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Annex 4
BEAM DELIVERY

Epithermal neutron beam for BNCT research at Washington State University

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Abstract. A new filter has been designed and analysed for the Washington State University TRIGA™ research reactor. Optimum balance of epithermal flux and background KERMA was obtained with a Fluental™ and alumina filter. The epithermal neutron flux calculated by the DORT transport code was approximately 9×10^8 n/cm^2–s with a background KERMA of about 3×10^{-13} Gy/n/cm^2. Operation of the beam for animal testing is expected to commence in 2000.

1. INTRODUCTION

Veterinary radiation oncology researchers at the Washington State University (WSU) School of Veterinary Medicine have made major contributions to the understanding of the *in vivo* radiobiology of Boron Neutron Capture Therapy (BNCT) over the years. For example, the large animal model studies of normal brain tissue tolerance in BNCT conducted by this group [1] provided a key component of the radiobiological basis for the resumption in 1994 of human BNCT trials in the US. Those studies used the epithermal-neutron beams available at Brookhaven National Laboratory and at the Petten facility, in The Netherlands, with technical support form the Idaho National Engineering and Environmental Laboratory (INEEL) in several areas of physics, biophysics, and chemistry. Recent attention has been focused upon the development of a more convenient and cost effective local epithermal-neutron beam facility for BNCT research and boronated pharmaceutical screening in large animal models at WSU. The design of such a facility, to be installed in the thermal column region of the TRIGA™ research reactor at WSU, was performed in a collaborative effort [2,3] of WSU and the INEEL. Construction is now underway.

2. FACILITY DESCRIPTION

Figure 1 shows an overall plan of the WSU research reactor facility. The new epithermal-neutron beam extraction components will be located in the thermal-column region of the reactor-shielding monolith. The original graphite has been removed from this region and is being replaced with a new epithermal-neutron filtering, moderating, and collimating assembly as shown in Figure 2. The 1MW reactor core is suspended from a movable bridge above the pool. It can be positioned directly adjacent to a hollow truncated aluminum cone that extends horizontally into the reactor pool from the tank wall on the upstream side of the filtering and moderating assembly. Neutrons emanating from the core travel into the filtering and moderating region. The spectrum is tailored in this region such that most 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 lithiated polyethylene. Provision is made for several different exit port aperture sizes as shown. A heavily shielded concrete beam stop and treatment room will be located just outside of the thermal column opening in the reactor shield wall, as shown in Figure 3.

A key distinguishing feature of the WSU facility is the use of a new, high efficiency, neutron moderating and filtering material, Fluental™, developed by the Technical Research Centre of Finland [4]. Fluental™ is manufactured by hot isostatic pressing of a mixture of 69% (by weight) aluminium fluoride, 30% aluminium, and 1% lithium fluoride. A block of this material, having a thickness in the beam propagation direction of 0.64m and transverse dimensions of approximately 0.6m, is surrounded by aluminium oxide to produce the neutron filtering and moderating region shown in Figure 2.

3. PERFORMANCE ESTIMATES AND DISCUSSION

DORT [5] radiation transport design calculations for the coupled core and filter-collimator assembly indicate that an epithermal neutron flux of approximately 10^9 n/cm^2-s at a reactor power of 1 MW will be produced at the exit port of the collimator. The background neutron KERMA (a measure of the fast-neutron contamination) for the beam is calculated tobe approximately 3×10^{-13} Gy/n□cm^2. The calculated neutron spectrum at the collimator exit port is shown in Figure 4. The computational methods used for this design were previously validated against measurements performed for a similar neutron beam facility that is already

