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Neutron Multiplicity Measurements for the AFCI Program

Quarterly Progress Report January-March 2005

UNLV Transmutation Research Project, Task 06
Principle Investigator: Denis Beller, Ph.D.

Purpose and Problem Statement

The U.S. Advanced Fuel Cycle Initiative (AFCI) is a program to develop economic and environmental methods to reduce the impact of waste from commercial nuclear fuel cycles. One concept for near-complete destruction of waste isotopes from used nuclear fuel is accelerator-driven transmutation. High-power accelerators would be used to produce high-energy charged particles, which then collide with heavy metal targets to create a cascade of neutrons. These neutrons then cause a nuclear chain reaction in subcritical systems. Fission neutrons then transmute fissile waste isotopes as well as other problematic isotopes such as technetium-99 and iodine-129. To design these systems, complex reactor physics computer codes and highly detailed data libraries are used to compute the reactivity of systems, reaction rates, destruction rates, and nuclear-induced damage rates to materials. This project was developed to test a



Figure 1. NMDS in the cubic configuration for cosmic radiation measurements.

Russian-built Neutron Multiplicity Detector System (NMDS) for measuring neutrons generated in a central target by a variety of accelerators. To assist in experiment design and evaluation, we use the most advanced high-energy radiation transport code, MCNPX, to model experiments. Experimental results are compared to computational predictions and discrepancies are investigated. Initial plans were to conduct experiments using a 70-MeV proton cyclotron at the Crocker Nuclear Laboratory at the University of California at Davis and/or a 20 to 40 MeV electron linac (linear accelerator) at the Idaho Accelerator Center (IAC) at Idaho State University (ISU). Finally, we planned to use the 800-MeV linac at the Los Alamos Neutron Science Center at Los Alamos National Laboratory.

Personnel

Principle Investigator: Dr. Denis Beller (UNLV Mechanical Engineering)

Students: Ms. Shruti Patil, a graduate student, is working on her M.S. thesis to upgrade the NMDS and to plan and conduct an experiment with the NMDS at the Los Alamos Neutron Science Center (LANSCE) or at Brookhaven National Laboratory (BNL). Ms. Patil is majoring

in computer engineering at UNLV. She will also upgrade the capabilities of the NMDS and improve data acquisition and analysis software. Mr. Timothy Beller, an undergraduate student (Mechanical Engineering), performed MCNPX calculations and consulted with Ms. Patil to operate and troubleshoot the NMDS. Tim was employed on TRP Task 27, RACE. A second undergraduate student, Mr. Brice Howard, began working on this project to use MCNPX to model detector performance.

UNLV Graduate Student Thesis Advisor: Prof. Rama Venkat, Department Head, Electrical and Computer Engineering, UNLV, is Ms. Patil's thesis advisor.

National Laboratory Collaborators: Dr. Eric Pitcher (AFCI Experiments, LANSCE-12, Los Alamos National Laboratory); Dr. Stephen Wender (LANSCE-3 Group Leader, Los Alamos National Laboratory); and Dr. Michael Todosow (Brookhaven National Laboratory).

DOE Collaborator: Dr. Thomas Ward (UNLV Russian Collaboration Science Adviser, TechSource, Inc.)

Issues:

Budget: The expenditure rate has been less than projected because we have not been able to travel to a national lab to conduct accelerator-driven testing. A request for a no-cost extension through the end of December will be submitted in June. This will allow for the modification of the system and the completion of Ms. Patil's M.S. thesis.

Management: The laboratory space that the NMDS occupies in the Harry Reid Center was allocated to another PI, thus requiring the removal of the NMDS. We haven't located a suitable place on campus to relocate it. Therefore, it will be dismantled and placed into storage until a suitable laboratory facility is located.

Technical: Dead time appears to be extremely high, with a resolving time constant for a single detector, many detectors, or the whole system on the order of 5 to 10 ms, which limits the count rate of the NMDS to less than 200 counts per second, and reduces its efficiency to a few percent when counting high-activity sources. It appears the problem is simply a limitation of the processing capability of the CPU in the "special computer." One CPU is simply trying to process too much information when count rates are high. Thus, the NMDS is only useful for sources between a few hundred to a thousand neutrons per second.

Summary Report for Jan-Mar 2005

The NMDS, which was suffering from a number of malfunctions, was completely repaired and components are performing as expected for low count rates. However, the system loses much of its data when counting high-activity neutron sources. It will not count more than two hundred counts per second. Much of the effort this quarter has been in determining the cause of this data loss and determining potential methods to improve electronic performance.

