

COMPACT IGNITION TOKAMAK CONVENTIONAL FACILITIES OPTIMIZATION^a

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Abstract

A high-field ignition machine with liquid-nitrogen-cooled copper coils, designated the Compact Ignition Tokamak (CIT), is proposed for the next phase of the United States magnetically confined fusion program. A team of national laboratory, university, and industrial participants completed the conceptual design for the CIT machine, support systems and conventional facilities. Following conceptual design, optimization studies were conducted with the goal of improving machine performance, support systems design, and conventional facilities configuration. This paper deals primarily with the conceptual design configuration of the CIT conventional facilities, the changes that evolved during optimization studies, and the revised changes resulting from functional and operational requirements (F&ORs). The CIT conventional facilities conceptual design is based on two premises: (1) satisfaction of the F&ORs developed in the CIT building and utilities requirements document, and (2) the assumption that the CIT project will be sited at the Princeton Plasma Physics Laboratory (PPPL) in order that maximum utilization can be made of existing Tokamak Fusion Test Reactor (TFTR) buildings and utilities. The optimization studies required reevaluation of the F&ORs and a second look at TFTR buildings and utilities. Some of the high-cost-impact optimization studies are discussed, including the evaluation criteria for a change from the conceptual design baseline configuration. The revised conventional facilities configuration are described and the estimated cost impact is summarized.

Introduction

The CIT conceptual design report (CDR) dated June 1986 [1] focused on a small tokamak with a major radius of 1.2 m with toroidal magnetic fields in the range of 10 Tesla on axis. During optimization studies, the CIT major radius was expanded to 1.75 m, a diagnostic neutral beam device was added, and the tokamak external press structure was completely revised. Plant and capital equipment (PACE) funding for the CIT Project was held constant during the optimization studies; therefore, it was necessary to reevaluate high-cost portions of the project, such as the field coil power supplies and the conventional facilities. The optimization studies of the conventional facilities were accomplished, including a second look at the maximum utilization of existing Tokamak Fusion Test Reactor (TFTR) buildings and utilities, and were evaluated by the CIT Engineering Review Board (ERB), who approved selected options. The CIT conventional facilities functional and operational requirements (F&ORs) [2] were revised and reissued as the basis for revised conceptual design of the conventional facilities. Described here are the conventional facilities baseline 1986 concept, options studied, evaluation criteria used, conventional facilities revised baseline, and estimated cost impact.

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Conventional Facilities 1986 Baseline Concept

The CIT Conventional Facilities 1986 Baseline proposed a new CIT support facility located adjacent and west of the existing TFTR test cell. The general arrangement of the 1986 Baseline Concept is shown by Figure 1. Major facility features included a small circular test cell with a 10 m inside radius, 2.8-meter-thick concrete shield walls and a 2.8-m-thick rotating shield ceiling with a 40-ton-capacity polar bridge crane operating above; a basement area below the test cell to accommodate the vacuum pumping system and gaseous nitrogen (GN₂) heating and cooling skid; the press structure, power leads for field coil magnets, and coaxial cable for ion-cyclotron resonance heating; a light steel frame structure to provide space for fabrication assembly and mockup (FAM) and diagnostics; a shielded hot cell, warm cell, decontamination cell and tritium fuel injection cell arrangement; and miscellaneous electrical, mechanical, health physics, and restroom space.

CIT Optimization Studies

Following completion of the CIT Project Conceptual Design Report (CDR), optimization studies were conducted that resulted in a growing of the CIT machine major radius from 1.2 m to 1.75 m, addition of a large diagnostic neutral beam, and a major change in the tokamak external press. These changes had significant impact on the test cell, basement configuration, and impacted peripheral space, causing a general increase in the estimated cost of the conventional facilities. Facility optimization studies were done in an attempt to return to the baseline budget. These studies included the following:

- Reevaluation of the use of the TFTR Test Cell for CIT
- Evaluation of a circular test cell with conventional shield roof
- Evaluation of a rectangular test cell configuration
- Deletion of the FAM Building
- Utilization of the TFTR Hot Cell for the CIT hot cell and warm cell functions and use of general plant project (GPP) funding
- Evaluation of relocation of the decontamination cell from the basement to the ground floor
- Evaluation of reduction in the test cell basement height
- Evaluation of a reduction in other basement areas
- Evaluation of a reduction in the test cell shielding wall thickness, taking full credit for the igloo shield
- Consideration of the diagnostic neutral beam in the test cell versus out of the test cell
- Evaluation of the impact of the CIT Tokamak press structure on the Test Cell and basement.

