Establishing Standard X-ray Narrow-beam Radiation Qualities for CNESTEN Calibration Laboratory

T. ZIDOUZ[1,2*], M. ALIBRAHIMI[1], E. CHAKIR[1], A. ALLACH[2], A. DIDI[2], A. MOUHSSINE[2], A. TALBI[2]

[1] LPMS, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco
[2] National Centre for Nuclear Energy, Science and Technology, Rabat, Morocco
* E-mail : taibi.zidouz@uit.ac.ma

1. Objective

The narrow-beam series (N-series) radiation qualities are of great importance for the radiation protection aspects of diagnostic radiology. The purpose of this work is to develop the same reference X-Ray beams qualities as recommended in International Standardization Organization (ISO) 4037 narrow spectrum series (N-40, N-60, N-80, N-100, N-150 and N-200) at CNESTEN calibration laboratory.

2. Materials and methods

2.1. Determination of inherent filtration

The first step for X-ray beam establishment and following ISO 4037-1 is to determinate the inherent filtration of the X-Ray tube. The tube used in this work is a HOPEWELL X80-225kV, Model MXR-225-22 has a tungsten anode with a 20° target angle and an inherent filtration of 1 mm de beryllium with a range of high voltage applied from 10 to 225 kV.

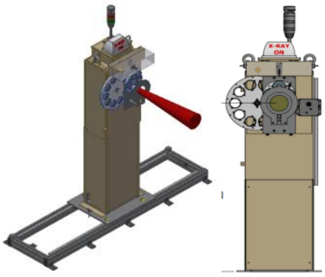


Figure 1 : X-Ray Generator

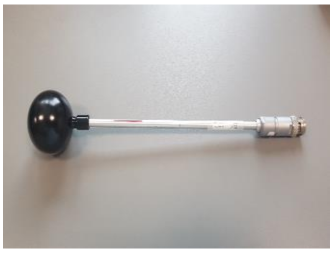


Figure 2 : Ionisation chamber used

For the filter attenuators used for inherent filtration determination are the sheets of aluminum with different thicknesses positioned on filter support between the generator and the detector (ionization chamber: Figure 2) with purity 99,9 %. Following the ISO 4037-1-2019 standard the inherent filtration is measured using the equipment described above with a voltage 60 kV without any additional filtration, bay tracing the attenuation curve in aluminum.

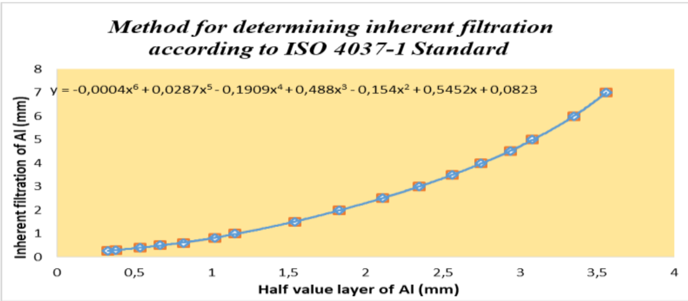


Figure 3: Measured attenuation curve in aluminum for 60 kV

The beams qualities depends on the total filtration used during irradiation, the total filtration includes both inherent and additional filtration. The inherent filtration is usually measured using the ionization chamber placed at 1 m from the tube center.

Table 1: Inherent filtration by ISO 4037-1-2019

First HVL Mm of Al (60kV)	Inherent filtration (mm)
0,33	0,25
0,38	0,3
0,54	0,4
0,67	0,5
0,82	0,6
1,02	0,8
1,15	1
1,54	1,5
1,82	2
2,11	2,5
2,35	3
2,56	3,5
2,75	4
2,94	4,5
3,08	5
3,35	6

The value of HVL obtained is 0,431 between 0,38 and 0,54 mm of aluminum, indeed the value of inherent filtration is determined by using the database of ISO 4037 standard (Figure 3)

The inherent filtration of our generator can be estimated by two methods:

- ✓ Extrapolation: Statistical method beamed at understanding the unknown data from the known data: 0,33 mm
- ✓ Curves: From the equation of the curve by ISO 4037 standard: 0,37 mm

