CONF-970607--5

PRELIMINARY RADIATION TRANSPORT ANALYSIS FOR THE PROPOSED NATIONAL SPALLATION NEUTRON SOURCE (NSNS)

Jeffrey O. Johnson and Richard A. Lillie
Computational Physics and Engineering Division
Oak Ridge National Laboratory*
Oak Ridge, Tennessee 37831-6363

Paper to be Presented at the
American Nuclear Society
1997 Annual Meeting
June 1-5, 1997
Orlando, Florida

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*Managed by Lockheed Martin Energy Research Corporation for the U. S. Department Of Energy under Contract No. DE-AC05-96OR22464.

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Preliminary Radiation Transport Analysis For The Proposed National Spallation Neutron Source (NSNS)

Jeffrey O. Johnson and Richard A. Lillie
Computational Physics and Engineering Division
Oak Ridge National Laboratory

INTRODUCTION

The use of neutrons in science and industry has increased continuously during the past fifty years with applications now widely used in physics, chemistry, biology, engineering, and medicine. Within this history, the relative merits of using pulsed accelerator spallation sources versus reactors for neutron sources have been debated. A consensus from the neutron scattering experiment community has finally emerged endorsing short pulse spallation sources as the preferred option for the future. To address this future need, the Department of Energy (DOE) has initiated a pre-conceptual design study for the National Spallation Neutron Source (NSNS) and given preliminary approval for the proposed facility to be built at Oak Ridge National Laboratory (ORNL). The DOE directive is to design and build a short pulse spallation source in the 1 MW power range with sufficient design flexibility that it can be upgraded and operated at a significantly higher power at a later stage.

The pre-conceptual design of the NSNS initially consists of an accelerator system capable of delivering a 1 to 2 GeV proton beam with 1 MW of beam power in an approximate 0.5 microsecond pulse at a 60 Hz frequency onto a single target station. The NSNS will be upgraded in stages to a 5 MW facility with two target stations (a high power station operating at 60 Hz and a low power station operating at 10 Hz). Each target station will contain four moderators (combinations of cryogenic and ambient temperature) and 18 beam lines for a total of 36 experiment stations. This paper summarizes the radiation transport analysis strategies for the proposed NSNS facility.

RADIATION TRANSPORT ANALYSIS STRATEGY

The radiation transport analysis, which includes the shielding, activation, and safety analysis, is important for the construction of an intense high-energy accelerator facility because of its impact on conventional facility design, maintenance operations, and because the costs associated with incorporating the results of the radiation transport analysis shares a considerable part of the total facility costs. Traditional concepts utilized in current facilities are being re-examined, and new concepts will have to be considered to meet the higher power challenge of the NSNS. A calculational strategy utilizing coupled low and high energy Monte Carlo calculations and multi-dimensional discrete ordinates calculations is being implemented to perform the radiation transport analysis of the proposed NSNS.

The radiation transport analysis of the NSNS can be subdivided into four principal categories: (1) neutronic performance; (2) energy deposition distribution; (3) material damage and activation; and (4) shielding design. Within each of these categories there is an optimization procedure to follow which will yield the best design allowing for the interdependent relationships the four categories have with respect to each other and the implications associated with the overall facility design. Collaborative efforts interfacing the radiation transport analysis with the neutron and proton beam transport systems design, thermal hydraulic analysis, structural materials selection, remote handling/target maintenance requirements, and general facility layout are being implemented. The radiation transport analysis will incorporate the state-of-the-art cross-section data bases and computer codes modified and/or developed, and verified under the NSNS Neutron Source Systems Research and Development Plan.

The determination of the neutronic performance involves characterizing the target station and accelerator radiation environments. Calculations are being performed to determine the neutron, proton, heavy ion, and gamma-ray flux spectra as a function of time, energy, and space for all components of the target station (target, moderators, reflectors, etc.) and accelerator (linac, ring, beam dumps, etc.). These calculations will optimize (maximize or minimize) these distributions depending on the target station or accelerator component in question and desired design criteria. Within this analysis, target/moderator/reflector configurations and material selections will be determined to yield the optimum neutron source for the experiment stations.

The energy deposition distribution analysis is directly tied to neutronic performance and interfaces with the thermal hydraulic analyses to determine the optimum target station design with respect to heat transfer and fluid flow requirements. Energy deposition profiles are also being determined for the beam dumps associated with the accelerator design. These calculations are being performed for all components of the NSNS requiring heat removal and/or subjected to thermal shock phenomena.

Material damage and activation analyses are being performed to assess facility component lifetime estimates and aid in the structural materials selection process. In particular, gas production, displacement damage, and primary knock-on atom (pka) spectra are being determined for target station and selected accelerator components. Material selections will be determined utilizing this information in conjunction with additional material issues (compatibility, machinability, costs, etc.). Activation analyses are being performed to determine facility radioactive waste streams, on-line material reprocessing requirements (mercury, liquid hydrogen, cooling water, etc.) and