U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

PI: **Steven Grimes** **Proposal No.: 99-0228**

Institution: **Ohio University**

Collaborators: **Pennsylvania State University, National Institute of Science & Technology**

Title: **Novel Investigation of Iron Cross Sections via Spherical Shell Transmission Measurements and Particle Transport Calculations for Material Embrittlement Studies**

We propose a multi-year project to perform precision measurements to accurately determine the iron non-elastic scattering cross section, the objective of which is to alleviate the well-known deficiency that exists in reactor pressure vessel (RPV) neutron fluence determinations. The cross section measurements will be performed using the spherical shell transmission method, employing iron shells with different thicknesses. Moreover, the measurements will be complemented by detailed particle transport calculations, as a means of both optimizing the experimental setup, and also in order to ascertain how well the newly measured cross sections predict neutron transport through thick section steel.

Nuclear data play a governing role in the design, operation, and safety of nuclear systems for both current and future generations of nuclear power plants. Knowledge of iron scattering cross sections is essential due the extensive use of iron in the construction of nuclear plant systems, including the reactor vessel and shielding structures. Iron cross sections are extremely important and are needed to adequately assess plant design and operational characteristics, such as the structural integrity of reactor pressure vessels. For cross section evaluations, such as the Evaluated Nuclear Data Files (ENDF), measurements of this nature are especially important because of the small uncertainties that can be obtained with them.

The spherical shell neutron transmission method using thin iron shells is especially well suited to measurements of the non-elastic cross section, which, for the energies of interest, is dominated by inelastic scattering. The measurements will be performed at the Ohio University Accelerator Laboratory, using neutron time-of-flight spectroscopy techniques and accelerator-based neutron sources, principally at energies greater than approximately 1 MeV. We propose to perform two distinct types of measurements. Firstly, we will perform neutron time-of-flight measurements at selected energies with a thin spherical iron shell positioned over the neutron source. Positioning the iron shell over the source provides the advantage that the measurements may be performed with the time-of-flight technique, so that in addition to the determination of the total non-elastic cross section, we will also be able to investigate various components of the non-elastic cross section for which there are neutrons in the exit channel. In addition, complementary measurements with a thin shell located over the detector will also be made. Measurements of this type have the advantage that the variation in energy and effects due to the non-isotropic nature of the angular distribution of the

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source neutrons can be made small by increasing the source to detector distance. After we perform the thin shell transmission measurements, we will perform similar experiments employing a thick iron sphere. The thick sphere work retains much of the sensitivity of the thin shell measurements, but more importantly, such work provides a way of determining the quality of evaluated microscopic cross section data by an application to a macroscopic system through which neutron transport can be determined.

Detailed transport calculations will be performed at The Pennsylvania State University to optimize the experiment, and to generate continuous-energy and multigroup cross sections for comparing the measurements to calculations of the neutron transport through the shells. Time-dependent Monte Carlo neutron transport calculations will be used to investigate different experimental configurations in order to optimize the experiment. For this task, we will utilize the A^3MCNP (Automated Adjoint Accelerated MCNP) computer code, and the 3-D S_n parallel PENTRAN (Parallel Environment Neutral-particle TRANsport) code. We will subsequently analyze the experimental data using Monte Carlo and deterministic discrete ordinates neutron transport techniques in order to obtain information about energy regions where problems may exist with the ENDF evaluation.

In addition to preparing a continuous energy cross section set, we will also generate multigroup cross sections that are necessary for performing deterministic calculations. Multigroup cross sections are the major source of the uncertainty associated with deterministic calculations. The collapsing procedure, multigroup structure, and the group-wise neutron spectrum employed are the principal factors affecting the accuracy of multigroup cross sections. Comparisons of continuous energy and multigroup Monte Carlo calculations (for reactor pressure vessels) has demonstrated that results based on the available multigroup libraries are significantly different from those obtained using the continuous energy formulation. In order to reduce this discrepancy, we are proposing to use a bi-linear adjoint weighted formulation for determining the group-averaged constants. Further we propose to use "contribution" theory for developing a general approach for selecting problem-dependent "effective" group structures.

As the first generation of US nuclear power plants reaches its design end of life, accurate assessments of their neutron exposure become increasingly important, not only from a nuclear safety perspective, but also from an economic standpoint. The information learned from this investigation is therefore directly applicable to the design of the next generation of advanced nuclear power reactors. Better knowledge of these important nuclear data will enable reactor engineers to fully integrate the inherent advantages of realistic vessel operational life times into the overall plant design at the outset of the design phase. As such, this may significantly impact the plant's ultimate design of achieving an optimally safe and economical nuclear electric generating station.

The applicable fields of research are materials science, experimental nuclear data, and computational science.