By increase the selected value is 0,37 mm of aluminum

2.2. Narrow spectrum series validation

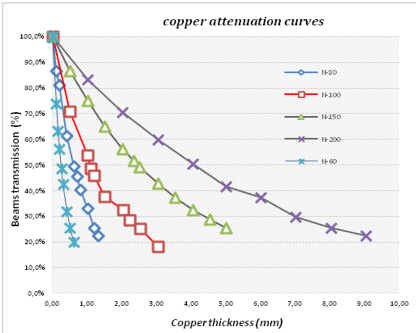
Table 2: Ionization chamber characteristics

Nominal sensitive volume	27.9 cm3
Direction of incidence	Radial
Nominal response	900 nC/Gy
Energy response	≤ ± 5 % (48 keV ... 60Co)
Directional response in air	≤ ± 0.5 % for rotation around the chamber axis and ≤ ± 3 % for tilting of the axis up to ± 45°

Figure 3: Experimental setup for half-value layer measurement

The collected charge was measured for each radiation quality and each absorber thickness 5 times. Each measurement was performed for the duration of 60 s. The results of copper attenuation curves for each radiation quality (N-60 to N-200) are shown in figure 4.

3. Results and discussions



The results of the curves make it possible to deduce the thicknesses which correspond to the transmission rate of 50 and 25% (1st and 2nd HVL).

$$C = C_0 . e^{-\mu x}$$

C : Initial beam (Charg)
C_0 : Transmed beam
μ : Attenuation factor
x : filters thinckness

$$\ln(C/C_0) = -\mu x$$

Figure 4 :Measured attenuation curves for narrow spectrum series at CNESTEN laboratory.

At a thickness equivalent to the 1st HVL, the counting is reduced to half, which makes it possible to write:

$$1^{st}\ HVL = \ln 2/\mu$$

Table 2: HVL measurement results (Narrow spectrum series developed)

Beam Quality	Added filtration(mm)				1st HVL Standard (mm)	1st HVL Measured (mm)	Deviation (µm)
	Pb	Sn	Cu	Al			
N-60	/	/	0,6	4,0	0,234	0,246 ±0,007	12
N-80	/	/	2,0	4,0	0,578	0,609 ± 0,03	31
N-100	/	/	5,0	4,0	1,09	1,07 ± 0,06	18
N-150	/	2,5	/	4,0	2,30	2,441 ± 0,13	196
N-200	1,0	3,0	2,0	4,0	3,92	4,12 ± 0,30	197

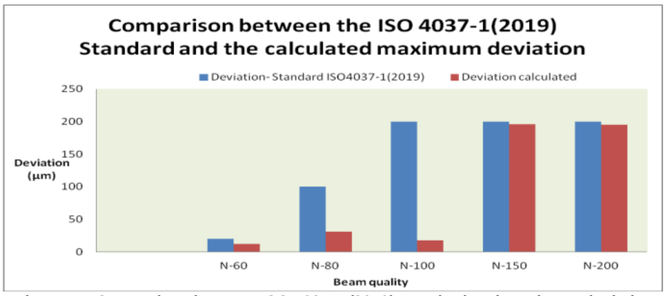


Figure 5 : Comparison between ISO 4037-1 (2019) standard and maximum deviation calculated

4. Conclusions

This work is a part of setting up an X-ray calibration platform for diagnostic radiology radiation protection, the measured HVLs for each developed X-ray quality are in good agreement with the reference values of ISO 4037-1(2019) and IAEA. Indeed, all beams quality developed in laboratory are compliant for calibration.

The precision of the conformity of the beams decreases with increasing beam energy it can be seen that the maximum deviation on HVL (197 µm) for N-200, indeed, it is necessary to optimize the quality of the beam to obtain more precision bay using simulation method.

References:

[1] Safety Reports Series No.16 «« Calibration of radiation protection monitoring instruments » International Atomic Energy Agency, Vienna, 2000.
[2] Safety Series 115 International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources. IAEA, Vienna, 1996.
[3] X and gamma reference radiation for calib. Part 1, ISO 4037-1, 2019
[4] Shimizu, S., Sawahata, T., Kajimoto, Y., Shikaze, Y., Yoshihara, Y. and Tatebe, Y. Establishment of X-ray refe. Japan Atomic Energy Agency. 2011-008.