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TMX UPGRADE EXPERIMENTAL OPERATING PLAN

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July 1, 1981

Lawrence Livermore Laboratory

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under Contract W-7405-Eng-48.

CONTENTS

ABSTRACT

This document describes the operating plan for the TMX Upgrade experiment. This plan covers the period from November 1981 to March 1983 and describes how the TMX will be brought into operation, our schedules and milestones, and how we will determine if the TMX Upgrade program milestones have been met.

1. PURPOSE AND OUTLINE OF THE TMX UPGRADE OPERATING PLAN

This document describes our operating plan for the TMX Upgrade experiment at the Lawrence Livermore National Laboratory. A schematic drawing of TMX Upgrade is shown in Fig. 1. The major modifications to the TMX facility are scheduled for completion on October 31, 1981. Milestones which define the experimental program are listed in Table 1 and illustrated in Fig. 2. This document describes our plan to bring TMX Upgrade into operation, our schedules, and our methods to diagnose and evaluate plasma performance to determine if we have met the program milestones. This plan will be modified, if needed, based on new information, funding levels, and experimental results.

The outline of this plan is as follows. In the next section, we summarize the physics of TMX Upgrade. Then, we briefly describe the TMX Upgrade experimental facility, followed by our plans for system checkout and system integration. Subsequently, we describe the objectives of the initial plasma experiments and ECRH plasma experiments (Sections 5 and 6). In Section 7 thermal barrier and axial confinement experiments are described. The key physics issues, and the methods to be used to evaluate them, are identified and discussed. And finally in Section 8, we describe central-cell radial-confinement experiments that can be carried out in TMX Upgrade. Radial-transport experiments were not a motivating factor for construction of TMX Upgrade and hence were not discussed in the proposal. However, radial transport is a major issue for tandem-mirror systems so we have included it in the TMX Upgrade program.

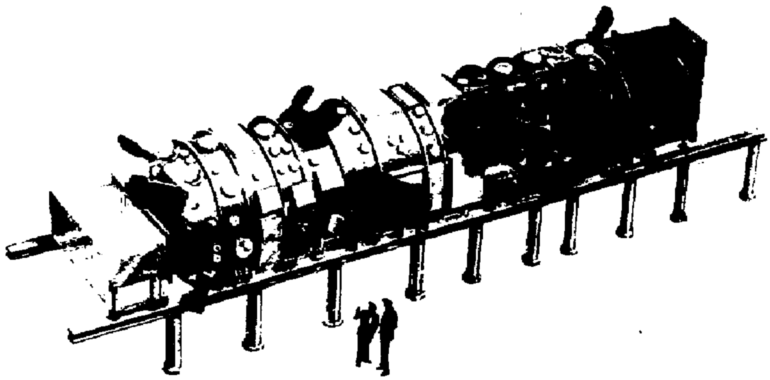

Figure 1. Cutaway drawing of TMX Upgrade

TABLE 1. TMX Upgrade program milestone schedule.

	Milestone	Target Date
1.	Submit TMX Upgrade experimental plan	July 1981
2.	Begin checkout of TMX Upgrade	Nov. 1981
3.	Produce initial plasmas in TMX Upgrade	Mar. 1982
4.	Demonstrate end-plug sloshing-ion distribution with 1-MW neutral-beam power per plug	May 1982
5.	Submit plan for incorporation of axisymmetric end plugs on TMX Upgrade	May 1982
6.	Submit report on initial TMX Upgrade experimental results	July 1982
7.	Demonstrate electron heating with 200-kW microwave power per plug	Sep. 1982
8.	Submit report on TMX Upgrade ECRH results	Nov. 1982
9.	Demonstrate existence of thermal barrier and improvement of central cell containment due to barrier	Dec. 1982
10.	Complete radial-transport measurements	Mar. 1983
11.	Submit report on radial transport in TMX Upgrade	June 1983
12.	Submit final report on TMX Upgrade results	Aug. 1983

