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Abstract

The Tritium System Test Assembly (TSTA) project at Los Alamos National Laboratory is charged with developing and demonstrating the fusion fuel processing requirement for the magnetic fusion energy program. The key fusion fuel streams are the plasma exhaust and the blanket stream. At present, the technology under development at TSTA includes only the plasma exhaust. The blanket is a logical upgrade to TSTA. This possible upgrade is the subject of an ongoing study among LANL, JAERI, and Argonne National Laboratory (ANL). This program, called The Breeding Blanket Interface (BBI), is being investigated with the intention of installing such a processing system at TSTA in the 1992-1993 time frame. The BBI program was initiated in July 1987. The conditions of the tritium product streams of various blankets were determined. Pre-conceptual designs of the BBI systems were developed for two blanket concepts: Aqueous Lithium Salt Solution Blanket and Solid Breeder Blanket. Preliminary estimates of costing and the schedule of the TSTA/BBI program have been developed. This paper covers the schedule and planning of the TSTA/BBI program. The goal of the program is to establish the engineering data basis of the fuel cycle for an ITER type machine. The operation of the TSTA/BBI hardware is expected to cover the period of 1993 to 1996.

Introduction

The blanket tritium stream is an essential part of the tritium fuel cycle for fusion reactors. More importantly, the blanket part of the fuel cycle must be developed, ready for use, and reliable for the IAEA-sponsored International Thermonuclear Engineering Reactor (ITER). Questions which must be addressed include not only the recovery of bred tritium from the blanket but also how the bred tritium product is to be processed and integrated with the rest of the tritium fuel cycle. The Breeding Blanket Interface (BBI) is that system which performs the necessary processing and recycle of the tritium recovered from a fusion reactor blanket. Although considerable attention has been given to studies of tritium breeding and recovery and also many aspects of tritium processing, very little work has been done on the BBI. Therefore, a study was initiated to define the necessary components of this BBI system and to plan for testing such an integrated system of components.

The Tritium Systems Test Assembly (TSTA) at Los Alamos has as its charter the development and testing of the tritium systems for fusion reactors. The TSTA facility is fully integrated and it has the highest tritium throughput of any tritium facility in the world, about one Kg per day. This throughput is the same order of magnitude as ITER, depending on the plasma burn fraction of ITER. The TSTA is the only facility of such a

scale capable of performing both steady-state and transient tests on an integrated system. At present the TSTA includes the major fuel cycle components and tritium processing components except for the BBI. Addition of the BBI is a logical upgrade to the TSTA. This possible upgrade is the subject of an ongoing study, which began July 1987, involving Los Alamos National Laboratory (LANL), the Japan Atomic Energy Research Institute (JAERI), and Argonne National Laboratory (ANL). Presented herein is an overview of the status and plans for the BBI program.

Objectives

The overall objective of the BBI program is to develop the technology for the blanket part of the fusion fuel cycle. The goal is to design, develop, and test the BBI as an integral system. The operation of BBI with TSTA will establish the mutual interaction of two fuel cycle components, in particular for the transient conditions. A specific emphasis is to support the ITER fusion reactor design. Pursuit of the stated goal is expected to support ITER activities in various ways:

1. Design of the BBI provides more complete definition of the components of the ITER tritium systems.
2. Evaluation of the BBI systems affects blanket design, and possibly even blanket selection for ITER.
3. Evaluation of the design trade-offs (e.g., fuel processing vs. tritium recovery) provided the basis for optimization of tradeoffs for all blanket systems. For example, for a solid breeder blanket, BBI systems will be simpler and less expensive as the He purge flow and the amount of hydrogen (H_2) in the purge decreases. These benefits to BBI must be balanced against blanket tritium inventory requirements. Design of BBI systems and conceptual evaluation of the trade-offs sets up a framework for optimizing overall blanket system performance.
4. Operation of the BBI will provide the necessary engineering data for ITER. The data will provide a quantitative basis for optimizing the trade-offs discussed above.
5. The experience of operating the BBI will likely lead to design changes and/or modifications in order to assure required levels of reliability and performance.

