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INTRODUCTION

The Idaho National Laboratory (INL) and Washington State University (WSU) have constructed a new epithermal-neutron beam for collaborative Boron Neutron Capture Therapy (BNCT) preclinical research at the WSU TRIGA^{TM} research reactor facility [1]. More recently, additional beamline components were developed to permit the optional thermalization of the beam for certain types of studies where it is advantageous to use a thermal neutron source rather than an epithermal source. This article summarizes the results of some initial neutronic performance measurements for the new thermalized system, with a comparison to the expected performance from the design computations.

FACILITY DESCRIPTION

Figure 1 shows a schematic diagram of the WSU epithermal-neutron beam facility. The beam extraction components are located in the thermal-column region of the reactor-shielding monolith. The neutron spectrum is tailored in the filtering and moderating region of the assembly such that most (>95%) of the neutrons emerge with energies in the epithermal energy range (0.5 eV – 10 keV). Downstream of the filtering and moderating region is a bismuth and lead gamma shield, followed by a conical neutron collimator composed of bismuth surrounded by borated polyethylene. This arrangement produces a high-quality epithermal neutron source suitable for large-animal *in-vivo* radiobiological studies typical of BNCT applications.

Nonetheless, a thermalized beam is often more suitable for small animal and cell culture radiobiological studies. Results of a series of design calculations indicated that filling the entire 34-cm deep collimator with heavy water (D_2O) offered the simplest approach to thermalization of the epithermal beam while still producing acceptable flux intensity at the irradiation point. A polyethylene double-walled bag system was designed to fit inside the collimator. This double bag was then inserted in a single-wall bag, giving a triple containment system that is desirable since small amounts of tritium are formed in the heavy water during beam operation. Figure 2 shows the bags installed in the collimator as well as the placement of the bismuth plate that restrains the bags in the collimator. The bismuth plate is bolted to the collimator cone at the downstream end. The irradiation point for thermal beam operations is defined on the outer surface of this plate. The cables that are visible at the bottom of the plate lead to fission chambers mounted inside the collimator and used for on-line beam monitoring.

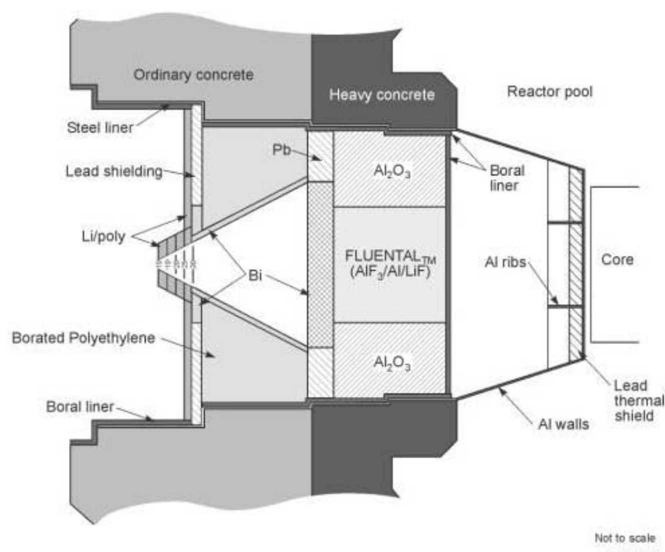

Figure 1. WSU column assembly, with epithermal neutron filter in place.

NEUTRONIC CHARACTERIZATION

Neutronic computations for the thermalized beam were performed using the MCNP [2] and DORT [3] radiation transport codes. Initial measurements of the beam performance were performed with bare and cadmium-covered gold and manganese foils placed at the center of the outer surface of the bismuth plate. The reactor was operated for one hour. The induced activity in each of the four foils was measured using a high purity germanium gamma spectrometer system (Canberra/Genie^{TM}). The measured activity was converted to saturation activity and the thermal flux was then estimated using the cadmium difference method [4].

RESULTS

The measured thermal neutron flux (Energy < 0.414 eV) for a reactor power of 1 MW was 3.61×10^8 n/cm^2-sec with an uncertainty of 5.2% (1σ) when estimated from the data for the bare and Cd-covered Au foils and 3.43×10^8 n/cm^2-sec with an uncertainty of 5% from the data for the bare and Cd-covered Mn foils. The cadmium ratio was 32.6 for the Au foils and 299 for the Mn foils, indicating a reasonably well-thermalized beam. The DORT design calculations for this configuration yielded an expected thermal flux of 2.68×10^8 n/cm^2-sec at 1 MW. Future work will include additional measurements of the detailed full-range neutron spectrum using more comprehensive activation and direct least-square unfolding protocols worked out earlier by INL for this type of medical neutron beam dosimetry [5].

DISCUSSION

The WSU facility is the third clinical-scale reactor-based epithermal-neutron source for BNCT research that has been brought into operation in the U.S. It features an epithermal neutron spectrum and intensity typical of the most recent generation of neutron sources of its type. The initial results presented here demonstrate that the beam also can be modified in a very simple manner to produce a useful thermal neutron source. The intensity of the thermalized beam will allow typical irradiations of interest to the BNCT research community to be performed over times of a few hours or less, depending on the boron administration protocol, the fractionation scheme of interest, and other relevant factors.

ACKNOWLEDGEMENT

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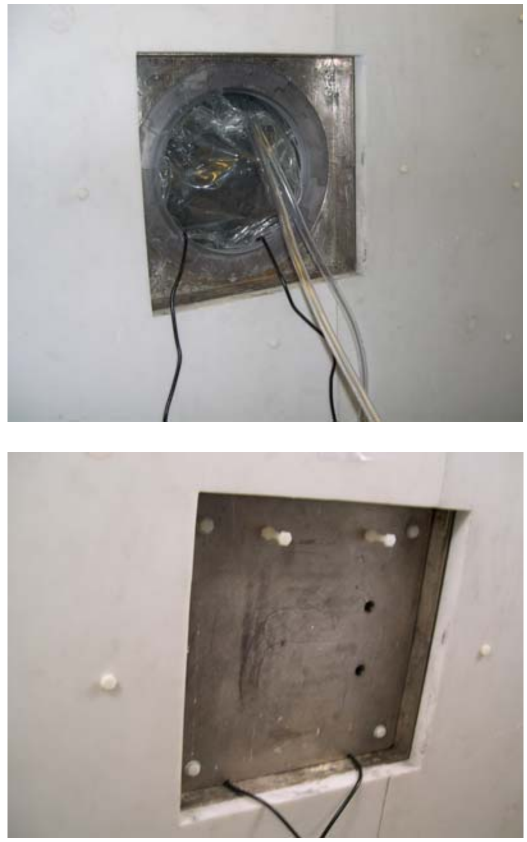

Figure 2. Top: Polyethylene bags installed in the collimator. Tygon fill and vent lines are shown. Bottom: Bismuth plate installed over the downstream bismuth collimator opening.

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