Indonesian Journal of Physics and Nuclear Applications
Volume 4, Number 2, June 2019, p. 71-77
e-ISSN 2550-0570, © FSM UKSW Publication

Commissioning Testing for in Vitro-in Vivo Facility at Radial Piercing Beam-Port of The Kartini Research Reactor for Boron Neutron Capture Cancer Therapy

Widarto[1*], Argo Satrio Wicaksono[1]
[1]*Centre for Accelerator Science and Technology, National Nuclear Energy Agency, Jalan Babarsari kotak pos 6101 ykbb, Caturtunggal, Depok, Kabupaten Sleman*

ARTICLE INFO

Article history:

Received: 14 August 2018
Received in revised form: 01 June 2019
Accepted: 30 June 2019

Keywords:

Commissioning, in vitro/ in vivo
Radiation exposure
Shielding
Radiation safety protection system

ABSTRACT

The purpose of the commissioning for in vitro in vivo test facility is to verify that the the facility has fulfilled the safety standards requirements, especially those related to radiation exposure. The standard requirement for environmental radiation exposure by IAEA is 20 mSv/hour. Otherwise results of the premilinary commissioning testing at the distance of 3 meters from in vitro in vivo test facility at radial piercing beam-port for 100 kW power level of the Kartini research reactor is for radiation exposure being around 9 mSv/hour. This means that the radiation exposure is less than the IAEA safety standard requirement of 20 mSv/hour. This is also less than the requirement of The Indonesian Regulatory Body limitation which is restricted to 15 mSv/hour. It can be concluded that when the reactor is operated at 100 kW power level for utilization by experiments in vitro/in vivo test, the facility is safe. However in order to be more safe at the restricted area, implementation of total quality management system should be completed with standard operating procedure (SOP) conducted with distance, time and shielding of radiation exposure for radiation safety protection system in utilization of the in vitro in vivo test facilities. When the SOP of the utilization of the in vitro in vivo test facility is implemented, the procedure is safer.
.

1. INTRODUCTION

When utilizing nuclear radiation attention must be paid to safety, especially safety for radiation workers, society and the environment. Since 2014, Indonesia has been developing utilization of nuclear radiation for cancer disease, by using Boron Neutron Capture Therapy (BNCT). Cancer is a disease that belongs to a group of non-communicable diseases (NCD). There are several standard methods of cancer therapy including surgery, chemotherapy, and radiotherapy. Each of these therapeutic methods have limitations and drawbacks that may cause side effects in treating cancer, Thus treating cancer involves more than the methods of treatment. Combination drug therapies aim to suppress the side effects and increase the effectiveness of therapy in order to obtain maximum results.

BNCT method utilizes non-radioactive nuclide 10B to capture neutrons through the reaction 10B(n, α)7Li. Results of the reaction have the characteristics of high Linear Energy Transfer (LET) (for α particles approximately close to 150 keVμm-1 and for 7Li approach 175 keVμm-1). Coverage of these particles is approximately 4.5 μm to 10 μm, so that the energy deposited is limited to a single cell (cell diameter of 18 ± 2 μm).

---

[*] Corresponding author. Tel.: +62 813 9250 5652; E-mail address: widarto_widarto@yahoo.com

To support the BNCT facility, a neutron source is needed with certain criteria such as a nuclear reactor. The TRIGA MARK-II, Kartini Research Reactor, which is located in Yogyakarta Special Province, is one of the three reactors in Indonesia that have been used for facility BNCT research. The radial piercing beam port of Kartini Research Reactor (KRR) is a radiation channel perpendicular through to the reactor core, which is mounted to penetrate the shield of the reactor tank. The number of channels in KRR is 4 pieces used to provide neutron beam and gamma radiation. Three channels are connected in radial and the other channel in tangentially. The two radial channels mounted to penetrate the shield's reactor until outside the reactor core is called the radial beam port. The channel which goes through until the reactor core is called the radial piercing beam port. The following figure is the cross section of the radiation beam line channel drawings presented in Figure 1. Horizontal cross section of the Kartini research reactor.

For the radiation shield design in vitro BNCT test facility at the beamport penetrating form of the reactor core, a radial arrangement of paraffin boxes was constructed by placing hundreds of paraffin boxes in front of the radial piercing beam port. The function of these boxes of paraffin is for radiation shielding in vitro/in vivo test facility as utilization of radial piercing beamport for the Kartini research, for the safety of the environment and human workers.

