Task 6

Neutron Multiplicity Measurements of Target/Blanket Materials

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BACKGROUND

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 nuclear reactions in subcritical systems.

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. In this project, a Russian-built detector system was used to make measurements of neutrons generated in a central target by a variety of accelerators.

RESEARCH OBJECTIVES AND METHODS

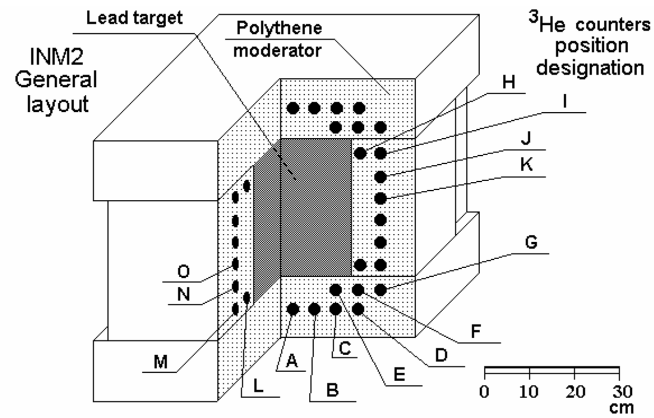
A prototype modular Neutron Multiplicity Detector System (NMDS) with 64 ^{3}He gas counting tubes was developed to measure the neutron multiplicity of scaled lead accelerator targets. Its modularity allows it to be configured for a variety of experiments to measure neutron multiplicity from different sources: protons, electrons, high-energy neutrons, or even cosmic particles such as muons.

This system may be used to measure neutron production in a variety of configurations, on a variety of targets, with a variety of source particles, and over a range of energies (10 to 800 MeV) to produce a large database that may be used to validate neutron multiplicity predictions. This should enable the quantification of systematic errors in the latest version of MCNPX and its accompanying data libraries. Time-dependent measurements of neutron production in the NMDS should provide a systematic set of precise data that will enable direct comparison with code calculations.

Comparison of results from the NMDS may decrease uncertainties and allow the derivation of relative measurements in the few percent range at the 95 percent confidence level. In addition, discrepancies that are discovered with this system can contribute to the improvement of the codes and data libraries. Improved models of beam line experiments, accelerator targets, and detector designs will result from these code improvements.

RESEARCH ACCOMPLISHMENTS

Initial work in this project included the development of geometric models of the target-detector assemblies for use with the MCNPX radiation transport code to optimize the design of the NMDS. Radiation transport calculations of neutron detection efficiency were completed and interpreted prior to developing designs of the neutron detection systems needed to perform multiplicity measurements. Following completion of the modeling, a fabrication effort was initiated. A series of MCNPX models were developed at UNLV for a cylindrical target. Another generic model was created to examine response times, collection efficiencies, and escape probabilities. In addition to modeling at UNLV, colleagues at the V.G. Khlopin Radium Institute (KRI) completed preliminary radiation transport modeling using the CONTROL code developed by KRI researchers.



NMDS in the INM2 ("CUBE") geometry.

The 64-element ^{3}He-detector-based NMDS was fabricated by KRI and shipped to UNLV. It was assembled at UNLV in the "CUBE" geometry (30 cm x 30 cm x 30 cm of lead inside and 8 to 12 detectors on each of the 6 sides of the cube. Detection efficiencies in ^{3}He as well as fractional capture in Pb and polyethylene were calculated. A ^{252}Cf source was used to calibrate the NMDS. Measured efficiencies were comparable to calculations and measurements were completed at KRI.

<u>ISU-IAC Experiments</u>
To evaluate its usefulness for measurement of spallation neutrons, the NMDS was transported to the Idaho Accelerator Center at Idaho State University where it was used in conjunction with a linear accelerator to determine its performance.