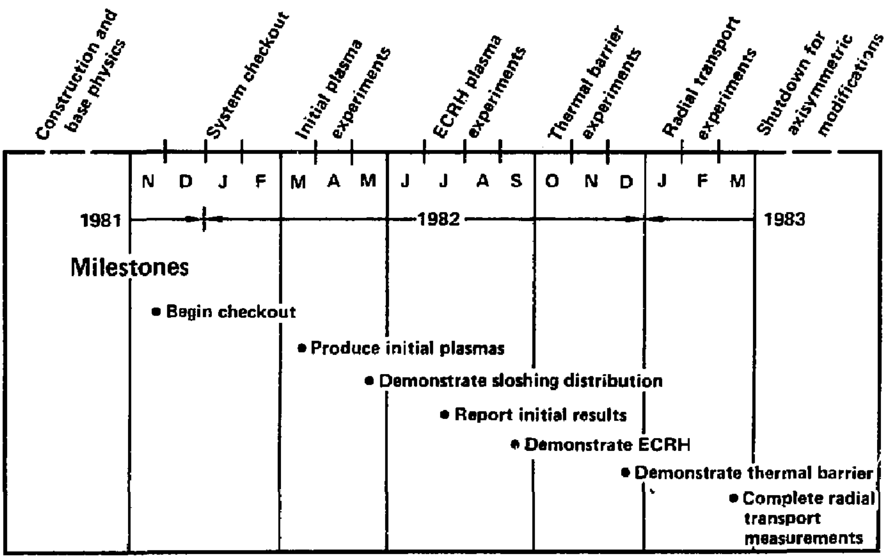

Figure 2. TMX Upgrade experimental program plan

2. PHYSICS OF TMX UPGRADE

The TMX experiment successfully generated the tandem-mirror configuration by neutral-beam injection. Both ion and electron confinement were improved relative to single mirrors. The TMX Upgrade will verify that thermal barriers further improve potential confinement and thus increase the attractiveness of the tandem-mirror reactor concept. TMX Upgrade is also designed to avoid microinstabilities. TMX Upgrade is the first complete tandem-mirror system to test these thermal-barrier and microstability concepts

The advantage of the thermal-barrier concept is the larger confining potential illustrated in Fig. 3. The depression in plasma potential ϕ_b isolates the higher-temperature plug electrons from the cooler central-cell electrons. If the density of electrons passing between these two regions is sufficiently small, a large electrostatic barrier ϕ_c can be generated by using microwave heating of the plug electrons. Increasing this potential allows higher energy central-cell ions to be electrostatically confined. Thereby, central-cell plasma confinement is improved at higher temperature.

The physics objectives of TMX Upgrade were outlined in the project proposal as:

1. To investigate a complete tandem-mirror thermal-barrier system
   - Achieve microstability
   - Maintain MHD stability
   - Generate potential profiles by electron heating
   - Control axial-electron temperature gradients.

2. To improve the performance of TMX.

In Section 7 of this plan, we discuss these goals in more detail and describe the criteria we will use to evaluate the performance of TMX Upgrade. These goals will be met upon completion of milestone No. 9 of Table 1. An improvement in plasma confinement of TMX Upgrade relative to TMX will be an unequivocal demonstration of the thermal-barrier concept.

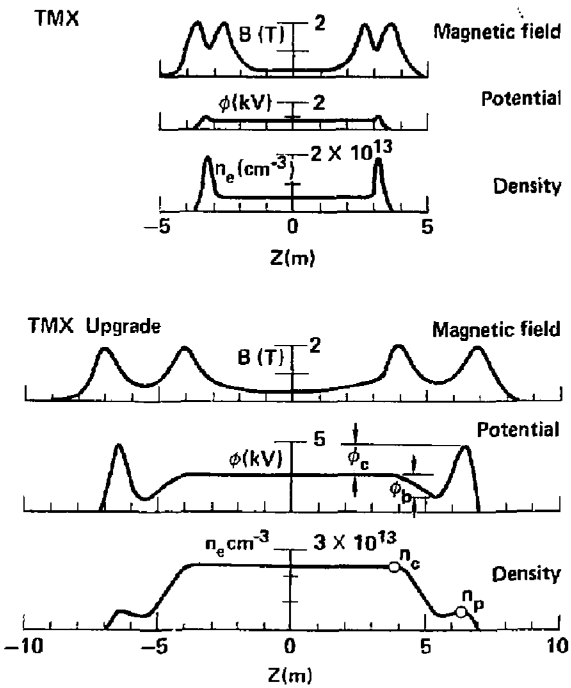

Figure 3. Comparison of axial magnetic field, potential and density profiles measured in TMX to those projected for TMX Upgrade.

