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Abstract: Studies with levitated hoops in a pulsed toroidal octupole were undertaken with gun injected and microwave produced plasmas. Density decay rates were less than Bohm and were less with levitated hoops than with supported hoops.

A levitated toroidal octupole has been constructed to study plasmas in highly axisymmetric minimum B geometries in the absence of hoop supports. Major dimensions are shown in Fig. 1 and the magnetic field is supplied by a 5 kV, 0.6 MJ capacitor bank which provides 1.3 MA peak current with a half sine duration of 43 msec. Peak field is 14 kG and this gives a minimum of 22 gyroradii for 100 eV protons.

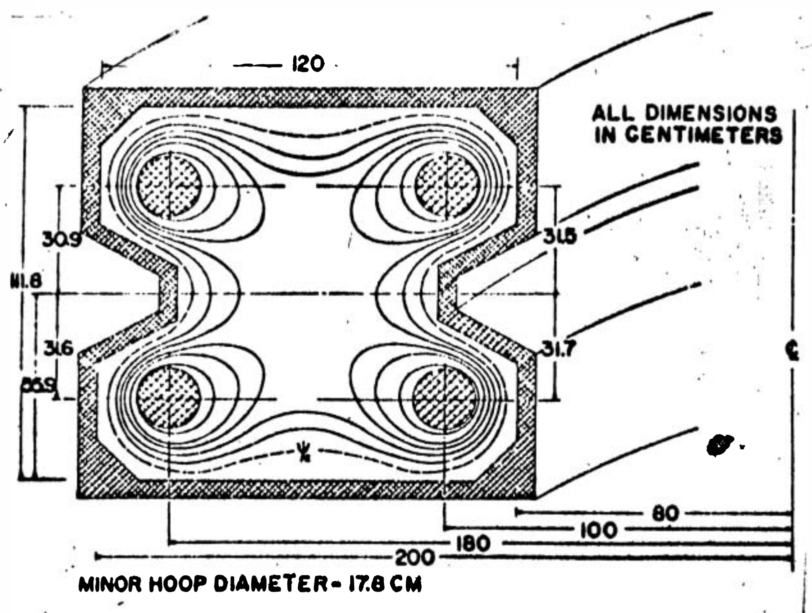

FIGURE 1

Magnetic field errors were minimized by distributing the primary and image current continuity windings to match the wall current density. The excitation gap edge was resistively trimmed to give an effective width proportional to the major radius. Tapered port plugs insure a thick skin contact when wedged in. Field errors at the surface of the hoops due to support sockets or resistivity differences in the welds were measured and are $\lesssim$ 1%.

Sixteen pneumatically driven, bellows-sealed removable levators support the four aluminum hoops whose total mass is 2300 kg. These supports are reinserted to catch the hoops after the pulse.

Gun injection and some vacuum pumping are accomplished through a single 10 cm diameter opening. The aluminum vacuum tank of $8.6 \cdot 10^6$ cm^3 reaches a base pressure of $2 \cdot 10^{-6}$ torr with a turbo-molecular pump in parallel with a 25 cm diameter titanium orbitron pump. Pressures of $2 \cdot 10^{-7}$ are reached using a single filament Mo-Ti wire located in the center of the lid but outside of $\Psi_{critical}$ and heated with 40 amperes to evaporate approximately 5 mg/hr.

Hot ion ($kT_i \sim$ 20-30 eV) hydrogen plasmas with densities of $\approx 10^9$ cm^{-3} and $kT_e \sim$ 3-5 eV are produced by a coaxial gun. Cold ion plasmas are produced in the field by electron cyclotron resonance heating using either high power (100 kW), pulsed (144 μsec) microwave heating at high pressure ($\sim 10^{-4}$ torr) to produce a plasma with $n \simeq 10^8$ cm^{-3}, or by low power ($\lesssim$ 1 kW), CW heating at lower pressure ($\gtrsim 3 \cdot 10^{-7}$ torr) to produce a plasma with $n \lesssim 10^{10}$ cm^{-3} and $kT_e \sim$ 3-5 eV. The CW source can be turned off abruptly to study the plasma decay in the afterglow. Hot electron plasmas with average electron energies of $\sim$ 1-10 keV are produced by high power pulsed microwave heating at low background pressure using gun injection or CW microwave pre-ionization.

