SUMMARY OF TARGET PHYSICS DISCUSSIONS AT ICANS-IV

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Target physics (the basic processes governing spallation reactions which occur inside a target bombarded by energetic particles such as protons) affects the overall design of a spallation neutron source. For example, the total number, energy, and angular distribution of neutrons emitted during the spallation process determine the amount of shielding for the source, and (together with the target-moderator-reflector configuration) the ultimate source intensity. Also, energy deposition mechanisms inside the target affect target and target-cooling-system design. Energy deposition by particles and gamma-rays emmitted from the target affect premoderator, moderator, decoupler, and reflector design (including their cooling systems), and may influence the design of the inner part of the massive neutron shield. Target handling, disposal and the need to cool the target (when there is no incident proton beam) depend on the progeny produced in the spallation reactions. Whether or not a target will fission is important in target design and can affect facility safety considerations. The performance and design of spallation neutron sources have (in general) been calculated using a variety of computer code packages. Experimental data relevant to the design and performance of both pulsed and steady-state spallation neutron sources are just recently becoming available. The details of present computational capabilities and current experimental data relevant to spallation neutron sources are contained in the various papers presented at ICANS-IV. Overviews of these topics are given below.

Most computations relevant to spallation neutron sources begin with the High Energy Neutron Transport Code (HETC) developed at the Oak Ridge National Laboratory. This code uses Monte Carlo methods and includes the intranuclear-cascade-evaporation model as a series of subroutines; the code calculates (as needed) particle production data from nucleon-nucleus and pion-nucleus collisions. In general, HETC is used to transport neutrons with energies $\gtrsim$15-20 MeV. Below these energies, evaluated differential neutron cross-sections exist, and these "low-energy" neutrons are transported using more conventional Monte Carlo and reactor codes. Until (relatively) recently, HETC did not include fission reactions in competition with the evaporation process. This so called "high-energy" fission should be important for spallation neutron sources using depleted uranium as a target (similar arguements hold for thorium and uranium targets and/or blankets in the Accelerator Breeder application). Several laboratories (including the Oak Ridge and Brookhaven National Laboratories in the United States, the Japan Atomic Energy Research Institute, and the Rutherford and Appleton Laboratories in the United Kingdom) have independently modified HETC to include high-energy fission effects. Depending on the quantity of interest, the output of HETC and the low-energy neutron transport code are analyzed in a variety of ways. The application of these code-packages for facility

design and comparison with experimental data are detailed in several ICANS-IV papers. Because of the variety of computer code packages used at the various ICANS laboratories, it may be useful to intercompare computed results between laboratories. Within the framework of the ICANS, relevant benchmark experiments could be identified, and the various code packages intercompared with the experiments.

Until the last couple of years, experimental data relevant to spallation neutron sources have been relatively scarce for incident proton energies of 500-1100 MeV. Neutronics, energy deposition, radiation damage, neutron shielding, spallation progeny production, target fission, and neutron beam quality data are important in spallation neutron source design and performance. Details of experiments performed at existing spallation neutron sources and data being gathered for more intense spallation neutron sorces are given in several ICANS-IV papers. In some of these experiments, basic data were measured such as:

- angular- and energy-dependent neutron production cross-sections for a variety of materials,
- angular-dependent neutron and proton spectra from thick targets of lead and uranium,
- angular-dependent high-energy ($\gtrsim$20 MeV) neutron yield from a thick lead target,
- total neutron production from a variety of thick targets,
- delayed neutron fraction in a thick uranium target, and
- radionuclide production inside a thick uranium target.

Such experiments are valuable in testing the fundamental processes and assumptions employed in the computer codes used to calculate spallation reactions and neutron transport. Other experiments have measured the effectiveness of neutron shields, total power produced in tungsten and uranium targets, local power density in a uranium target, and nuclear heating in cold moderators and other materials. Still other experiments deal with measuring thermal neutron beam intensities, spectra, and pulse widths from moderators. These latter measurements depend on the particular target-moderator-reflector configuration used, and depend upon whether the spallation neutron source is pulsed or steady-state. Specific details of target-moderator-reflector design and the presence or absence of neutron decouplers (used in the configuration) determine the ultimate performance of the system as a thermal or epithermal neutron source. Significant gains (factors of 2) can be attained in some moderator designs. Beam quality (the amount of gamma-ray, charge particle, and high-energy neutron contamination in thermal and epithermal neutron beams) is important. Once a target-moderator-reflector configuration is chosen for a spallation neutron source, absolute thermal and epithermal neutron beam intensities, spectra, thermal neutron pulse widths (where applicable), and beam quality should be measured, and the experimental results compared with calculated predictions.