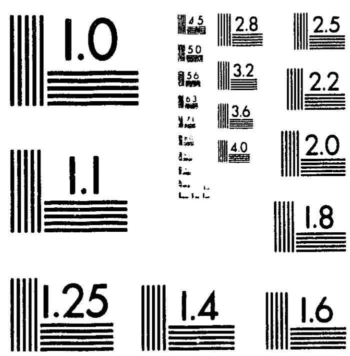
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THE CONFIGURATION DEVELOPMENT AND INTEGRATION OF THE TPX DEVICE*

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Abstract-- The TPX configuration was designed to meet the physics objectives and subsystem requirements in an arrangement that allowed access for remote maintenance. The steady state operations of TPX favored the use of superconducting magnets for both the toroidal and poloidal field systems. The desire to react the TF centering and overturning forces in a simplified wedged system lead to a TF case concept incorporating "two-coil" TF modules in a 90° four-coil quadrant arrangement. Low ripple and tangential plasma access to accommodate TFTR neutral beams were leading factors in determining the size and number of TF coils. The need for a large amount of space for the divertor and first wall component coolant services further influenced the shaping of the vacuum vessel. Additional configuration influences included: low activation considerations, divertor pumping, remote maintenance requirements, service access and compatibility with the existing TFTR text cell facility. The TPX configuration development and integration process has evolved through the conceptual design period and is now ready to enter the Preliminary Design Phase of the project. This paper describes the status of the configuration development and integration of the major TPX tokamak subsystems components.

I. INTRODUCTION

The design point for the TPX tokamak device has been established based on the steady state and advanced tokamak mission requirements. Table 1 provides a listing of some of the major physics and component parameters. The reference design has a major radius of 2.25 m, a toroidal magnetic field of 4 T, a vertically elongated cross section and a spacious poloidal divertor. An elevation view of the TPX configuration is shown in Figure 1.

Superconducting magnets are used for both the toroidal and poloidal field systems because they are steady state by nature and offer low power consumption. Since the device uses deuterium fuel, in-vessel components are being designed to be remotely maintainable. To permit hands-on access to the fullest extent possible low-activation materials have been specified for use in all applications where technical and cost feasibility permits. Following this plan, titanium is the candidate material for the vacuum vessel and titanium is used in the central portion of the cryostat, a region where the large horizontal ports penetrate and local activation is possible. A modular construction concept was adopted for the TF coil and vacuum vessel to enhance machine assembly and remote maintenance features. The configuration accommodates a double-null plasma arrangement with divertor pumping ducts located at the top and bottom of the device. The TPX device will be located in the TFTR test cell, to take advantage of TFTR site credits.

Table 1. TPX Machine Parameters

Major radius	R_0 (m)	2.25
Minor radius	a (m)	0.50
Aspect ratio	A	4.5
Magnetic Field	B (T)	4.0
Plasma Elongation	k_x	2.0
Plasma current	I (MA)	2.0
TF Overall Height	(m)	4.9
TF Overall Width	(m)	3.2
Cryostat Height	(m)	8.4
Cryostat OD	(m)	9.8

II. TPX CONFIGURATION

Magnet Systems

The elevation view of Figure 1 highlights the major features of the TPX configuration. A double-wall vacuum vessel structure separates superconducting TF coils and plasma components within the bore of the TF coil. A combination of water between the vacuum vessel double-walls and exterior attached vacuum vessel shield tiles limits the nuclear heating to the TF coils and activation of external components. Local shielding is also used around the large penetration ports. Superinsulation is layered on the outside of the vacuum vessel shield to limit its heat load to the TF coils. The plasma vacuum vessel ports interface with an external vacuum cryostat which consists of a cylindrical side wall, a flat built-up base structure and removable lid. A superinsulation/nitrogen shield is hung off the inside wall of the cryostat and a similar shield is attached to the base structure and lid. Superconducting PF coils, comprising an 8 section solenoid coil and six ring coils, surround the TF coil. The vertical loads of the PF coils are supported by the TF coil system.

