TPX REMOTE MAINTENANCE AND SHIELDING

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ABSTRACT

The Tokamak Physics Experiment machine design incorporates comprehensive planning for efficient and safe component maintenance. Three programmatic decisions have been made to insure the successful implementation of this objective. First, the tokamak incorporates radiation shielding to reduce activation of components and limit the dose rate to personnel working on the outside of the machine. This allows most of the ex-vessel equipment to be maintained through conventional "hands-on" procedures. Second, to the maximum extent possible, low activation materials will be used inside the shielding volume. This resulted in the selection of Titanium (Ti-6Al-4V) for the vacuum vessel and PFC structures. The third decision stipulated that the primary in-vessel components will be replaced or repaired via remote maintenance tools specifically provided for the task. The component designers have been given the responsibility of incorporating maintenance design and for proving the maintainability of the design concepts in full-scale mockup tests prior to the initiation of final fabrication.

Remote maintenance of the TPX machine is facilitated by general purpose tools provided by a special purpose design team. Major tools will include an in-vessel transporter, a vessel transfer system and a large component transfer container. In addition, tools such as manipulators and remotely operable impact wrenches will be made available to the component designers by this group. Maintenance systems will also provide the necessary controls for this equipment.

SHIELDING

Shielding to limit the nuclear heating of the TF coils and to reduce the activation of components outside the vacuum vessel is provided by a combination of borated water in the annulus of the double walled vessel and solid blankets on the exterior piping. In addition to the shielding requirements the borated water will be used to heat the vessel to 150°C for operation. The basic shield configuration is shown in Figure 1.

The 10,000 gallon, closed loop borated water system monitors the concentration of the solution at 110 gm of boric acid per liter of water. Deposits may form at greater concentrations or if the temperature falls below 150°C; thus during shut-downs the boron will be maintained at the operating state. The water pumping system and vessels are to be designed according to the ASME Boiler and Pressure Vessel Code for 75 psi. Titanium Ti-6Al-4V will be used throughout the system due to low activation and corrosion requirements.

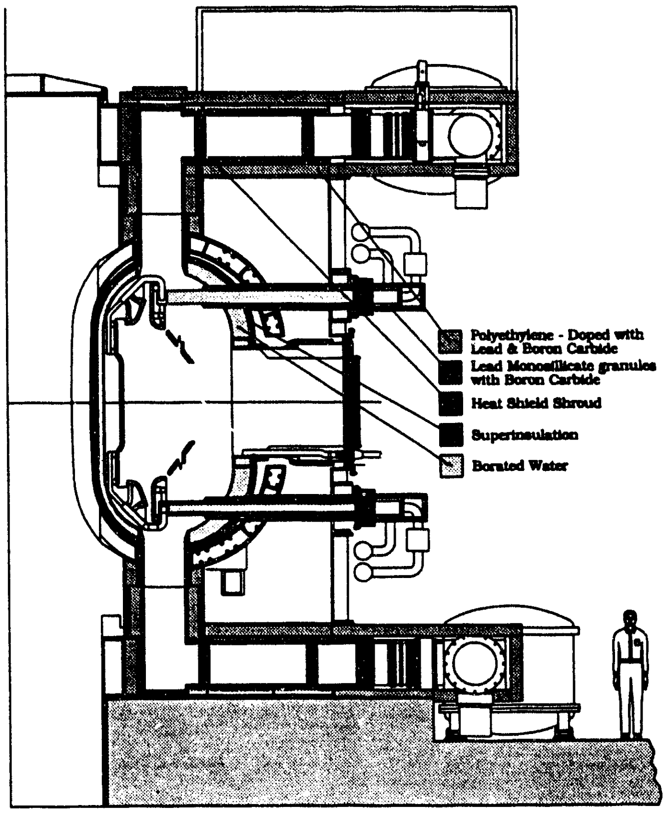

Figure 1
TPX Shielding Configuration

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The pump duct shielding consists of layers of commercial polyethylene doped with boron and lead as shown in Table 1. It will be installed in pre-manufactured blocks after completion of the vessel installation. Thermal protection will be provided by helium cooled shrouds mounted between the ducts and the polyethylene blankets (see Figure 1).

