

UCRL-85002  
PREPRINT

CONF-801011--7

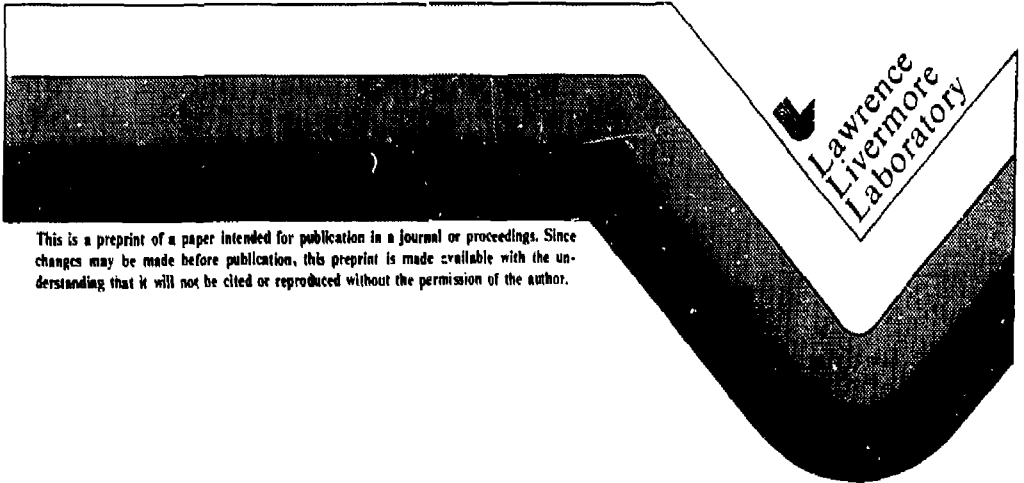
MFTF--PROGRESS AND PROMISE

K. I. Thomassen

**MACTED**

This paper was prepared for publication in the Proceedings of the Fourth ANS Topical Meeting on The Technology of Controlled Nuclear Fusion, King of Prussia, PA, October 14-17, 1980.

October 3, 1980



This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

## MFTF--PROGRESS AND PROMISE\*

R. I. Thomassen  
Lawrence Livermore National Laboratory, University of California  
Livermore, CA 94550

The Mirror Fusion Test Facility (MFTF) has been in construction at Lawrence Livermore National Laboratory (LLNL) for 3 years, and most of the major subsystems are nearing completion. Recently, the scope of this project was expanded to meet new objectives, principally to reach plasma conditions corresponding to energy break-even. To fulfill this promise, the single-cell minimum-B mirror configuration will be replaced with a tandem mirror configuration (MFTF-B). The facility must accordingly be expanded to accommodate the new geometry. This paper briefly discusses the status of the major MFTF subsystems and describes how most of the technological objectives of MFTF will be demonstrated before we install the additional systems necessary to make the tandem. It also summarizes the major features of the expanded facility.

### MFTF Progress

As originally planned, MFTF has several major subsystems which present technical challenges in their construction. These are the vacuum vessel and associated cryo and vacuum pumping systems, a large Nb-Ti superconducting magnet, an 80-kV neutral beam system, and the associated computer control system to operate all systems in the facility and to process machine and plasma data. The many additional auxiliary systems include plasma guns and 20-kV short-pulse neutral beams for plasma production and startup; neutral beam injector accessories for beam steering, shielding, neutralizing, and gas control; and plasma diagnostic instruments. In general, completion of these auxiliary systems will be delayed until the last 2 years of the MFTF-B construction.

To date, costs and commitments have reached 82% of the total construction monies. Based on an earned value system, the magnet is 92% complete, the vessel and vacuum systems 95% complete, and the 80-kV beam system 72% complete. Auxiliary components, as well as R&D and testing, are funded from operating monies, and these activities are 36% complete.

\*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

Both halves of the yin-yang magnet have been wound, have their 1/2-in.-thick steel inner case around them, and have been placed in their 3-in.-thick steel structural cases. Spaces between the inner and structural cases have been filled with urethane injection (except for a guard vacuum region excluded by a "muffin tin" bladder). Final welding of the structural cases is in progress (see Fig. 1), and the halves will soon be joined. Installation in the vessel is scheduled for May 1981.

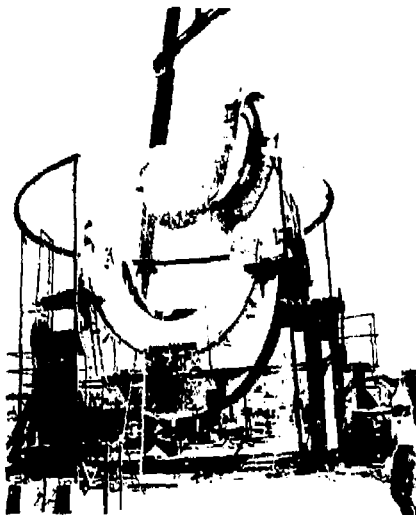


Fig. 1. One half of the MFTF yin-yang magnet in construction. The magnet winding is inside the case resting in the top half of the lower structure. A structural cover is being lowered over it.