It was concluded that utilization of the TFTR Test Cell for the CIT machine was not feasible, owing to the schedule impact on the CIT Project and the high cost estimate for decontamination and decommissioning of the activated TFTR machine and peripheral systems. The results of the remaining studies were presented to the CIT ERB for evaluation and decision.

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Evaluation Criteria

The evaluation was based upon rating each option against the following evaluation criteria:

- CIT conventional facilities F&ORs
- CIT remote maintenance philosophy
- CIT safety requirements and design objectives.

After evaluation, the ERB recommended that options be incorporated into the conventional facilities concept, as follows:

- Incorporate the circular test cell with a conventional shield roof, the result of its high evaluation rating and lowest cost
- Delete the CIT FAM building and utilize existing space in the TFTR FAM or in the coil assembly storage (CAS) addition
- Utilize the TFTR hot cell for CIT hot cell and warm cell functions, and defer funding from PACE to future GPP funding
- Relocate the CIT decontamination cell from the basement to the ground floor at the test cell north entrance
- Reduce the height of the test cell basement consistent with space envelopes of basement equipment, ducting, and power lead requirements

- Reduce other basement areas and relocate their associated functions on the ground floor level or in mezzanines
- Do not reduce the test cell shielding thickness at this time
- Locate the diagnostic neutral beam external to the test cell
- Provide a pit in the test cell basement for accommodating the CIT tokamak press structure.

Revised Conventional Facilities Baseline

Based on the ERB recommendations, revised F&ORs were prepared and approved, which set the stage for preparation of a revised CIT conventional facilities CDR. The completed CDR will provide a new baseline design and cost estimate. The baseline design may be revised later during title design via action of the CIT Change Control Board. At this point, the conventional facilities baseline design is illustrated by Figures 2, 3, and 4. The CIT tokamak is shown in the center of the new CIT support building enclosed in a cryostat, mounted in a preload press structure, surrounded by an igloo shield, and all supported and housed in a circular test cell. The test cell and its basement will be coupled with an adjacent transfer/airlock area for easy remote handling and transfer of maintenance equipment and machine and system components to the decontamination cell. From that point, transfer will be over a site road to the TFTR hot cell/warm cell complex.

Test Cell

The circular test cell will have 2.8-m-thick shielding wall and roof, and a 2-m-thick shielding floor over the test cell basement. The upper portion of the test cell will be haunched externally to allow space for an overhead polar bridge boom mounted robot manipulator and a 100-ton polar bridge crane. The test cell internal radius will be 12 m, in order to provide space for the CIT machine located at the test cell centerline, and the cryostat and igloo shield that will enclose the machine. The test cell radius also provides annular space for igloo block removal to allow for ex-vessel maintenance and space for the in-vessel articulated boom manipulator (ABM) remote maintenance casks. The test cell clear height from the floor to ceiling will be 19 m in order to provide vertical space for buildup of the CIT machine, cryostat, igloo shield, preload-press structure, polar bridge manipulator, and polar bridge crane. Attached to the test cell outer wall will be a shielded neutral beam diagnostic cell and a shielded tritium pellet injector cell. The test cell will be structurally supported by the test cell basement walls and foundation mat.

Basement and Foundations

The floor of the test cell basement and adjoining areas will be 5.5 m below the ground floor to provide 3.8-m clearance height for installation of the vacuum pumping system, GN₂ cooling/heating skid, 4 wall-mounted unit coolers and field coil power leads in the basement. A large pit in the center of the test cell basement will provide space for the CIT tokamak press structure, which will support the CIT machine. The pit walls and basement walls will support the test cell loads, which include the test cell floor and multiple large concrete portable shielding blocks that make up the igloo shield. The basement floor will be ramped to meet the existing TFTR building basement corridor floor, where the facilities will be joined through a wide opening in the west wall of the TFTR basement corridor. The test cell basement walls

and pit walls will be supported by a 2-m thick concrete foundation mat resting on rock. The below-grade structure in other basement areas will be constructed of reinforced concrete columns, footings, beams, and slabs on rock. The portion of the CIT support building which has no basement will have a floor constructed as a floating slab on grade; the columns and walls will be supported on spread footings.

