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Maintainability Features of the Compact Ignition Tokamak*

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The Compact Ignition Tokamak (CIT) is a deuterium-tritium (D-T) device envisaged to be the next experimental reactor in the U.S. Fusion Program. The reactor will initially operate in a nonactivated hydrogen phase for approximately two years. This will permit verification of the integrity of the total system and allow hands-on repair to equipment which has experienced shakedown and early operation failures. Once D-T operations commence, reactor maintenance will require remote handling techniques.

An evaluation has been completed to determine what maintenance operations must be performed on the CIT. A maintenace philosophy has been developed which is based upon the use of manipulator systems and robotics in the test cell. Replacement of life-limited equipment will be accomplished using a modular design approach for components, with simple remotely operable interfaces. Examples of operations to be done remotely include:

- Replacing of rf antennae and Faraday shields
- Uncoupling diagnostic and fueling penetrations
- Removing of all port covers
- Replacing first wall armor tiles, optical mirrors, and vacuum windows

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- In-vessel and ex-vessel inspections
- Diagnostic equipment adjustments and modifications
- Vacuum/coolant leak repairs

It is not planned to replace major components which are not affected by wearout, such as the magnetic coils, the vacuum vessel, or primary structure. These components will undergo extensive quality assurance measures during fabrication and installation, and operational testing during the hydrogen phase to verify their reliability. A change in philosophy to plan for remote disassembly of the CIT to replace these components would result in an increase in the reactor cost.

Two categories of CIT maintenance activities have been identified: those required in the vacuum vessel; and those external to the vessel but within the test cell. One of the difficult in-vessel operations is replacement of the graphite tiles. This requires the use of a manipulator operating within the geometry of a small torus with a major radius of the order of 1.0-1.3 m and a minor radius of about 0.4 to 0.7 m. Access into the vessel is through ports which have openings of about 20 × 80 cm. Preliminary studies indicate that the use of robot arms or articulated arms like that of JET may not have sufficient dexterity in these small reactors. Therefore, it appears that unilateral (one-armed) manipulators, installed in alternate pairs of ports, can be operated as bilateral systems to replace tiles on 60° segments of the vessel. Existing manipulators can be modified for this task and fitted with special end-effectors. Peripheral equipment modules (i.e., diagnostics) which are installed on these ports will first be remotely removed and temporarily stored in the test cell.

In-vessel inspection of first wall surfaces for CIT is expected to be a frequent occurrence. Therefore, it is desirable for inspection equipment (i.e., CCTV) to interface with the reactor through an airlock, or be contained within an extension of the reactor vacuum boundary. This eliminates the need to frequently open the vessel and incur lengthy downtimes to recondition the plasma chamber. A remotely operated TV camera mounted to the end of an articulated arm is one way to perform such inspections. Installation of this system on two ports which are 180° apart can provide full internal viewing of the vessel. Toshiba Corporation has manufactured a system with eight joints and 17 degrees-of-freedom which appears applicable to CIT. Like other inspection equipment, it requires radiation hardening to be cost-effective.

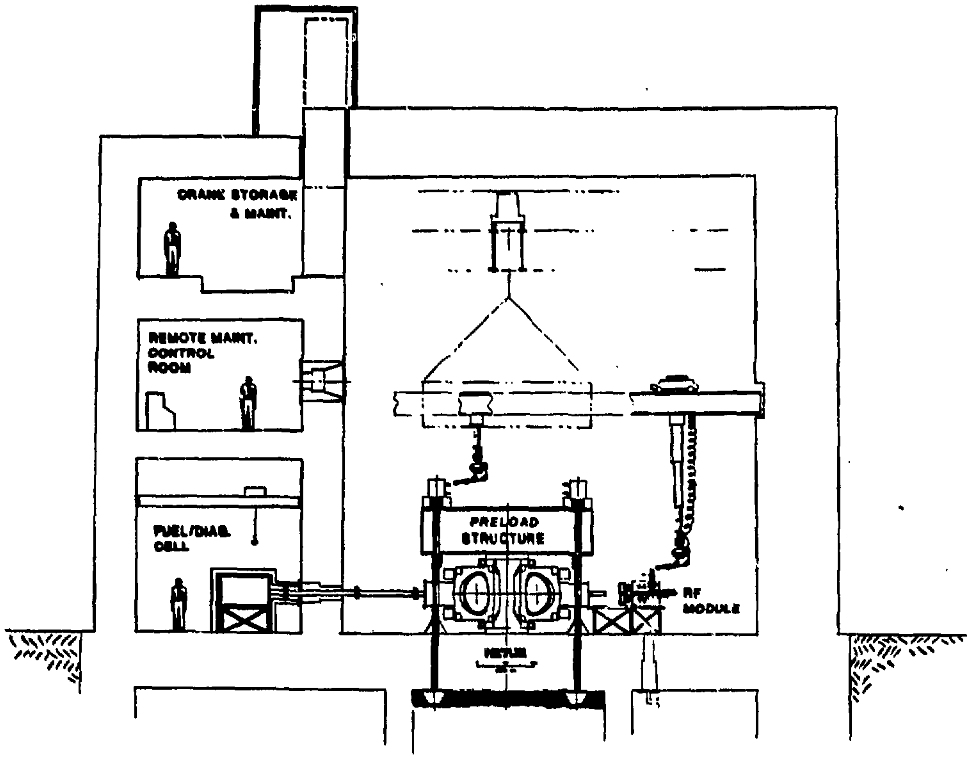
Remote maintenance activities performed within the test cell will be accomplished primarily with the use of at least one crane-mounted manipulator system, a movable floor-mounted manipulator, and an overhead crane. In addition to the use of this equipment, the reactor subsystems will be designed and installed in a manner which eases remote handling. For example, the rf module will use a permanent platform to provide alignment and support for the module during remote replacement of the antennae and shields. This approach is shown in Fig. 1a which is an elevation view illustrating a preliminary test cell arrangement configured at the Fusion Engineering Design Center. Also shown is an overhead crane with a capacity of approximately 100 tonnes, capable of lifting the entire reactor module (excluding the preload structure). Cranes are stored in overhead alcoves during D-T plasma operations to preclude activation. Figure 1b shows an elevation of a test cell arrangement configured by Princeton Plasma Physics Laboratory[1] which uses a polar crane installation. The rotating shield has a removable section which permits crane access to all areas of the test cell.