Components of biological neutron radiation shielding design for in vitro/in vivo test facility of BNCT method on radial piercing beam port of the Kartini Research Reactor were simulated using MCNPX code. According to the material available in the PSTA BATAN an array of paraffin boxes was used as a radiation shield for radiation. The total number of paraffin boxes required was 150 pieces. Gamma radiation shielding was arranged in the form of lead after boxes of paraffin. The design includes 5 arrangements of lead that are located on the left side, right side, top side, bottom side and rear side. On the left and right sides the lead is arranged up to a thickness of 13 cm. On the upper side it is arranged up to a thickness of 16 cm. On the back side it reaches a thickness of 15 cm. On the bottom 10 cm is enough because it does not deal directly with humans.

2. MATERIALS AND METHODS

The purpose of commissioning an installation is to make sure that the installation will operate in accordance with the planning and safety. The Kartini research reactor as a neutron source has 4 beamports. One of them is the radial piercing beamport, which is perpendicular directly to the reactor core and will be used for the in vitro/in vivo test facility. Figure 1. Horizontal cross section of the Kartini research reactor follows. The neutron flux in this facility is higher than others.

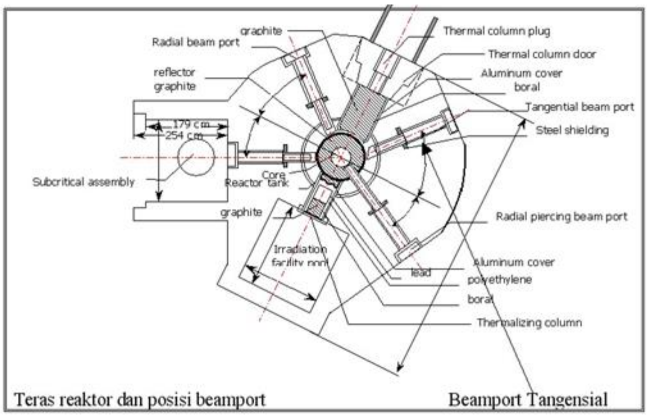

Fig 1. Horizontal cross section of the Kartini research reactor.

Radiation shielding means that radiation will be less when radiation passes through shielding material. Figure 2. shows the basic principle of the neutron absorption mechanism to the material mentioned. When neutron intensity I_0 passed on specific material with a thickness of x (cm), the absorbed neutron intensity will be I_x, where :

$$I_x = I_0 e^{-\mu x} \qquad (1)$$

I_x = radiation intensity after pass paraffin shielding

I_0 = radiation intensity before pass paraffin shielding

μ = coefficient absorption

x = material thickness

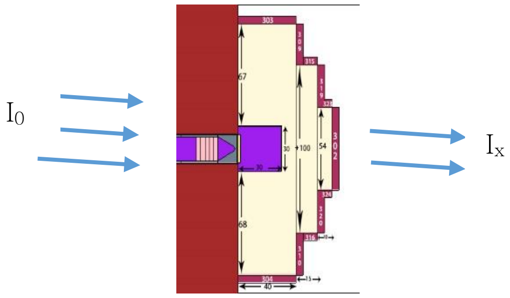

Fig 2. Neutron absorption mechanism

Simulation of MCNPX for conceptual design shielding of radial piercing beamport as a result of the radiation dose rate that came out after passing through the radiation shield is presented in Figure 3. These results are in accordance with the safety standards recommended by BAPETEN, which is 20 mSv.year^{-1}, equivalent to 2.78 nSv.s^{-1}.

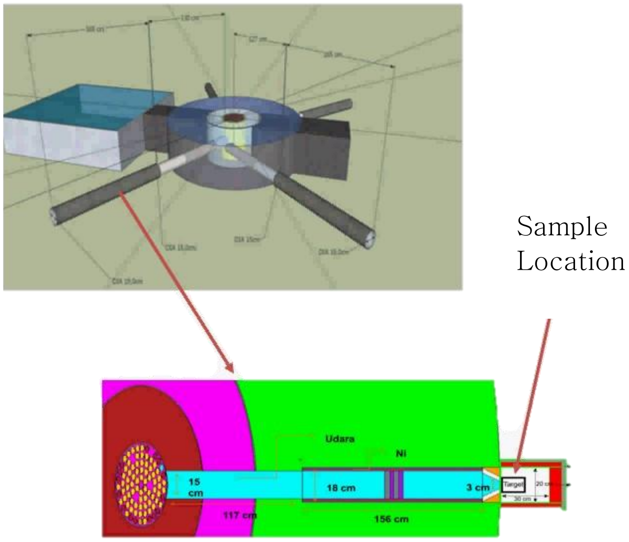

Fig 3. Conceptual design of shielding paraffin for BNCT method

Based on this conceptual design, the basic design to implement according to the MCNPX simulation is as follows in Figure 4. Basic design of shielding paraffin for in vivo/in vitro test facility of BNCT method, which will be installed at the front of the radial piercing beamport.

