CONF-791225--1

LA-UR -79-3395

TITLE: FRX-C AND MULTIPLE-CELL EXPERIMENTS

AUTHOR(S): R. E. Siemon and LASL Compact Torus Staff

SUBMITTED TO: PPPL Symposium on Compact Toruses and Energetic Particle Injection

MASTER

DISCLAIMER

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545
An Affirmative Action/Equal Opportunity Employer

Form No. 336 R3
St. No. 2629
12/78

UNITED STATES
DEPARTMENT OF ENERGY
CONTRACT W-7405-ENG. 36

FRX-C AND MULTIPLE-CELL EXPERIMENTS

R.E. Siemon, and LASL Compact Torus Staff
Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87545

Background

Two new compact torus experiments have recently been proposed[1] and one (FRX-C) is now under construction. The proposed experiments are based on recent theoretical advances[2] and experimental results obtained with the LASL FRX-A and FRX-B field-reversed theta-pinch devices.[3] These recent experiments demonstrate a formation method and establish some of the confinement properties for one type of plasma compact torus--an elongated prolate plasma torus confined by purely poloidal magnetic field. The plasma displays a quiescent phase, free of any gross MHD instabilities, that persists much longer than either characteristic MHD times or open-field line loss times. The quiescent phase is terminated by an n=2 mode that is correlated experimentally with a steadily increasing plasma rotation that eventually exceeds the theoretically predicted threshold for instability (approximately 1.5 Ω^* where Ω^* is the angular diamagnetic drift frequency). The rotation is interpreted as resulting from a preferential loss of ions that carry angular momentum in a particular direction leaving the plasma to spin in the opposite direction. According to this point of view a significant fraction (about one-half) of the plasma must be lost to the closed-field configuration before the plasma reaches the threshold for instability, and therefore the n=2 disruption can be viewed as a secondary consequence of the more important cross-field transport processes. Both the FRX-C and Multiple-Cell experiments are intended to investigate ways of reducing cross-field transport.

FRX-C

The FRX-C experiment is a scaling study which will extrapolate the FRX-B results toward the higher temperature and longer lifetime needed for fusion. As shown in Fig. 1, the FRX-C coil dimensions are approximately twice those of FRX-B. Two high-voltage banks in a dual-feed arrangement are used to produce strong implosion heating. Larger variation of plasma density and temperature should be possible as a result of the higher voltage, because the higher voltage allows a larger variation in initial filling pressure as shown in Table I. For the same temperature in FRX-C as in FRX-B, the larger diameter coil results in an increase of a/ρ_i, where a is the plasma minor radius and ρ_i is the ion gyro radius. Thus, the important scaling of confinement with plasma size will be tested.

Another important design objective of FRX-C is to use a small amount of adiabatic compression, and thereby to produce a "fat" plasma characterized by a large ratio of the separatrix radius to the metal wall radius, r_s/r_w. As a general rule, better confinement in this type of field-reversed configuration has been observed experimentally when r_s/r_w is made larger (see discussion of literature in Ref. 1). The reason for improved confinement with large values of r_s/r_w (typically > 0.4) is, theoretically, a result of reduced pressure on

