9.1 FUSION MATERIAL IRRADIATION TEST STATION (FMITS) AT SNS –Mark Wendel, Phil Ferguson (Oak Ridge National Laboratory)

OBJECTIVE

The Fusion Materials Irradiation Test Station (FMITS) is a plan for an irradiation facility at the Spallation Neutron Source (SNS). The objective of the current effort is a feasibility study based on a 30% design to quantify the risk to normal operations and safety at the SNS. The deliverables are a Feasibility Study Report, 30% Design Review, and a Preliminary Safety Assessment. The original study of FY2012 estimated a total project cost of $10M over a 3-year schedule. The current estimate for implementation of the FMITS at SNS is $13.4 M including a 25% contingency.

SUMMARY

FMITS irradiations at SNS would occur on samples welded inside an FMITS target harness in two horizontal tubes which project out in front of the mercury target. For these specimen locations, the back-scattering neutron flux spectra should be close to the ITER fusion spectrum. The PKA spectra at the FMITS samples were also compared to those for ITER, and the results show good agreement. Radiation damage rates would be 1.6–5.5 dpa/y for steel, with the range of helium-to-dpa production ratios starting close to those expected in D-T fusion, and increasing toward beam center locations.

The deliverables for the FY14 funding from OFES have all been met:

1. A review of the 30% design for FMITS was conducted on June 2-3,
2. The feasibility study report was completed July 1, 2014, and
3. The preliminary safety assessment was completed July 1, 2014.

The 30%-design review committee found that the FMITS design was feasible in that all of the technical and safety issues were addressed at a level appropriate for a 30% design. Specific recommendations were addressed in the feasibility study report appendices.

Other highlights of the FMITS 30% design progress during the past 6 months include a completed preliminary seal mock-up test, improved remote handling tooling and procedures, and a completed project resource-loaded schedule and contingency analysis.

Progress and Status

During FY14, workable solutions have been identified to the technical engineering challenges for implementation of FMITS. Also, a comprehensive analysis has been completed evaluating the impacts of FMITS on SNS operations and SNS safety. Communication with SNS key operations staff and fusion materials scientists has taken place in monthly meetings and special topical technical meetings on experiment design, instrumentation, mechanical design, remote handling, and safety are conducted as needed. As of July 1, 2014, all of the promised deliverables have been completed.

The FMITS 30% design review committee members were:

- Michael Baumgartner, Chair–Mechanical Systems and Operations Group Leader; SNS, ORNL
- Dr. Jeffrey Binder—Director, Applied Research Institute; University of Illinois
- Dr. David Cook—Safety Basis Authority; Research Reactors Division, ORNL
- Dr. Kenneth Herwig—Instrument Projects and Development Group Leader; SNS, ORNL
- Patrick Hurh—Mechanical Support Department Head; Accelerator Division, FNAL
- Dr. Stuart Maloy—Transmutation Core Materials Technical Lead; FCRD Advanced Fuels Campaign, LANL
- Brad Nelson—US ITER Chief Engineer; US ITER Project Office, ORNL
- Mark Rennich—Target Systems Engineer; Instrument and Source Division, ORNL

- Dr. Steven Zinkle—UT/ORNL Governor's Chair; Dept. of Nuclear Engineering & Dept. of Materials Science & Engineering, University of Tennessee

The broad charge to the committee was to comment on the feasibility of the FMITS design. The committee was also asked to make the following judgments:

1. Identify significant technical challenges and issues that should be addressed.
2. Has the case for technical success of FMITS to fusion materials science been made?
3. Have all of the significant safety concerns (threats to personnel or the environment) been identified and addressed at an appropriate level for this stage of the project?
4. Has the operational risk to the SNS neutron science mission been sufficiently defined, and are the planned mitigation strategies appropriate?
5. Is the FMITS project planning effective and at the appropriate level?

A brief summary of the committee's judgments in response to the charge follows. Detailed discussion and recommendations can be found in the charge sections of the committee report.

In summary, the committee's response is that the FMITS design is feasible. All aspects of the engineering challenges appear to have been addressed. In part this judgment is based on the planned tests and mock-ups intended to resolve the remaining technical challenges and mitigate design risks, specifically those categorized as "itemized technical risks." The committee identified issues associated with minimizing the impact of FMITS on the SNS facility and provided recommendations.

The case for the technical success of FMITS to fusion materials science has been made. FMITS would allow the US to develop a scientific understanding of radiation effects in materials for fusion applications at low doses (~10 dpa) with the concurrent production of helium and hydrogen. This data, when coupled with simulations from physics-based models, would develop insight into fusion-relevant radiation effects for three key phenomena (the listed temperatures are relevant for ferritic/martensitic steels):

- Radiation hardening at low temperatures 250-400°C (synergistic H, He, defect effects),
- Void nucleation and growth leading to swelling at 400-500°C, and
- Helium embrittlement effects above 500°C.

This improved understanding of radiation effects under prototypic fusion conditions gained from low-to-intermediate dose data coupled with modeling results:

- Would help to optimize material choices for near-term machines, such as ITER test blanket materials,
- Would provide important scientific information to guide the development of next-generation ferritic steels specifically tailored for the D-T fusion energy environment,
- Would allow one to systematically explore mechanisms to control effects of He such as trapping on nano-scale particles, and
- Would provide a scientific basis for more informed use of IFMIF or other fusion materials irradiation facility options in the future.

All significant safety concerns have been identified and addressed at a level appropriate for this stage of the project. The set of hazards and associated consequences to the public, onsite workers, and environment were adequately considered and appropriate judgments regarding engineering and administrative controls made. For each of the unmitigated events evaluated as part of the gas system and water system hazard evaluations, numerous methods of detection and minor controls for prevention or mitigation of the events were identified.

The committee determined that the operational risk presented by FMITS to the SNS neutron science mission had been sufficiently defined and that planned mitigation strategies were appropriate for this stage of the FMITS effort. The design would have negligible effect on target system thermal-hydraulic and neutronic performance. The design team identified the operational technical challenges (FMITS harness

handling, core vessel seal design, target Imaging system calibration) that remain to be solved and strategies to minimize risk.

The committee found the FMITS project planning effective and at the appropriate level for the pre-CD-1 stage of the design effort. A cost estimate and logic driven schedule were developed from the ~350 project activities associated with the design, fabrication, and installation of FMITS. Derived from the technical scope of work, the overall schedule was reasonable but did not incorporate the resource and facility access constraints of the provisional SNS operating schedule. Similarly, the FMITS cost estimate was reasonable but largely dependent upon successful outcomes resulting from the identified tests and on a funding profile that supported the proposed schedule.

With the FMITS 2014 report and review completed, and the feasibility of FMITS confirmed by the committee, the decision for continuing into the next phase of design and mock-up testing is left to DOE. Specifically, DOE must decide whether FMITS is a viable project at the SNS.

PUBLICATIONS AND REPORTS

1. R. Battle, S. Chae, M. Dayton, J. Denison, V. Graves, T. Lessard, W. Lu, S. Parson, R. Stoller, M. Wendel, SNS Fusion Materials Irradiation Test Station Feasibility Study, SNS-ISDD-NSD-TD-0001-R00, July 1, 2014.
2. D. Freeman and M. Harrington, Preliminary Safety Assessment for FMITS Feasibility Study, SNS-102030102-ES0074-R00, July 1, 2014.