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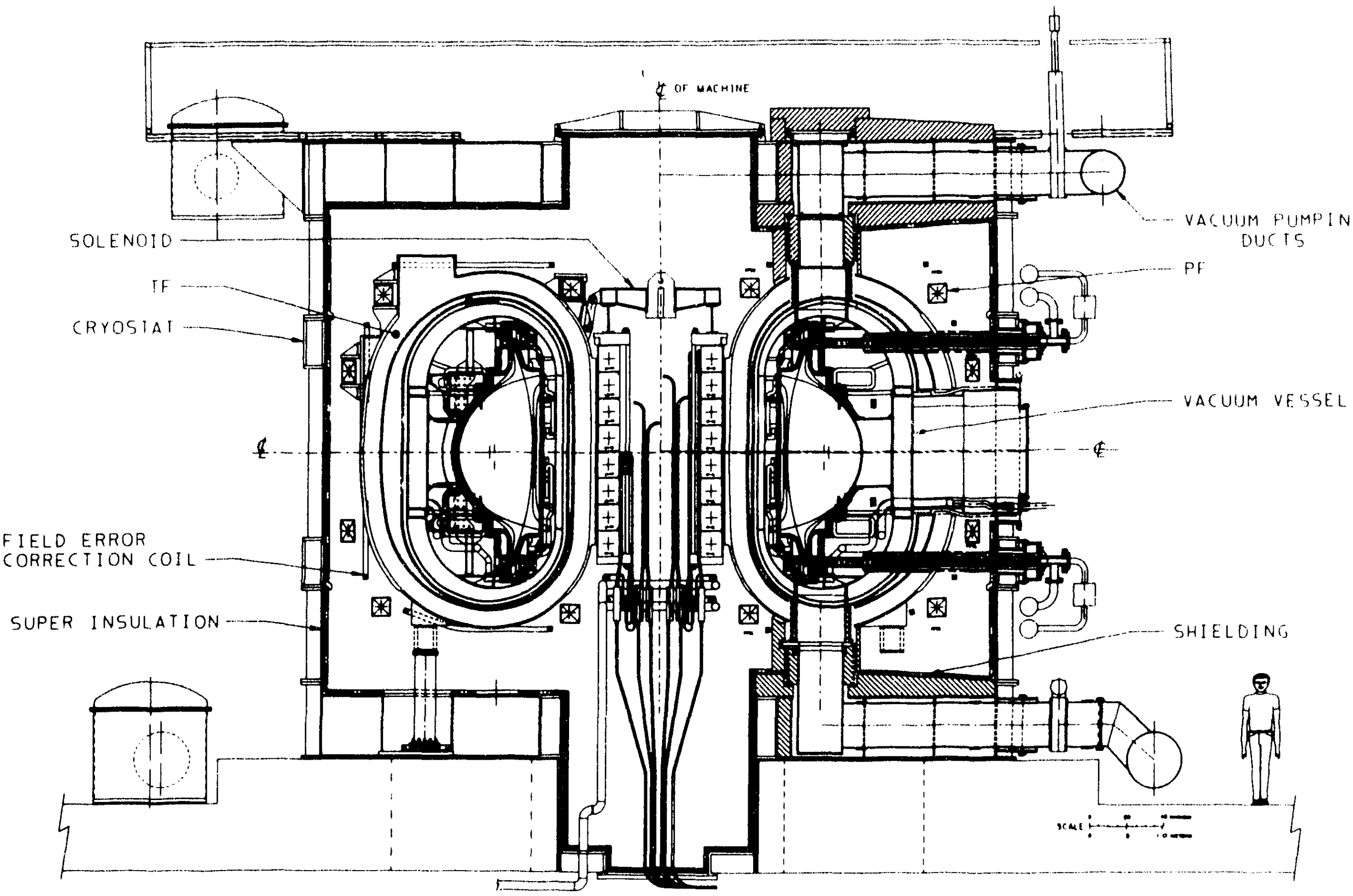

Fig. 1 Elevation View of TPX Configuration

A 16 coil TF arrangement was selected for the baseline configuration with the position of the outer TF leg set by the space requirements of the tangentially aligned neutral beams and the included space for superinsulation, vacuum vessel port side walls, and assembly gaps.