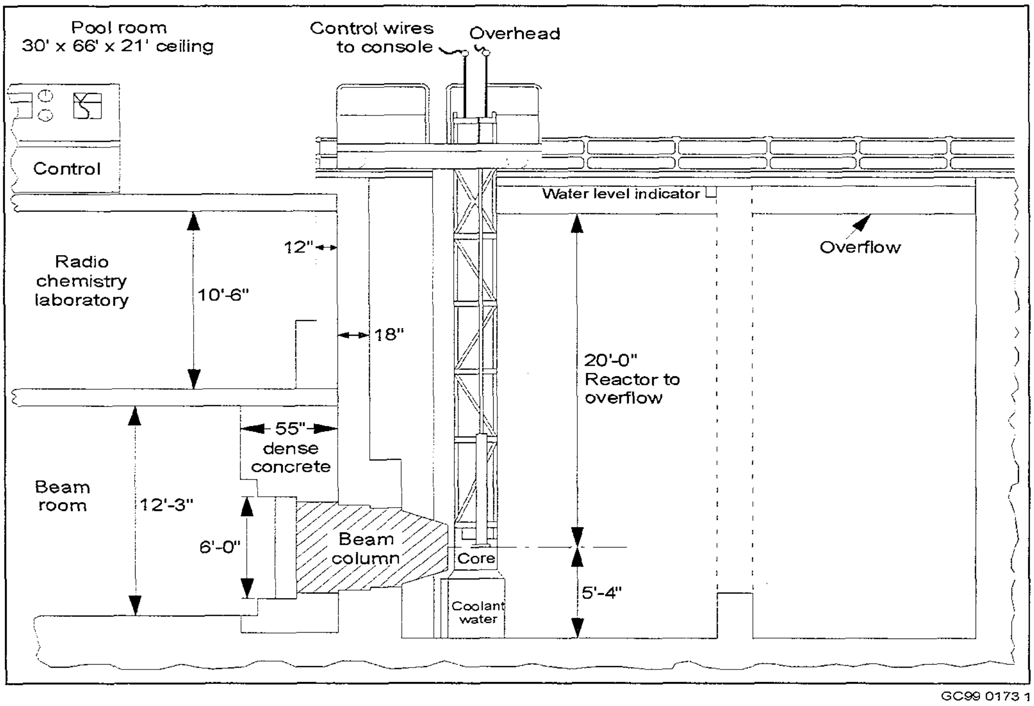

Figure 1. Elevation plan sketch of the Washington State University Research Reactor.

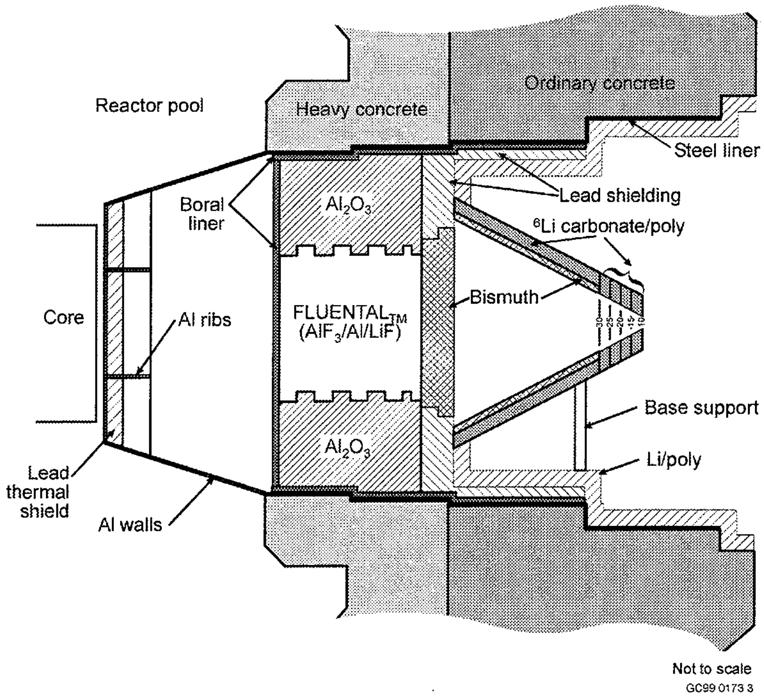

Figure 2. Washington State University column assembly with epithermal-neutron filter.

