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STATUS OF THE OAK RIDGE SPALLATION NEUTRON SOURCE (ORSNS) PROJECT

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ABSTRACT

The current status and future plans of the Oak Ridge Spallation Neutron Source (ORSNS) are reviewed. The ORSNS is a new project initiated by the U.S. Department of Energy (DOE) beginning October 1, 1995, to prepare the conceptual design for a new spallation neutron source.

INTRODUCTION

There have been numerous studies in the United States and Europe detailing the need for a next-generation neutron source. Assessments in the U.S. date from the early 1970s with the most recent being the U.S. Department of Energy's Basic Energy Sciences Advisory Committee (BESAC) report *Neutron Sources for America's Future* (so-called Kohn Panel report). The first recommendation of this report was construction of the Advanced Neutron Source (ANS), a steady state research reactor, and the second recommendation was to initiate conceptual design for a complementary pulsed spallation neutron source. Because of cost and other considerations, the ANS project was cancelled and the DOE has now concluded that design and construction of a pulsed spallation neutron source will be the department's top priority for a new neutron source. In light of these changes, the BESAC has been charged by the DOE to complete a follow-up study to identify the scope and trade-offs for such a project that could be built for about one billion dollars. In addition, BESAC will assess upgrades to the existing DOE neutron sources that are necessary to maintain the U.S. neutron capability while this new source is being built.

The Oak Ridge National Laboratory has been identified as the preferred site for the spallation neutron source and has been asked to perform the conceptual design and R&D by the DOE. Design and R&D are proceeding for a high power, pulsed spallation neutron source that can be built in stages to accommodate evolving neutron science needs and available funds. These efforts will be carried out to achieve the performance goals set by the neutron science community and reflected in the upcoming BESAC assessment and will involve broad ranging collaborations with other DOE laboratories, industries, universities, and the international community.

ORNL TECHNOLOGY APPROACH

In their initial assessment, the scientific community, through the BESAC report *Neutron Sources for America's Future*, considered the long-term consequences if the ANS were not built and concluded:

"If the ANS is not built, a 5-MW PSS would be needed to basically cover its capabilities in neutron scattering. Other essential capabilities of the ANS would not be available.

"Thus, an approach that would combine a possible future 5-MW PSS (if successfully developed) with a new HFIR reactor would provide capabilities comparable overall to the ANS alone (e.g., much better at high energies but considerably worse for a number of important beam research areas, particularly with cold neutrons), but at a considerably greater estimated cost of construction and operation. . . . ."

Extrapolating from this guidance, the ORNL is pursuing a two-phased approach to meeting the future needs of the U.S. neutron science community.

1. Design and construction of ORSNS
   - Design a 5 MW pulsed (μs) spallation neutron source that can be constructed in stages.
   - Align the technology choices with performance criteria established by the neutron users (BESAC assessment).
   - Design and construct the first stage at a power consistent with available technology and funds, and upgrade in the future as technology and funding allow.

2. Complementary upgrade of the High Flux Isotope Reactor (HFIR).
   - Upgrade the HFIR to maintain U.S. neutron science capabilities in areas such as isotope production, materials irradiation and testing, neutron activation analysis, and continuous neutron beams that cannot be provided by a spallation neutron source.

STATUS AND FUTURE PLANS

CURRENT STATUS OF ORSNS

The ORNL received funds to begin conceptual design and R&D on ORSNS in the fourth quarter of Fiscal Year 1995. Progress to date includes initiation of the following tasks:

1. Target Design

   The target needed to accommodate an energetic pulsed proton beam delivering 5 MW of power presents formidable challenges as documented in these proceedings. As a result, initial design efforts have focused on both solid and liquid target concepts. The results from these efforts will be reported when they are more complete, but the work so far has been in the nature of scoping studies to identify the needs for R&D and technology development. Studies underway include the following:

   - Solid targets. The materials being considered are W, Ta and Pb in various configurations including rods, packed beds, and monoliths with cooling channels.
   - Liquid targets. The systems being considered are Hg and Pb/Bi.
   - Neutronics calculations. Neutronics calculations have been done for various target/moderator systems to establish the spatial, temporal, directional, and energy dependent particle and neutron fluxes. In addition, the correlated spatial and temporal energy deposition distributions, damage profiles, gas production, and activation products are being calculated to assist in damage assessments and materials selection.

In these investigations, both continuous and pulsed beam spallation sources are being simulated. A combination of Monte Carlo and discrete ordinates codes are necessary and those used are:

- CALOR95. Monte Carlo Hadronic/Electromagnetic Transport Code System (HETC95, EGS4, SPECT95, MORSE/MICAP/MCNP)
- HETC95. Monte Carlo Hadronic Transport Code (~20 MeV <E <20 TeV)
- EGS4. Monte Carlo Electromagnetic Transport Code (~.01 MeV <E <1 TeV)
- MORSE/MICAP/MCNP. Monte Carlo Neutron and Gamma-Ray Transport Codes (E <20 MeV)
- ANISN/DORT/TORT. 1-D/2-D/3-D Discrete Ordinates Neutron and Gamma-Ray Transport Codes (E <20 MeV)

All of these codes with the exception of MCNP and EGS4 have been developed by ORNL for various applications over the years and have been widely adapted and used by many other institutions.

2. Materials qualification

   Materials issues important for target, moderator, windows, etc., include radiation effects, compatibility, corrosion, thermal shock, and fatigue. Materials of interest include a range of alloys and liquid metals. Initial goals are to evaluate irradiation responses based on relevant existing data and calculations/extrapolations, examine existing high energy/dose irradiated materials that are available, participate in international efforts assessing spallation neutron source materials, and perform reactor and high energy irradiations to fill in gaps. Qualification of liquid metal targets will require building prototypes and test stands for direct tests.

