MAINTENANCE CONCEPT DEVELOPMENT FOR THE COMPACT IGNITION TOKAMAK*

CONF-890304--27

DE89 004914

D. Macdonald
Central Engineering
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6353

To be presented at the
Third Topical Meeting on
Robotics and Remote Systems
Charleston, South Carolina
March 13-16, 1989

*Research sponsored by the Office of Fusion Energy, U.S. Department of Energy, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

MAINTENANCE CONCEPT DEVELOPMENT FOR THE COMPACT IGNITION TOKAMAK*

D. Macdonald
Central Engineering
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6353
(615)574-6388

ABSTRACT

The Compact Ignition Tokamak (CIT), located at the Princeton Plasma Physics Laboratory, will be the next major experimental machine in the U.S. Fusion Program. Its use of deuterium-tritium (D-T) fuel requires the use of remote handling technology to carry out maintenance operations on the machine. These operations consist of removing and repairing such components as diagnostic equipment modules by using remotely operated maintenance equipment. The major equipment being developed for maintenance external to the vacuum vessel includes both bridge-mounted and floor-mounted manipulator systems. Additionally, decontamination (decon) equipment, hot cell repair facilities, and equipment for handling and packaging solid radioactive waste (rad-waste) are being developed. Recent design activities have focused on establishing maintenance system interfaces with the facility design, developing manipulator system requirements, and using mock-ups to support the tokamak configuration design.

*Research sponsored by the Office of Fusion Energy, U.S. Department of Energy, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

INTRODUCTION

The CIT will be the first D device that will study the phys ignited plasma. The use of requires applying remote technology for ex-vessel mainte disassembly of machine co Highly activated and con components of the fusion auxiliary systems, such as di and rf heating, must be replac remotely operated maintenance in the test cell. In maintenance operations include decontamination, hot cell rep solid rad-waste handling and p The development of the ma concept for CIT has been t responsibility of Oak Ridge Laboratory.

The machine will operate in a nonactivating hydrogen p approximately one year. This wi verification of the integrity total system and allow hands-on any equipment that fails during or early operation. In addit operation of maintenance installed in the test cell demonstrated. Once deuterium-operations begin, device mainte expected to require remote techniques. Recent design ac have focused on the study of alt test cell arrangements to machine access and maintenance operations. A secondary objective of these cell arrangement studies was the reconfiguration of the maintenance facilities into an integrated decon/repair cell and rad-waste handling facility.

MAINTENANCE CONCEPT DESCRIPTION

The fusion device is located in the center cell of the test cell facility. After D-T operations commence, personnel access into that cell will be prohibited. At that time, repair and replacement of machine components will be accomplished by remotely operated maintenance equipment.

Virtually all machine components that interface with the vertical and horizontal ports of the vacuum vessel will be designed for remote replacement and handling. These components will be repaired in the hot repair cell. Permanent installations [such as the toroidal field (TF) and poloidal field (PF) coils, the vacuum vessel, and the primary support structure] are not considered replaceable after D-T operations commence.

In the preliminary conceptual design, the ex-vessel maintenance philosophy for the circular test cell was radically influenced by the close-fitting neutron-gamma igloo shield surrounding the machine.[1] Hands-on access to components in the test cell was permitted with the shield intact, but remote operations were required when the shield was disassembled. A polar bridge-mounted manipulator system and an overhead crane were used to maintain or replace equipment modules that interfaced with the machine.

The difficulty in gaining access to the vertical and midplane ports on the machine for repair of auxiliary machine components was studied extensively with three-dimensional, computer-developed, kinematic models of the port areas. These studies highlighted the severe restraints on viewing and component access imposed by the igloo shield design.