The basic component of the configuration is the tokamak module which is made up from two stainless steel TF assemblies (each housing two TF coils), a one-quarter vacuum vessel segment, local port connections for three large horizontal ports and two upper and lower divertor pump ducts. The details of the TF assembly is shown in the isometric view of Figure 2 The TF assembly has a central structural weldment and two end closure weldments. The conductor winding is inserted into the central weldment from the sides. A final closure weld is made between the end closure assemblies and the central assembly, along the inside and outside surfaces. Two TF assemblies are joined together along the intercoil structure parting plane with an electrically isolated bolted joint. Four tokamak modules form the tokamak core with wedging in the nose region. The tokamak modules are welded together vertically at the intercoil structure interface along the back surface. The weld interfaces are being designed for remote cutting and rewelding for module replacement. A bolted connection at all TF assembly interfaces is also being considered as an alternate design approach. Module interfaces are on radial lines with no vacuum vessel ports located on the parting plane. Smaller auxiliary ports are located on each side of the vacuum vessel parting plane, allowing the vacuum vessel segments to be

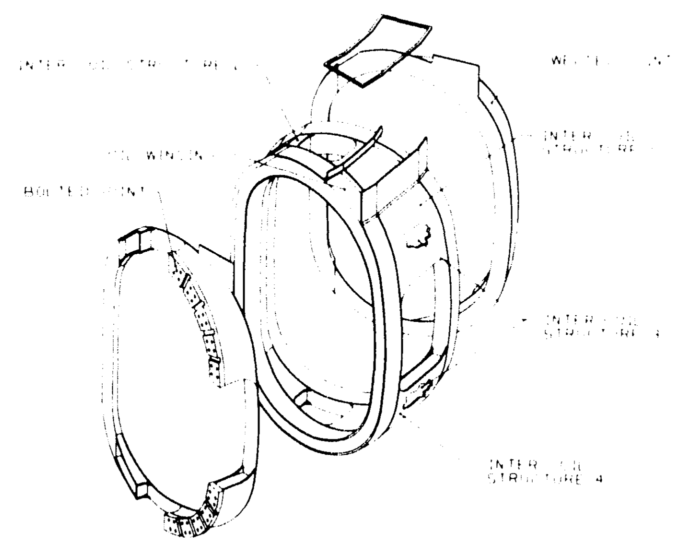

Figure 2 TF Assembly Isometric View

joined by a continuous weld. The tokamak module is designed for a vertical replacement without removing the cryostat side walls.

Vacuum Systems

The double-wall vacuum vessel has an elongated shape divided into four 90° segments for ease of assembly. Horizontal ports have been vertically lengthened to allow service lines to pass above and below plasma interfacing components that reside within the horizontal ports. The vacuum vessel is supported from the center lower pumping port through a link system attached to the cryostat base. The arrangement of first wall and divertor components have been established to meet the physics requirements for a double-null divertor, surface protection for the ICRH launcher and close-in (continuous) passive plate surfaces for plasma control. The divertor is sub-divided into 16 fully integrated modules with 32 horizontal coolant feeds that supply water to each module from outside the cryostat. The divertor modules are designed for remote maintenance using an in-vessel rail mounted manipulator system. Figure 3 shows the details of plasma facing components (PFC).

