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ENGINEERING CONSIDERATIONS IN THE SELECTION OF THE TOKAMAK TO FOLLOW THE TOKAMAK FUSION TEST REACTOR (TFTR)*

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T. E. Shannon
Oak Ridge National Laboratory
Fusion Engineering Design Center
P.O. Box Y
Oak Ridge, TN 37831

Abstract: The tokamak to follow the Tokamak Fusion Test Reactor (TFTR) should satisfy two important objectives. First, it should be a significant step in physics and engineering goals in order to maintain the level of progress which the U.S. has established as the world leader in fusion energy development. The second objective should be to provide the information necessary to support the strategy and goals of the long-range Department of Energy (DOE) Fusion Program. In their Comprehensive Program Management Plan [1], the DOE identifies the need for a reactor technology program in the 1990s in which the major goal is to prove engineering feasibility. In this paper, the specific engineering needs are identified which have been developed through the tokamak design studies over the past decade. On the basis of these needs, it appears that several options are available for the next tokamak to follow TFTR. The final choice of the concept will involve consideration of the technical needs and the reality of the Fusion Program budget.

Introduction

Since the start of the TFTR Project in 1974, the Fusion Program has been searching for the definition of the "Next Step." Five different candidate options, ranging from an Experimental Power Reactor (EPR) to a Tokamak Fusion Core Experiment (TFCX), have been studied with an expenditure of more than 500 man-years. Almost a decade has passed, the TFTR is in operation, and the program has yet to commit to a new major construction project. Although excessive cost and technical uncertainty have been causes for rejection of the proposed options, a lack of general endorsement by the Fusion Community has been the predominant problem.

The EPR (1974-76) [2], [3], [4] was obviously an overly ambitious step to be proposed in 1975. These studies, however, were most useful in providing insight into the major engineering problems which existed at that time. The EPR designs provide a good reference to measure the progress that has been made. The tokamak concept has progressed from the rather impractical EPR design to a concept which now looks quite promising for possible power reactor applications.

The Next Step (TNS) series of studies (1977-78) [5], [6], [7] produced an innovative set of options, but there was major disagreement and lack of consensus among the tokamak labs over the definition of the concept. The Next Step studies were consolidated with the formation of the Fusion Engineering Design Center (FEDC) in 1979. The first concept proposed was an Engineering Test Facility (ETF) [8] with the idea that the program would focus on the construction of a facility and thereby take the emphasis off the device itself. This concept was relatively short-lived and was not endorsed by the scientific advisors to the Fusion Program. It was too early for engineering testing as the focus for the program.

The passage of the Fusion Engineering Act of 1980 [9] opened the door for the construction of a Fusion Engineering Device (FED) [10] and the formation of a Center for Magnetic Fusion Engineering. Unfortunately, the program was unable to define a project to simultaneously meet the performance and cost guidelines outlined in the Act, and, once again, the Program searched for a better option.

In an attempt to satisfy the recent federal budget limitations, the DOE has proposed a long-range program assuming no near-term budget increases. This plan identifies the next step as an Engineering Test Reactor (ETR) which would be constructed — starting in the late 1980s. This concept has not been favorably received by most members of the Fusion Community because of the concern over the delay in starting the next major program for another 4 to 5 years.

The most recent proposal, a concept called the Tokamak Fusion Core Experiment (TFCX) [11], has evolved through deliberations of a panel of the Magnetic Fusion Advisory Committee (MFAC). The basic concept has been endorsed by the full Committee [12]. The Princeton Plasma Physics Laboratory (PPPL) is leading a national effort to define the specific concept and to perform the conceptual design. Whether or not the TFCX will finally advance to a construction project will be determined on the basis of both technical and political considerations over the next several years.

Engineering issues have been the primary cause for disagreement and hence the lack of general endorsement of an option for the next step. In the following sections, the major engineering issues will be discussed. For this discussion, it is assumed that the next tokamak will be designed to operate with D-T. This does not rule out the possible need for additional, smaller-scale tokamak experiments for physics and technology development. It is assumed that experiments of this type will be carried out in parallel with the major tokamak project.

Engineering Issues

The discussion is organized around three comprehensive issues: 1) ignition and burn, 2) magnet technology, and 3) engineering development and testing. When factored into a tokamak design, the issues result in three classes of machines, each representing an incremental step when taken in the order given above. The three classes are compared on the basis of plasma size in Fig. 1. The TFTR and a commercial power reactor plasma (Starfire) are shown to illustrate the total range of development required.

The major parameters of the TFTR are given for reference in Table 1.

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Ignition and Burn

Ignition and long-pulse operation are the most desirable advancements for the next tokamak project. In order to understand the operations and control

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