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THE COMPACT IGNITION TOKAMAK PROJECT OVERVIEW*

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Summary

As the next major step in the U.S. fusion program, the Compact Ignition Tokamak (CIT) Project has the objective of reaching ignition in order to address the scientific issues associated with ignited plasma regimes. The present level of uncertainty in plasma confinement scaling requires that the CIT have a high design margin to ensure ignition. The need for adequate margin, coupled with declining budgets in the U.S. fusion program, requires both conservatism and flexibility in the development of the design and operating parameters for the device. To accomplish this, the design includes the provision for an upgrade in performance, which will be partially built into the initial machine installation at Princeton Plasma Physics Laboratory (PPPL).

Design Strategy

In the last decade, several proposals (Coppi,[1] Conn et al.,[2] and, more recently, Schmidt et al.[3]) have advocated small, compact, high-field copper magnet tokamaks as a means of obtaining sufficient confinement for ignition in a relatively low-cost machine design. PPPL has developed a conceptual design of the CIT,[4] which, when coupled with existing facilities at Princeton and other existing equipment in the fusion program, can be built at a fraction of the cost of more conventional larger machines, which rely more on plasma size for ignition.

The difficulty with the compact machines is in the thermal and structural design problems that result from the high-field operation. Magnetic field in the toroidal field (TF) coils of a tokamak results in an outward loading similar to that of a pressure vessel. The equivalent pressure loading vs magnetic field is shown in Fig. 1. The figure also shows, for purposes of comparison with CIT, the magnetic field values for two currently operating large tokamaks, the Tokamak Fusion Test Reactor (TFTR) and the Joint European Torus (JET). Note that the pressure level for the CIT is at least three times that of existing large tokamaks designed to operate with deuterium-tritium (D-T) fuel. Thermal loading on the first wall and divertor plates is likewise strongly influenced by the magnetic field. Figure 2 shows the plasma power density vs magnetic field for the CIT design assumptions. Note that the CIT value is more than three times that of power reactor designs such as the International Tokamak Reactor (INTOR) and Starfire. The CIT design is thus very much driven by thermal and structural engineering design requirements.

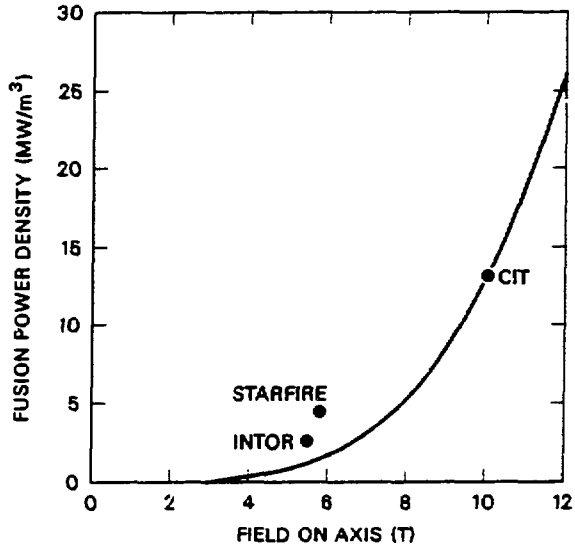

Fig. 2. Fusion power density vs field on axis.

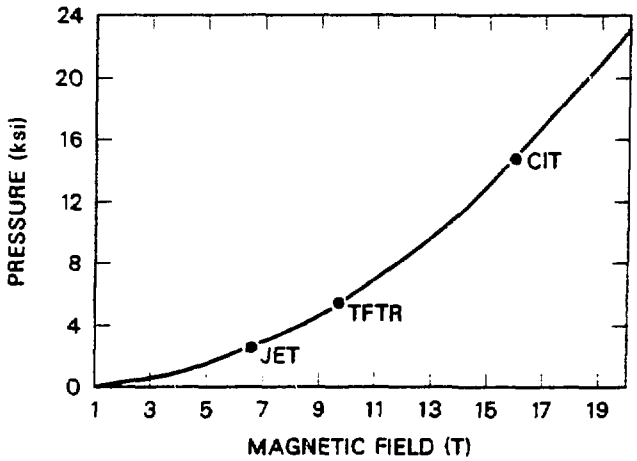

Fig. 1. Magnetic field vs pressure.

The physics/operating requirements have been selected to ensure ignition. In the past year, the major radius described in the CIT Conceptual Design Report[4] has grown by about 0.5 m (from 1.22 to 1.75 m). The bar chart in Fig. 3 shows the individual changes that have occurred, resulting in the total growth. The plasma configuration has been optimized for ignition in a compact size to include all of the goodness factors indicated by recent tokamak confinement experiments.[5] The plasma features high field and high current in a highly elongated cross section with a double null poloidal divertor.

In the event that the CIT fails to achieve the necessary confinement for ignition, even under the rather conservative assumptions used in the present design, the project is providing the capability for a machine upgrade. A preload structure now being designed can be installed at a later date to allow a 20% increase in the magnetic field. Additional machine and facility modifications such as additional power supplies will also be required.

Design Description

Selected machine parameters are shown in Table 1. The initial operating values are consistent with the project funding level; the upgrade values are for increased performance, if required later, by means of increased magnetic field.

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