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TMX, A NEW FACILITY

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Summary

As a mirror fusion facility, the Tandem Mirror Experiment (TMX) at the Lawrence Livermore Laboratory (LLL) is both new and different. It utilizes over 23,000 ft^2 of work area in three buildings and consumes over 14 kWh of energy with each shot. As a systems design, the facility is broken into discreet functional regions. Among them are a mechanical vacuum pumping system, a liquid-nitrogen system, neutral-beam and magnet power supplies, tiered structures to support these supplies, a neutron-shielded vacuum vessel, a control area, and a diagnostics area. Constraints of space, time, and cost have all affected the design.

Description

A basic premise in designing TMX is the maximum utilization of existing laboratory assets. This expedites the construction schedule by using on-hand equipment and borrowing established technology from earlier mirror fusion experiments. For the base case of experimentally establishing a potential well between two mirror plasmas, this means a machine plasma approximately 6.5 m long.[1] Nominal vacuum pumping guidelines based on scaled neutral-beam requirements from 2XIIB size a vacuum vessel 13-1/2 ft in diameter by 46-1/2 ft long (Fig. 1). Initial neutral beam injection will begin with 24 Lawrence Berkeley Laboratory (LBL) neutral-beam modules, 12 per plug. Expansion to 20 modules per plug is possible with some future modifications. To maximize access to the plasma, the vacuum vessel is mounted over a pit, giving 360° access about the major axis.

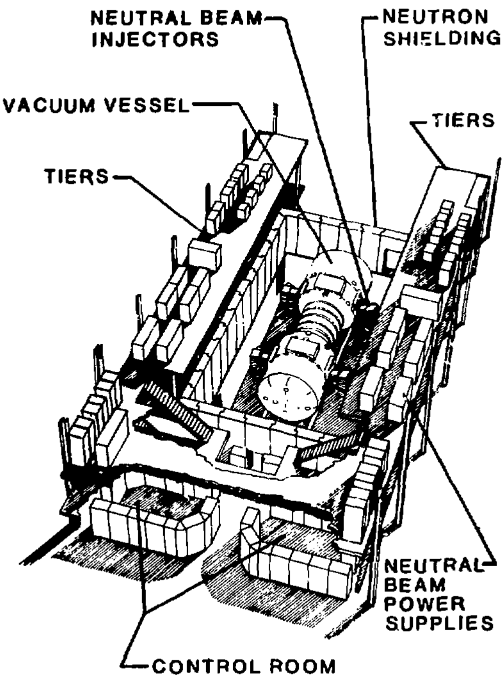

Figure 1. Building 435 High Bay Area.

An experiment of this size requires shielding from the neutrons produced by the plasma DD reactions. To remove this neutron flux hazard, a wall of concrete panels surrounds the perimeter of the pit. The combined pit and concrete shielding design have some practical constraints. First, overhead crane access must be preserved; second, sufficient space adjacent to the pit must be allocated for neutral-beam injector power supplies. The vacuum vessel, the neutral-beam injectors, their power supplies, and the machine control area must all fit within the high-bay portion of building 435.

Site Development

Though the TMX facility is primarily in the west end of the building 435 high-bay, it draws a large part of its utilities from other areas of the Magnetic Fusion Energy site (Fig. 2). Primary power to the TMX facility comes from three site substations. These substations pulse 28 rectified, constant-current power supplies in building 436 that are cabled to the TMX coil sets. The supplies power the coil sets up to 16.5 MW for a 3-s pulse.[2] To minimize the electrical interference of this pulse with the machine controls and diagnostics, general power to building 435 comes from a fourth, independently-fed substation.

Running the neutral-beam injectors requires capacitor banks in buildings 446 and 436, three-phase 480-V ac line power, and newly developed battery banks. The electrolytic capacitor banks in building 436 supply accel/decel grid power to eight 40-keV modules. The oil capacitor banks in building 436 supply accel/decel grid power to sixteen 20-keV modules. Both the filament and arc power supplies are of two types — existing supplies driven by three-phase 480-V ac line power and new storage battery banks.[3] All these components, along with the plasma target guns, are arrayed about the machine pit area in building 435 on a two-tiered support structure. The close proximity to the machine minimizes the impedance of the injector cabling.