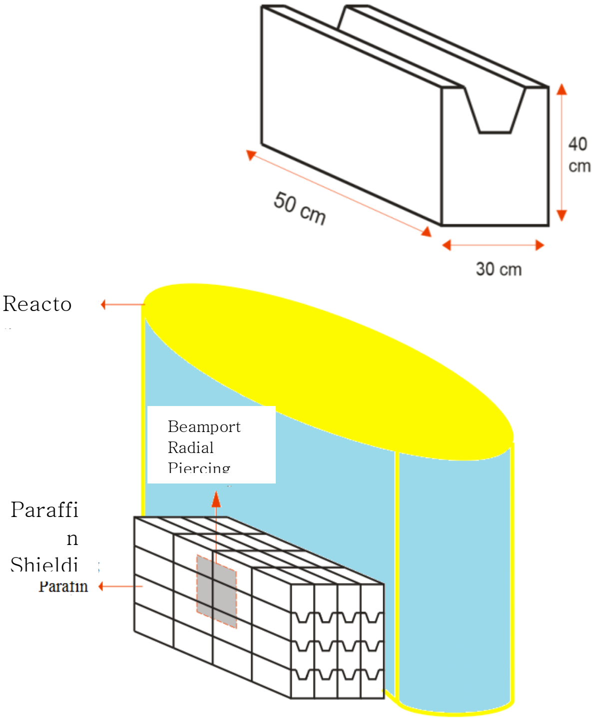

Figure 4. engineering design of shielding paraffin for BNCT method.

Fig 5. The actual radial piercing beamport neutron source of Kartini Reactor.

Figure 5. shows the actual radial piercing beamport, which is the neutron source from the Kartini reactor core to be used for in vitro/ in vivo test facility based on BNCT method. Blocks of paraffin placed in front of the radial piercing beamport hole as a shielding of radiation and the construction of the shielding paraffin can be seen in Figure 6.

Fig 6. Separate shielding boxes of paraffin

Since the structure of the paraffin shielding boxes was deformed due to the environment (room) temperature, they were placed inside cubical aluminum boxes (2 m x 2 m x 2 m) to prevent deformation. The process of revitalizing the deformed paraffin shielding using cubicle aluminum is seen in Figure 7 and Figure 8.

The reconstruction of the shielding paraffin used a box consisting of 150 pieces as shown in Figure 9. The structure of the shielding design consisted of 150 boxes of paraffin shielding (50 cm x 40 cm x 30 cm); each box had given an aluminum casing and was filled with paraffin shielding in order to prevent deformation.

Fig 7. Revitalization of paraffin shielding placed in cubical (2 x 2 x 2)m^3 in size.