Layer	1,2 &3	4	5
Composition	95% poly	70% poly	19% poly
(by volume)	0% lead	0% lead	80% lead
	5% boron	30% boron	1% boron
Hydrogen	.96 of water	.83 of water	.64 of water
Density	.95 g/cc	1.1 g/cc	4.2 g/cc
Th'k. Inside Cryo.	15 cm	5 cm	5 cm
Th'k. Outside Cryo.	10 cm	5 cm	5 cm
Total Weight	22 tonnes	13 tonnes	46 tonnes

Table 1
Pumping Duct Shielding Blocks

The penetration shielding consists of double-wall titanium plugs filled with borated water fitted to the large ports in the vessel. The plugs will be integrated into the vessel closed loop water system. Local modifications are made to accommodate diagnostics, cooling lines and other penetrations. In restricted areas where low-cost shielding is not adequate, such as vertical pumping ducts in the TF coil region; the neutral beam duct openings, tungsten carbide plates are used to shield the TF coils. Preliminary nucleonics calculations (Ref. 1), summarized in Figure 2, indicate low contact dose rates outside an earlier version of the shielding system. Updated nucleonics calculations will be available in mid-June 1994.

Corrosion studies are underway at ORNL to determine the interaction of the borated water and titanium vessel in TPX operating conditions. Particular attention is being focused on the welds and heat effected zones.

MODULARIZATION

Modularization of components to be handled by the remote maintenance tools is central to the operational efficiency of TPX. The process of packaging a group of small components into a single unit provides several advantages which will permit the maintenance tools to function inside the compact TPX system while also improving overall reliability. For example, the number and type of fasteners used inside the vessel will be limited to reduce the variety and cost of tools. Further, the reduction in the number of elements inside the vessel will minimize

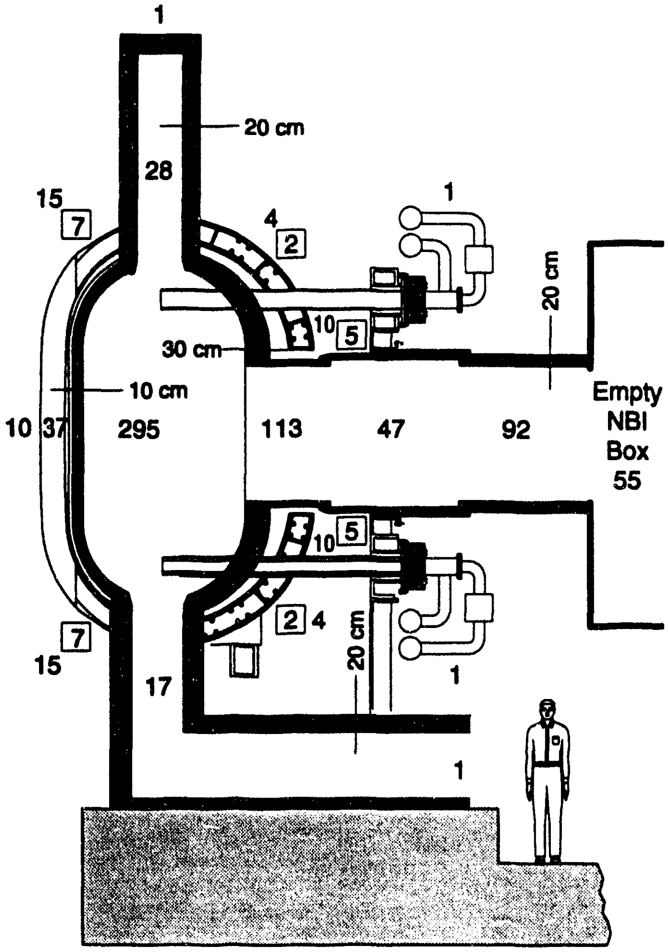

Figure 2
Contact Dose Rates (mr/hr) 1 week after 10 years of D-D Operation

the number of pipe welds which are considered to be the most important challenge faced by the maintenance systems. Further improvements have been planned by locating the 64 inner and outer divertor cooling pipe welds for access from outside the vessel. The remaining 166 pipe welds are designed in a standard form for access from the plasma facing side of the module where remote operation is feasible. A preliminary tabulation of the number and weight of modules inside the vessel is provided in Table 2.