Approach

The program, begun in July 1987, includes five phases which are:

- Phase 1 - The Concept Phase
- Phase 2 - Pre-Conceptual Design Phase
- Phase 3 - Engineering Design
- Phase 4 - Hardware and Construction
- Phase 5 - Operation of the BBI at TSTA

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The purpose of Phase 1 is to define the tritium product streams for various blankets, so that design of the BBI itself in subsequent phases can proceed. As part of the Phase 1 studies, a certain amount of investigation of the blanket itself was performed, in order to specify the blanket system in sufficient detail to proceed. For example, if several tritium recovery methods are possible, the options were compared and one method was selected.

Phase 2 involves pre-conceptual design of the BBI, including definition of components, cost estimates, and a schedule. Phase 2 work has been completed for a baseline option, however the limitations of current funding require that the funding level of TSTA/BBI be kept at the current TSTA level. Current efforts are seeking to identify the best minimum-cost option. Upon completion of Phase 2, subsequent Phases 3-5 are planned.

In terms of operation and function, the BBI, as described above applies equally well to Inertial Confinement Fusion (ICF) or to Magnetic Confinement Fusion (MCF) concepts. Specific details (composition, etc.) for both the blanket tritium systems will be different, but the overall kinds of processing methods will be quite similar.

Phase 1 Results

Phase 1, the Concept Phase, involved determining the conditions of the product tritium output streams for various blankets. Blankets investigated (Table 1) included most of the major blanket types (liquid metal, solid breeder, aqueous salt solution). The conditions determined included: temperature, flow rate, chemical composition, and concentrations of impurities and radionuclides. As a part of Phase 1, a methodology was developed to systematically evaluate impurity source terms and to follow the transport of impurities and radionuclides through the paths of the system to the blanket output stream. We performed such Phase 1 analysis for three blankets: liquid lithium [1-3], aqueous salt solution [4,5], and solid breeder [5,6]. Useful data to support our studies of the Aqueous Salt Solution Blanket was kindly provided by Dr. Otto Kveton of the Canadian Fusion Fuels Technology Program (CFFTP). In addition to our Phase 1 studies, a study of the BBI for a liquid Li-Pb blanket was performed [7]. The results of our Phase 1 studies were found to be quite useful for the US-ITER designs. For the solid breeder blanket, a very detailed study of probable impurity levels was performed [6] -- this data was directly used to calculate blanket activation and afterheat in the blanket [8]. For the Aqueous Salt Solution Blanket, our studies uncovered and/or quantified a number of problems such as radiolysis, electrolysis, and corrosion [4,5]. As a result of our studies, the US-ITER blanket design was changed [9].

Table 1. Blankets Investigated

Blanket Name	Coolant	Tritium Recovery Method
Liquid Lithium	Lithium	Molten Salt Extraction
Aqueous Lithium Salt Solution	Salt Solution	Water Distillation + Vapor Phase Catalytic Exchange
Solid Breeder Li_2O	Water	He Purge
Lithium-Lead	Li-Pb	Permeation Window

The results of Phase 1 were detailed descriptions of the conditions of the tritium product streams for each blanket. These results were a necessary starting point to perform Phase 2, design of the BBI.

Phase 2 Results

Phase 2, pre-conceptual design of the BBI itself, was performed for two of the blankets: Aqueous Salt Solution Blanket and Solid Breeder Blanket. A companion paper [5] presents a bit more technical details. Major results are summarized herein. It is to be noted that a key safety concern that arose hydrogen inventory and associated issues. The optimum fusion blanket system will have to minimize hydrogen inventory as well as tritium inventory. Flow diagrams were developed for each concept as illustrated in Fig. 1 and Fig. 2. For each component in each flow diagram, the function and the recommended process to fulfill the function were identified. Each component was evaluated and its parameters and required performance determined. Then cost estimates for each of the components as well as a total BBI system at TSTA were prepared. The reference scenario assumed a BBI that included the necessary functions for each of the two blankets as an integral part of the TSTA. For the reference scenario, program schedule and costs were developed, as shown in Tables 2 and 3. Owing to the current budgetary situation, funds are not available to pursue the reference scenario. Therefore, current efforts are looking at various options, to identify the best choice at minimum cost.