A number of test cell arrangements for the machine and its interfacing equipment were generated. The option selected was a rectangular test cell with a fixed, sliding roof shield. This design offers a number of improvements: all peripheral components can be housed within the test cell; personnel access to the north and south equipment/diagnostic cells is permitted; close-in shield walls with a sliding roof shield provide an enclosure of improved seismic design that minimizes the volume of activated air or cover gas, and a shielded high bay provides radiation protection for the overhead bridge systems. Unlimited personnel access to the north and south cells, the high bay, and the basement is permitted 24 hours after shutdown. Penetrations into these areas from the center cell will be locally shielded as required. Figures 1 and 2, which are elevation and plan views of the shielded facilities, show the arrangement of the various cells. The rectangular cell and crane bay allow a runout over the equipment transfer bay. This approach uses the overhead cranes for vertical transfer of equipment to and from the test cell. Vertical transfer provides for improved contamination control and eliminates the need for major penetrations through the test cell wall and special transport equipment.

A bridge-mounted manipulator system is the primary means for remote operations on the upper vertical ports and the horizontal ports of the machine and on the floor area of the center cell. A floor-based mobile robot performs remote operations in the area under the machine, including the lower vertical ports. In general, these two systems accomplish the ex-vessel remote maintenance operations.

Two articulated boom manipulators (ABMs) located 180 degrees apart, and attached to dedicated horizontal ports,

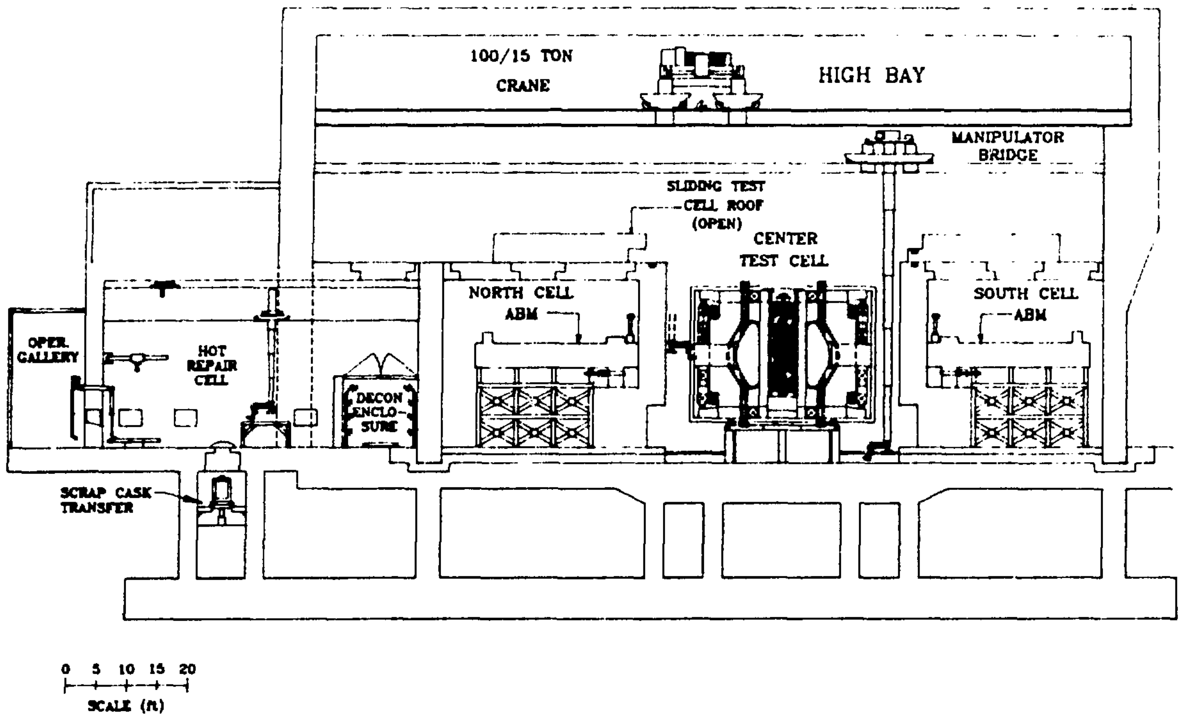

Fig. 1. Section view of test cell and hot repair cell.