Fig 8. Final Revitalization of cubical paraffin shielding (2 x 2 x 2)m^3

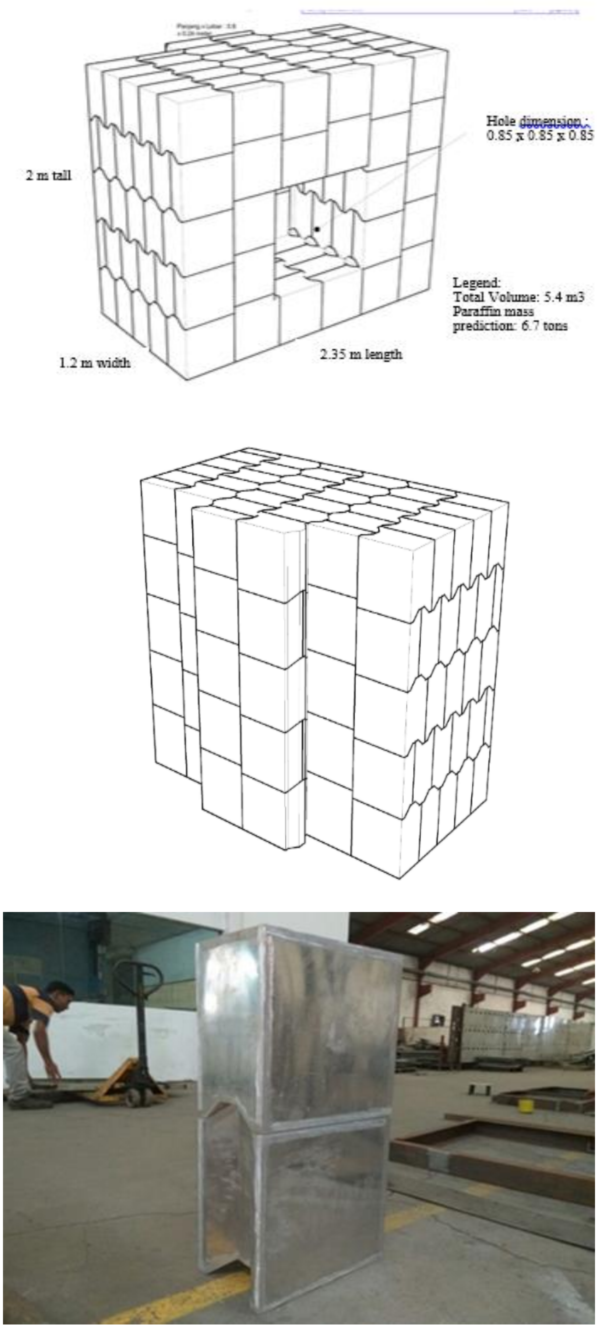

Fig 9a. Shielding construction of paraffin block

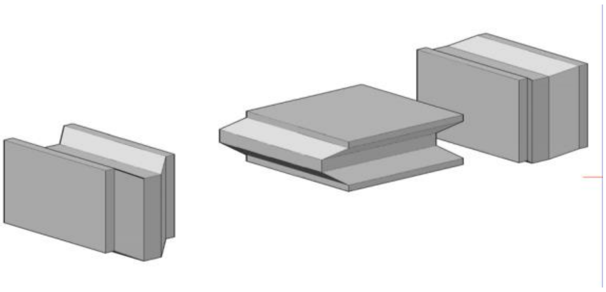

Fig 9b. Casing aluminum box for shielding

Fig 9. Manufacturing of aluminum shielding casing box

3. RESULTS AND DISCUSSION

According to the simulation using MCNPX code for preparing the shielding of in vitro/in vivo test facility with BNCT method paraffin material was used. The shielding structure was 150 boxes of paraffin covered by aluminum casing of 3 mm thick. As long as the project of BNCT is concerned with preparing for in vivo/in vitro test facility, the nuclear radiation shielding should be made of paraffin material. After the shielding is installed in front of the radial piercing beamport, then the reactor can be operated for preliminary commissioning purposes of the in vitro/in vivo test facility. The results of the measurement of radiation exposure for a distance of 3 meters at various thermal power from 10 kW, 20 kW up to 100 kW can be seen in Table 1.

Table 1. Radiation Exposure Measurement at the in vivo/in vitro Test Facility

Power (kW)	Distance (Meter)	Neutron Radiation exposure (μSv/jam)	Gamma Radiation exposure (mR/jam)
10	1,5	2,1	1,6
20	2	1,3	5
30	3	2,7	2,6
50	3	4,2	4,7
70	3	5,5	6
100	3	9,0	9,6

Radiation Protection System for Safety Aspect.

The basic concept of a radiation protection system is to ensure the nuclear radiation is controlled and is safe for the radiation worker, other humans and the environment. Regulations for nuclear radiation aspects and control systems are created by regulatory states, i.e Indonesian Regulatory Body called The Nuclear Energy Control Agency (BAPETEN). The BAPETEN, as a nuclear radiation regulatory body, produces all safety-related regulations for utilization of nuclear radiation.

A statement by The International Commission on Radiological Protection (ICRP) declared that the philosophy of radiation safety must be based on the principles of justification, optimization, and limitation.

Justification on every utilization of nuclear radiation has to be based on the advantage aspect. Activity on utilization which is related to potential nuclear radiation exposure should fulfil all safety requirements and the advantages must be greater than the disadvantages for individuals, society, all human life, as well as the environment.

The principle of optimization on utilization of nuclear radiation means that every safety aspect of ***As Low As Reasonably Achievable (ALARA)*** should be fulfilled. It means that when nuclear radiation energy is used, it should be planned and operated by a management control system in order to keep radiation exposure as low as possible in the restricted area.

The principle for limitation of nuclear radiation exposure is achieved by maintaining a dose limit equivalent received by individual radiation workers, society and also the environment. The purpose of the effective dose limit for radiation workers is to prevent deterministic and minimize stochastic effect. According to The National Nuclear Control Board (BAPETEN), the effective dose limit requirement for radiation workers is 50 mSv (5000 mrem) per year; this is equivalent with a dose rate of 2.5 mrem per hour.