In January Tim Beller conducted a dead-time measurement experiment in collaboration with Dr. Warnick Kernan at the Remote Sensing Laboratory (RSL) of the Nevada Test Site. Dr. Kernan has a joint appointment at UNLV and Bechtel-Nevada. Data was analyzed, deadtime coefficients were determined, and Ms. Patil prepared an oral report for presentation at the annual student conference of the American Nuclear Society. The measurement was conducted using a cubic configuration and 64 detectors arranged in four banks of 8. Two ^{252}Cf neutron sources of 13,000 and 78,000 neutrons/second were used to perform two-source deadtime measurements. Figure 2 illustrates the layout of the experiment.

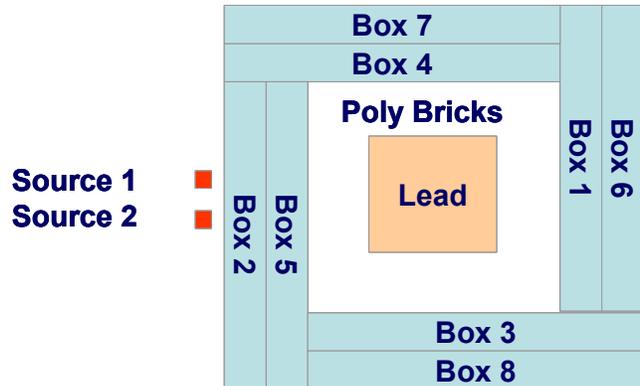


Figure 2. Top view of the two-source NMDS experiment. Each “Box” represents 8 detectors stacked vertically.

Results indicated that the performance of individual detectors depends upon the number of detectors operating as well as the source strength (see Figure 3). The individual detector were determined to have a deadtime coefficient of a few ms,

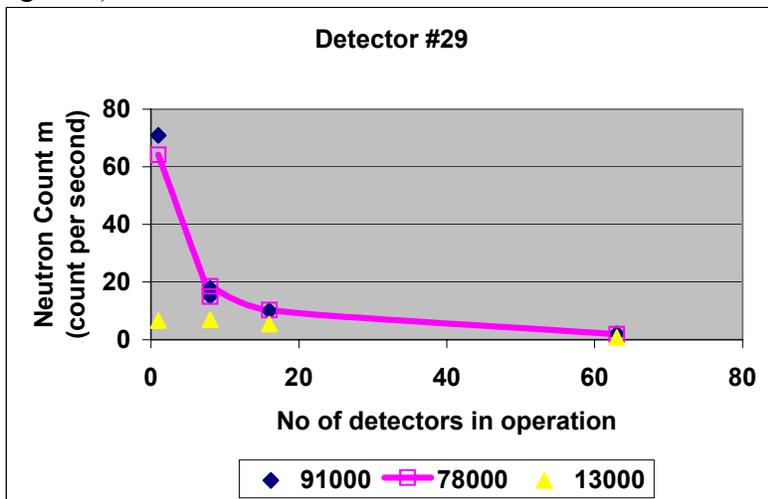


Figure 3. Performance of Detector #29 versus number of detectors in operation and source strength. The combined strength of the two sources is 91,000 n/s. The number of detectors were 1, 8, 16, and 64. Dual data points at the second position represent two measurements, one with 8 detectors in one box, the other with 8 detectors split between two boxes.

which would indicate a capability of the total system to count several thousand neutrons per second. However, we have never counted more than 200 n/s. In addition to deadtime of the individual ^3He tubes and pre-amps, signal processing boxes which support 8 detectors each also contribute to deadtime. We determined that 8 detectors distributed across two boxes counted at a higher rate and had less deadtime than 8 detectors in a single box. In the final analysis, though, these experiments demonstrated that the performance of the system is critically limited because the “special computer” simply cannot handle the data throughput during high count rates. In contrast, we have measured 50 or more counts from cosmic neutrons in a single $256\ \mu\text{s}$ burst, a rate of 2×10^5 counts per second, but these events never happen even once a second. As a consequence of these experiments, we are formulating a plan to acquire a modern data acquisition system that will support the maximum performance of each detector and all the detectors combined.

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To expand on the experiments that were conducted in January at the RSL, Ms. Patil conducted measurements using a Cf-252 source placed at different distances from the detector system to measure efficiency, dead time, and CPU losses. Mr. Howard performed a parametric radiation transport study with MCNPX for comparison to the above efficiency measurements. Data is currently being analyzed.

As a result of performance limitations, we cancelled future experiments at LANL because we cannot make measurements in intense neutron fields. Dr. George Green of Brookhaven National Laboratory believes they can produce a low-intensity source less than 200 protons per second, so we have re-initiated planning for a Fall 2005 experiment. This may take some creative funding however.