Tokamak Reactor Systems Studies

Progress Report for the Period
November 1, 1991 to October 31, 1992

Fusion Technology Institute
University of Wisconsin-Madison

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1 Introduction

Fusion Technology Institute personnel actively participated in the ARIES project during the present contract period. Numerous presentations were made at ARIES project meetings, several papers were published [1, 2, 3, 4, 5, 6], and a very large number of electronic-mail and regular-mail communications were sent. The participation of Fusion Technology Institute engineers and scientists in ARIES meetings is shown in Fig. 1 and a list of presentations is given in Table 1. The remaining sections of this progress report will detail the work accomplished for the ARIES project during the contract period, November 1, 1991 to October 31, 1992. The main areas of effort were

- ARIES-II and ARIES-IV
 1. Neutronics
 2. Shield Optimization and Design
 3. Safety
 4. Systems
 5. Startup and Shutdown
 6. Ripple Loss
- ARIES-III
 7. Contributions to Final Report

Figure 1: *University of Wisconsin participation in ARIES project meetings.*

Table 1: *University of Wisconsin Fusion Technology Institute presentations at ARIES project meetings.*

MEETING	AUTHORS	TITLE
December 3-6, 1991	El-Guebaly	Neutronics Analysis for ARIES-II and ARIES-IV Designs
February 24-26, 1992	El-Guebaly Khater	Shielding and Activation Analysis for ARIES-II and ARIES-IV
April 27-29, 1992	El-Guebaly	Tritium Breeding and Shielding Issues
June 8, 1992 (ANS Topical)	El-Guebaly	Blanket and Shield Issues
June 30-July 1, 1992	El-Guebaly	Shielding Issues and Blanket Neutronics

2 Summary of Tasks Accomplished During FY92

2.1 Neutronics

The extensive, comprehensive calculations necessary for a credible design were performed for both ARIES-II and ARIES-IV in the following areas:

1. First wall and blanket neutronics

- (a) Radiation damage
- (b) Nuclear heating
- (c) Tritium breeding ratio

2. Activation analysis

- (a) First wall
- (b) Vanadium blanket
- (c) Shields

First wall, blanket, and shield neutronics We calculated nuclear heating, radiation damage, and tritium breeding for both the ARIES-II and the ARIES-IV designs. The nuclear heating was necessary to perform the power cycle thermal hydraulics analysis. Radiation

damage calculations for V, SiC, Be, and C/C-composite stabilizing shell candidates were done to assess the blanket lifetimes. Tritium breeding requirements were accurately evaluated in order to assure that the blanket would provide sufficient tritium to support the fuel cycle. A key conclusion was that it does not appear possible to get net tritium breeding from a solid-breeder blanket without including beryllium in the design. On the other hand, the Li blanket can breed without the need for a neutron multiplier.

Activation analysis The activation of the first wall, blanket, and shield was calculated for the ARIES-II design in order to provide input to the safety and environmental analysis. The activity, biological hazard potential (BHP), decay heat, waste disposal rating (WDR) and dose after shutdown were computed in detail. Contributions were also made to the analysis of the possibility of recycling the vanadium in ARIES-II.

2.2 Shield Optimization and Design

For both the ARIES-II and the ARIES-IV designs, we performed a complete optimization and design of the magnet shields, including evaluation of candidate materials, variation of composition, and computation of radiation effects on the magnets. A key contribution for ARIES-II was the idea that the shield should be split into two parts, with the boundary at the damage level where the outer part would be a full-lifetime component of the reactor. This idea saved considerable cost for the reactor. Shielding requirements around penetrations, such as those of RF antennas and divertors, were also assessed. Parameters for metallic (SS) and SiC/SiC-composite shields were scoped out. Corresponding algorithms for shield thickness were given to the ARIES systems code group. Optimizing the shield was an ongoing effort throughout the course of the ARIES-II and ARIES-IV designs.

2.3 Safety

Fusion Technology Institute personnel have been heavily involved in the analysis of ARIES-II and ARIES-IV safety, which is a critical fusion reactor issue. Activities included providing background information and detailed safety analyses. Analysis of activation, waste disposal ratings, afterheat, LOCA, and other safety issues were investigated. A key contribution was the recognition that the highest radioactivity levels may occur before the end-of-life fluence is reached, due to isotopes with short and intermediate half-lives. Thus, the worst-case accident may cause a higher release of radioactivity than the value calculated from end-of-life fluences.

2.4 Systems

University of Wisconsin personnel were active during this contract period in helping benchmark and correct the ARIES systems code (ASC). Contributions included providing information related to radial builds for ARIES-II and ARIES-IV, the blanket lifetime, and other first wall, blanket, and shield areas; performing detailed checking and commenting on the ARIES systems code (ASC) strawmen; and commenting on the ARIES-III Systems chapter.

2.5 Startup and Shutdown

Both startup and shutdown scenarios were defined for the ARIES-II and ARIES-IV tokamak designs. This included generating POPCON plots for the time-dependent profiles of density, temperature, and current required to reach the plasma parameters of the steady-state operating point.

2.6 Fusion Product Ripple Loss

In a second-stability tokamak, ripple loss of fusion products is expected to lead to more stringent constraints than in a first-stability tokamak, due to the high rotational transform in the second-stability regime. Fusion Technology Institute personnel pointed out that ripple loss in ARIES-II and ARIES-IV would potentially be a problem, and contributed to the assessment of its effects.

2.7 Contributions to ARIES-III Final Report

The ARIES-III Final Report will be published in late 1992 or early 1993 and, although most of the Fusion Technology Institute contributions were finished in FY91, some effort was required to finish a few sections and to read and comment upon other draft chapters for the final report. Final editing and proofreading of Fusion Technology Institute sections will have to be done when the sections are returned from the present editing stage. The sections with Fusion Technology Institute contributions are listed in Table 2.

*preprints reviewed.
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Table 2: *University of Wisconsin Fusion Technology Institute contributions to the ARIES-III Final Report.*

AUTHORS	TITLE
<i>Chp. 1: Overview</i>	
Santarius	Sec. 1.3.1: Operating Regime
Wittenberg	Sec. 1.3.14: Fuel Supplies
Santarius	<i>Chp. 2: Comparison of First and Second Stability Regimes for D-³He Tokamaks</i>
<i>Chp. 5: Second Stability Transport</i>	
Santarius	Sec. 5.4: Ripple Loss of Fusion Charged Products
<i>Chp. 8: Plasma Startup Operations</i>	
Emmert	Sec. 8.2.1: Plasma Kinetics and Power Balance (D- ³ He)
Emmert	Sec. 8.3.1: Plasma Kinetics and Power Balance (D-T)
Sawan	Sec. 8.3.2: Neutron Energy Limit
<i>Chp. 12: First Wall, Shield, and Power Conversion</i>	
Blanchard	Sec. 12.2.2: Structure Material
Sviatoslavsky	Sec. 12.5.1: Flow Configuration
Sviatoslavsky	Sec. 12.5.2: First Wall Design and Fabrication
El-Guebaly	Sec. 12.6: Magnet Shielding
Sawan	Sec. 12.7: Neutronics Analysis
Khater	Sec. 12.8: Activation Analysis
Mogahed	Sec. 12.10.3: Thermal Analysis
Blanchard	Sec. 12.10.4: Stress Analysis
Santarius	Sec. 12.11.1: Advanced Power Conversion Options
<i>Chp. 13: Safety</i>	
Sawan, Khater	Sec. 13.2: Activation Analysis
Khater	Sec. 13.4: Waste Disposal
Wittenberg	<i>Chp. 15: ³He Fuel Supply</i>

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