Estimated Cost Impact

The cost of the Conventional Facilities was estimated at \$28 million dollars in 1986 (w/o contingency) for the FY 1986 CIT-CDR, and the costs were confirmed by an independent Department of Energy audit. The cost impact owing to the revised

conventional facilities baseline configuration has not yet been determined by an in-depth bottoms-up cost estimate; however, a parametric cost estimate indicates that the increases and decreases are a trade-off, with no significant change in the conventional facilities 1986 budget.

References

1. J. A. Schmidt, H. P. Furth, Compact Ignition Tokamak (CIT) Conceptual Design Report, PPPL-A-860606-P-01, June 6, 1986.
2. Conventional Facilities Functional and Operational Requirements, T-870814-PPPL-02, CIT Controlled Document, August 1987.

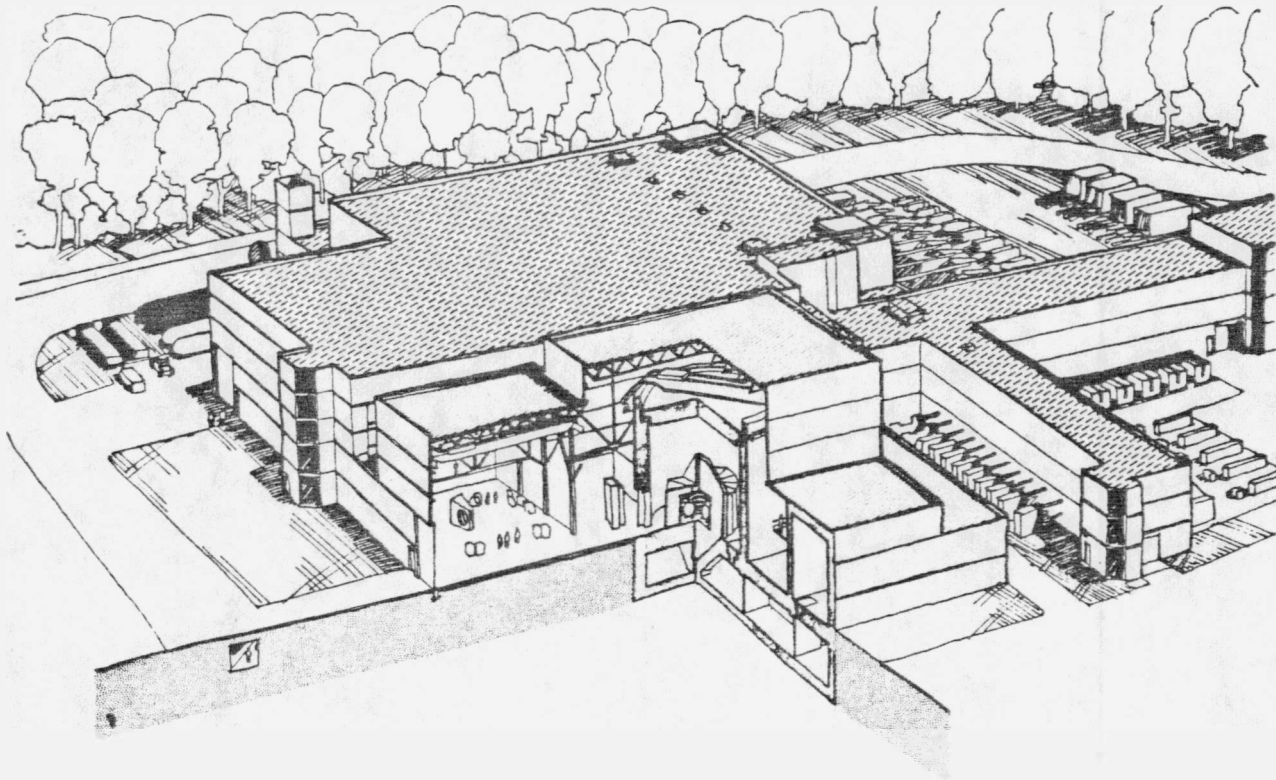


Figure 1. CIT conventional facilities 1986 baseline concept.