Pulsed magnet and injector power systems require that special attention be given to machine grounding. Low-impedance grounding planes are established within the machine pit area and throughout the tiers. These planes are tied into a common ground established through buildings 435, 436, and 446.

On the south side of building 435 is the mechanical vacuum pumping station for TMX. The pumping station consists of seven pumps for a combined capacity of 1700 ft^3/min at atmospheric pressure commonly manifolded to a roughing line and foreline (Fig. 3). The foreline manifolds to four 16-inch diffusion pumps, two per plug tank, and two 10-inch diffusion pumps on the central tank. All diffusion pumps are cooled by an independent, chilled-brine system stationed on the south side of building 435. These diffusion pumps are backed by two parallel Roots*-type blowers. This pump-manifolding network minimizes roughing time of the vacuum vessel, provides various levels of backing for the diffusion pumps and the Roots blowers, and allows individual pump cutout without interrupting system operation.

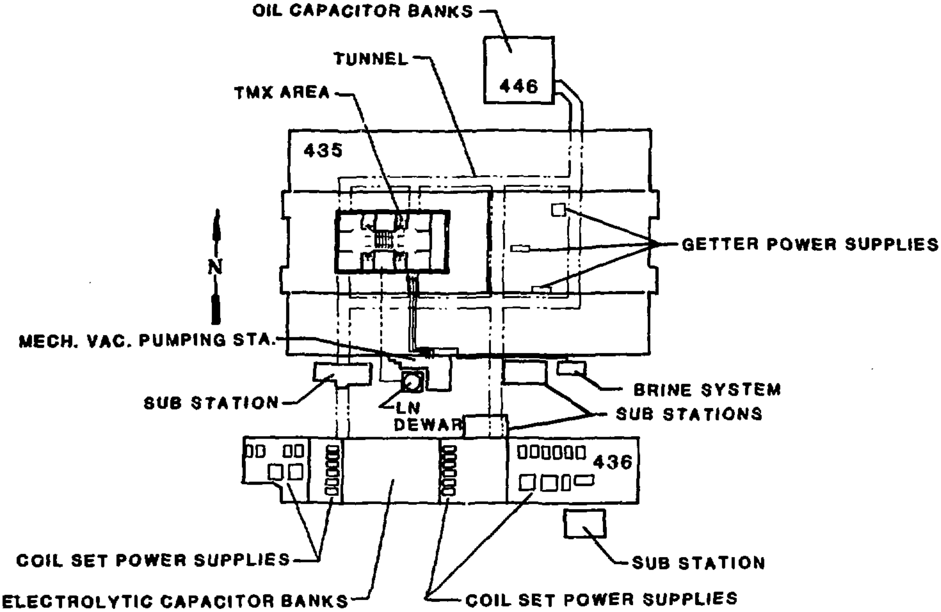

Figure 2. Site Plan.

All of the pumps are protected with liquid-nitrogen (LN) trapping. During machine operation, high-speed pumping is provided by LN-cooled, titanium-gettered surfaces.[4] Liquid nitrogen requirements for these surfaces and for the rest of the TMX facility, based upon scaling of present 2XIIB consumption, are projected to average 11,000 gal/day. Installation of a 23,000-gal storage dewar will permit continued operation through normal weekend interruption of scheduled LN deliveries.

