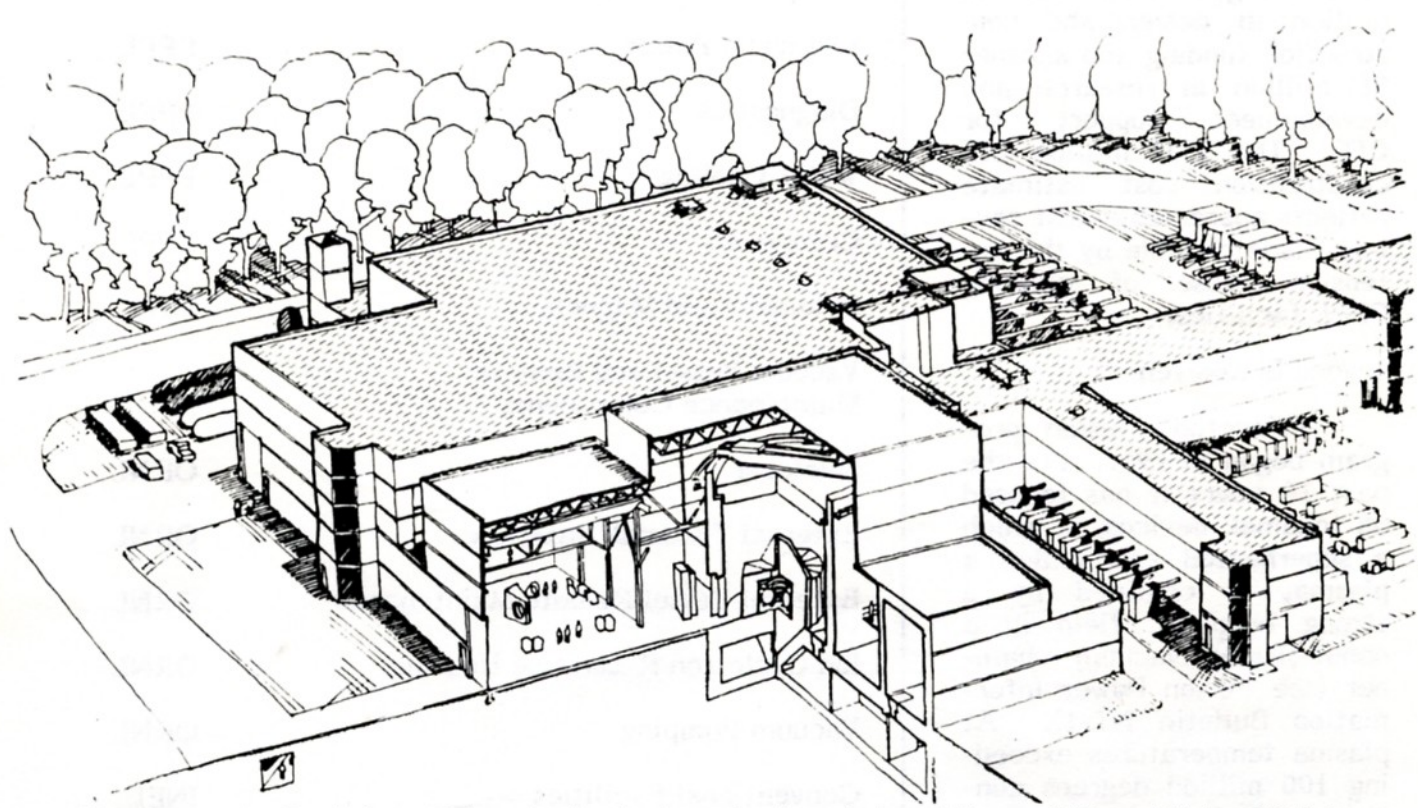
PPPL
PRINCETON PLASMA PHYSICS LABORATORY
HOTLINE
SPECIAL EDITION MAY 1987

PRESIDENT PROPOSES CIT AT PRINCETON



The Compact Ignition Tokamak is being designed to fit readily within PPPL's existing TFTR facility, resulting in substantial cost savings in power supplies, computers and other support systems.

President Reagan's 1988 budget, which was submitted to Congress on January 5, proposes initial funding for the design and construction of a Compact Ignition Tokamak (CIT) at the Princeton Plasma Physics Laboratory (PPPL). In June, 1986, a national design team, led by PPPL, proposed that the $357 million CIT device should be the next step in the development of magnetic fusion energy as an inexhaustible, safe and environmentally acceptable means of generating electricity. This project, if approved by Congress, and funded according to the proposed schedule, would begin operation in 1993.

"We are encouraged by the strong leadership of Secretary Herrington and the Department of Energy in moving forward with this important CIT project" noted Princeton University President William Bowen, "and we are very pleased that Princeton will be the site of the new device. We appreciate the excellent work of the CIT national design team, and we look forward to working together to bring the CIT into operation as soon as possible."

In addition to PPPL, the CIT national design team includes scientists and engi-

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neers from Massachusetts Institute of Technology, Oak Ridge National Laboratory, Los Alamos National Laboratory, Idaho National Engineering Laboratory, and Lawrence Livermore National Laboratory.