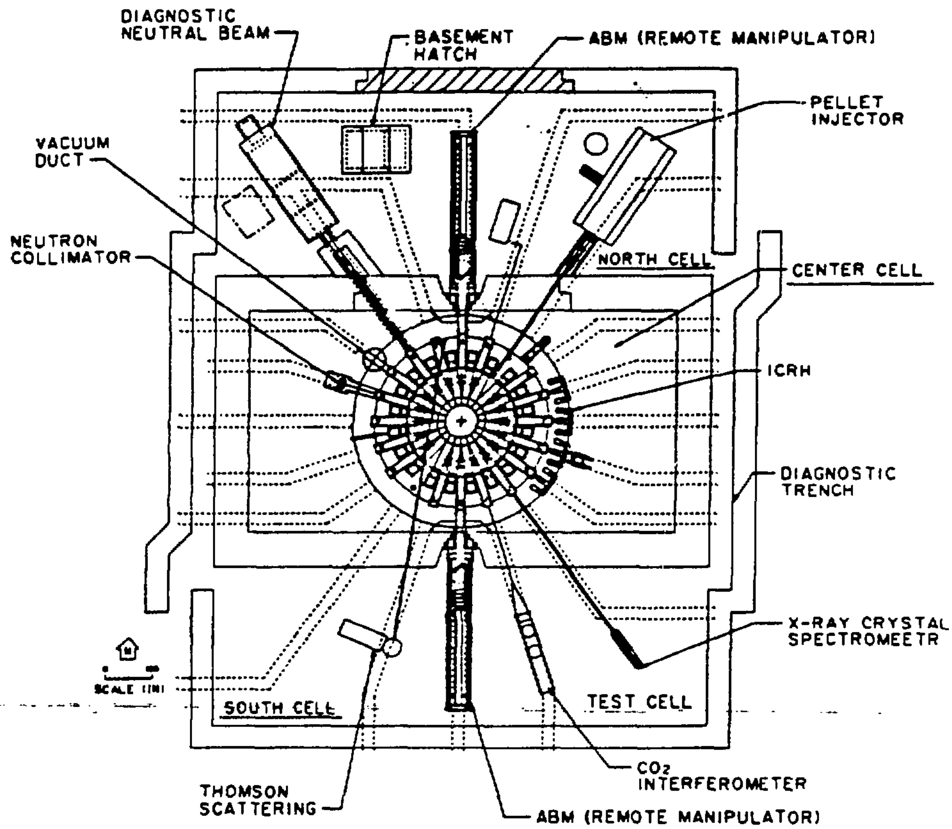

Fig. 2. Plan view of test cell facility
(rotated 90° from Fig. 1).

accomplish the in-vessel remote operations,[2] which are not discussed here.

Every activated or contaminated component that requires maintenance in the repair cells must first pass through the decon cell. Replacing equipment in the center test cell requires opening the sliding roof, decoupling components remotely, and enclosing them in a containment to prevent the spread of contaminants in the high bay area. These operations are performed remotely using the servomanipulator and crane hook reaching down from their high bay bridges. CCTV cameras mounted on the manipulator and overhead bridges give overall and close-up views of these tasks to the operators in the maintenance control room.

Components in the north and south cells will be decoupled by hand, packaged as required, and positioned under a hatch opening by the low-capacity cell crane for overhead lifting by the high bay crane. At this stage of the design, it is uncertain if activation levels in these cells will require addition of remote handling capability.

The high bay area includes everything above the test cell facility and the decon cell where the main crane and manipulator bridges have free movement. Personnel access to the high bay (always with the roof shield closed) requires contamination containment for machine components passing overhead.