Rough pumping of the vacuum vessel has begun. The 11-m diam by 18-m long tank (see Fig. 2) has two large end domes and numerous small, medium, and large (2-m diam) ports which are being leak tested in the process. Components of the nitrogen and helium system are being tested, and a system test will begin in December 1980 after some of the cryopanel have been installed in the vessel. The 3-kW helium

#### DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranties, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or approval by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.



Fig. 2. The MFTF vacuum vessel with the far end dome in place. This 11-m-diam by 18-m long cylinder with its numerous penetrations is now being pumped out and leak-tested.

refrigerator for the cryopanel and magnet is part of a closed-loop system. The open-loop nitrogen system cools the magnet liner and the chevron surfaces in front of the cryopanel.

Power supplies for the 80-kV system are being built under contract with industry, and the first units (one at the contractor site and one at LLNL) are in test, with full production well underway. The LLNL site work for the dc supplies and the 250-MW substation to energize the supplies have been completed. A first supply delivered to LLNL will be incorporated into the High-Voltage Test Stand at the end of this year, and source tests will begin in 1981.

During 1981, while MFTF-B construction begins, demonstrations of key technologies will be carried out. The major tests are energization of the magnet and the simultaneous running of four neutral beams at 80 kV. Since both tests take place in the vacuum vessel, all vessel systems must be operable with the MFTF control computers.

#### The Tandem Mirror Upgrade

In the tandem configuration, the MFTF performance increases significantly. Measured in terms of the confinement parameter  $n\tau$ , MFTF was designed to reach  $10^{12} \text{ cm}^3\text{-s}^{-1}$ , whereas MFTF-B should reach  $5 \times 10^{13} \text{ cm}^3\text{-s}^{-1}$ . Perhaps more significantly, the performance at a given beam energy is much better in a tandem than in the yin-yang cell. In Fig. 3, the confinement parameter is plotted against the ion energy in the machine (central-cell energy in the case of a tandem).

Two different scaling laws are represented, one corresponding to magnetic trapping with a mirror ratio  $R = 2$ , the other to electrostatic trapping with a potential barrier of 2 times the central-cell ion temperature. As shown, MFTF-B reaches conditions corresponding to energy breakeven.

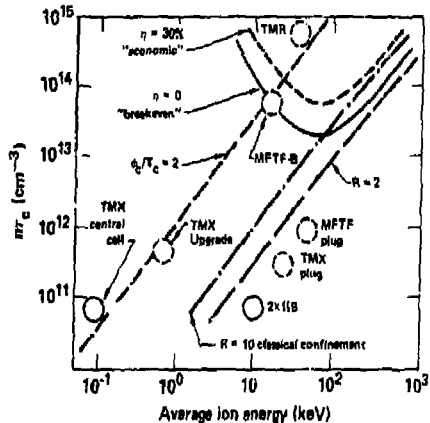


Fig. 3. Progress toward improved confinement product in various mirror machines.

With MFTF-B, the technology of mirror fusion reactors is advanced substantially. All magnets are superconducting, allowing long-pulse operation. Neutral beams and gyrotrons for electron rf heating are both to be pulsed for 30 s to sustain the plasma at the operating point in Fig. 3. Since MFTF beam power supplies were designed for 30-s pulses with a 15% duty cycle, MFTF-B operation was limited to this pulse length and repetition rate. At this pulse length, which should be 10 to 15 times the energy containment time, interactions between the plasma surface and neutral gas should be in equilibrium. Also important will be phenomena on surfaces in the vessel and on cryopanel as plasma radiation and charge-exchanged particles are incident on them. To maintain the plasma operating point requires limitations on recycled gas and on gas buildup at the ends of the machine. A problem not addressed by MFTF-B, but one which will be important in future mirror devices, is the ability to pump continuously with cryopanel. At present, gas loads must be periodically purged by warming the surfaces to 10 K.

Neutral beams for MFTF-B are used for initial startup (20 units, 10 ms pulse, 100A, 20 kV), for establishing the thermal barrier (16 units, 500 ms pulse, 80A, 80 kV) and for maintaining equilibrium (7 units, 30s, 60A, 80 kV) for the 30s duration of the pulse. Also required for this equilibrium is rf power at the electron cyclotron frequency using 200-kW gyrotrons. Two gyrotrons are required at 28 GHz

(1-T resonant field) and six at 56 GHz (2-T resonant field).

As described above, the performance of HFIF-B and the technological advances it makes

represent a major step forward in the mirror program. With the successful demonstration of these items, a D-T burning machine producing substantial thermonuclear power could be built.

#### NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights.

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.