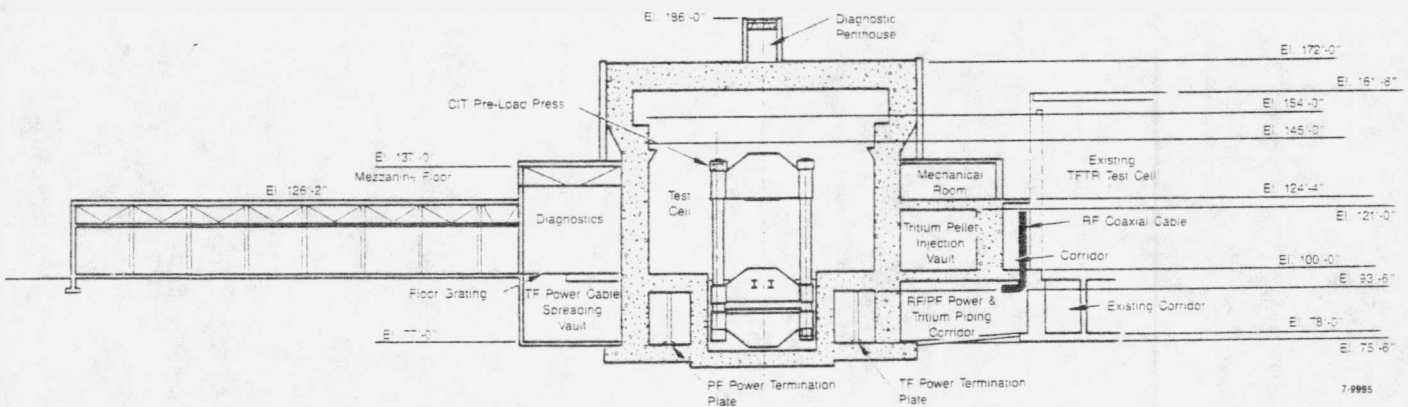


Figure 2. Cutaway of CIT conventional facilities baseline design.