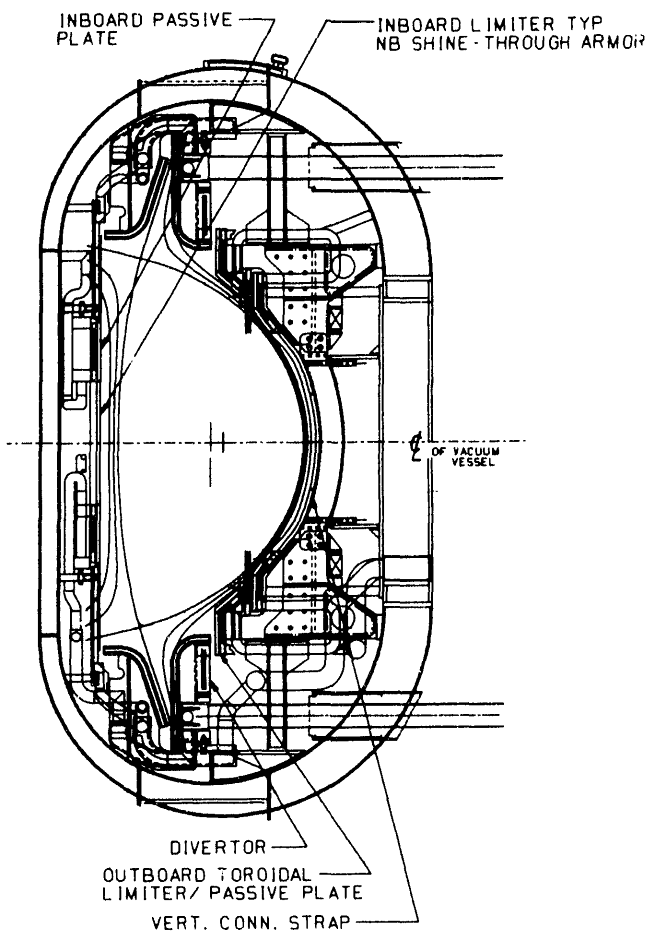

Figure 3 Elevation View of PFC Arrangement

III. CONFIGURATION UPGRADES

Adjustments are being made in the TPX configuration to refine the build dimensions of the tokamak core components to enhance component fabrication tolerances and add additional space for assembly. Also, design modifications of in-vessel components and service arrangements are being developed to improve in-vessel remote maintenance characteristics. One example of a recent refinement made to the TPX configuration is the reshaping of the inboard passive plate. A change proposal was submitted and approved that repositioned the inboard divertor and also reconfigured the inboard passive plate surface, reshaping it to be flush with the inner first wall surface. The configuration change more effectively utilized the space in this region. It allowed for increased space for FW/divertor services, greater space for shielding and added fabrication space for the TF coil. A more compact divertor module arrangement was also developed, allowing the removal of the outboard divertor module in a single vertical motion with improved maintenance features. The divertor removal path for this new arrangement is shown in Figure 4.

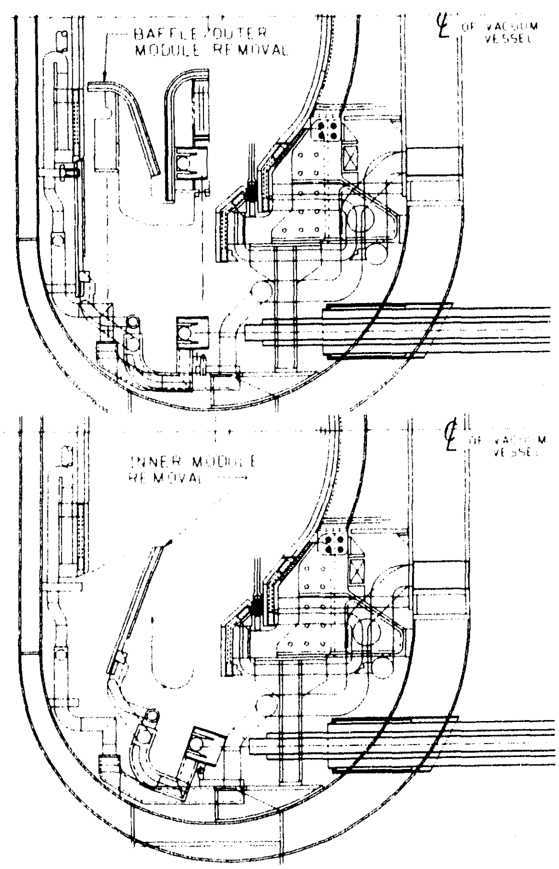

Figure 4 Divertor Removal

The outboard passive plate geometry and the in-vessel service lines have been adjusted to enhance the maintenance of the lines and the components that they service. The lines that feed the inboard passive plates have been extended up into the region behind the inboard limiter, allowing the lines to be cut (using a tube weld head) after the removal of the inboard limiter. The outboard passive plate service connections and line routings were spaced and oriented to allow a tube weld head to access the lines for maintenance. The coolant plenum and feeds to the outboard passive plate have been relocated to the bottom of the plates, extending the lower outboard plate below the top of the divertor surface. An isometric view depicting the current arrangement of in-vessel components and services are shown in Figure 5.