MAINTENANCE FACILITIES

An objective of the maintenance facility design effort has been the reconfiguration of the previously designed decon cell, transfer area, and cask loading areas in the CIT facility into an integrated decon/repair cell and rad-waste handling facility. This arrangement eliminates the transport of contaminated equipment in shielded casks to repair facilities located in another building. Only packaged waste would need to be transported out of the facility to a shielded storage area. The conceptual layout of these facilities in Fig. 3 includes facilities for equipment decontamination and remote repair, conditioning of new and repaired vacuum components, rad-waste handling and packaging, and contact repair of equipment after decontamination.

A proposed arrangement for a component handling and transfer area in the decon facility is shown in Fig. 4. The transfer bay is the primary path for movement of components to and from the test cells, repair cells, and decon area. Components from the test cells are lowered through the roof hatch that gives access to the high bay and placed on a motorized cart with a 5-ton capacity, which is remotely controlled from the contact repair cell or the hot cell operating gallery. The cart transports the component via floor rails into the enclosure for decontamination; if residual levels permit, the cart may then travel directly into the contact repair cell via the shielded doorway. A transfer lock is proposed for equipment transfer between the hot cell and the contact repair cell to minimize the need for frequent opening and resealing of the large shielded door.

Transport to the transfer bay and decon enclosure is provided by extending the runways for the hot cell crane and manipulator bridges over a shadow shield wall from the hot repair area. Although the area is equipped for remote handling, it can be entered by suited personnel during that interim period before sustained full-power D-T operation raises radiation levels of components to an untenable level.

BRIDGE-MOUNTED MANIPULATOR

The ex-vessel maintenance operations consist of repairing and replacing auxiliary components and performing inspections primarily within the center test cell. The key element of the test