3. THE TMX UPGRADE FACILITY

Machine parameters for TMX Upgrade are given in Table 2. TMX has been modified and systems have been added, as briefly described below, to carry out the thermal-barrier experimental objectives outlined above.

The longer plug magnets allow access for neutral-beam injection at 45° in order to achieve microstability. The higher 4:1 plug-mirror ratio confines 45° injected ions. The magnetic field strength was selected to allow the use of commercially available 28-GHz gyrotrons for microwave heating. The 0.3-T central-cell magnetic field strength has an axisymmetric increase in field strength to reduce resonant neoclassical radial transport of central-cell ions.

A high-power ECRH microwave heating system was added to generate magnetically-confined electrons to form thermal barriers. The 28-GHz gyrotron system is also needed to raise the end-plug electron temperature to increase the confining electrostatic potential well.

Several changes were necessary in the neutral-beam system. The capability for injection at 45° rather than 90° for microstability has already been mentioned. Thermal-barrier pumping beams inject at 18°. Since the temperatures and plasma size are larger in TMX Upgrade, it was necessary to increase the output power of the neutral-beam system to 10 MW. To sustain plasmas for several confinement times, and to allow time for buildup, the beam duration was increased from 25 to 75 msec. TMX Upgrade will operate with hydrogen, rather than deuterium, in order to increase the central-cell radial confinement and to increase the heating rate of ions injected by central-cell neutral beams. The pump beams will operate with deuterium for increased trapping efficiency.

TABLE 2. Comparison of major differences between TMX and TMX Upgrade.

System	TMX	TMX Upgrade
Magnet		
End-plug midplane field, T	1.0	0.5
Plug-mirror ratio	2:1	4:1
Plug length, m	0.9	3.0
Central-cell length,	5.5	8.0
Central cell field strength, T	0.2	0.3
Magnet power system, MW	13	26
Neutral Beam		
Duration, ms	25	75
Maximum power, MW	5	10
Plug injection angles, deg.	90	90, 65, 45, 18
Central-cell injection angles, deg.	90	90, 70, 58.5
ECRH		
Number of gyrotrons	0	4
Maximum power per gyrotron, kW	-	200
Frequency, GHz	-	28
Vacuum		
Overall machine length, m	15	22
Volume, m^3	120	225
Pumping speed, l/s	3×10^7	5×10^7
Gas feed system	Pulsed	Programmable

The diagnostic instruments which will be available for the initial experiments are listed in Table 3 by location and number of channels. A total of 191 measurements will be carried out. In addition, 56 machine-related parameters will be measured and archived; for a total of 247 measurements. These diagnostics will enable us to bring TMX Upgrade into operation and to evaluate its initial performance. This is twice the number of diagnostic channels initially available on TMX, but 30% less than during the final experiments. Additional diagnostic capability will be added during FY82 to more fully investigate thermal-barrier and radial-transport physics. Diagnostics for these detailed studies are listed in Table 4 and will be operational by late 1982 and early 1983.

