NEUTRON AND GAMMA MEASUREMENT WITH WATER PHANTOM FOR BORON NEUTRON CAPTURE THERAPY (BNCT) REACTOR TRIGA PUSPATI

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ABSTRACT

Thermal neutron beam from thermal column was selected for a Boron Neutron Capture Therapy (BNCT) system utilising the Malaysian TRIGA MARK II reactor. Determination of shielding materials for fast and epithermal neutron was conducted. The materials selected were polyethylene, paraffin and water. For gamma-ray shielding, lead was used. The objective of this paper is to present the simulation and verification of an optimal design of BNCT collimation at a beam line viewing the thermal column. A collimator was made from polyethylene pipe with 8 cm of diameter filled with paraffin. An experiment with water phantom was conducted to simulate the human biological conditions. Gamma dose rate was 30.92 mSvhr^{-1} at 0.0 cm depth and increasing up to 174.56 mSvhr^{-1} at 16.5 cm depth. Neutron flux was 5.00E+06 ncm^{-2}s at 0.0 cm depth and 3.00E+07 ncm^{-2}s at the depth of 0.8 cm and then decreased to 1.00E+06 ncm^{-2}s at the depth of 8.1 cm.

ABSTRAK

Alur neutron terma dari turus terma telah dipilih untuk sistem Boron Neutron Capture Therapy (BNCT) menggunakan Malaysia TRIGA MARK II reaktor. Penentuan bahan perisaian untuk neutron epiterma dan cepat telah dibuat. Bahan yang dipilih adalah polietilena, parafin dan air. Untuk perisaian sinar gama, bahan plumbum telah digunakan. Objektif kertas ini adalah untuk bentang simulasi dan pengesahan satu reka bentuk optimum pengkolimatan BNCT di alur laluan turus terma. Satu pengkolimat telah dibuat dari paip polietilena dengan garis pusat 8 cm diisi dengan parafin. Satu ujian dengan fantom air dijalankan untuk mensimulasikan keadaan biologi manusia. Kadar dos gama ialah 30.92 mSvhr-1 di 0.0 cm kedalaman dan menambahkan sehingga 174.56 mSvhr-1 di 16.5 cm kedalaman. Fluks neutron *ialah 5.00E+06 ncm-2s di 0.0 cm kedalaman dan 3.00E+07 ncm-2s di kedalaman 0.8 cm dan kemudian mengurangkan kepada 1.00E+06 ncm-2s pada kedalaman 8.1 cm.*

Keywords: Boron Neutron Capture Therapy, TRIGA, fast and epithermal, neutron

INTRODUCTION

A very promising cancer treatment called Boron Neutron Capture Therapy (BNCT) is selected to be studied in this research. BNCT is a radiation therapy for the treatment of cancers like melanoma and glioblastoma multiforme (Yanagie H. et al., 2010). BNCT is done by firstly, a stable isotope of boron-10 (^{10}B) is administered to the patient via a carrier drug and then the patient is irradiated with a neutron beam. ^{10}B will then undergo the capture reaction $^{10}B(n, \alpha)^{7}Li$ where ^{10}B capture cross section for thermal neutrons is 3840 barn (Valda A. *et al.*, 2005,). This is the scientific fact on why thermal neutron is used in BNCT.

MATERIALS AND METHODS

This experiment was conducted after the TRIGA MARK II reactor was not in operation for two days. Firstly, a crane was used to take out a concrete plug in the Thermal Column door. The concrete plug was then replaced with collimator. After that, a shielding box was placed covering the hole. Water Phantom contains TLD-600 and TLD-700 detectors were placed inside shielding box. The reactor was operated at 100 kW of power for 15 minutes. After that, all TLDs detectors were replaced with new TLD detectors. The reactor was then operated at 100 kW of power for another 15 minutes. After 15 minutes, Water Phantom was taken out and all TLD detectors were red with TLD reader (Martins M. M. *et al.,* 2010; Liu H. M. *et al.,* 2011; Loiseau P. *et al.,* 2013).