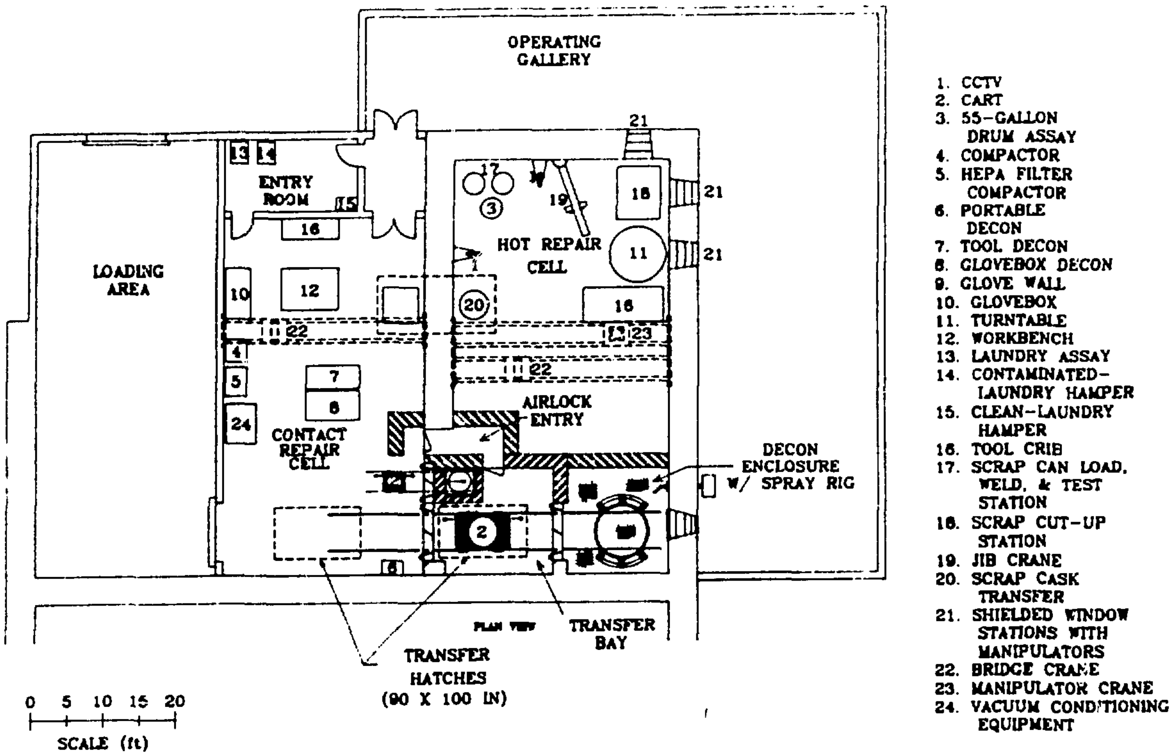

Fig. 3. Conceptual arrangement of maintenance facility.

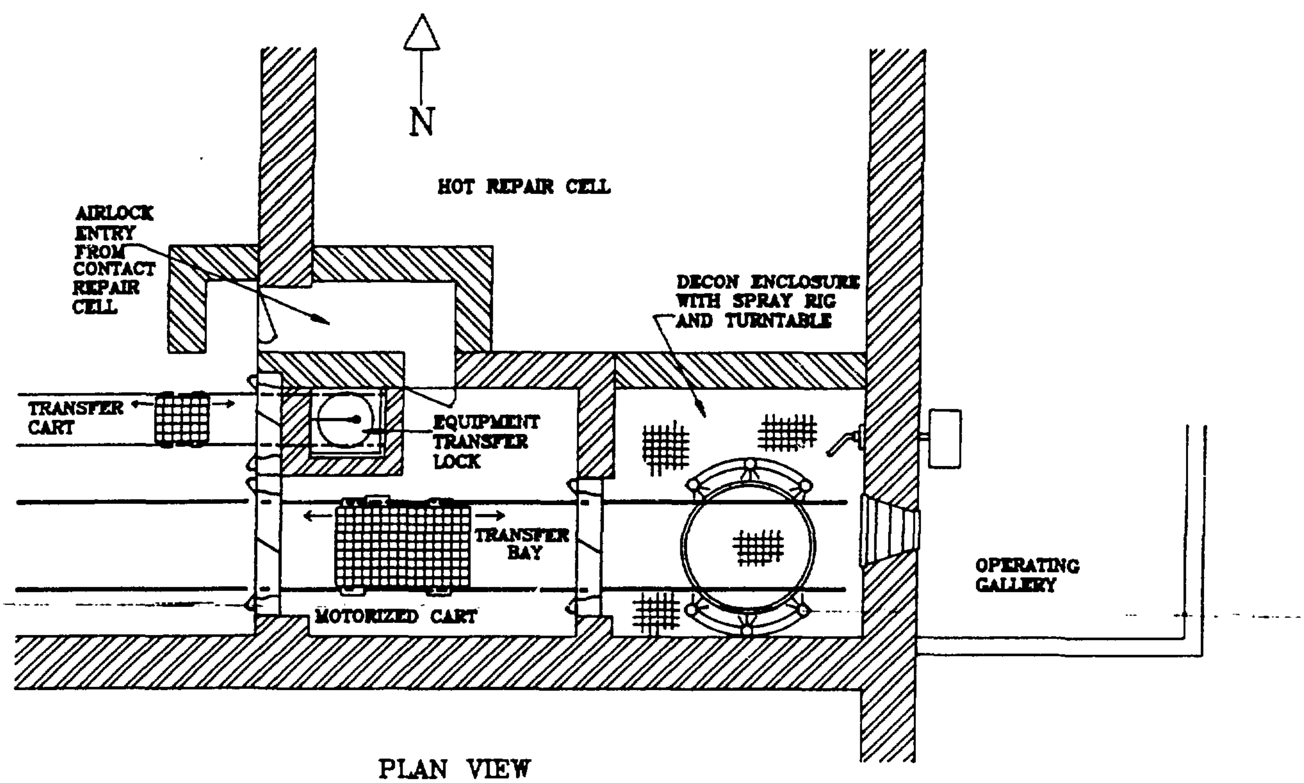

Fig. 4. Decon cell with transfer lock (version 2).

cell maintenance system is a pair of bilateral, force-reflecting servomanipulator arms mounted on a telescoping boom supported from an overhead transporter to provide dexterous manipulation throughout the test cell. A remotely operated bridge crane will remove and replace equipment and shield modules and work in conjunction with the manipulator system.