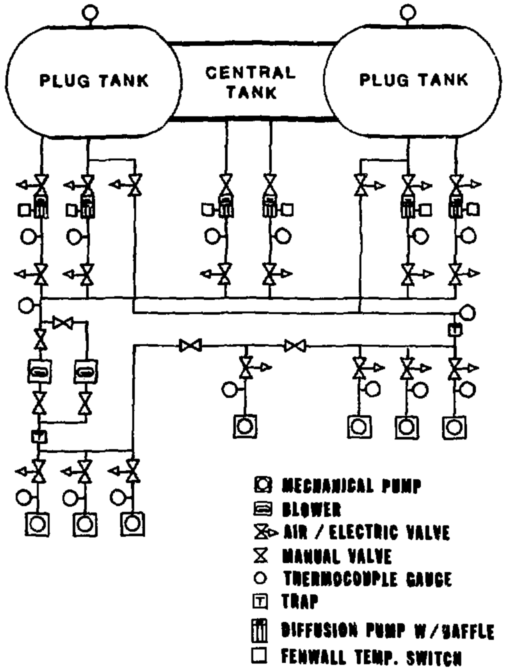

Figure 3. Vacuum Pumping Schematic.

System Integration

The machine pit area in building 435 houses the TMX vacuum vessel, neutral-beam injectors, and coil sets, all surrounded by concrete neutron shielding. Peripheral to the machine pit area are neutral-beam power supplies on a two-tiered support structure and control rooms. The entire complex is spread over four levels: 1) the pit floor, 2) the building ground floor, 3) the first tier floor and 4) the second tier floor (Figs. 4, 5, 6, 7).

At the pit floor level, cabling to the confinement coil sets and getters, the vacuum roughing and foreline piping, the brine supply and return, and most other general utilities flow into the area transverse to the major plasma axis. All manifold along the longitudinal walls of the pit to minimize secondary line lengths and maximize machine access. Besides the tunnel access routes, twelve 4-in-diam conduits run from the east wall of the pit to the control rooms. These conduits and similar cabling tray runs, under the floor of each tier, route control of the TMX facility from all corners of the high bay.

The pit is 32-ft wide by 56-ft long by 12-ft deep. The major plasma axis is 16 ft above the pit floor, giving equal clearance from the axis to the floor or walls. The pit is integrally designed with the surrounding concrete neutron shielding and tiers; the walls support 2100 lb/ft^2 in compression as well as a transverse load of 500 lb/ft^2. Correspondingly, the surrounding ground floor and tier floors are each designed to support 150 lb/ft^2. Each concrete shielding panel is capable of being independently removed from the wall without affecting wall stability, simplifying machine maintenance logistics. Similarly, flooring in any tier column bay can be removed for crane access without affecting overall structural stability.

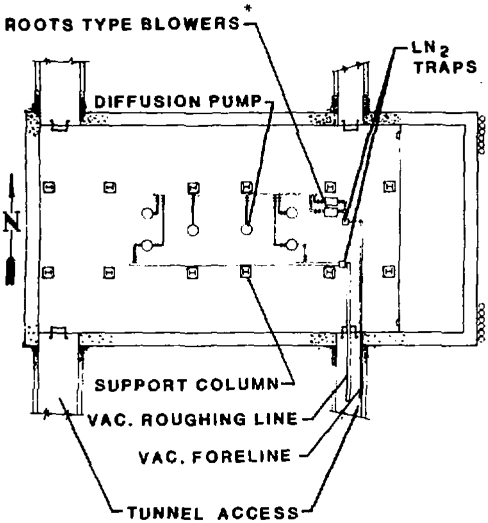

Figure 4. Pit Floor Plan.

In the pit, a generalized structure supports the vacuum vessel, coil sets, and neutral-beam injectors. The vacuum vessel rests on a primary pair of girders that run the length of the pit. Such a design accommodates disassembly and separation of the vacuum vessel for routine internal maintenance and provides flexibility in the arrangement of the vacuum vessel. The structure also supports the beam injectors which are assembled and disassembled using an overhead beam and post fixture. Such an arrangement permits single injector modules to be swung clear of the injector bundles for removal with the building crane.[5] The support structure also accommodates an ancillary, modular access platform. Such platforms would locally give access to specific hardware components attached to the machine. Altogether, the entire pit structure will support over 250,000 lb.