IN-VESSEL VEHICLES

A two-vehicle, track-mounted system will be used to maintain or replace the in-vessel modules (See Figure 3). A track-mounted system was selected because of the limited working volume inside the TPX vessel and the requirements for stability under heavy loading. The functional vehicle, PFC Modules

	Name	Quantity each	Avg. Wgh Lbs
1	In-board Lim. & Pass. Plt's	16	476
2	In-board Divertors	32	325
3	Out-board Divertors	32	816
4	Out-board Passive Plates	32	689
5	Poloidal Limiters	3	108
6	Ripple Armor	29	250
7	Neutral Beam Scrapper	3	409
	Total	**147**	**74,945**
	Average Module Weight		**510**

Table 2
PFC Module Parameters

referred to as the tractor, will mount manipulators, lights, and cameras. All functional systems will be electric powered and controlled through a single umbilical cable. The cable will be deployed from access Port "A" on a constant tension reel with provisions for feed in both directions. Thus the vehicles will cover the interior of the vessel by moving 180° to either side of the access port.

A mating vehicle, the trailer, operating on the same track will mount handling fixtures designed in conjunction with the PFC's. Drives and operators on the trailer will be powered via a jumper cable from the tractor, thus, eliminating the need for additional umbilicals to the exterior of the vessel. Acting in tandem the tractor will position and operate the trailer via remote control from the central maintenance systems control station. Both the tractor and trailer vehicles will have aluminum frames with slide mounted wheel sets to enable the assembly to be compressed to fit the 48 in X 37 in port opening. The wheels will be engaged with a remotely operated, self-locking ACME screw. Control of the wheel system will be maintained by video monitoring of the wheel positions over the track.

The total weight of the IVV system including a typical PFC module will be approximately 2500 lbs. Consequently, the contact stress on the lower in-vessel rail is relatively high. A test program is planned to evaluate several existing titanium coating systems to select the best candidate for use inside the TPX vessel.

TRANSFER SYSTEM

A multipurpose transfer system will be stationed at Port "A" of the TPX vessel (See Figure 4). Its primary function will be to move the in-vessel maintenance systems and components in or out of the vessel with the necessary shielding and environmental protection. A remotely operated horizontal boom will be equipped with special effectors for handling each component or tool. A shielded transfer container with bagging capability will be integrated into the system to provide safe, non contact, movement of contaminated components to the TPX hot cell. Transfer containers will be normally be constructed to match the