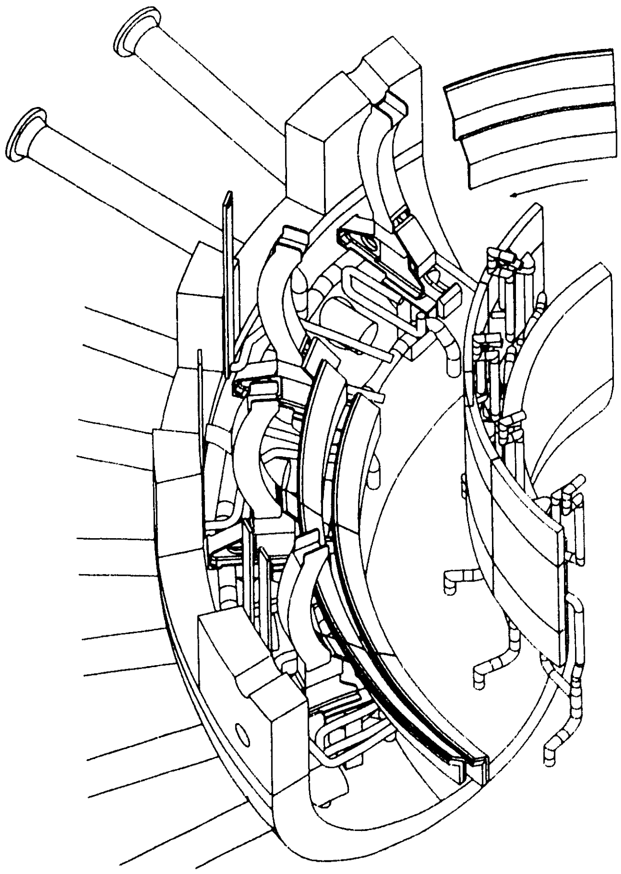

Figure 5 Isometric View of the PFC arrangement

To satisfy plasma kink mode stability requirements additional current carrying structure is benig added to the outboard passive plate system. Ten vertical current carrying structures (located on each side of the large horizontal ports) have been added, connecting the upper and lower passive plates. Three additional structures are located at the center of each neutral beam port, providing added connections and support for poloidal limiter surface. Center port connections do not interfere with the tangential alignment of the neutral beams and diagnostic systems in these ports. Additional local current carrying structure can be added at different port locations to maximize the poloidal coverage of the conducting shell. The design and arrangement of stabilizing structure is being developed consistent with remote maintenance operations. An isometric view of the kink mode stabilization structure is shown in Figure 6.

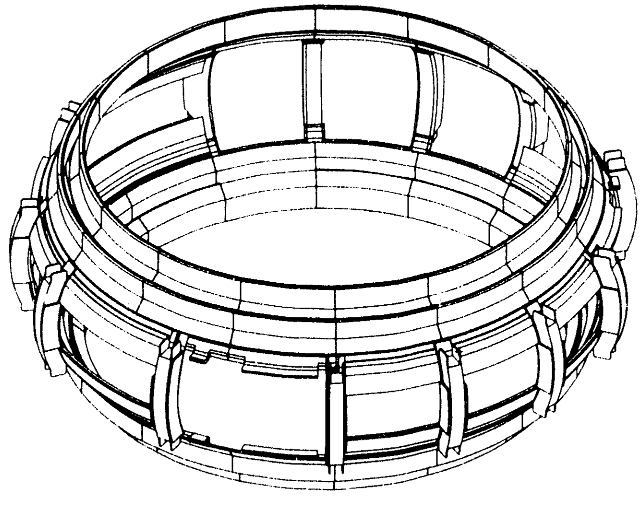

Figure 6 Kink Mode Stabilization Structure

A modified vacuum vessel concept has been developed which provides an in-wall coolant supply system, relocating the supply lines that feeds the inboard PFC's and moves them between the walls of the vacuum vessel. Supply lines can be located at the ends of a 90° segment, at the bottom of the vacuum vessel. The lines would transition to a toroidal manifold that feeds 4 lines that run up the inner vacuum vessel wall (between ribs) attaching to through-the-wall PFC connections. The return system would mirror the supply system (located at the top of the vacuum vessel) and be located between the next series of ribs. As a further addition to this concept, the main in-wall coolant supply line was located in a larger pipe, allowing the outer pipe to supply borated water to the vacuum vessel walls (with the return at the top), forming an independent shield system. There is space between the intercoil structure at the ends of a 90° segment to bring insulated coolant lines out to the cryostat. Serious consideration is being given to this approach as a means to improve the shield design and better optimize the space between the plasma and TF magnet.

V SUMMARY

The TPX configuration meets the physics operation objectives in an arrangement that provides plasma component access and remote maintenance serviceability. The configuration design will continue to evolve through the Advanced Conceptual Period to optimize the overall system arrangement and develop a comprehensive set of Advanced Conceptual Design drawings to be available for the start of Preliminary Design.

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