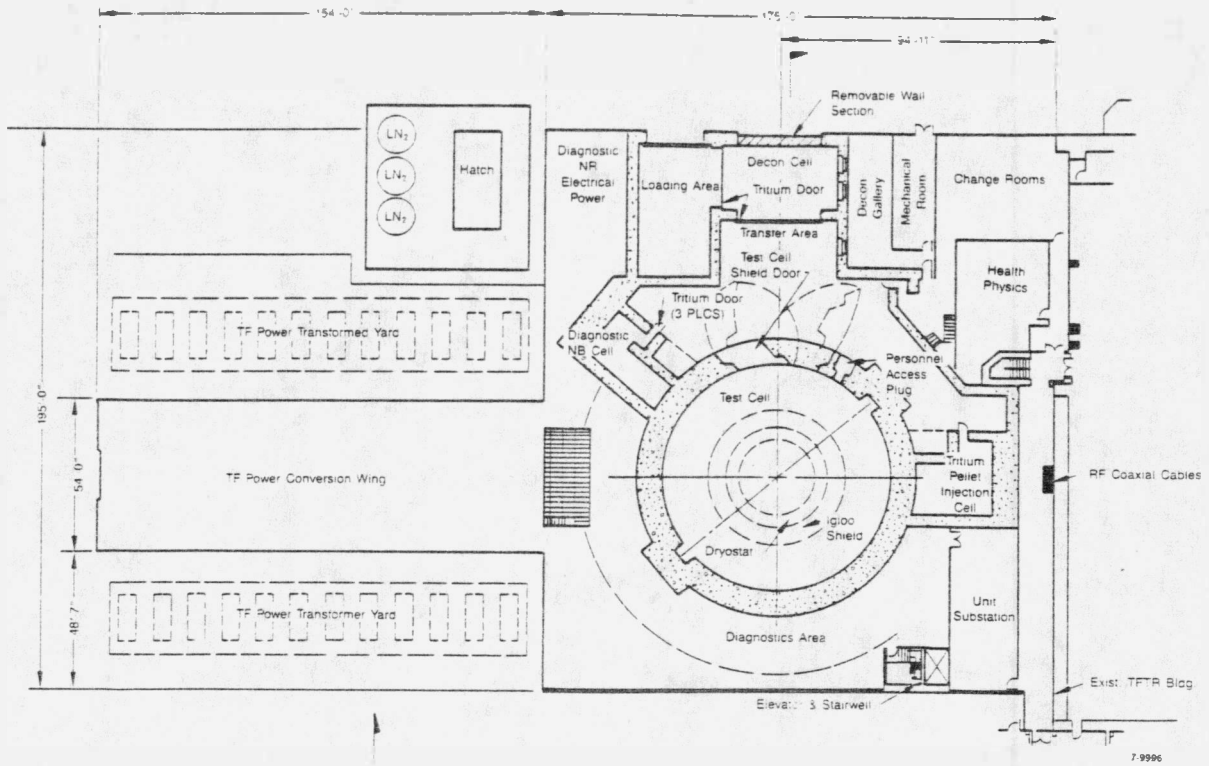


Figure 3. Floor plan of CIT conventional facilities baseline design.

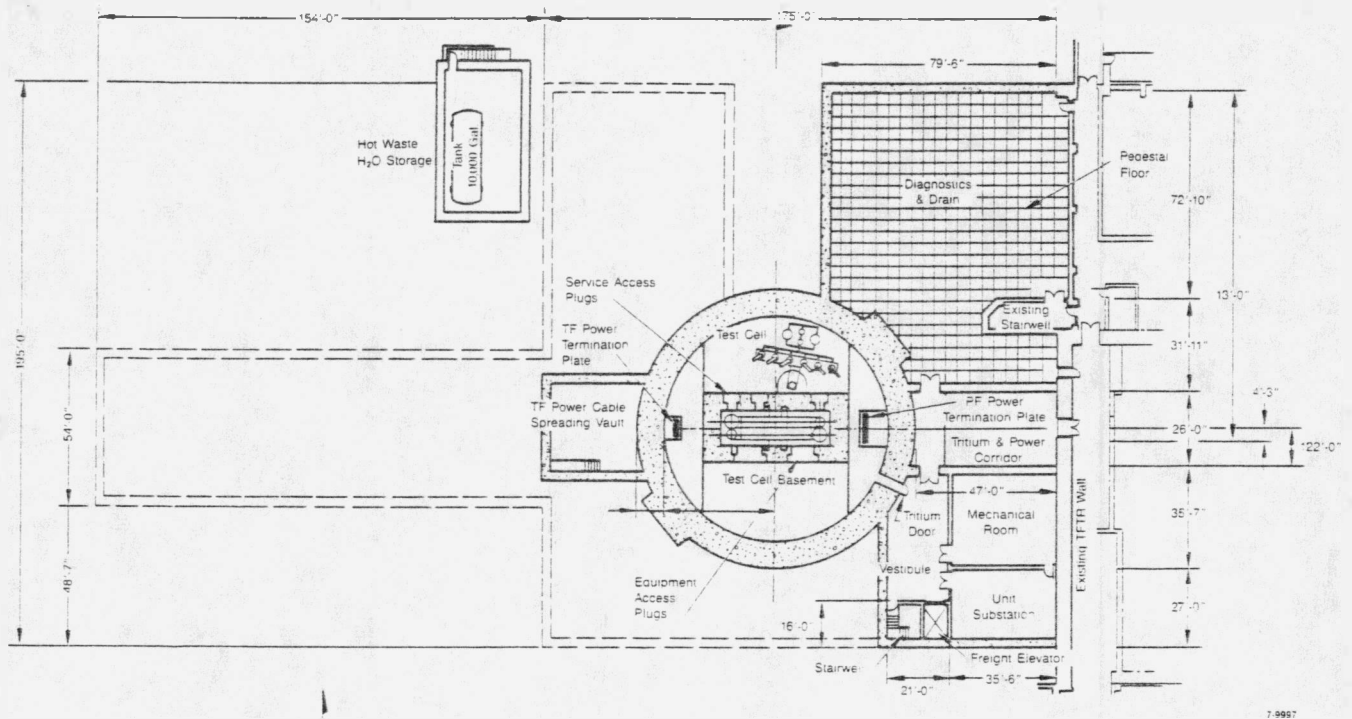


Figure 4. Basement floor plan of CIT conventional facilities baseline design.