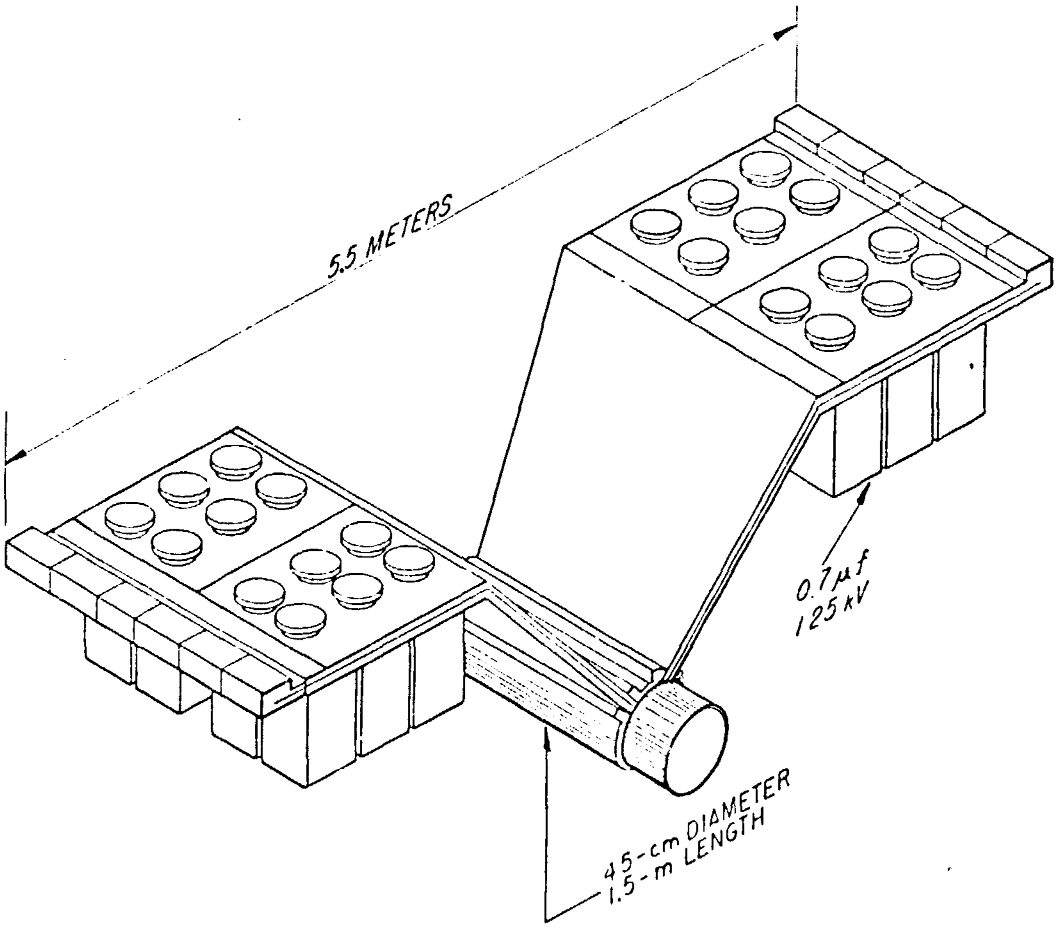

Fig. 1. FRX-C experiment showing high-voltage capacitor banks, dual-feed collector plates, theta-pinch coil, and discharge tube. "Gull wing" arrangement makes optimum use of the available space adjacent to the CTX, a vacuum tank and mirror coil for compact torus translation, trapping, and confinement studies.

TABLE I.
FRX-C Experimental Parameters

Theta-Pinch Parameters

Coil diameter (cm)	45
Coil length (cm)	150
Source voltage (kV)	250
Magnetic field (kG)	9
Field quarter period (μs)	1.8

Anticipated Plasma Parameters

Initial filling pressure (mtorr)	2.4	24
Plasma density (cm^{-3})	1.2×10^{15}	6.8×10^{15}
Electron temperature (eV)	500	90
Ion temperature (eV)	1100	200

the separatrix and a corresponding reduction of cross-field transport at the boundary of the plasma. It is a necessary consequence of pressure balance that the plasma pressure at the separatrix is reduced as r_s/r_w increases.[2]

The minimum amount of adiabatic compression (maximum r_s/r_w) results when the maximum reversed flux is trapped in the plasma. Trapping the maximum flux in the ordinary theta pinch requires reversing the magnetic field quickly, because during the reversal phase the preionized plasma tends to expand, interact with the wall, and allow flux to be lost. The high voltage of FRX-C produces a rapid magnetic field reversal, and the resulting ratio r_s/r_w should be larger than in FRX-A or FRX-B.

The FRX-C experiment is located adjacent to, and on a centerline with, the CTX vacuum tank and d.c. magnetic mirror coils. Thus, the device is planned to serve as a plasma source for confinement studies of CT's containing no toroidal field. As much flexibility as possible is being designed in the FRX-C system to allow variation of the basic configuration. Important options are the addition of electrodes for I_z to include toroidal field,[4] and the introduction of barrier fields and trigger coils for study of the Kurtmullaev mode of operation.[5]

Multiple-Cell Experiment

In addition to possible reactor implications, a linear array of compact torus plasma cells makes possible interesting studies of the confinement system. In a single-cell experiment such as FRX-B, the plasma on open field lines is unconfined, and ions leave in approximately one thermal transit time. The radial pressure profile presumably drops abruptly at the separatrix producing enhanced cross-field transport. In the proposed Multiple-Cell Experiment, the confinement of plasma on open field lines is expected to be markedly improved by the influence of multiple magnetic mirrors created by the linear array of plasma cells as shown in Fig. 2. The resulting pressure profile should be smoother and the plasma confinement in the closed-field configuration should improve.

