CHAPTER 2: INTRODUCTION

2. INTRODUCTION

The APEX study was launched in early 1998 as part of the US Fusion Energy Sciences program initiative to encourage innovation and scientific understanding. APEX focuses on innovative concepts and the underlying engineering sciences for the Chamber Technology, i.e. those components in the immediate exterior of the plasma (e.g. first wall, blanket, divertor, and vacuum vessel). Chamber Technology has a tremendous impact on the economics and the safety and environmental attractiveness of fusion energy systems.

The primary objective of APEX is to identify and explore novel, possibly revolutionary, concepts for the Chamber Technology that can substantially improve the attractiveness of fusion energy systems. A key feature of the APEX study is providing a research environment conducive to innovation. There is also emphasis on understanding and advancing the underlying sciences as a prerequisite for innovation. The study covers conceptual design, modelling, and experiments for new and revolutionary ideas for the Chamber Technology.

The APEX study is being carried out by a multi-disciplinary, multi-institution integrated team. The team members are drawn from twelve US institutions that include universities, national laboratories, and industry as shown in Table 2.1. In addition, there is significant international participation by scientists from Germany, Japan, and Russia.

The composition of the APEX team and the study approach emphasize partnership between plasma physics and technology and strong interactions among the key technical areas and functional disciplines such as thermofluids, thermomechanics, magnetohydrodynamics, materials, plasma-material interactions, system studies, and safety.

This “Interim Report” documents the technical results obtained from APEX for the period January 1998 to July 1999. In the very early part of the APEX study, some effort was devoted to understanding the limitations of traditional first wall/blanket concepts. This effort aided the team in the search for novel ideas that could overcome these limitations. This part of the APEX effort has already been published (see reference 1) and will not be repeated in this Interim Report. Rather, the report focuses on the new innovative concepts that were explored in the first eighteen months of the study.

A number of promising ideas for new innovative concepts have already emerged from the first phase of the APEX study. While these ideas need extensive research before they can be formulated into mature design concepts, some of them offer great promise for fundamental improvements in the vision for an attractive fusion energy system.

These ideas fall into two categories. The first category seeks to totally eliminate the solid “bare” first wall. The most promising idea in this category is a flowing liquid wall concept. The liquid wall idea is “concept rich”. These concepts vary from “liquid first wall", where a thin layer (< 2 cm) of liquid is flown on the plasma-side of the first wall, to "thick liquid wall", where an all-flowing thick (> 40 cm) liquid serves as liquid wall/liquid blanket. Other variations in the liquid wall concepts include the type of "restraining force" utilized to "control" the movement and geometry of the liquid. Candidate liquids range from high conductivity, low Prandtl number liquid metals to low conductivity, high Prandtl number liquids such as the molten salt flibe. While all concepts in the liquid wall category share some common advantages and issues, each concept has its own unique set of incentives and issues.

The second category of ideas focuses on extending the capabilities, particularly the power density and temperature limits, of solid first walls. A promising example is the use of high temperature refractory alloys (e.g. tungsten) in the first wall together with an innovative heat transfer and heat transport scheme based on vaporization of lithium.

This report is organized as follows. Chapters 3 and 4 summarize the study approach and evaluation criteria. Chapters 5, 6, and 7 explore a number of ideas for liquid wall concepts and are dominated by the thermofluid scientific foundations for liquid walls as well as the integrated technical considerations in formulating the liquid walls into conceptual designs. Chapter 8 deals with the property data base available for liquid breeders/coolants. Chapters 12 and 15 cover the critical topic of the plasma-liquid interactions. Chapter 12 addresses the plasma-liquid "surface" interactions, plasma-edge modelling, and limitations on liquid wall surface operating temperature. Chapter 15 explores potentially very beneficial synergy between liquid walls, plasma physics performance, and reactor attractiveness.

Chapter 9 explores a concept that eliminates the solid structural first wall and utilizes gravitational flowing Li_2O particulates. Chapters 10 and 11 explore two concepts that extend the power density and operating temperature capabilities of a solid first wall by using a high temperature refractory alloy coupled with innovative cooling schemes.

Chapters 13, 14, 16, and 17 address key considerations of materials, safety, tritium, and power conversion for all concepts.

Most chapters define the key technical issues and required R&D in their respective areas. All these R&D issues are assembled in Chapter 18 for the reader's convenience. Beyond this interim report, the next stage of APEX will focus on two classes of concepts: 1) liquid walls with its many variations, and 2) a high-temperature refractory alloy (tungsten) with two-phase lithium flow. The exploration of these two classes of concepts will involve substantial modelling, experiments, and analysis efforts. These efforts will develop the scientific understanding and predictive capabilities necessary to assess, advance, and evaluate these concepts.

References

1. Mohamed A. Abdou, The APEX Team, "Exploring Novel High Power Density Concepts for Attractive Fusion Systems", Fusion Engineering and Design, Vol. 45 (1999), pp. 145-167

Table 2.1: APEX Team

US Organizations

- University of California-Los Angeles
- Princeton Plasma Physics Laboratory
- Sandia National Laboratory
- Argonne National Laboratory
- Oak Ridge National Laboratory
- University of Wisconsin
- Lawrence Livermore National Laboratory
- General Atomics
- Idaho National Engineering Laboratory
- University of Texas
- University of California-San Diego
- Los Alamos National Laboratory

International Participants

- Two scientists from FZK, Germany
- Three professors from Japanese Universities
- One scientist from Russia