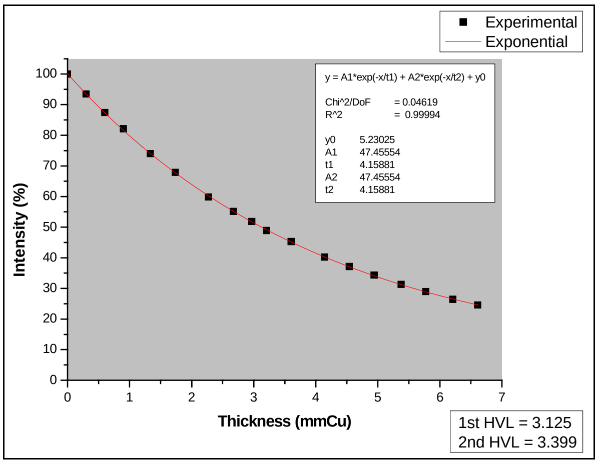


Figure 18: Attenuation curve–W250 beam quality

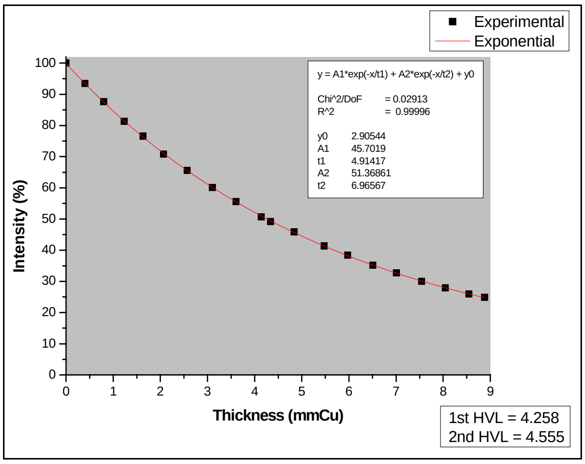


Table 2: Parameters comparison of the reference radiations implemented in CDTN and established by ISO

Reference Radiation	1st HVL (a)		2nd HVL (a)	
	ISO 4037-1	CDTN	ISO 4037-1	CDTN
N30	1,15	1,18	1,30	1,29
N40	0,084	0,081	0,091	0,094
N60	0,24	0,23	0,26	0,27
N80	0,58	0,58	0,62	0,60
N100	1,11	1,15	1,17	1,17
N120	1,71	1,76	1,77	1,80
N150	2,36	2,43	2,47	2,57
W200	3,08	3,13	3,31	3,40
W250	4,22	4,26	4,40	4,56

(a) values in mmCu, except for N30 in mmAl

3. Conclusion

The results confirmed the similarity between the radiation beam qualities implanted in CDTN and the specified by ISO 4037-1 standard; they certify their applicability for calibrating dosemeters and doserate meters, for determining their response as a function of photon energy, for carrying out performance tests of instruments used in dosimetry for industrial, medical, environmental or any other radiation protection purposes.

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