Remote inspection in the test cell can be accomplished by one of many inspection robots already developed. The surveillance robot (SURBOT), developed by the Remote Technology Corporation for the Nuclear Regulatory Commission is capable of such inspection after appropriate radiation hardening.

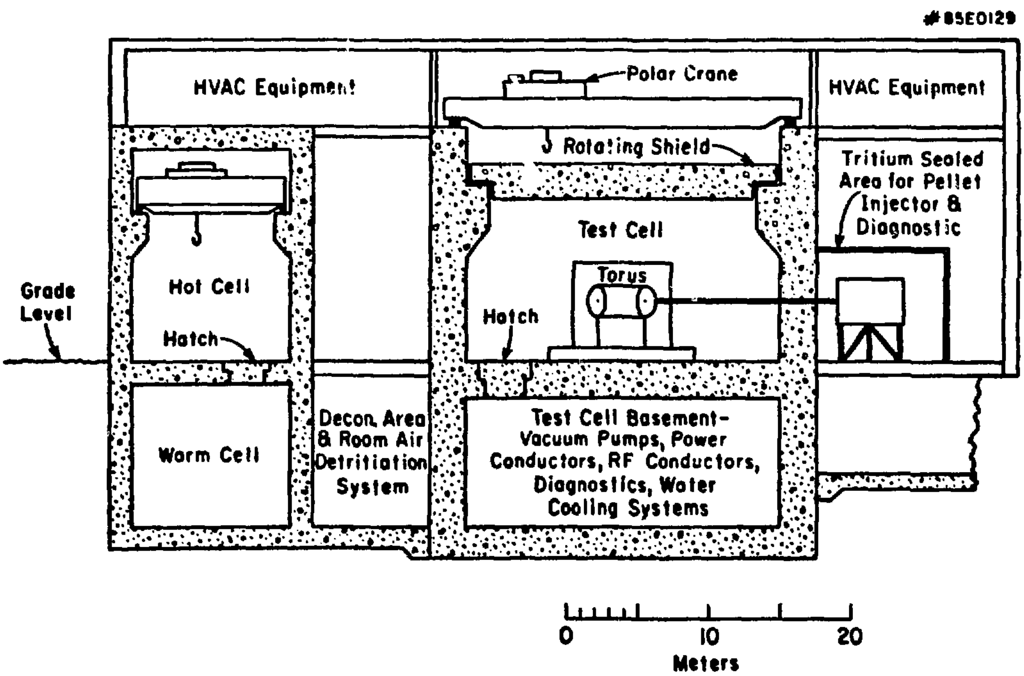
The preconceptual design work for the CIT reactor and for various test cell arrangements indicates that designs leading to a maintainable reactor system are possible and can be developed in a cost-effective manner. The arrangements shown in Fig. 1 embody the preliminary considerations for remotely maintaining and inspecting reactor subsystems using rotobics and manipulators. Much of this equipment is available and appears to be applicable to CIT maintenance with relatively minor modifications and development required.

Reference

1. R. B. Fleming, Facilities and Auxiliary Systems for a Compact Ignition Machine; Proc. of the 11th Sym. on Fusion Engineering, Austin, TX, November 1985.



(a) Rectangular test cell arrangement.



(b) Circular test cell arrangement.

Fig. 1. Preliminary test cell arrangements are being investigated for the CIT.