The Characteristics for BNCT facility in Hanaro Reactor

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ABSTRACT

The BNCT(Boron Neutron Capture Therapy) facility has been developed in Hanaro(High-flux Advanced Neutron Application Reactor), a research reactor of Korea Atomic Energy Research Institute. A typical tangenial beam port is utilized with this BNCT facility. Thermal neutrons can be penetrated within the limits of the possible maximum instead of being filtered fast neutrons and gamma rays as much as possible using the silicon and bismuth single crystals. In addition to, the liquid nitrogen (LN_2) is used to cool down the silicon and bismuth single crystals for the increase of the penetrated thermal neutron flux. Neutron beams for BNCT are shielded using the water shutter. The water shutter was designed and manufactured not to interfere with any other subsystem of Hanaro when the BNCT facility is operated. Also, it is replaced with conventional beam port plug in order to cut off helium gas leakage in the beam port. A circular collimator, composed of $^6Li_2CO_3$ and polyethylene compounds, is installed at the irradiation position. The measured neutron flux with 24 MW reactor power using the Au-198 activation analysis method is 8.3×10^8 n/cm^2 s at the collimator, exit point of neutron beams. Flatness of neutron beams is proven to $\pm6.8\%$ at 97 mm collimator. According to the result of acceptance tests of the water shutter, the filling time of water is about 190 seconds and drainage time of it is about 270 seconds. The radiation leakages in the irradiation room are analyzed to near the background level for neutron and 12 mSv/hr in the maximum for gamma by using BF_3 proportional counter and GM counter respectively. Therefore, it is verified that the neutron beams from BNCT facility in Hanaro will be enough to utilize for the purpose of clinical and pre-clinical experiment.

Keywords : BNCT(Boron Neutron Capture Therapy), Hanaro reactor, water shutter

1. INTRODUCTION

Boron neutron capture therapy (BNCT) is an investigational form of a radiation therapy which has the potential ability to selectively kill tumor cells embedded within normal tissue[1,2]. Currently, there are some sites in the U.S., Japan, and Europe where a clinical BNCT program exists. And also, the reconstructions of facilities are in progress for the purpose of performing BNCT in many research nuclear reactors in the world. The feasibility study had been started in KCCH and KAERI since 1995. Since then, the possibility of BNCT facility installation in Hanaro reactor of KAERI had been examined and affirmatively evaluated for it using thermal neutrons had been derived. Thus the BNCT facility in Hanaro Reactor has been installed since 1999. As the new starters of BNCT have a tendency to pursue the method using epithermal neutron beams, the BNCT facility using thermal neutron beams is still required to perform a pre-clinical research because epithermal neutron beams not enough slow down to irradiate small animals. Therefore, the feasibility study of BNCT should be preceded to perform the reactor based BNCT and optimized for this purpose. In this paper, the results of BNCT irradiation facility development and acceptance tests are described.

2. MATERIALS AND METHODS

2.1. Irradiation Facility

2.1.1. Collimator

The conical collimator was fabricated by compression shaping with enriched $^6Li_2CO_3$ and polyethylene and installed at the neutron beams exit points. The width of beams can be selective of 10 cm or 15 cm diameter respectively. The collimator with 146.7 mm diameter was used in this neutron flux measurement[2].

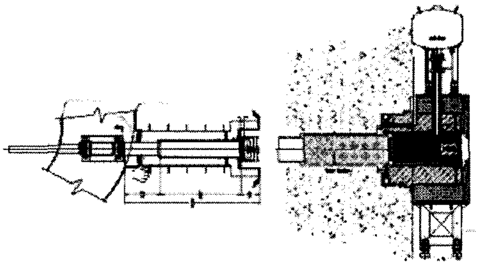

Fig. 1 Hanaro IR Tube and BNCT Facility

2.1.2. Shielding Tent

Plastics contained boron were used as materials of neutron shielding tent surrounding a patient and satisfied with thin thickness. Because the direction of the treatment table can be varied dependent on patient's setup position, the shielding tent was designed and manufactured to cover variable circumstances. It is highly maneuverable. Also, because it is required to monitor the condition of patients during treatment, transparent shielding material that can be seen the part of patient head was installed. It was used lead glass for gamma shielding and selected the Pyrex glass having 2 cm thickness. The view of neutron shielding tent is shown as Fig. 2.

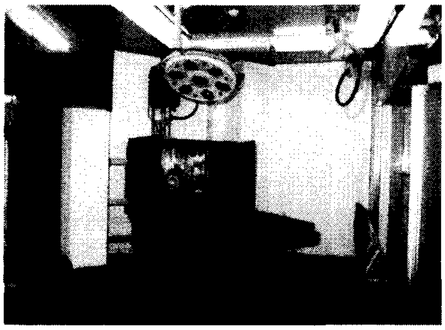

Fig. 2. The inner view of irradiation room.

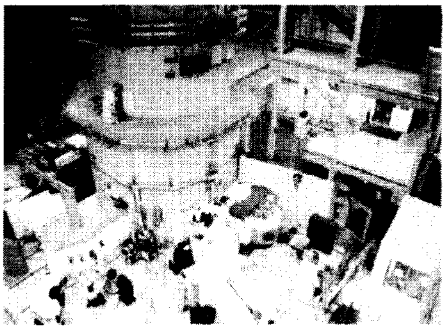

Fig.3. The outer view of the BNCT facility.

The radiation level in the irradiation room was measured to confirm the effect of neutron shielding tent after the neutron beams had been opened for long time then beam shutter was closed.

