Estimation of X-ray Beam Qualities for Performance Test on Personal Dosimetry Systems

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1. Introduction

Nuclear utilities should be taken performance test on personnel dosimetry systems to assure the quality of dosimetry performance. According to the Enforcement Regulations for the Nuclear Safety Act, test is carried out in the eight test categories of ionizing radiation, such as low and high energy photons, beta particles and neutrons. And several NIST beam codes are used as low energy photon in the test categories[1]. To provide the reference radiation field for the performance test regarding low energy photon categories, the X-ray generators have been installed in the laboratory of KHNP CRI. X-ray beam qualities are affected by tube voltage/current, collimator, filtrations and the objects in the facility. Therefore, in this work, to ensure that the beam codes made by KHNP-CRI are consistent with the regulations, beam qualities were estimated

2. Method

The X-ray beam qualities could be evaluated by the measurements of the 1st half value layer and the homogeneity coefficient, spectral measurement and a computer simulation. In this work, the measurements of 1st HVL and homogeneity coefficient were performed.

2.1 Characteristics of NIST Beam code

The characteristics of X-ray beam qualities are listed in Table 1. According to the reference, the specified half value layer and homogeneity coefficient should be duplicated to within 5% and 10%, respectively, if necessary by adjusting the tube potential [1].

Table 1. Characteristics of NIST photon beam techniques

No	added filter	Half-value Layer[1)]	Homogeneity Coefficient[2)]	$\bar{E}$ (keV)
M30	0.5 mm Al	0.36 mm Al	65 (Al)	20
M60	1.56 mm Al	1.68 mm Al	68 (Al)	34
M100	5 mm Al	0.2 mm Cu[3)]	55 (Cu)[3)]	51
M150	5 mm Al +0.25 mm Cu	0.67 mm Cu[3)]	62 (Cu)[3)]	70
H150	4 mm Al + 4 mm Cu +1.51 mm Sn	2.5 mm Cu[3)]	95 (Cu)[3)]	117

1) Half-value layer : The thickness of material that reduces the air kerma of a radiation beam by one half
2) Homogeneity coefficient: The ratio of the first and second half-value layers times 100
3) Values are equivalent to those of Al

2.2 Estimation of 1st HVL and Homogeneity coefficient

The X-ray generator, used in this experiment, consists of 160 kVp high voltage generator and tube with tungsten target material. The inherent filtration inside the tube is 0.8 mm Be, which has been validated in the preliminary study[2]. The X-ray generator was set as 2 mA, the tube voltage and added filter were controlled for each beam code given in the reference. A calibrated spherical ionization chamber (model A3, Exradine) was used to measure the output of the X-ray generator. The chamber was positioned in the center of the 18 cm × 25 cm field at a distance of 2 m from the source to obtain the desirable beam size considering the amount of dosimeter tested. Measurements were repeated by adjusting the filter thickness until approached the expected 1st HVL and 2nd HVL. 1st HVL and 2nd HVL were calculated as a function of filter thickness and current measured by ion chamber. Finally, homogeneity coefficients for each beam qualities were determined.

Fig. 1. X-ray generator in KHNP CRI.

3. Results and Discussion

The results of comparison between X-ray beam qualities of KHNP and those of NIST are listed in Table 2. Except for M30 beam code, the relative difference of 1st HVL against NIST are ranged from -1.5% to 3.6% and those of homogeneity coefficients are ranged from -2.8% to 1.2%, which is satisfied with the acceptance criteria.

Table 2. Comparison between X-ray beam qualities of KHNP and those of NIST[1]

Beam code	Half-value Layer(KHNP)	Difference (%)	Homogeneity Coefficient (KHNP)	Difference (%)
M30	0.42 mm Al[1)]	17.0	-	-
M60	1.741 mm Al	3.6	68.8 (Al)	1.2
M100	0.197 mm Cu	-1.5	55.5 (Cu)	1.0
M150	0.666 mm Cu	-0.6	60.2 (Cu)	-2.8
H150	2.503 mm Cu	0.1	92.4 (Cu)	-2.7

In case of M30, beam qualities given in the reference was defined at a distance of 0.5 m from the generator to the chamber. However, in this experiment conditions, the increase of the distance hardens X-ray spectrum which results in out of acceptance criteria of 1st HVL. To compensate for those hardening effect, added filter thickness was adjusted from 0.5 mm Al to 0.384 mm Al. As a result, the relative difference of 1st HVL against NIST is 0.2% and that of homogeneity coefficient is 0.5% as shown in Table 3.

Table 3. The results of corrected M30 beam qualities of KHNP

Beam code	Half-value Layer(KHNP)	Difference (%)	Homogeneity Coefficient (KHNP)	Difference (%)
M30	0.361 mm Al[1)]	0.2	64.3 (Al)	0.5

4. Conclusion

1st HVL and homogeneity coefficient for each beam qualities were determined. The results are within the acceptance criteria. The X-ray generator of KHNP CRI was proved that it could provide the reference radiation field. However, further study on estimation by other method such as MCNP simulation and comparison of measurement results are necessary to obtain comprehensive information on X-ray beam qualities.

REFERENCES

[1] Ministry of Science, ICT and Future Planning, “Enforcement Regulations for the Nuclear Safety Act”(2016).

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