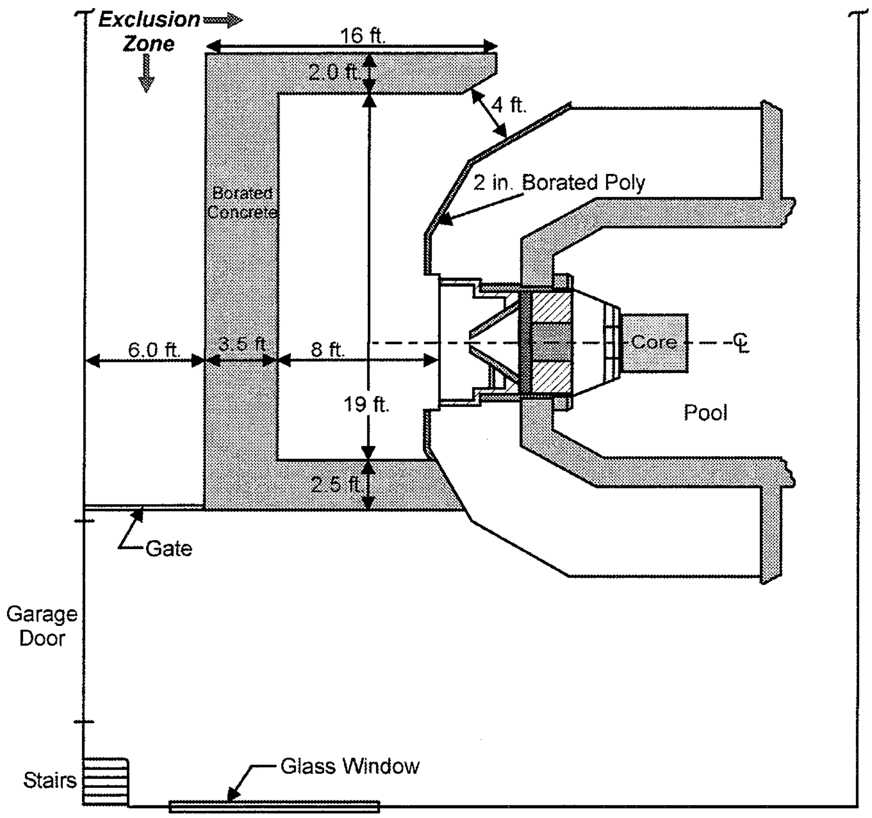

Figure 3 Approximate WSU beam stop layout.

in operation at the FiR1 TRIGA™ research reactor in Finland [6]. Additional validation calculations for the WSU application were performed using the MCNP [7] Monte Carlo code.

An additional key feature of the WSU beam facility design is the provision for adjustable filter-moderator thickness to systematically explore the radiobiological consequences of increasing the fast-neutron contamination above the nominal value associated with the baseline system described above. This is an important clinical issue for BNCT. Thinner filter/moderator arrangements will produce epithermal beams having correspondingly harder spectra and greater levels of fast-neutron contamination. The components shown in Figure 2 are designed for relative ease of disassembly and re-assembly compared to other reactor-based epithermal-neutron facilities that are currently in operation. Thus it will be possible to have a number of different filter/moderator arrangements over the life of the facility.

Construction of the new WSU beam facility was started in 1998 with initial testing scheduled for late 1999. Operation for animal research applications is anticipated in 2000 and beyond. The WSU facility will be the third clinical-scale epithermal-neutron source for BNCT research in the US.

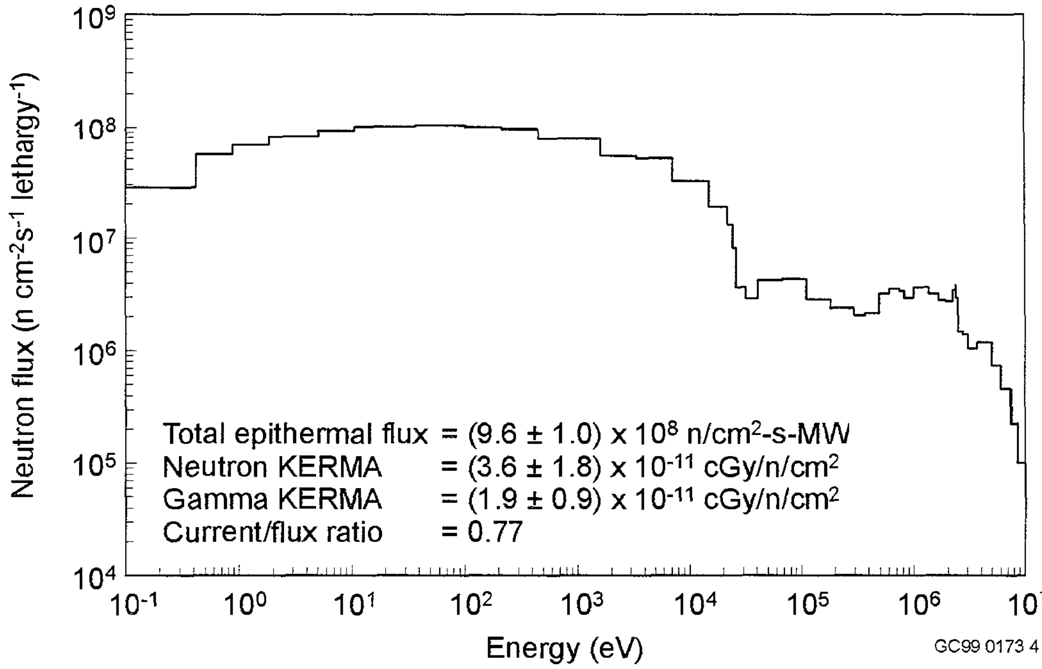

Figure 4. Calculated WSU epithermal neutron beam neutron spectrum at the collimator exit.

ACKNOWLEDGEMENT

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