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HYDROGEN RECYCLING IN TANDEM
MIRROR MACHINES

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INTRODUCTION

This paper describes hydrogen recycling in tandem mirror machines. In TMX,[1] hydrogen (or deuterium) is introduced by the neutral beam injection system and by the solenoid gas feed system. Pumping is achieved by titanium gettering on liquid nitrogen panels. Mirror machine recycling differs from that in a tokamak. In mirrors, plasma losses are mainly to the large volume at the ends of the machine, remote from the hot plasma region. Similar techniques have been employed on 2XIIB.[2,3] The design of the TMX vacuum system was described by Atkinson.[4] MFTF also employs an integral beam line vacuum system. However, since in MFTF the pulse length is 0.5 sec, helium cryopanels are used to extend the pumping duration. Also special neutral beam and beam-ion dumps are employed.

The TMX Vacuum System

The sketch in Fig. 1 shows many features of the TMX vacuum system. The system consists of two large stainless steel tanks which house the end plug magnets. These tanks are subdivided to pump gas from the 25 msec duration neutral beam injectors. Most surfaces in this region are at liquid nitrogen temperature. The aluminum solenoid tank is at room temperature. All tanks are equipped with titanium getter wires[5] which deposit a few monolayers of titanium per cycle throughout the machine. In total about 75 meters of 3 mm dia. getter wire is heated on each cycle.

TMX Vacuum System Measurements

The end tanks of TMX must pump gas from the neutral beam injectors similar to a tokamak neutral beam line. Measurements of the pressure rise in various regions of TMX due to neutral beam gas has been carried out. Fig. 2 shows that the baffles between regions delays gas buildup into the plasma chamber and to the end fan region. These measurements are without gettering and with the liquid-nitrogen liners warm. Fig. 2 shows that gettering in the end fan region substantially reduces the pressure rise. Fig. 3 shows much further reduction in the pressure rise when the liners are cooled with liquid nitrogen. These measurements show that TMX plug vacuum system is performing qualitatively as designed. Detailed comparisons with calculations are in progress.

Hydrogen Fueling of the TMX Solenoid

Hydrogen is fed into the TMX solenoid either by gas boxes or by a puffer valve. The gas boxes are located at the ends of the solenoid near the regions of high magnetic field where the plasma has a thin elliptical cross section. The puffer valve feeds hydrogen into the middle of the solenoid. The solenoid vacuum chamber radius is 42 cm. The plasma 1/e density radius is 20 to 35 cm.

An example of pressure rise in the solenoid without and with plasma is shown in Fig. 4. This case is an example of high gas feed rate with the puffer valve. We observe that plasma pumping reduces the ambient pressure. We find that if the gas valve is turned off during a shot, the plasma density rapidly decays indicating that the gas input controls the feed rather than wall recycling.

TMX Clean-Up

We have observed that it is necessary to getter both the end plug and center cell regions of TMX before we can get plasma buildup after initial pumpdown. After gettering, we find that a few dozen shots with further gettering are required to extend the plasma duration to the full 25 msec neutral beam pulse. The extent to which gettering, as opposed to plasma-wall interactions, is important in this second step has not been studied.

REFERENCES

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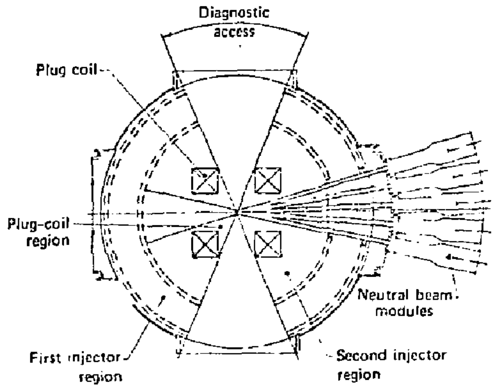
Figure 1



Cross section of the center of the plug tank.

Table 1. Characteristics of TMX pumping regions; areas and volumes are given on a per-plug basis.

Region	Surface temperature, °C	Surface area, m^2	Volume, m^3
First injector	−195	65.5	17.9
Second injector	−195	45.4	8.5
Plasma end dump	−195	33.8	14.8
Plug coil	20	4.7	3.0
Central cell	20	34.4	10.6

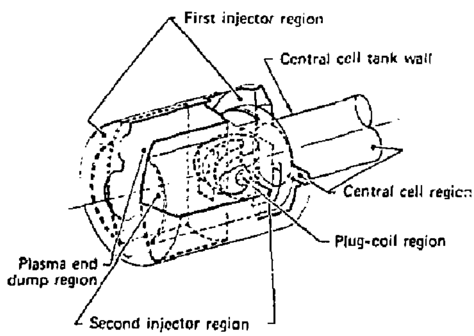
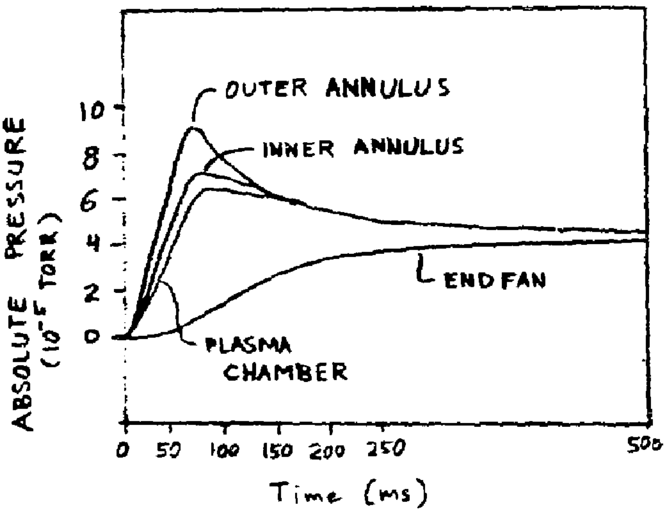


Diagram of the TMX internal liners showing the pumping regions.

Figure 2

PRESSURE RISE DUE TO A 60 ms GAS PULSE FROM ONE SOURCE

A. EFFECT OF BAFFLES



B. EFFECT OF GETTERING

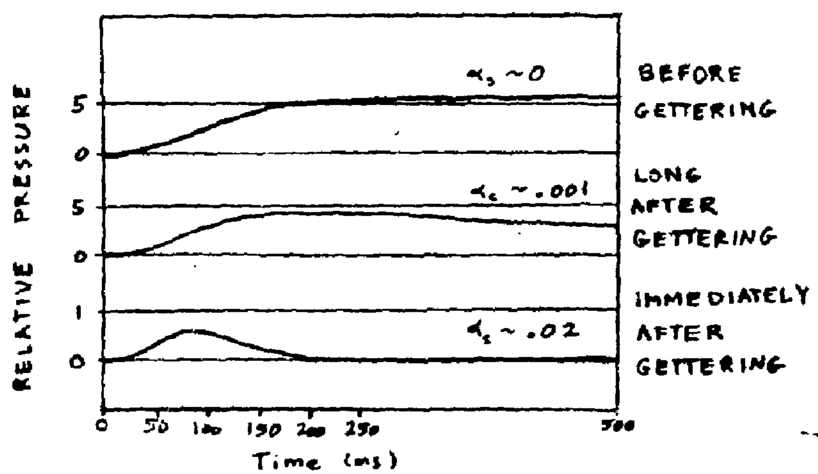


Figure 3

PRESSURE RISE AFTER GETTERING DUE TO A 55ms GAS PULSE FROM 8 BEAMS (~240 torr-l-s^{-1})