   It is already clear that spallation irradiation conditions for solid targets in particular are outside the existing experience base acquired for fission and fusion applications. Spallation materials will experience higher transmutation gas and solid impurity production rates, proton radiation damage, particle energies, pulsed damage delivery schedule, and possible synergistic effects. These anticipated severe materials problems are also a motivation for considering liquid metal targets.

3. Thermal hydraulics

   The heat transfer group and test facilities developed for the ANS project have been adapted to SNS needs to evaluate heat removal schemes for the target/moderator designs thermal shock/cycling effects, transient heat flux effects, and average energy deposition effects.

4. Design-to-cost model

   A design-to-cost model is being constructed as a project management tool to assist in making technical choices, and calculating the performance, cost, and project risk associated with these choices. This model will be validated using data from other spallation source designs and related projects. This approach to making technical choices is necessitated by the need to design a facility capable of meeting the future needs of the neutron science community but one whose first stage can be constructed for about one billion dollars.

5. Cooperative projects

   - A cooperative effort with Brookhaven National Laboratory (BNL) was started to cost validate the BNL design for a 5 MW pulsed spallation source using rapid cycling synchrotrons (RCS). This design could be built in stages and will help validate the design-to-cost model.

   - A cooperative effort for similar purposes with BNL was started to consider accumulator rings instead of RCS for their 5 MW source and to assess superconducting linac alternatives to conventional linacs.

   - A cooperative effort with the Rutherford Appleton Laboratory ISIS facility was started to evaluate the effects of background radiation that occur during the proton pulse at various instrument locations and shielding configurations. This study is important to assess the feasibility of continuous spallation sources as well as target/shielding/moderator designs and instrument development at pulsed sources.

   - Project structure. Those project management and technical programs that were developed for the ANS project, and are applicable to ORSNS, have been transferred.

FUTURE ORSNS PLANS AND COLLABORATIONS

The receipt of funding for the ORSNS project in the FY 1996 budget will allow the full R&D and design group to be completed. The target and other design activities started in FY 1995 will continue at full pace. An accelerator design effort will be put in place to facilitate selection of the technologies that will be used to design a spallation neutron source. These technology choices will be aligned with guidance received from the DOE as a result of the BESAC assessments concerning scope, trade-offs, and budget constraints.

It is anticipated that a high power short-pulse, 5 MW, spallation neutron source will be needed to ensure that the U.S. remains competitive in neutron scattering in the future. Budget and technology constraints will likely require that a 5 MW source be designed that is capable of being built in stages. The first stage would be a fully operational source that could be constructed with available technology and consistent with the current budget constraints. However, the design would allow subsequent upgrades to full performance.

The ORSNS project will take full advantage of the work that has been done at various laboratories around the world in developing spallation neutron sources. The technology evaluations and feasibility studies that have been performed by the other DOE laboratories in the U.S., and studies in Europe and Japan will be evaluated and utilized. The ORSNS R&D design and construction efforts will utilize the existing expertise of these same laboratories as well as those currently operating spallation neutron sources. Because of the similarity in design activities and goals, the ORSNS will maintain close cooperation with the European Spallation Source project and its member laboratories. This will include collaborations on mutually beneficial R&D, science and technology, instrumentation development, and personnel exchanges. In short, ORSNS will be a highly collaborative team effort involving national and international partners directed toward a high-intensity, next generation neutron source to serve the U.S. community.

HFIR UPGRADES

The second part of the ORNL technology approach is to upgrade the HFIR steady state research reactor to address those needs of the neutron science community that cannot be performed at a spallation neutron source. ORNL is planning a three phased approach to HFIR improvements.

1. Phase I: Improvements within existing funds
   - Request to the DOE to operate at 100 MW again based on improved techniques for fuel plate inspection/selection.
   - Improve irradiation and neutron activation analysis facilities.
   - Develop a new gamma irradiation facility.
   - Develop new neutron scattering instruments and layout for more effective use of existing beams.
   - Improve beam part for neutron tomography and radiography.

2. Improvements requiring additional funds
   New funds (Scientific Facilities Initiative) have been requested in the FY 1996 Budget by the DOE Office of Energy Research to improve operation of DOE user facilities. These and other DOE funds will be used to make several improvements to HFIR.
   - Install a new liquid hydrogen cold source in an existing HFIR beamport with a brightness equivalent to the ILL vertical cold source (two years estimated completion).
   - Develop new instruments in collaboration with HFIR users and collaborators.
   - Propose a new guide hall for cold neutron research.
   - Extend core life and thus greater availability through use of an improved fuel developed for ANS.

3. Full upgrade of HFIR[2]
   The beryllium reflector at HFIR must be replaced at or before the end of its lifetime in ~1999. This presents the opportunity to upgrade the HFIR and greatly improve its lifetime and performance.
   - The beryllium reflector would be replaced with a thin-walled, annular tank of heavy water surrounding the core.
   - An aluminum, steel, or zircalloy sleeve would be placed between the core and the present reactor vessel; the present vessel would then no longer be a pressure boundary and its embrittlement would be of no consequence.
   - A new, large cold source would be added in the heavy water tank, located in a thermal neutron flux about three times higher than the vertical cold source at ILL.
   - Several new beam tubes and more guide hall space would be added.
   - Irradiation and activation facilities would be improved as well as reactor controls and instrumentation.

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