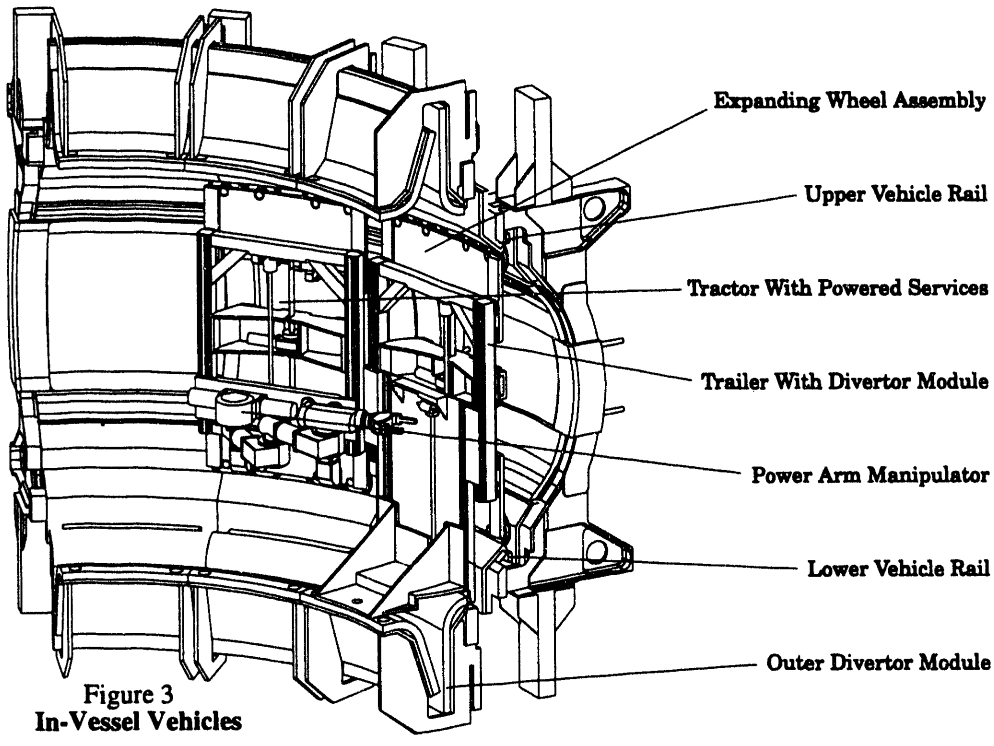

Figure 3
In-Vessel Vehicles

specific requirements of the components to be handled. Thus, shielding for the actual level activation and contamination may range from sheetmetal in the first years of operation to a couple of inches of iron in the final years.

Personnel will have access to the interior of the transfer system through a airlock entry and change room. On-board ventilation will be provided in the transfer system for operations in which the vessel entry hatch is closed. The vessel will also be equipped with a separate ventilation system as required for personnel entry to the vessel interior; primarily for operations occurring during the first two years of service and during the initial startup.

LARGE COMPONENT TRANSFER CONTAINER

Large port mounted components which become activated during the operation of the TPX machine will be removed for maintenance with a special purpose shielded container. Vessel containment will be maintained by sealing the container to a special flange outside the component mounting connection. The component transfer will be performed remotely with an electric operated drive system inside the container. Once loaded the container can be detached from its base for movement via the overhead bridge crane.

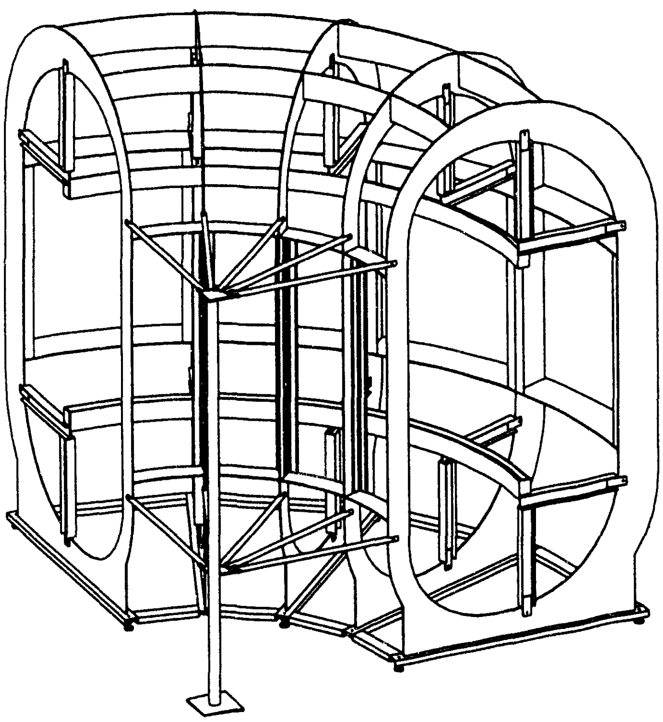

Figure 4
Transfer System

MOCKUPS AND TESTING

Mockup testing is considered to be the key to the success of the maintenance systems; consequently, all components designated to be remotely maintained will be tested at each stage of design in a series of mockups. Two primary full-scale mockups will be used to verify remote maintainability. The first, shown in Figure 5, will be located at ORNL for demonstrations of the proposed design concepts for the in-vessel components, module handling fixtures, and maintenance systems. The frame will be constructed from carbon steel and the internal systems will be fabricated from aluminum, wood, and other inexpensive materials. Emphasis will be placed on quickly trying new ideas and techniques early in the design process.

The second mockup, located at PPPL, will include a sector of the vessel and functional features such as piping and feed throughs. It will be operational throughout the life of the project for use in operator training and unusual event analysis as well as verification of the final designs of the component modules and in-vessel maintenance systems.

The maintenance system will be used during PFC installation and during the first two years of operation in conjunction with hands-on repair of the TPX system. It will be during these operations that the transfer system and in-vessel vehicles will receive the most important testing and evaluation.