The manipulator system configuration will be similar to that shown in Fig. 5. This figure is not meant to show any selected equipment, but rather to illustrate what kind of equipment should be included in the system. It consists of a dual-arm master-slave manipulator with camera positioners and a hoist at the slave. This auxiliary hoist is particularly necessary since the arm capacity is limited by the need for a small manipulator envelope because of the difficult access to some areas in the CIT.

Collision avoidance capability is planned for the manipulator system including the transporter, the manipulator, and the auxiliary equipment to protect the system during motion from one work location to another. The physical interaction of the components of the manipulator with the machine and with each other will be monitored and predicted.

FLOOR-BASED MOBILE ROBOT

Several maintenance tasks have been identified in the pit area under the machine: general inspection, replacement/repair of the diagnostic vacuum pipes and nitrogen coolant lines, and repair of a laser beam dump. In order to accomplish these, a mobile telerobot is under consideration. This system would also perform routine surveillance and inspection tasks throughout the test cell.

At this time, the definition of system requirements must be preliminary because task definitions and the geometry of the area under the machine are still evolving. The mobile robot would be equipped with two force-reflecting, master-slave electric manipulators with teleoperator control, cameras, lights, batteries, instruments, telemetry, controls, and other associated on-board equipment. The electronic control system would provide both wired and wireless vehicle control, telemetry, and power management.

The tasks to be performed by the robot manipulator system are similar to those of the overhead manipulator, except that operations are carried out in a totally different environment under the machine. The mobile robot must be operated in a very confining, cluttered environment restricted by the floor below and the machine above, as shown in Fig. 6. Access to the diagnostic equipment is further limited by the machine supports and the many coolant lines penetrating the floor. Compact size, maneuverability, and collision avoidance are paramount requirements for operation in this cluttered space without damage to the vehicle or to the diagnostics. The lack of overhead clearance precludes the use of the auxiliary hoist that proved useful during remote demonstrations with the overhead manipulator.

REMOTE MAINTENANCE TASK EVALUATIONS

Throughout the CIT remote maintenance studies conducted to date, two methods were used to evaluate remote operational requirements: component design and mock-up, and computer modeling. Both approaches have been used extensively to investigate manipulator access with respect to maximum envelope, reach, and kinematics. At present, mock-up demonstrations for upper diagnostic hardware and midplane port devices have been designed and completed.[3] Three-

