Proceedings of NFSM 2012
SAND2012-0441C
Chicago, I[illegible]
Paper 5623

Sodium Fast Reactor Fuels and Materials: Research Needs

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INTRODUCTION

This paper summarizes the results of an expert opinion elicitation concerning the state of research needed to ensure reliability and regulatory confidence of the potential fuels and structural materials to be used on a generic Sodium Fast Reactor (SFR). The expert panel was chaired by Leon Walters and consisted of representatives from a range of National Laboratories. The panel focused on determining what R&D is required to license a SFR design utilizing the two most mature SFR fuels types: metallic and oxide fuels. Both fuel types have more than 50 years of experimentation and analyses the results of which are captured in voluminous publications and reports[1,2,3].

METHODOLOGY

Expert opinions were elicited on the current state of knowledge for the underlying phenomena affecting SFR fuels and structural materials performance. Experts were asked to rank these phenomena according to the:

- Importance of the phenomena with respect to regulatory and reliability concerns,
- State of the experimental database, and
- State of current, quantitative understanding of the phenomena.

For this work, only non-proprietary and publically available data was used.

RESULTS

A SFR could be designed and licensed today within the envelope of a conservative data base. The boundaries of a conservative data base would be a fuel burnup of 10 at% or less, either metallic or oxide fuel, a peak cladding temperature of 600°C or less, a peak dpa of 100 or less, and with fuel that has not been reprocessed. Both the steady-state and off-normal data base would be sufficient to support such a design. The only qualifications to the above statement are the following: The existing data must be retrievable and in a form, from a QA standpoint, that is acceptable to the licensing body. Fabrication experience for fuel, cladding, and ducts must also be retrieved to provide assurance that the core materials could be replicated such that the existing data base is applicable. It must be appreciated that vendors for these materials for the most part no longer exist. Thus for fresh fuel at moderate burnup two gaps exist:

1. An effort should be made to inventory the existing data base, collect the hard copy information and store it in approved storage locations, and transfer this information to an electronic data base that can be readily queried.
2. Exactly the same effort should be carried out for the fabrication information.

The last variation of 316 stainless steel, that being cold-worked with titanium and other alloy additions, designated as D9, is suitable for both oxide and metallic fuel cladding and ducts up to modest burnup levels and dpa less than 100. Vendors are readily available. The only identified gap was that more information is needed relative to fuel-cladding-chemical-interaction for reprocessed fuel with fission product carry-over, particularly the issue of lanthanide migration to the fuel-cladding interface in metallic fuel[4].

The ferritic/martensitic alloys have the potential to solve the irradiation enhanced swelling issue for both cladding and ducts up to at least 150dpa[5,6]. However, the majority of the high dose data originates from a duct that operated at a relatively low temperature compared to fuel cladding temperatures. Thus the following gap exists for both HT-9 and for the advanced cladding T91 (9Cr1Mo):

1. High dose-high temperature swelling data do not exist for HT-9 or T91. Any data that exist or will be generated will originate from foreign SFRs.
2. Recent attempts to obtain a small heat of HT-9 revealed that there are no vendors readily available to produce reactor grade material.

Several gaps were identified in the discussion of fuel performance codes.

1. Virtually all the gaps were related to the fact that there has been little attention given to fuel performance code development for the last two decades. Most of the code routines are empirically based as opposed to mechanistically based and thus are useful primarily for interpolation when adequately validated with existing data.
2. In addition, relatively few people are adept in exercising the codes with documentation less than adequate for the training of new users.

Two overarching gaps were apparent throughout the gap analysis discussions. These gaps were:

1. The need for a test SFR such as EBR-II or FFTF is required to enhance the existing knowledge base.
2. Uncertainty in the state of the existing knowledge base. Operating information, fuel performance data, and fabrication experience exists in a number of locations. Some exists on electronic media, which may or may not be queried easily, some on hard copy reports that are stored in substandard locations, and some may be lost.

It is extremely important to preserve the existing data base because without EBR-II, FFTF, and TREAT the information cannot be duplicated. Even in the event that such facilities become available in the future, duplication of these irradiations would be expensive and timely.

CONCLUSIONS

The expert panel concluded that an SFR could be designed and licensed based upon the technology base developed from the successful operation of EBR-II and FFTF. However, the design would be constrained within the limitations of the technology base established by those reactors. Additionally, a well-funded knowledge management and preservation program is desperately needed if this capability is to be preserved.

A complete summary of the expert panel findings was compiled as a Sandia SAND report available for unlimited distribution entitled: "Sodium Fast Reactor Fuels and Materials: Research Needs"[7].

ACKNOWLEDGMENTS

This work is a product of a project supported by the US Department of Energy under work package number A-11SN040201. The views presented here are those of the authors and do not necessarily represent the views of the US Department of Energy.

This work was overseen and managed by Jeffrey LaChance (Sandia National Laboratories), who provided guidance on the approach taken, attended the expert elicitation panel meeting, and provided useful input during the report preparation. Recognition is also given to Tyrell Arment (MIT) for his assistance during the expert elicitation process.

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