TABLE 3

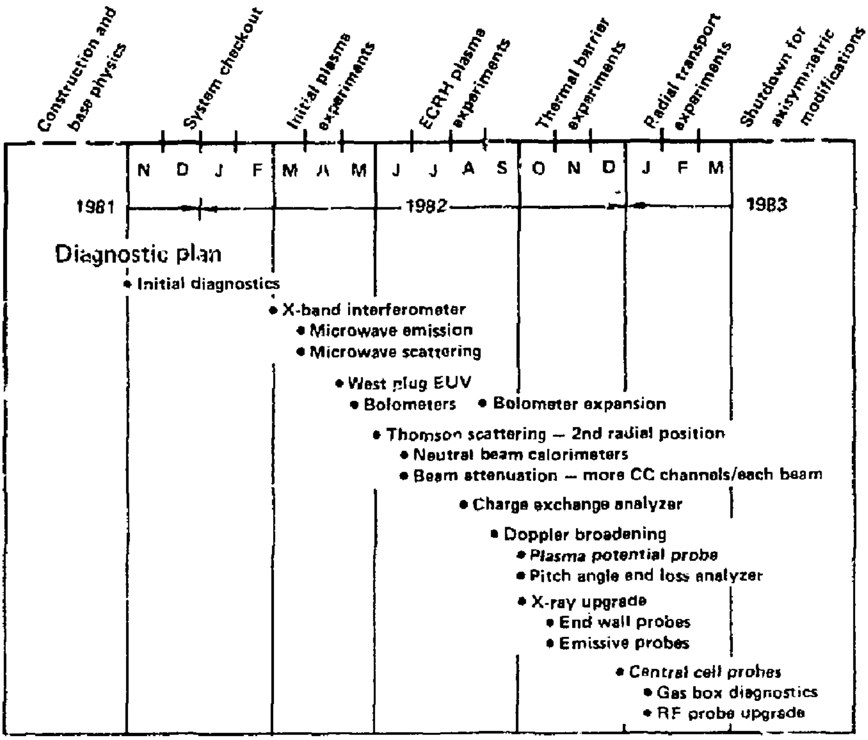

Figure 4. Plan for implementation of new diagnostics

4. SUBSYSTEM CHECKOUT AND SYSTEM INTEGRATION (November 1981 - February 1982)

Program Milestone:
Begin Checkout of TMX Upgrade .... November 1981

During the second through fifth months of FY82, the TMX group will debug individual subsystems of the TMX-Upgrade experiment and complete systems integration in preparation for the initial physics experiments. The subtasks that must be accomplished to bring up each subsystem are outlined in Table 4. Considerable freedom is possible in the scheduling of many items, other than the subtasks on the critical path, to achieve machine operation for physics experiments and allow for the efficient use of manpower

The checkout and debug period for 2XIIB was four months; the equivalent period for the more complicated TMX experiment was nine months. We expect to be able to bring up TMX Upgrade in a four-month period for two reasons: the entire TMX organization is now more experienced in the operation of larger facilities (and much of TMX Upgrade is simply an expansion of TMX hardware) and the TMX Base Program is carrying out detailed tests of many subsystems in advance of debug of TMX Upgrade. An overview schedule of the debug period and the three months preceding is shown in Table 5. The critical path to achieve physics operation is shown by the dashed line through the schedule. A major air cycle is scheduled for late January and early February to allow for major diagnostic calibrations, minor diagnostic sensor installation, and complete ECRH waveguide system installation. After the machine is back under vacuum, approximately three weeks will be spent in beam workup and final system checks before attempting the initial experiments.

TABLE 4. Debug tasks by system.

System	Tasks	
Magnet	1. Controls and interlock tests 2. Low-power field tests 3. Full-power tests	4. Magnet alignment checks 5. Magnet system calibration 6. Reference case check
External Vacuum	1. Initial pumpdown 2. Main vessel pumpdown 3. Turbopump operation	5. Cryopump operation 6. Cryopump recycle check 7. Auxiliary pump check
Internal Vacuum	1. Initial pumpdown 2. Leak checking, liner plumbing checking 3. Initial high-vac operation 4. Getter controls check	5. Initial getter operation 6. Glow discharge cleaning 7. Base case determination
Neutral Beam	1. Controls and interlock tests 2. Simultaneous dummy-load tests 3. Source hipot tests 4. Initial operation - one per quadrant	5. Multiple source operation 6. ECRH interference check 7. Conditioning to full power
ECRH	1. Controls and interlocks check 2. Fit dummy-load tests 3. Diagnostic system checkout	5. Beam interference check 6. Single waveguide tests 7. Integrated system tests
Startup and Fueling	1. Stream gun controls and supplies tests 2. Stream gun plasma mapping	3. Gas box controls tests 4. Gas box calibration
Diagnostics	1. Timing systems integration 2. Shot leader console checkout 3. Diamagnetic loop calibration	4. Thomson scattering calibration 5. Noise and interference checks
Computer	1. Hardware checkout 2. Acquisition of data from recorders 3. Write data files	4. Produce graphics output 5. Run primary processors 6. Run secondary processors

TABLE 5. Initial debug and integration sechedule.