Current Studies

The work planned for the coming fiscal year is to evaluate minimum-cost options. Various methods of reducing the cost are being evaluated. These methods under consideration include:

1. Concentrate the BBI effort on the solid breeder blanket (Li_2O).
2. Evaluate testing scenarios in an effort to minimize the TSTA/BBI budget while maintaining the stated programmatic goals.
3. Evaluate reducing the scope of the testing and/or the possible range of experimental variables.
4. Selection (with input from ANL, LANL, and JAERI) of the most attractive option and definition of the experimental program for this option.

Summary

The addition of BBI to TSTA is a logical step, and the benefit to the fusion program is significant in a number of ways:

1. The BBI is an essential part of the fusion reactor tritium fuel cycle.
2. The BBI study is equally applicable to Inertial Confinement Fusion (ICF) or Magnetic Confinement Fusion (MCF).
3. The BBI program supports ITER in both design and operating phases of the work.
4. Many technical issues associated tritium inventory, system reliability, and safety will be addressed in both during the design phase and the operating phase.
5. The BBI program is international in scope.

References

1. R.G. Clemmer, P.A. Finn, L.R. Greenwood, T.L. Grimm, D.K. Sze, J.R. Bartlit, J.L. Anderson, H. Yoshida, and Y. Naruse, "The Requirements for Processing Tritium Recovered from Liquid Lithium Blankets: The Blanket Interface," Argonne National Laboratory Report ANL/FPP/TM-216 [formerly ANL-87-59] (March 1988).
2. R.G. Clemmer, T.L. Grimm, P.A. Finn, D.K. Sze, L.R. Greenwood, J.R. Bartlit, J.L. Anderson, H. Yoshida, and Y. Naruse, "The Blanket Interface to TSTA: The Requirements for Liquid Lithium Blanket Processing," Third Topical Meeting on Tritium Technology in Fission, Fusion, and Isotopic Applications, May 1-6, 1988, Toronto, Ontario, Canada.
3. D.K. Sze, P.A. Finn, R.G. Clemmer, J.L. Anderson, J.R. Bartlit, Y. Naruse, and H. Yoshida, "The Role of a Blanket Tritium System on the Fusion Fuel Cycle," International Symposium on Fusion Nuclear Technology (ISFNT), April 10-15, 1988, Tokyo, Japan, Fusion Engineering and Design 10 (1989) 203-207.
4. P.A. Finn et al., "The Blanket Interface to TSTA: REquirements for an Aqueous Lithium Salt Blanket, 8th Topical meeting on the Technology of Fusion Energy, Salt Lake City, UT, October 8-13, 1988.
5. R.G. Clemmer, P.A. Finn, L.R. Greenwood, D.K. Sze, J.R. Bartlit, R. Sherman, J.L. Anderson, H. Yoshida, Y. Naruse, K. Okuno, and M. Enoeda, "The Breeding Blanket Interface (BBI): Recent Results for the Solid Breeder and Aqueous Salt Solution Blanket Concepts," 13th Symposium on Fusion Engineering, Knoxville, TN, October 2-6, 1989.
6. R.G. Clemmer et. al., "The Breeding Blanket Interface for a Solid Breeder Blanket Concept," Argonne National Laboratory Report ANL/FPP/TM-232, to be published.
7. J. Reimann S. Malang, and H.U. Borgstedt, "Requirements for Tritium Processing Recovered from a Self-Cooled Pb-17Li Blanket," Kernforschungszentrum Karlsruhe Report IRB-546188, August 1988.
8. Y. Gohar, "Solid Breeder Blanket Option for the ITER Conceptual Design," 13th Symposium on Fusion Engineering, Knoxville, TN, October 2-6, 1989.
9. M.E. Sawaan, "An Aqueous Lithium Salt Blanket for ITER," 13th Symposium on Fusion Engineering, Knoxville, TN, October 2-6, 1989.