An americium-beryllium (AmBe) source with a neutron production rate of 2500 n/s ±10% was placed against the face of the Pb in all 5 configurations to measure the overall efficiency of the system. This weak source exceeded the counting capacity of the NMDS, such that its efficiency was reduced to 3.5% compared to earlier values at UNLV of 20-30% with source strength of ~600 n/s. This was the first indication of a severe count-rate limitation of the NMDS.

To accommodate this limitation, the accelerator was "de-tuned" to reduce the neutron production rate within the boundaries of the detectors. All results from the ISU-IAC accelerator-driven experiments were influenced by a count-rate limitation that is inherent in the NMDS hardware and software.

Accelerator-based testing commenced with the electron beam and several parameters and results were examined and compared to radiation transport predictions in these studies. These parameters include the neutron absorption time or lifetime, efficiencies of the systems and individual detectors, and multiplicity distributions.

NTS-RSL Experiments

In an effort to determine system contributions to deadtime, a deadtime measurement experiment was conducted at the Remote Sensing Laboratory (RSL) of the Nevada Test Site (NTS). Results indicated that the performance of individual detectors depends upon the number of detectors operating as well as the source strength. The individual detectors were determined to have a deadtime coefficient of a few ms, which would indicate a capability of the total system to count several thousand neutrons per second. However, the system has never counted more than 200 n/s, even with strong neutron sources. Each system component contributes to deadtime. In the final analysis, however, these experiments at ISU-IAC and NTS-RSL demonstrated that the performance of the system is critically limited by the Russian hardware and, as a consequence of these experiments, a modern data acquisition system was acquired that will support the maximum performance of each detector and all the detectors combined.

Graduate student Shruti Patil checks signals on one of the 8-detector control boxes of the NMDS.

TASK 6 PROFILE

Start Date: August 2001
Completion Date: December 2005

Conference Proceedings:

T. Beller, D. Curtis, D. Beller, A. Rimsky-Korsakov, and T. Ward, "The UNLV Neutron Multiplicity Detector System," *Proceedings of the Eighth Information Exchange Meeting on Actinide and Fission Product Partitioning & Transmutation*, OECD/NEA, Paris, France, pp 687-698, 2005.

T. Ward, A. Rimski-Korsakov, N. Kudryashev and D. Beller, "Integral Neutron Multiplicity Measurements from Cosmic Ray Interactions in Lead," *Proceedings, XVII Particle and Nuclei International Conference (PANIC05)*, Santa Fe, New Mexico, October 24-28, 2005.

D. Curtis, D. Beller, C. Hull, A, Rimsky-Korsakov, and T, Ward, "Modeling Neutron Multiplicities in a 60-element ^{3}He Detector System," *Proc. of the Sixth International Meeting on Nuclear Applications of Accelerator Technology (AccApp'03)*, American Nuclear Society, pp. 190-194, 2004.

T. Beller, D. Curtis, D. Beller, A. Rimsky-Korsakov and T. Ward, "The UNLV Neutron Multiplicity Detector System," Eighth Information Exchange Meeting on Actinide and Fission Product Partitioning & Transmutation (OECD/NEA), Las Vegas, NV, November 9-11, 2004.

D. Curtis, D. Beller, C. Hull, A. Rimsky-Korsakov, and T. Ward, "Modeling Neutron Multiplicities in a 60-Element 3He Detector System," Sixth International Meeting on Nuclear Applications of Accelerator Technology (AccApp'03), American Nuclear Society, San Diego, CA, June 1-5, 2003. (Awarded Best Overall Poster for AccApp'03)

T. Ward, A. Rimski-Korsakov, M. Todosow, G. Greene, M. Divadeenam, C.L. Snead, Jr., A. Hanson, E. Pitcher, D. Beller, C. Hull, W. Culbreth, A. Hechanova, and G. Cerefice, "Note on the Benchmark and Validation of the LAHET Code System," ANS Conference, Reno, NV, November 11-15, 2001.

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