The Administration's 1988 budget calls for $8 million in design and construction funding and another $8 million in research and development support for CIT. The $357 million CIT construction cost estimate reflects appreciable cost savings made possible by the extensive reuse of existing PPPL facilities.

FUSION LABORATORY RESPONSIBILITY
FOR CIT ELEMENTS

CIT Element	Responsible Laboratory
Management	PPPL
Toroidal Field Magnets & Structure	PPPL
Electrical Power	PPPL
Diagnostics	PPPL
Water Cooling	PPPL
Cryogenics	PPPL
Poloidal Field Magnets	MIT
Vacuum Vessel and Remote Maintenance Components	IS
Shielding	ORNL
External Tokamak Structure	ORNL
External Vessel Remote Maintenance	ORNL
Ion Cyclotron Resonance Heating	ORNL
Vacuum Pumping	ORNL
Conventional Facilities	INEL
Instrumentation and Control	LLNL/PPPL
Cleaning, Disposal, and Monitoring	LANL
Fueling	LANL

ORNL = Oak Ridge National Laboratory
MIT = Massachusetts Institute of Technology
LLNL = Lawrence Livermore National Laboratory
LANL = Los Alamos National Laboratory
INEL = Idaho National Engineering Laboratory
IS = Industrial Subcontractor to be selected

Beyond Breakeven

Princeton's fusion program began in 1951. For the past 16 years it has focused on tokamak devices, in which a superheated gas, called a plasma, is confined by a strong magnetic field in a donut-shaped vacuum chamber (see Fusion Power Information Bulletin NT-1). At plasma temperatures exceeding 100 million degrees centigrade, fusion reactions convert mass to energy, providing a potential source of useful power for generating electricity.

The Tokamak Fusion Test Reactor (TFTR), currently operating at PPPL, has as its primary mission the attainment of "scientific breakeven", where the total fusion power equals the auxiliary heating power required to maintain the plasma near 100 million °C. CIT will go a step further. It will be capable of producing an ignited plasma in which enough fusion power is produced to sustain the 100 million °C temperature without the aid of auxiliary heating. Although considerably smaller than TFTR, CIT is expected to generate about ten times the fusion power, thanks to improvements in confinement techniques.

Both TFTR and CIT are designed to use small quantities of plasma fuel consisting of a mixture of deuterium and tritium, the fuel likely to be

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used in the first commercial fusion reactors. In deuterium-tritium (D-T) reactions, 20% of the fusion energy produced is in the form of alpha particle kinetic energy. Since they are charged, the alphas remain trapped in the magnetic field of the tokamak and through collisions transfer their energy to the plasma, heating it. At ignition, alpha particle heating alone is sufficient to sustain the 100 million °C plasma temperature.

An ignited plasma is analogous to a conventional fire. Initially, some energy must be input to the fuel to start the fire. However, once ignition occurs, the fire is self-sustaining as long as fuel is available. The initial energy input to a CIT plasma "fire" will come from ohmic (resistive) heating, as in any tokamak, and to a much larger extent from auxiliary heating from injected radio frequency waves.

CIT will be capable of providing a 4-second plasma burn, long enough for physicists to study alpha particle heating and plasma characteristics in the range required for future power plants.

As the world's first ignited fusion experiment, CIT will help to maintain U.S. technological leadership in the fusion energy field. It will serve as a cost-effective bridge between the experimental operation of the current generation of major tokamaks in the U.S., Europe, Japan, and the U.S.S.R. and the construction, probably on an international basis, of a large-scale Engineering Test Reactor (ETR) to be operated at a new site about the year 2000. ETR would take advantage of physics knowledge gained on CIT coupled with advanced engineering and materials development, allowing sustained ignition and a demonstration of the actual conversion of fusion energy to heat and then to electricity.

PRINCIPAL CIT PLASMA/MACHINE PARAMETERS

Average Operating Temperature	10 keV (100 million °C)
Plasma Density (Volume Averaged)	$\leq 6.5 \times 10^{14} cm^{-3}$
Energy Confinement time (Minimum for Ignition)	0.3-0.5 sec
Plasma Current	10.0 MA
Pulse Length	4.0 sec
ICRH Power (Initial)	10 MW
ICRH Power (Full)	20 MW
Toroidal Field Strength	10.4 Tesla
Number of Full Field Pulses	3000
Number of 70% Field Pulses	50,000
Major Radius	1.60 m
Minor Plasma Radius	.51 m
Fusion Power	300 MW
Alpha Heating Power	60 MW

CIT Physics

Simply stated, the mission of CIT is to demonstrate plasma ignition at relatively

