New Core-Moderator Assembly and Neutron Beam Ports Development and Installation at the Radiation Science and Engineering Center

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INTRODUCTION

The Penn State Breazeale Reactor (PSBR), the centerpiece of the Radiation Science and Engineering Center (RSEC), first went critical in 1955 and is the nation's longest continuously operating university research reactor. The PSBR is a 1 MW, TRIGA with moveable core in a large pool and with pulsing capabilities. A variety of dry tubes and fixtures are available in or near core irradiations. A pneumatic transfer system is also available for irradiation of samples. Unfortunately, an upgrade in reactor power and a change in fuel type made in the 1960s left only one of seven beam ports aligned with the centerline of the reactor core. The others are significantly below the core's centerline. This inherent design issue has greatly limited the utilization of the neutron beam capabilities of the facility. A significant change of the core-moderator assembly, reactor core upper and lower grid plates, safety plates, reactor tower structure and new and geometrically aligned neutron beam ports are being installed. After this upgrade and improvements, full use of the PSBR's capabilities and the establishment of state-of-the-art neutron beam facilities will be possible.

CURRENT STATUS OF PSBR BEAM PORTS

The existing PSBR pool has seven beam ports (BP) built into the shielding wall. With the current setup of the core-moderator assembly, only one beam port is at the vertical centerline of the TRIGA core. Four beam ports are five inches below the centerline of the core and two beam ports are eleven inches below the centerline of the core. The core grid assembly does not permit lowering the core more than the current arrangement. When the PSBR was built, MTR-type fuel elements with an active length of 24 inches were used. With the MTR-type fuel, the beam port arrangement did not limit the maximum neutron output. In 1965 the PSBR was converted from MTR to TRIGA-type fuel, resulting in the current availability of only two beam ports. One beam port, with 3 x 10^7 n/cm^{2}sec flux at the exit of the biological shield, is used for research, primarily neutron imaging, and another one, with ~10^5 n/cm^{2}sec neutron flux, is used for service activities involving neutron transmission measurements. Since one the beam port collimators are primarily designed and optimized for neutron radiography and radioscopy measurements, it is not practical to perform short-term modifications to the port to obtain the desired results for other measurements. We are currently trying to use only one beam port for all of our research projects. Due to this limitation, we must shuffle delicate research equipment around. More importantly, each project or experimental technique at the RSEC should be optimized with its own dedicated neutron beam with different collimations and neutron flux. Due to inherent design issues with the current arrangement of beam ports and reactor core-moderator assembly, the potential for the development of innovative experimental facilities utilizing neutron beams is extremely limited. Therefore, a new core-moderator assembly in the PSBR pool and new beam port geometry are being installed in order to achieve the full potential of the neutron beam capabilities.

NEW CORE-MODERATOR ASSEMBLY AND BEAM PORTS AT THE RSEC

Several studies were completed to examine the existing beam ports for neutron output and to investigate new core and moderator designs that would be accessible by new additional beam ports [1-4]. A schematic drawing of the new core/moderator assembly location with respect to new neutron beam ports are shown in Fig. 1.

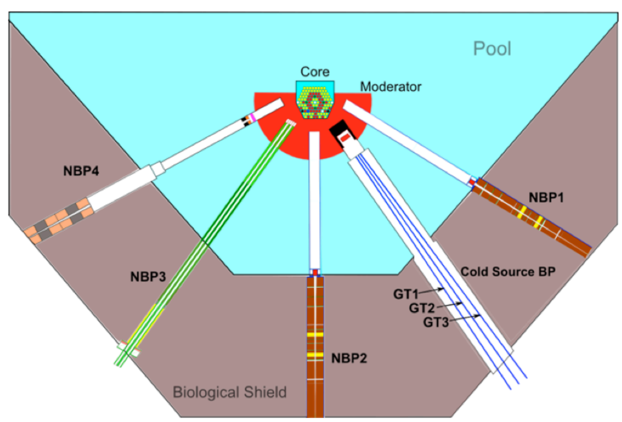

Fig. 1: A schematic layout of the final PSBR design with four thermal neutron beam ports and one cold neutron beam port in which three guide tubes are channeled.