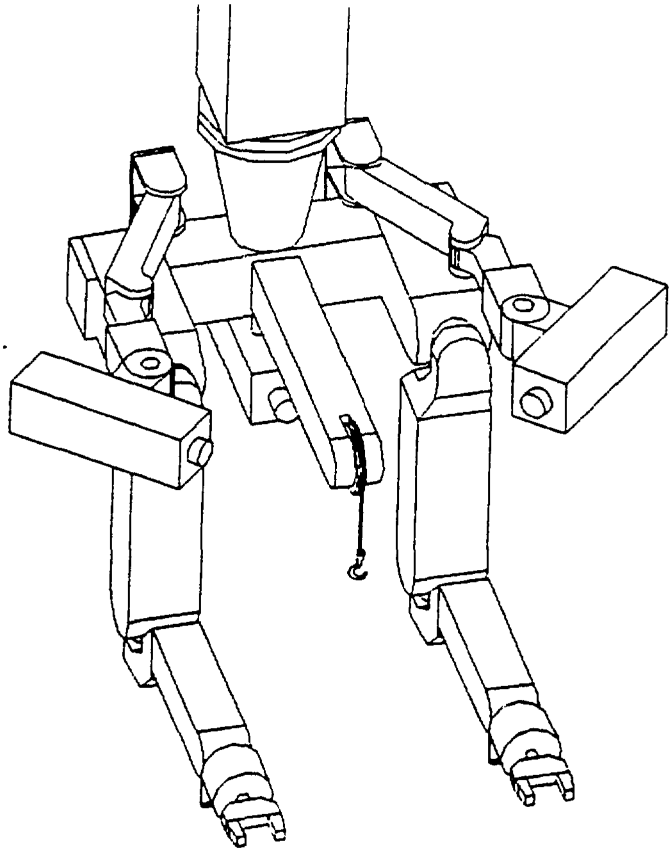

Fig. 5. Manipulator system configuration.

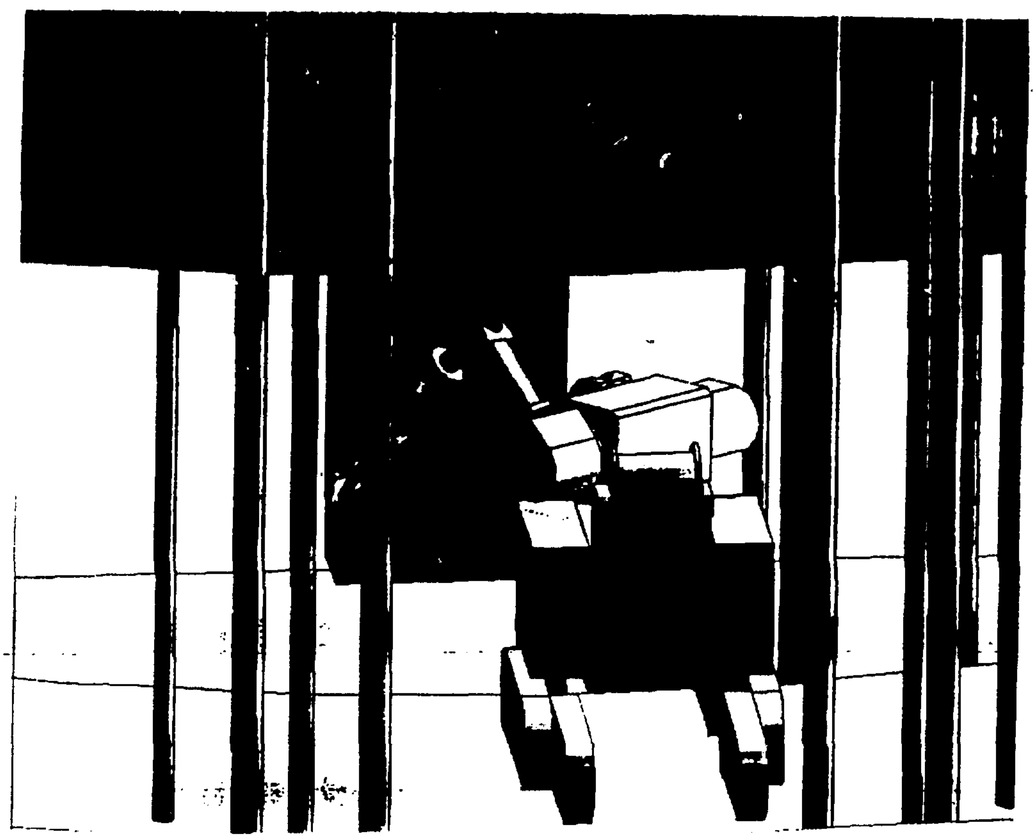

Fig. 6. Mobile robot underneath machine.

dimensional, CATIA-developed, kinematic models of manipulators and solid models of the CIT machine are proving to be powerful tools in our efforts to evaluate access requirements. Figures 7 and 8 are examples of the CATIA system models.