TPX-ITER

The TPX maintenance system is based on the experience of the TFTR and JET systems. It will provide a bridge of understanding to the larger more complex problems to be encountered in the International Thermonuclear Experimental Reactor by demonstrating an in-vessel maintenance system which matches comprehensive modular design with mission specific in-vessel maintenance tools.

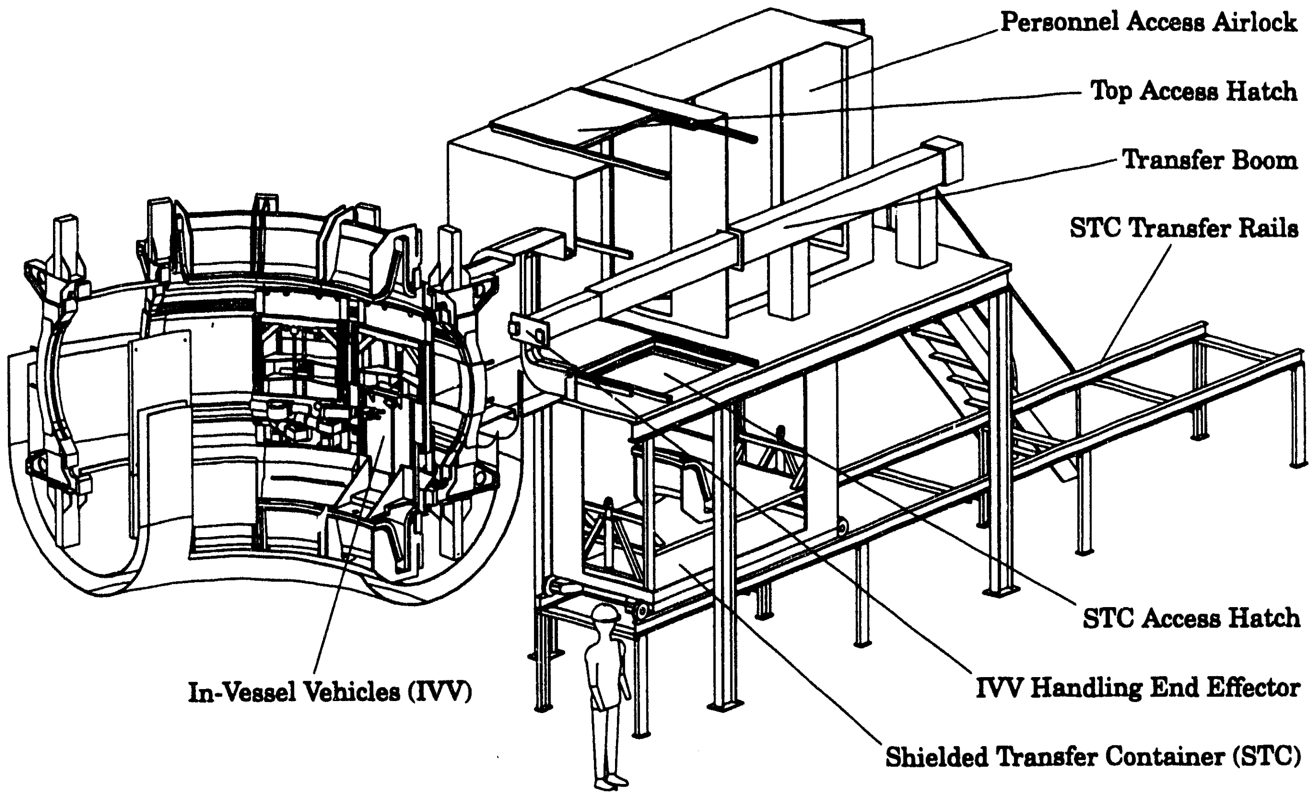

Figure 5
Maintenance System Demonstration Mockup

REFERENCES

1. P. J. Heitzenroeder, "The TPX Vacuum Vessel and In-vessel Components;" to be published in the *Transactions of the Eleventh Topical Meeting on the Technology of Fusion Energy; 1994.*

2. S. L. Liew, "Preliminary TPX Dose Map," presented at the TPX Engineering Meeting, November 4, 1992.

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