The computer models used for this analysis were all Monte Carlo based, written in MCNP, TRIGSIMS (a proprietary core management code developed at Penn State) and MURE. The final design was optimized using MURE (MCNP Utility for Reactor Evolution). This code allowed construction parameters to be varied in the search for the optimal design. The D_2O tank and beam port arrangement were designed to maximize the thermal flux while minimizing the contamination from fast neutrons and gamma radiation. The computer simulations for the new design were first benchmarked on the existing D_2O tank and core structure using activation foil measurements. The design of the reactor core structure was changed to optimize the transmission of neutrons to the new wrap-around D_2O tank while maintaining the passive safety of the TRIGA fuel. Also, the thermal hydraulics of the TRIGA core was modeled using COBRA-TF. The thermal hydraulics model was benchmarked on the current core design. Measurements of fuel temperature, water channel temperature and flow conditions of the actual core were supplied to verify the model results. The new D_2O Tank/Core structure design is the result of these analyses. An AutoCAD drawing of new D_2O Tank is shown in Fig. 2. The thermal neutron flux at the new beam ports is predicted to be 85% higher with 90% lower fast flux and 50% lower gamma radiation. Measured thermal neutron flux at existing beam port (BP#4) is 3 x 10^7 n/cm^2 s. The MCNP predicted flux value for the same location with the new design would be 5.6 x 10^7 n/cm^2 s with much lower fast neutron and core gamma components. The peak core fuel temperatures will be unaffected by the new design, remaining well below the safety limits for the natural circulation TRIGA design. Also all beam ports will be in same elevations from the reactor pool floor and they will be looking at the centerline of the TRIGA core. With this arrangement the problem mentioned related to our inherent beam alignment will be eliminated.

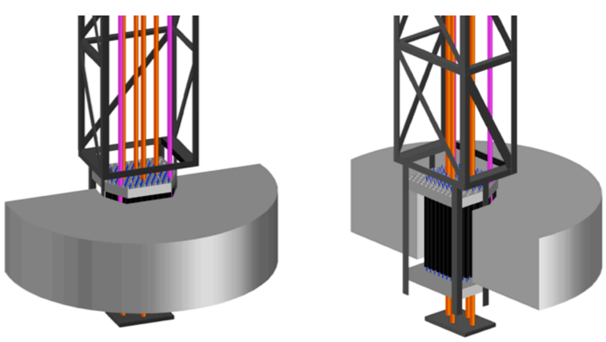

Fig. 2. Drawings of PSBR new core-moderator assembly.

New beam ports would be geometrically aligned with the core-moderator assembly for optimum neutron output. Five new neutron beam ports were designed for the PSBR facility. This new arrangement would require cutting and removing a section of the existing biological shield and placing five new beam ports with various diameters depending on the intended neutron beam technique to be applied. A mesitylene-based cold neutron source and three neutron guides will be installed in one of the beam ports. Four new experimental techniques (triple-axis spectrometer, conventional and TOF-NDP, neutron powder diffraction, and prompt gamma activation analysis) will be added to the existing neutron imaging and neutron transmission facilities. The geometrical configurations along with the filter and collimator system designs of each neutron beam port were selected based on the requirements of the experimental facilities. MCNP5 simulation results predicted that the thermal neutron flux would be increased by a factor of between 1.23 and 2.68 in the new beam ports compared to the existing design. In addition, the total gamma dose will be decreased by a factor of 100 in the new PSBR facilities.

The areas envisioned for the RSEC's new neutron beam port/beam laboratory are for mostly cutting-edge nuclear and materials science research. Some examples include: a NDP facility for depth vs. concentration measurements, impurity determination of He-3 and B-10 in semiconductors, metals, and alloys; a mesitylene-based Cold Neutron Source and Cold Neutron Prompt Gamma Activation Analysis for neutron focusing research, materials characterization, and determination of impurities in historically or technologically important materials; a Neutron Powder Diffractometer for structural determination of materials; and a Triple Axis Diffractometer to train students on neutron diffraction and perform structural determinations of materials.

ACKNOWLEDGEMENT

This project was sponsored by U.S. Department of Energy under Nuclear Energy University Program - Reactor Upgrades Grant DE-NE0000640.

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