	August	September	October	November	December	January	February	March
				Debug & integrate		Air cycle	Runup	Initial expts.
Magnets		Complete installation		Debug	Operable			
Vessel			Close	Leak hunt (10^{-5} Torr)	Liners & getters		Discharge Clean	Operable
Ext. vac			Roughing	Turbos	Cryos recycle		Operable	
Beams	Controls debug	Supply, dummy load tests		Initial operation			Runup	Operable
ECRH	Component tests	Gyros in pit		Single waveguide tests		Waveguide installation	Runup	Operable
Fueling				Check PS, guns, map			Calibrate	Operable
Timing sys.	Install & debug			Operable				
Diagnostics		Diamagnetic loop, Thomson scatt. inst.		Electrical and sensor debug		Calibrate install.	Debug	Operable
Computer		Raw data acquisition			Processed data acquisition			

5. INITIAL PLASMA EXPERIMENTS (March - May, 1982)

Program Milestones:

Produce initial plasmas in TMX Upgrade.................. March 1982

Demonstrate end-plug sloshing-ion distribution with 1-MW neutral-beam power per plug..................... May 1982

Submit report on initial TMX Upgrade experimental results....................................... July 1982

Once the TMX Upgrade facility is operational, initial plasma experiments will begin. In these experiments plasmas will be produced and provide verification of system integration and early indications of TMX Upgrade performance. The objectives of initial plasma experiments and the method by which they will be evaluated are given in Table 6. These experiments will be carried out with the diagnostic instruments listed in Table 3.

Past mirror machine experience has shown that cleanup of internal vacuum surfaces will be necessary in TMX Upgrade. This will be accomplished by baking, glow discharge cleaning, gettering and then prolonged operation with plasma. Plasma wall bombardment cleans the walls, gradually the plasma parameters improve, and the duration that plasma can be sustained increases. As this cleanup phase progresses, plasma diagnostics begin to detect signals and physics investigations begin.

Results from the initial experiments may indicate the need for minor machine and diagnostic modifications. Examples of possible modifications that could be necessary include: modifications to vacuum system baffles, changes in gas box limiter size or material, ECRH antenna modifications, rearrangement of neutral-beam injectors to different ports, improved shielding of diagnostics, etc. Such modifications could be rapidly implemented.

TABLE 6. Objectives and evaluation method of initial plasma experiments.

Objective	Method of Evaluation
• Vacuum system performance with plasma	
- Measure dynamic vacuum characteristics	Comparison with design codes
- Achieve plasma cleanup	Full duration plasma shots
- Minimize hot-ion charge exchange from cold gas	Secondary emission detectors
- Minimize impurity accumulation	Ultraviolet spectrometers
- Optimize gas fueling	All diagnostics
• Neutral-Beam Injection	
- Generate sloshing-ion distribution	Secondary emission detector angular array
- Demonstrate pumping by neutral beams	Measure density decrease
- Achieve end-plug/central-cell MHD stability	Diamagnetic loops variable
- Determine locations of neutral beam for next experiments	Varible beam current experiments
- Demonstrate central-cell neutral-beam injection	Diamagnetic loops
- Evaluate ion-cyclotron microstability	Rf probe measurements
• Microwave Heating	
- Demonstrate high-power operation with plasma	Full-power gyrotron output
- Eliminate any crosstalk introduced by plasma	Full-duration ECRH shots
- Measure antenna loading by plasma	Forward/reflected power
- Evaluate x-ray shielding performance	X-ray monitors
• Diagnostics	
- Obtain data from initial instruments	Measurements of plasma parameters
- Demonstrate data processing	Graphics output
- Reevaluate diagnostic priorities for next experiments	Results of measurements
- Identify new diagnostic needs	Results of measurements

6. ECRH PLASMA EXPERIMENTS (June - September 1982)

Program Milestones:

Demonstrate electron heating with 200-kW microwave power per plug........................ September 1982

Submit report on TMX Upgrade ECRH results......... November 1982

During this time period our emphasis will be on developing ECRH methods. Earlier, we will have produced plasmas by neutral beams. We will also have carried out preliminary ECRH experiments in which the microwave subsystems were put into operation, and solved initial technical problems such as plasma produced antenna breakdown. Thus, individual ECRH elements will have been demonstrated prior to these experiments.