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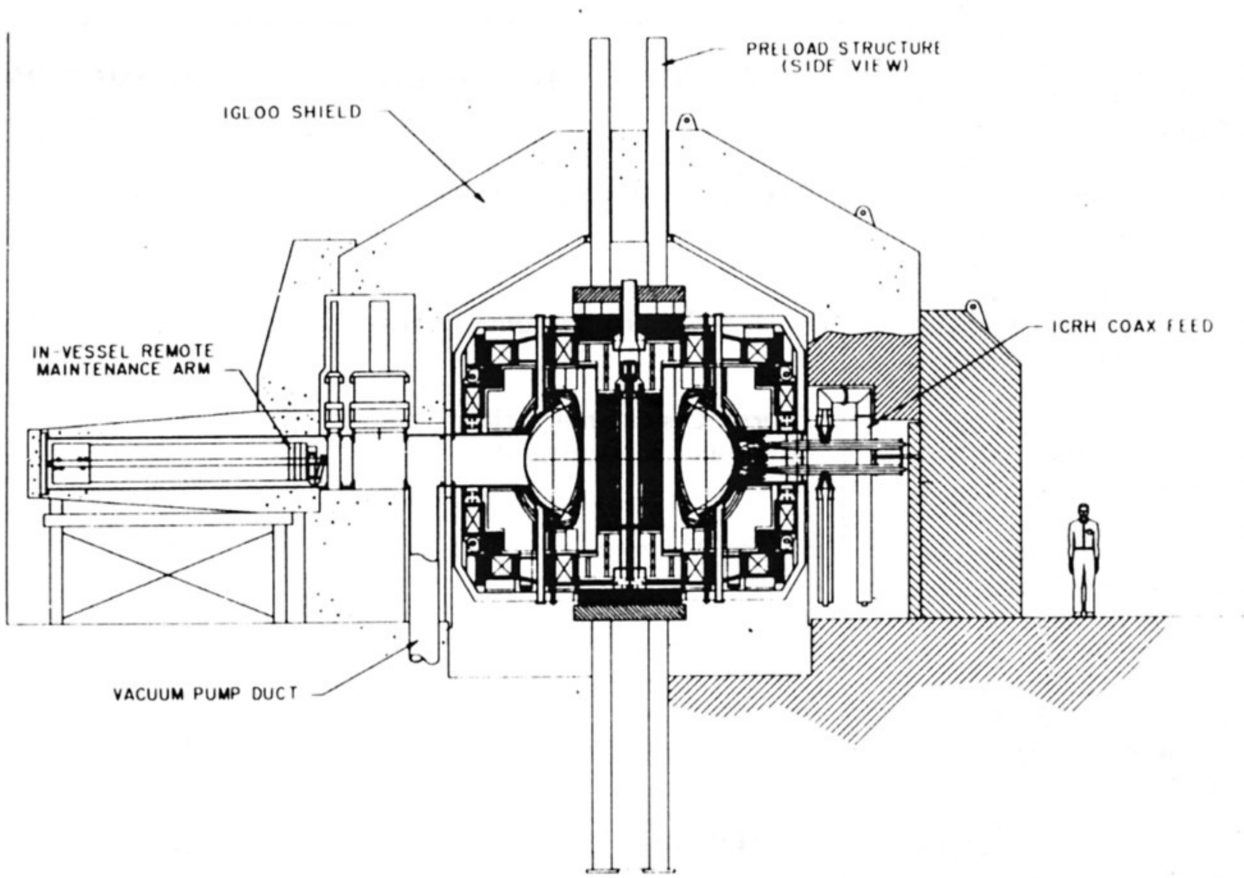

CIT Side Elevation View
Conceptual Design

low project cost with realizable engineering technology. This goal leads to the design of a compact device with strong magnetic fields, high plasma current and high fusion power densities.

To reach ignition CIT must attain $n\tau$ values of at least 3×10^{14} cm^{-3} sec, a factor of ten greater than required for breakeven on TFTR. This will be realized utilizing a magnetic field of 10 tesla (twice that of TFTR) to produce high density plasmas, $n \geq 6 \times 10^{14}$cm^{-3}. Higher density allows operation with correspondingly lower energy confinement time. Values as low as 0.3–0.4 second are all that will be needed on CIT for ignition at temperatures exceeding 100 million °C.

To reach these temperatures, ohmic heating must be supplemented. Initially CIT will be equipped with 10 MW of auxiliary plasma heating, most likely in the form of ion cyclotron radio frequency (ICRF) heating. ICRF is currently the most advanced method of rf plasma heating. The progress of other rf techniques, including lower hybrid and electron cyclotron resonance heating (ECRH), will be monitored for possible use on CIT.

CIT will employ a poloidal divertor at the boundary of an elongated plasma to minimize plasma interaction with the vacuum vessel wall. Plasma-wall interaction will be kept low to prevent the influx of impurities that can radiate energy out of the plasma, preventing ignition. The elongated plasma geometry is suitable to the attainment of high plasma current and high plasma pressure. Past experiments have demonstrated optimized energy confinement when poloidal divertors are used in conjunction with auxiliary heating. CIT will have the additional benefit of pellet injection fueling to produce a centrally-peaked plasma density profile to facilitate ignition.

The PPL HOTLINE is issued by the Princeton University Plasma Physics Laboratory, a research facility supported by the United States Department of Energy. Correspondence should be directed to PPPL Information Services, B380, C-Site, James Forrestal Campus, ext. 2750.