The dimension of water phantom is 20.0 cm x 20.0 cm x 20.0 cm. It consisted of 0.5 cm thick Perspex walls and filled with distilled water. Figure 1 shows the dimension of the water phantom. Figure 2 shows the photo of the Water Phantom used in this study.

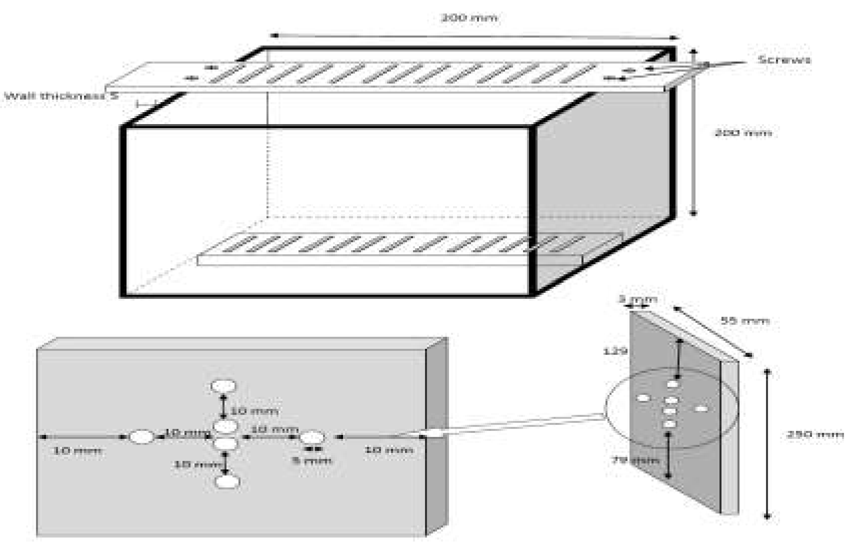

Figure 1. Geometry of the Water Phantom

Figure 2. Water Phantom used in this research

RESULTS AND DISCUSSION

Table 1 gives the dose rate of neutron and gamma from the first measurement. Gamma dose rate was 30.92 mSvhr^{-1} at 0.0 cm depth and increasing up to 174.56 mSvhr^{-1} or 0.17 Svhr^{-1} at 16.5 cm depth. Gamma dose rate at the depth of 0.0 cm when calculated for 1 MW of reactor power was 309.20 mSvhr^{-1} or 0.31 Svhr^{-1}.

Table 1. Neutron and gamma dose rate from the first measurement (1 MW of reactor power)

Position cm	n+γ mSv/hr	γ mSv/hr	n mSv/hr
0.0	210.66	30.92	179.73
0.8	948.06	28.74	919.32
1.6	330.61	41.97	288.64
2.5	324.09	23.63	300.45
3.3	264.61	37.87	226.74
4.2	218.30	29.35	188.94
5.6	173.38	99.33	74.03
8.1	175.30	133.52	41.78
12.2	75.62	117.31	-41.69
16.5	36.53	174.56	-138.02

Table 2 gives the flux of neutron and gamma. Neutron flux was 5.00E+06 ncm^{-2}s at 0.0 cm depth and 3.00E+07 ncm^{-2}s at the depth of 0.8 cm and then decreased to 1.00E+06 ncm^{-2}s at the depth of 8.1 cm. Neutron flux at 0.0 cm calculated for 1 MW of reactor power was 5.00E+07 ncm^{-2}s. Neutron flux at the depth of 0.8 cm calculated for 1 MW of reactor power was 3.00E+08 ncm^{-2}s. This was the highest flux measured outside the Thermal Column. With a few modifications, the standard of neutron flux for BNCT research can be achieved.