Since ECRH had not been previously employed on TMX, several elements must be experimentally optimized. These elements form the objectives of the ECRH plasma experiments as listed in Table 7. Primary diagnostics for these experiments will be diamagnetic loops, x-ray detectors, Thomson scattering and microwave emission detectors. The goal of the ECRH plasma experiments during this period will be to apply these techniques simultaneously on both ends of TMX Upgrade.

TABLE 7. Objectives of ECRH plasma experiments.

- *Generate energetic mirror-trapped* electrons
- Control energy to limit beta
- Control hot-electron anisotropy for microstability
- Evaluate alternate startup scenarios
- Select *ordinary/extraordinary wave for best heating profile*
- Test different magnetic-field profiles for best heating
- Determine antenna aiming for best heating
- Determine optimum mix between fundamental and second harmonic heating

7. THERMAL BARRIER AND AXIAL CONFINEMENT EXPERIMENTS (October - December 1982)

Program Milestone:

Demonstrate existence of thermal barrier and improvement of central-cell containment due to barrier.......... December 1982

With completion of the above milestone we will have met the physics goals set forth in the TMX Upgrade proposal. In this section we describe these thermal barrier and axial-confinement experiments. Experiments, measurements, and analyses required to meet the physics goals of the Upgrade experiment are identified and described. Present theoretical understanding of the major physics issues and experience from the earlier TMX experiment is sed to predict the most decisive outcome of the major experimental objectives.

Fundamental TMX Upgrade physics objectives are stated in Table 8. These correspond to program milestones 3,4,7 and 9 given in Table 2. A terse description of each experimental goal and decisive outcome is given in Table 8. Each of these experimental goals is now described in more detail.

TABLE 8. Objectives of thermal barrier experiments.

	Experimental goal	Decisive outcome
A.	MHD Stability	Production of finite beta plasma in Central cell (maximum expected = 0.2).
B.	End-Plug Microstability.	
	a) Create sloshing ions in end plugs	a) Measurements of $n(r,z)$, plasma diamagnetism, and angular distribution of charge-exchange flux will demonstrate a velocity distribution of sloshing ions
	b) Determine plug microstability to ion cyclotron modes (DCLC, AIC, ALC, ion two-stream, etc.)	b) Absence of rf degradation on plasma lifetime (plug and central cell) and measurements of ω and k of any rf fluctuations for mode identity
C.	ECRH	
	a) Generation of microstable magnetically-trapped species of electrons to form a thermal barrier	a) Diamagnetic loop and x-ray measurements of a high beta energetic electron plasma at desired energy and density.
	b) Heating of electrons outside thermal barrier increasing the plug electron temperature and forming a higher outside potential barrier	b) Measurement of $T_{ep} >> T_{ec}$ will confirm existence of thermal barrier. As plug potential increases ion end-loss current will show a higher directed energy at end wall.
D.	Central-Cell Axial Confinement Axial confinement should increase due to the formation of a higher outside potential barrier	Electrostatic confinement with central-cell density higher than the end-plug density

a. MHD STABILITY

Similar to the TMX design, the TMX Upgrade magnet was designed for MHD stability using computer codes that evaluate plasma beta limits due to interchange and ballooning. Neutral-beam access, single-particle adiabaticity and drifts were criteria for choosing the elongated baseball coil for the end cell. To avoid end fans of excessive ellipticity (to maintain 2 to 3 ion-gyro orbits in the thin direction), it was necessary to reduce the radial well depth of the TMX Upgrade from the TMX value of 2% to 0.4%.