A further refinement of computer modeling involves the use of an intelligent engineering work station for rapid graphic display of task simulations. This system uses a real-time interactive graphics software package that simulates concurrent operation of devices with input and output communication between them. This program provides dynamic viewing during simulation with color-shaded, three-dimensional images and real-time forward and reverse kinematics capability. It is planned to develop a model of the CIT facility, including the locations of all the auxiliary machine devices and diagnostic components as the details of each are defined. Remote maintenance scenarios will be displayed graphically, and the terrain in which the maintenance equipment must operate will be known.

REFERENCES

1. P. T. SPAMPINATO and D. MACDONALD, "Ex-Vessel Remote Maintenance Design for the CIT," Proc. of 35th Conference on Remote Systems Technology, pp. 179-186, November 1987.

2. M. A. TABOR et al., "In-Vessel Remote Maintenance of the CIT," Proc. of 35th Conference on Remote Systems Technology, pp. 174-178, November 1987.

3. J. D. SNIDER, "Development of a Remotely Maintainable RF Module for the CIT," Proc. of the Topical Meeting on Remote Systems and Robotics in Hostile Environments, March 1989.

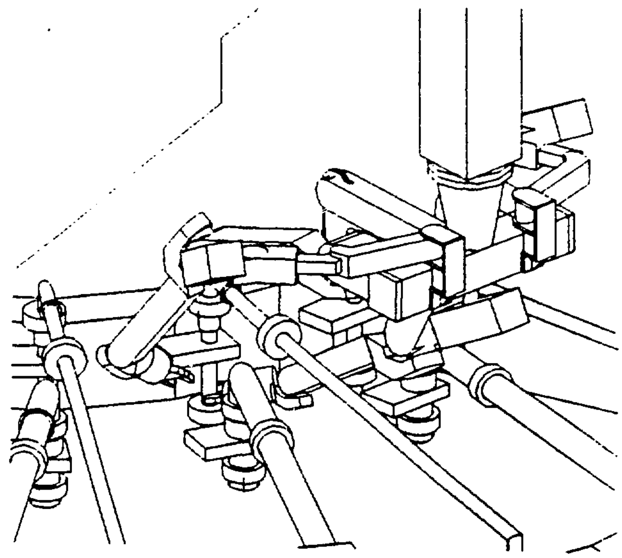

Fig. 7. Manipulator access to upper diagnostic piping.

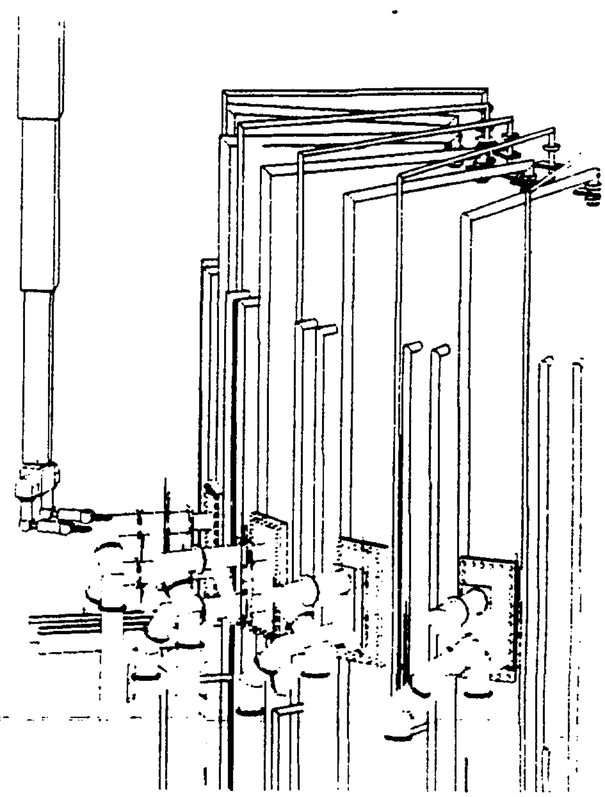

Fig. 8. Manipulator access to RF modules.