The improved confinement on the open magnetic field lines is a consequence of multiple magnetic mirror effects that become important when the classical ion mean free path becomes comparable to the cell length. For the plasma parameters expected in the experiment, the mean free path is approximately 30 cm, and the required condition is satisfied. Consequently, the plasma decay time on the open fields is increased from approximately 3 μs in FRX-B ($\tau \sim L/v_{th}$ where L is the half-length and v_{th} is the ion thermal speed) to approximately 60 μs in the proposed Multiple-Cell Experiment ($\tau \sim M^2L^2/\lambda v_{th}$ where M is the magnetic mirror ratio, and λ is the mean free path).

An experiment to test the effects of multiple plasma cells can be done by a straightforward modification of the existing 5-m Scylla IV-P theta pinch. The coil, discharge tube, and capacitor bank would be modified to match the FRX-B experiment in all respects except length. Providing field line tearing and reconnection can be controlled to generate a linear array of cells in the

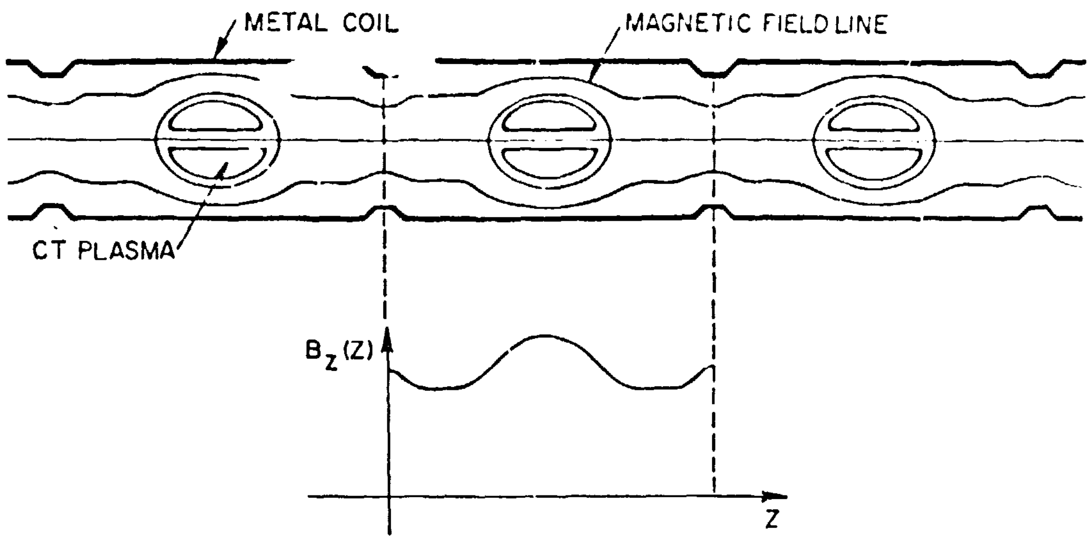

Fig. 2. Schematic drawing of magnetic fields surrounding linear array of compact torus plasma cells.

5-m coil, the influence of multiple cells can be studied for a plasma with the known single-cell characteristics of FRX-B. It has been pointed out that weak magnetic mirrors in the external coil structure may not produce tearing;[6] preliminary tests of methods for controlling tearing are being planned for FRX-A or FRX-B.

References

1. H. Dreicer et al., Proposal for FRX-C and Multiple-Cell Compact Torus Experiments, Los Alamos Scientific Laboratory Report LA-8045-P (1979).

2. D.C. Barnes, these Proceedings.

3. W. T. Armstrong, et al., Procedings this conference.

4. G. C. Goldenbaum, Bull. Am. Phys. Soc. 24, 1072 (1979).

5. A. G. Es'kov et al., Proc. of the Seventh IAEA Conference on Plasma Physics and Controlled Thermonuclear Research, 3E 15 (Innsbruck, 1978).

6. A. E. Robson, private communication.