Table 3 gives the dose rate for neutron and gamma from the second measurement. Gamma dose rate was 46.21 mSvhr^{-1} at 0.0 cm depth then increased in fluctuate move up to 175.84 mSvhr^{-1} or 0.17 Svhr^{-1}

at the depth of 16.5 cm. Gamma dose rate at 0.0 cm depth calculated for 1 MW of reactor power was 462.10 $mSvhr^{-1}$. This was almost equal to gamma dose rate measured in the first experiment. This proved that TLD detector is very reliable and accurate.

Table 2. Neutron and gamma flux from the first measurement (1 MW of reactor power)

Position cm	n+γ $cm^{-2}s$	γ $cm^{-2}s$	n $cm^{-2}s$
0.0	6.00E+06	9.00E+05	5.00E+06
0.8	3.00E+07	9.00E+05	3.00E+07
1.6	1.00E+07	1.00E+06	9.00E+06
2.5	1.00E+07	7.00E+05	9.00E+06
3.3	8.00E+06	1.00E+06	7.00E+06
4.2	7.00E+06	9.00E+05	6.00E+06
5.6	5.00E+06	3.00E+06	2.00E+06
8.1	5.00E+06	4.00E+06	1.00E+06
12.2	2.00E+06	4.00E+06	-1.00E+06
16.5	1.00E+06	5.00E+06	-4.00E+06

Table 3. Neutron and gamma dose rate from the second experiment (1 MW of reactor power)

Position cm	n+γ mSv/hr	γ mSv/hr	n mSv/hr
0.0	429.44	46.21	383.23
0.8	657.92	70.46	587.46
1.6	209.70	51.84	157.86
2.5	1446.00	87.07	1358.88
3.3	161.34	89.28	72.06
4.2	106.37	78.21	28.16
5.6	85.60	140.26	-54.66
8.1	53.89	151.55	-97.66
12.2	54.59	128.22	-73.63
16.5	56.80	175.84	-119.04

Table 4 gives the flux of neutron and gamma from the second measurement. Neutron flux was 1.00E+07 $ncm^{-2}s$ at 0.0 cm depth then increased to 2.00E+07 $ncm^{-2}s$ at 0.8 cm depth. After that, it was decreased to 5.00E+06 $ncm^{-2}s$ at 1.6 cm depth then increased very rapidly to 4.00E+07 $ncm^{-2}s$ at the depth of 2.5 cm. After that, it was decreased very rapidly to 2.00E+06 $ncm^{-2}s$ at 3.3 cm depth and then 8.60E+05 $ncm^{-2}s$ at the depth of 4.2 cm. After that, all neutron fluxes obtained were negative in value. Neutron flux at 0.0 cm depth calculated for 1 MW of reactor power was 1.00E+08 $ncm^{-2}s$. This was much higher than the first experiment which is 5.00E+07 $ncm^{-2}s$. It was believed that the few addition of neutron flux was coming from the first measurement because the second measurement was done immediately after the first measurement. Neutron from the first measurement was still around when the second measurement was conducted. Neutron flux at 0.8 cm depth calculated for 1 MW of reactor power was 2.00E+08 $ncm^{-2}s$. This is a little bit lower than the first measurement.

Table 4: Neutron and gamma flux from the second experiment (1 MW of reactor power)

Position cm	n+γ $cm^{-2}s$	γ $cm^{-2}s$	n $cm^{-2}s$
0.0	1E+07	1E+06	1E+07
0.8	2E+07	2E+06	2E+07
1.6	6E+06	2E+06	5E+06
2.5	4E+07	3E+06	4E+07
3.3	5E+06	3E+06	2E+06
4.2	3E+06	2E+06	860444
5.6	3E+06	4E+06	-2E+06
8.1	2E+06	5E+06	-3E+06
12.2	2E+06	4E+06	-2E+06
16.5	2E+06	5E+06	-4E+06

CONCLUSIONS

For 1 MW power reactor, the neutron flux measured outside the thermal column using TLD at the depth of 0.8 cm was the highest flux point. With a few modifications of collimation design and materials used for the collimation, the standard flux for BNCT can be achieved.

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