The measurements in front of the shielding with a distance of 3 meters when the preliminary commissioning was held at the facility can be seen in Table 1. The original facility shielding will be replaced by the new design in which the paraffin shielding is encased in aluminum as shown in Figure 9. According to the measurement result, it can be concluded that when the facility operates for 100 kW thermal power, the in vitro/in vivo test facility will be safe. The requirements of the operational policy must also be fulfilled including the standard operating procedures and the radiation safety analysis principle, i.e. attention to distance measurements from sources, thickness of shielding and adequate delay time, so that radiation workers, the society, and the environment will be safe.

4. CONCLUSION AND REMARKS

The results of the preliminary commissioning for the test facility to measure nuclear radiation exposure for a reactor operated at 100 kW thermal power with a distance of 3 meters from the shielding test facility for neutron radiation exposure is 9.0 μSv/hour and for gamma radiation exposure is 9.6 mR/hour. It can be concluded that utilization of in vitro/ in vivo test facility at the piercing radial beamport of Kartini research reactor is safe.

However the requirements of operational policy should also be fulfilled, such as standard operating procedures and principles of radiation safety such as attention to distance measurements from sources, thickness of shielding and adequate delay time. Following these procedures will ensure in the safety of the radiation workers, the society, and the environment.

REFERENCES

Accelerator technology and SPECT developments for BNCT, X Latin American Symposium on Nuclear Physics and Applications (X LASNPA), December 1-6 2013, Montovideo, Uruguay

Bünyamin Aygün, and Gökhan Budak. A new neutron absorber material: Oil loaded paraffin wax. *Faculty of Science, Department of Physics, Atatürk University.*Nuclear Science and Technology, 2012

Edi Sugianto, ST.2016. *Standard Operational Proceedure Dismantling Biological Shielding Sistem Eksperimental Set Up Uji In Vitro Invivo Metode Bnct Pada Beamport Tembus Radial Reaktor Kartini*. PSTA-BATAN. Yogyakarta

Edi Sugianto,ST.2016. *Standar Operasional Prosedur Pemasangan (Set Up) Shielding Proteksi Radiasi*. PSTA_BATAN. Yogyakarta

Filosofi Proteksi Radiasi, diakses dari http://www.batan.go.id/pusdiklat/elearning/proteksiradiasi/pengenalan_radiasi/2-4.htm, 29 juli 2016

Martinus I Made Adrian Dwiputra. 2015. *Pemodelan Perisai Radiasi Fasilitas Boron Neutron Capture Therapy Dengan Sumber Neutron Kolom Termal Reaktor Kartini Menggunakan Simulator Monte Carlo N Particle Extended.* Fakultas Teknik. Universitah Gadjah Mada.Yogyakarta

Perka BAPETEN nomor 4 tahun 2013 tentang Proteksi dan Keselamatan Radiasi dalam Pemanfaatan Tenaga Nuklir.

Bambang Hadi S. (2014). Pemodelan Perisai Radiasi Fasilitas BNCT Dengan Sumber Beamport Tembus Teras Reaktor Kartini Menggunakan MCNP5. Skripsi. Yogyakarta: Universitas Gadjah Mada.

BAPETEN. (2013). Peraturan Kepala Badan Pengawas Tenaga Nuklir (BAPETEN) Nomor 4 Tahun 2013 Tentang Proteksi Dan Keselamatan Radiasi Dalam Pemanfaatan Tenaga Nuklir. Jakarta.

BATAN. (2014). Standard Operational Procedure (SOP): Eksperimen Analisis Dan Kerakteristik Fluks Neutron Pada Beamport Tembus Radial Untuk Fasilitas Dan Kajian Pendayagunaan Reaktor Kartini. Nomor Dokumen: SOP 073.2/RN0001/STA 4. Yogyakarta: PSTA BATAN.

Indry Septyana Novitasari. (2015). Analisis Fluks Neutron pada Beamport Tembus Radial Reaktor Kartini untuk Fasilitas Uji In Vivo dan In Vitro Boron Neutron Capture Therapy (BNCT). Skripsi. Yogyakarta: Universitas Negeri Yogyakarta.

Kemenkes RI. (2013a). Profil Kesehatan Indonesia 2012. Jakarta.

Kemenkes RI. (2013b). Riset Kesehatan Dasar (Riskesdas) 2013. Jakarta.

Kemenkes RI. (2014). Profil Kesehatan Indonesia Tahun 2013. Jakarta.

Nina Fauziah. (2013). A Conceptual Design of Neutron Collimator in the Thermal Column of Kartini Research Reactor for Boron Neutron Capture Therapy. Skripsi. Yogyakarta: Universitas Gadjah Mada.