The decay of plasma density has been measured using Langmuir probes, 9 and 24 GHz microwave perturbation techniques, electrostatic ion energy analyzers and by integration of the escaping ion flux. Electron temperatures have been measured using an admittance probe and a swept Langmuir probe. For the hot ion, gun injected plasma and for the cold ion, microwave plasma, the density decay time of 10-20 msec near the peak magnetic field is longer than the 4 msec time calculated for Bohm diffusion and increases slightly when the hoops are levitated; however, further adjustments to attempt to decrease the decay rate have not yet been made. Figure 2 summarizes the results for gun injection.

Magnetic field

Levator position 7 cm/div

Probe ion saturation current
on axis 50 A/div (supported)

Probe ion saturation current
on axis 50 A/div (levitated)

Ion current to hoops and
supports 50 mA/div

Ion current to wall
50 mA/div (supported)

Ion current to a support
2 mA/div

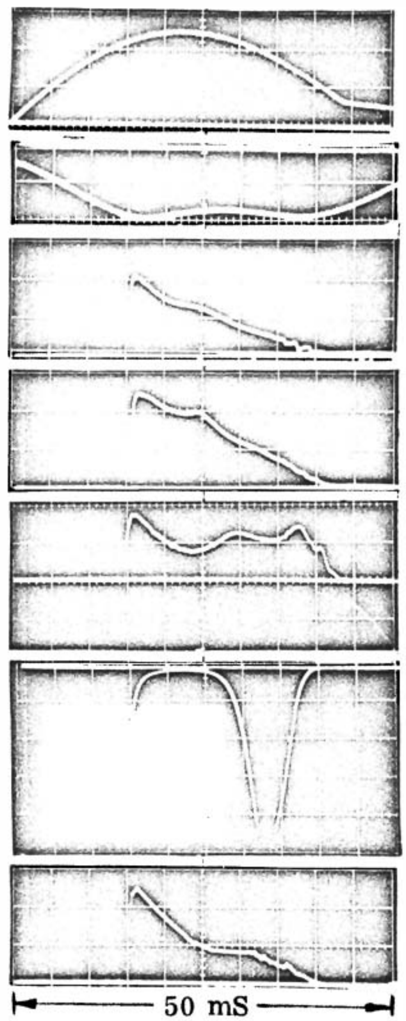

FIGURE 2

The density profile as measured by probes is peaked near the separatrix at early times with the peak moving out to the wall as the magnetic flux leaves the machine. The plasma is generally quiescent in the $\oint d\ell/B$ stable region, but large ($\sim$ 100%) fluctuations in ion saturation current are observed in the flute unstable region near the wall.

To measure losses in the machine, and therefore plasma lifetime, the four hoops with their sixteen supports were used as ion collectors. Small insulated wires were attached to each hoop and ion current to hoops and supports and to the hoops alone were measured by biasing the hoops and supports or the hoops to -45 V relative to the tank wall. Ion current to the walls was measured by biasing the hoops and supports or the hoops without supports to +45 V. Plasma lifetime determined by this method agreed with that obtained by other means. Ion current to a single support was measured by withdrawing it a short distance from the hoop and biasing it to -45 V. Telemetering equipment for measuring losses to completely isolated hoops is being tested.

Scintillator probes have been used to detect the energetic ($\gtrsim$ 3 keV) electrons in the tail of the nonmaxwellian distribution produced by pulsed microwave heating of gun or CW microwave plasmas. The intensity and lifetime of the scintillator probe signal increase significantly with decreasing neutral pressure and with levitation, indicating that ionization and support losses are important cooling mechanisms for these electrons.

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