TMX demonstrated that central-cell MHD stability can be achieved with minimum-*B* end plugs. Although TMX Upgrade also has minimum-*B* plugs, the well depth is less. However, the central-cell/transition region bad curvature drive is also less. Equilibrium calculations and stability analysis without beneficial finite Larmor radius effects have shown that central-cell betas up to 0.2 can be supported. With respect to MHD stability, there are two major differences between TMX Upgrade and TMX; hot electrons and high ambipolar potentials. First, in the thermal-barrier mode of operation for TMX Upgrade, the plug pressure is carried mainly by the hot electrons. Secondly, the potentials will be higher, consequently the centrifugal force drive, due to E x B azimuthal rotation, will be higher.

In addition to the standard operating regime, we expect to carry out MHD experiments which will address issues relevant to future experiments, such as MFTF-B and the axisymmetric TMX-S. The most basic diagnostic will be diamagnetic loops in several axial positions within the end cells and central cell to determine the plasma beta. Axial current sensors (such as Rogowski belts) and E x B rotation probe arrays (both magnetic and electrostatic) will also be used. The central-cell ion-energy distribution function will be obtained with a charge exchange analyzer. Radial measurements of the plasma potential will be made with a heavy-ion-beam probe. Movable end-loss analyzers will give radial potential measurements of the end cells.

b. END-PLUG MICROSTABILITY

The generation of a sloshing-ion distribution and the investigation of its stability is a central element of a complete tandem-mirror thermal-barrier experiment system. In the earlier TMX experiments, when axial central-cell losses were insufficient, electric field fluctuations near the plug cyclotron frequencies limited both plug and central-cell plasma lifetimes.

In terms of microstability, there is a major difference between TMX and TMX Upgrade. In TMX, the plug density and plasma potential peaked at the minimum in the magnetic well (the midplane). This required central-cell losses to stabilize the plugs. In TMX Upgrade, only central-cell density, rather than losses, are required. The Upgrade sloshing-ion distribution allows the potential to be peaked axially beyond the plug midplane. This increases the density of stabilizing central-cell plasma within the plug to the value required for stability. The thermal barrier adds possible new microstability constraints due to counter-streaming ion modes. They are predicted to be stable if we properly control the plasma parameters.

We will use beam attenuation detectors to measure plug line density profiles, and diamagnetic loops to measure axial variations of plug diamagnetism. Angular variations in the beam-plasma charge-exchange products will be measured by secondary emission detectors to substantiate the creation of a sloshing-ion distribution. Electrostatic and magnetic probes will determine whether the fluctuations degrade confinement.

We expect ion cyclotron fluctuations to be lower than in TMX and that the plasma lifetimes not to be significantly affected by the fluctuations. However, to achieve low fluctuation may require experimentally achieving the proper combination of sloshing-beam current, pump-beam current, ECRH heating and central-cell gas-feed rate.

c. ECRH

The generation and control of a thermal barrier requires manipulating the electron-density and temperature profile by ECRH. As a result of reducing the plasma density with neutral-beam pumping and by creating mirror-trapped electrons, with ECRH, the potential at the midplane of each end plug will be lower than that of the central cell. Additional ECRH applied at the outside density peak of the sloshing ions will further raise the outside potential peak. The electrostatic confinement of central-cell ions is enhanced, and a end-plug density less than the central-cell density is able to electrostatically confine a higher-density central-cell plasma.

The major physics issues of ECRH for the Upgrade will be controlling the populations of magnetic and potential trapped electrons. Important related issues for the hot electrons are control of energy and microstability. Control of energy is obtained by adjusting the microwave power and spacially restricting the microwave beam. The electron energy is limited as the energy-dependent resonance moves to the boundary of the heating zone. Hot electron instabilities may be driven by high anisotropy ($T_{e\perp}/T_{e\parallel}$), plasma beta, and the loss cone distribution. Control of the anisotropy drive will be achieved by adjusting the mirror ratio for heating by means of microwave beam aiming in the thermal barrier. Partial filling of the loss cone is obtained by the passing central-cell electrons.

