CONF-850610--11-Summ.

DE85 006216

Summary of invited paper to be presented at the 1985 American Nuclear Society Annual Meeting, June 9-14, 1985, Boston, MA

STARFIRE-II STUDIES*

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The U.S. Department of Energy's Office of Fusion Energy has initiated several studies during FY-1985 called Tokamak Power System Studies (TPSS). The TPSS is being carried out by several laboratories, universities and industry with the general objective of developing innovative physics and technology concepts to improve the commercial attractiveness of tokamak power reactors. The effort of Argonne National Laboratory, entitled STARFIRE-II, i an effort to update and improve STARFIRE,(1) which was the last comprehensive conceptual design study in the U.S. of a commercial tokamak power plant.

The STARFIRE-II effort has developed a number of goals in order to improve fusion commercial power plants based in part on several recent studies.(2-6) The primary goals for STARFIRE-II include the following:

- Reduced output per tokamak reactor. The target value is 400 MW(e) compared to STARFIRE's value of 1200 MW(e). It is anticipated tha two to four reactors would be located at each plant site, thus sharing support facilities and balance-of-plant equipment.
- Reduced reactor mass per output power. The relevant figure-of-merit is the mass utilization factor where the mass includes the blanket, shielding, magnets and torus structure.(4-5) The target value for STARFIRE-II is $\lesssim$ 10 tonnes/MW(e), which represents a factor of 2-3 improvement over STARFIRE.

* Work supported by the U.S. Department of Energy.

- Emphasis on maintaining fusion's inherent safety features. The goal is to continue to identify passive means for rapid plasma shutdown and first wall/blanket cooling so that no operator-initiated action is required. In practice this may require limiting the first wall neutron load to $\lesssim 5\ MW/m^2$.(6)
- Steady-state operating mode. Steady-state operation provides a number of cost advantages and design simplifications.(1-3)
- Design simplification. There are a number of design simplification ideas which need to be considered such as reduced magnetic fields and plasma currents, combined plasma current drive and heating systems, reduced vacuum pumping and shielding requirements, simplified blanket designs, etc.
- Overall plant efficiency. The goal is to achieve a net plant electrical output which is at least 25% of the total thermal power. Major issues include improved plasma current drive concepts (by improved current drive efficiency and/or reduced plasma current) and improved blanket power conversion systems by increased blanket energy multiplication and/or more advanced power conversion concepts.
- Minimize on-site fabrication/construction. The goal is to be able to factory produce and ship all components of the tokamak.

It is recognized that these various goals may not all be achievable and may in part be in conflict with each other. Nevertheless, they do form useful yardsticks by which we can measure the progress of the TPSS studies.

In order to support these objectives, the STARFIRE-II effort at ANL selected five major areas of study during FY-1985 which included:

- achieving higher β ($\gtrsim$ 25%),
- steady-state current drive,
- impurity control,
- blanket concepts, and
- tritium containment/processing.

The studies of higher β have concentrated on applying ideas of the so-called "second stability regime."[7] Design implications include optimizing at lower magnetic fields and higher aspect ratios as well as using rf current drive methods to achieve the necessary control of plasma current profiles. It has also been necessary to reassess confinement at the reduced sizes and plasma currents compared to STARFIRE.

The studies of current drive have emphasized the application of fast waves (or high phase speed magnetosonic waves) and the relationships between high β plasma configurations and steady-state current drive.

The impurity control studies have emphasized innovative design solutions to key problems including the application of "self-pumping" limiters,[8] the use of advanced materials which produce self-sustaining low-Z surfaces,[9] and the development of designs using non-water coolants.

The blanket design and tritium control tasks followed in the footsteps of the Blanket Comparison and Selection Study (BCSS).[10] The BCSS resulted in a high rating for liquid metal (particularly lithium) cooled blankets employing a vanadium alloy structure. The liquid metal blanket effort in STARFIRE-II concentrated on improved/simplified designs making use of lower magnetic fields (due to higher β), reduced neutron fluxes (due to decreased reactor output power) and the use of insulators in the blanket ducts to reduce MHD-generated pressures.

The tritium tasks have concentrated on how to control the HT/HTO release fraction of solid breeders, improved understanding of permeation-related issues such as the factors that control the oxidation rate of reduced tritium, and the development of tritium processsing concepts.

Based on the work carried out so far, the following reactor parameters have been used as a range of "typical" values:

Reactor thermal power	1200 - 1500 MW
Fusion power	900 - 1200 MW
Net electrical power	~ 400 MW
Major radius	~ 6 m
Aspect ratio	5 - 6
Neutron wall load	2.5 - 3.0 MW/m^2
Maximum field at TF coil	6 - 7 T
Plasma average beta	~ 25%

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