For reasons of safety and convenience, one of the most important aspects of the facility design is personnel flow about the area. A primary flow pattern on the pit floor is a loop about its perimeter (Fig. 5). Such a circuit allows easy access for assembly and disassembly of utility feeders along the pit walls and of the modular access platforms as experimental needs change in time. Further, it provides a minimum length path through equipment under the machine as well as multiple emergency exiting by any of the tunnels. Normal exiting is through the shielding walls at the ground level at both ends of the major machine axis. These exits are flanked to either side by stairways up the tiers.

Neutron Shielding Considerations

Appraisal of the biological hazards associated with the operation of TMX on deuterium indicate the need for neutron shielding. Concrete is used for the shielding because of its high neutron attenuation capability and the ease of its handling for quick assembly and disassembly in area maintenance work. To keep the time-average dose rate outside the shielding walls under 0.5 mrem/h, with an anticipated DD fusion neutron average source strength of 3×10^8 n/s, 2-ft-thick concrete shielding is required.[6] Although the most effective shielding would completely surround the experiment, economics and accessibility require that the top be uncovered. So, the biological dose rate outside the shielding is a combination of direct radiation through the wall and indirect radiation by air scattering over the wall. Simple analytical models show that the shield effectiveness is primarily a function of both the thickness of the shield on line-of-sight from source to observer and the included angle between the source, the observer, and the top of the shielding wall. Personnel present on different building levels in outlying areas of building 435 explain

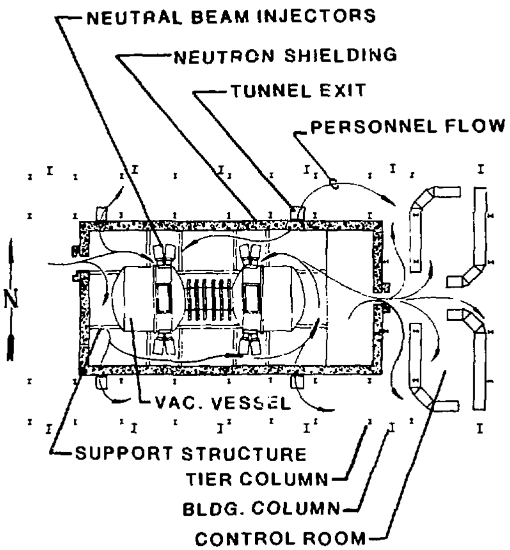

Figure 5. Ground Floor Plan.

the need for variation of shielding height. The tiers are not shielded from the neutron flux because they are high-voltage exclusion areas during machine operation. Radiation due to activation of surrounding building structure is insignificant. Later computer modeling of the TMX shielding using the MORSE-L program[7] has substantiated the design of the neutron shielding.[8]

* Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the Energy Research and Development Administration to the exclusion of others that may be suitable.

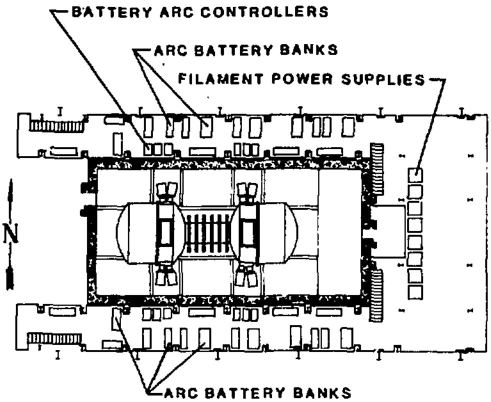

Figure 6. First Tier Floor Plan.

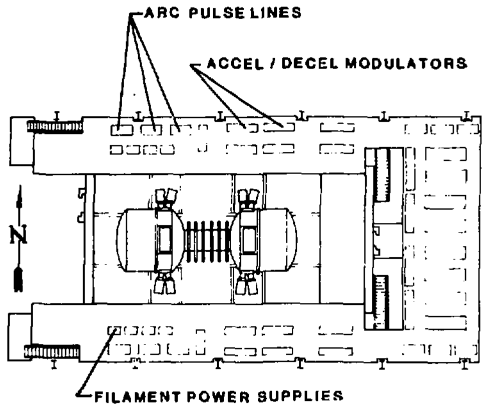

Figure 7. Second Tier Floor Plan.

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