Plasma startup and microwave absorption are the fundamental experimental issues. The heating time for the hot-electron population is longer than any other buildup time in the experiment. Since losses scale as the density squared, during startup, the plasma density will be increased from an initially low value and increased as the hot-electron energy increases. Possible creation of a run-away population during startup will be monitored by x-ray diagnostics. Microwave radial absorption profile will be controlled by adjusting the relative amounts of extraordinary and ordinary mode microwave power.

In addition to diagnostics similar to those of the earlier TMX experiment, such as Thomson scattering in the end plug and central cell, we will employ an extensive set of x-ray diagnostic instruments to measure the properties of energetic electrons produced by ECRH.

d. AXIAL CONFINEMENT

We will evaluate the central-cell ion-particle confinement by taking into consideration fueling, power balance, transport due to instabilities, and coupling with the end cell. In the earlier TMX experiment, central-cell axial losses dominated over end-cell particle losses allowing $n\tau_{\parallel}$ to be determined by central-cell density and end-wall ion-current measurements. Because of the high expected value of $n\tau_{\parallel}$ (10^{12} cm^{-3} sec.), it will be necessary to discriminate between end-plug and central-cell losses to determine $n\tau_{\parallel}$.

To evaluate $n\tau_{\parallel}$ an ion end loss current detector capable of differentiating between end-plug central-cell heating-ion losses, and bulk central-cell axial losses will be developed. Strong quantitative demonstration of improved axial confinement from thermal barriers would be electrostatic confinement for a plug density less than the central-cell plasma density. Qualitative demonstration will be high T_{ic} with $n_p < n_c$.

8. CENTRAL-CELL RADIAL-CONFINEMENT EXPERIMENTS (January - March 1983)

Program Milestones:

Complete radial-transport measurements.................. March 1983

Submit report on radial transport in TMX Upgrade......... June 1983

The objectives of the central-cell radial-confinement experiments are outlined in Table 9. With improved axial confinement, due to the thermal barriers, radial central-cell losses will dominate. The dominate radial losses are expected to be resonant neoclassical-ion transport which depend upon the transition magnetic-field design and the radial electric-field profiles. We plan to bulk heat central-cell ions using neutral-beam injection and ion cyclotron resonance heating (ICRH). TMX Upgrade operates with central-cell ion temperature of 0.9 keV and potential wells of 2.2 kV to maintain an axial confinement parameter, of 10^{12} cm^{-3} sec. All three parameters (temperature, potential, and $n\tau$) are approximately an order of magnitude higher than obtained in TMX. Without the aid of a thermal barrier the large potential barrier cannot be maintained. Resonant, neoclassical-radial transport is expected to set the radial-confinement parameter, $n\tau_{\perp}$, at 5×10^{11} cm^{-3} for $T_i = 0.9$ keV with the given TMX Upgrade transition magnetic field.

The earlier TMX experiment operated near the collisional regime with central-cell axial-confinement dominated by flow losses for a filled loss cone with an electrostatic barrier. TMX Upgrade will have high enough central-cell ion temperature that the loss cone will be empty and confinement will be described by the collisionless Pastukhov lifetime. Thus, TMX Upgrade will operate in the collisionless central-cell diffusion regimes appropriate to MFTF-B and tandem-mirror reactors.

Resonant neoclassical transport leads to nonambipolar radial losses. As in the TMX experiment, the measured net current at the end wall will quantify nonambipolar transport. Radial electric-field measurements with a heavy-ion beam probe will be used to determine theoretical transport rates. Ambipolar losses can be estimated from comparing electron end losses with predictions from central-cell fueling codes.

TABLE 9. Objectives of central-cell radial-confinement experiments

- Perform experiments with good axial confinement

  erate in collisionless regime with central-cell bulk-ion heating

- Carry out detailed particle and power balance studies

- Evaluate ambipolar transport data with fueling codes

- Evaluate nonambipolar transport data with transport codes

9. SUMMARY

In this TMX Upgrade experimental operating plan we have described how we intend to bring TMX Upgrade into operation, and how we will evaluate its performance to determine if we have met our program milestones.

ACKNOWLEDGEMENTS

We wish to acknowledge key contributions by D. L. Correll, R. P. Drake, R. S. Hornady, and W. L. Pickles in formulating this plan.