2.1.3. Water Shutter

Hanaro BNCT facility uses the water shutter as a neutron shutter. It spends about 3 min. for pumping water and about 2 min. for filling water. Thus it is difficult to exactly know the start and finish time of irradiation contrary to the experiments using a quick shutter. In addition to, when the patient is treated, a quick shutter cannot be used. Therefore, the neutron beams variation dependent on the motion of water shutter should be verified to obtain exact neutron flux and neutron fluence[2]. The count rate of nuclear fission ionization chamber, installed on the longitudinal center of the front shielding material, was measured at intervals of 10 sec. to verify neutron fluence dependent on the opening and shutting of the water shutter and the irradiation points of Au thin foil.

2.2. Characteristics of Neutron Beams

2.2.1. Neutron Flux

The absolute neutron flux, the distribution of neutron flux, the Cd ratios were measured at the front of BNCT irradiation facility. Neutron flux distribution dependent on the length of beam movement direction was measured. The measurements were performed with Si and Bi single crystals and no phantom at normal temperature[2]. Also the neutron flux was measured on the surface of humanoid phantom. For the purpose of measuring neutron flux at the beam exit point, collimator, Au thin foil, Au wire, Au thin foil doped Cd thin foil, etc. were installed on the surface of shielding material for the front of BNCT facility. Au thin foils were arranged horizontally to the center axis of the shielding material for the front of BNCT facility. Au thin foils covered with Cd thin foils having 0.02 inch thickness were arranged at -3.3 cm point. The thickness of each Au thin foil is 0.001 inch and the diameter is 0.5 inch. The experiment of neutron irradiation was performed in reactor output power 24 MV and each irradiation time was about 3 hours.

3. RESULTS

According to the result of the lead shielding material at front of collimator, the radiation level on the surface of irradiation facility and in the irradiation room is less than 5 μSv/h and it is approximate the background level of reactor room. It is verified that the increase of radiation level due to the activation in the irradiation room nearly does not exist. The radiation level in the irradiation room with closed shutter is about 1/100 of 50 mrem/h(500 μSv/h). On the basis of this result, it is confirmed that BNCT can be performed without stopping reactor operation. The measured signal of neutron detector is directly proportional to reactor output power. Also, it is validated that the condition of beam shutter is exactly monitored. The relationship between reactor output power and neutron detector signals is shown in Fig. 4. The neutron flux was measured at the beam exit point of collimator with no phantom by using Au thin foils. It is shown in Fig. 5. On the assumption that the neutron flux distribution is symmetric, reaction ratio at -3.3 cm position is compare with the reaction ratio of Au thin foil covered with Cd thin foil, then the measured Cd ratio is 104. Under the same condition, with reactor power 24 MW 8.3×10^8 n/cm$^2\cdot$ s, the Cd ratio is about 30 without lead shielding. Thus, the measured neutron flux is large as much as 14% and the Cd ratio is increased on a large scale. Thermal neutron flux and the Cd ratios are superior to expectations. Thermal neutron flux is measured 1.6265×10^9 with phantom and this value is increased as twice as the measured value of it without phantom. As it shown in Fig. 4, thermal neutron flux is negligible at the other part of it except collimator hole.

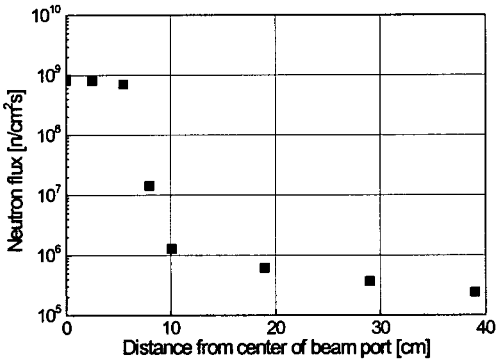

Fig. 4. The measured neutron flux at the collimator.

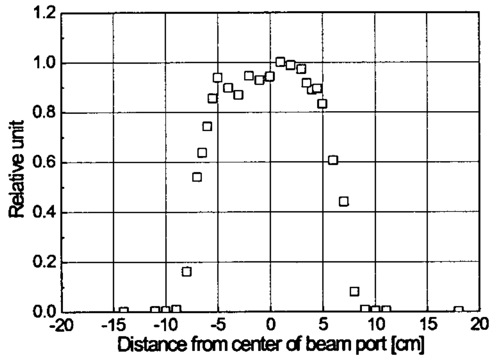

Fig. 5. The 24 MW neutron flux dependent o distance from beam exit.

4. DISCUSSION AND CONCLUSION

The BNCT irradiation facility has been installed in Hanaro. It is considered as optimization under the given condition. It is expected that enough thermal neutron flux to adopt for BNCT by using the filtering device. This filter was designed and manufactured not only to minimize fast neutrons and gamma rays but also to maximize thermal neutrons by using the silicon and bismuth single crystals cooled down to near the LN_2 temperature. Because the temporary surgical operation is performed in Hanaro, the separate shielding materials for gamma and neutrons was installed at the exit point of neutron beams instead of doping a neutron absorber. As there is no precedent to use the water shutter as a shielding material in BNCT facility, it is satisfied with water shutter as a neutrons and gamma filter in Hanaro BNCT facility. As there is no precedent to use the water shutter in BNCT facility, it is possible to use it for the purpose of shielding most of neutron beams and some of gamma rays in Hanaro BNCT facility owing to the neutron filter device. Adopting this concept enable to perform BNCT without interfering reactor operations. Hanaro BNCT facility can produce a high quality thermal neutron fields above large space. These neutron fields can be utilized for various purposes such as neutron detector calibration, seed mutation, etc. And also, the Hanaro BNCT facility would be used for the neutron radiography through some modifications.

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