# Plasma Measurements in
# A Levitated Pulsed Octupole

by

H.K. Forsen, D.W. Kerst, R.A. Breun, A.J. Cavallo
J.R. Drake and J.C. Sprott

June 1970

Submitted for presentation at the Rome Meeting, August 1970

Plasma Studies
University of Wisconsin

PLP 366

# PLASMA MEASUREMENTS IN A LEVITATED PULSED OCTUPOLE

by

H. K. Forsen, D. W. Kerst, R. A. Breun, A. J. Cavallo
J. R. Drake and J. C. Sprott

PHYSICAL SCIENCES LABORATORY
THE UNIVERSITY OF WISCONSIN
Madison, Wisconsin U.S.A.

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.

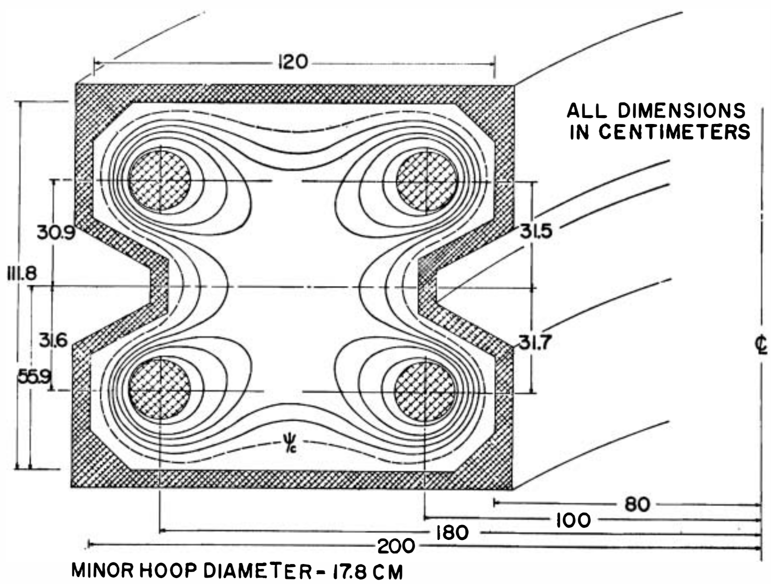


FIGURE 1

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 resistivity differences in the welds were measured and are less than 1%.

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

Gun injection and vacuum pumping are all 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 $2 \cdot 10^{-7}$ 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 hydrogen plasmas with densities of $\simeq 10^9$ cm$^{-3}$ and $kT_e \simeq 3$-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 ($\simeq 10^{-4}$ torr) to produce a plasma with $n \simeq 10^8$ cm$^{-3}$, or by low power (100 W), CW heating at lower pressure ($\gtrsim 3 \cdot 10^{-7}$ torr) to produce a plasma with $n \simeq 10^9$-$10^{10}$ cm$^{-3}$ and $kT_e \simeq 3$-5 eV. The CW source can be turned off abruptly to study the plasma decay in the afterglow. Hot electron plasmas in the kilovolt range are produced by gun injection or by CW microwave pre-ionization with subsequent high power pulsed microwave heating at low background pressure.

The decay of plasma density has been measured using Langmuir probes, 9 and 24 GHz microwave perturbation techniques and by integration of the ion flux to the wall, hoops, and supports. 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 rate at peak magnetic field is somewhat slower than the rate calculated for Bohm diffusion and decreases slightly when the hoops are levitated, but further adjustments to attempt to decrease the decay rate have not yet been made. Figure 2 summarizes the results for gun injection.

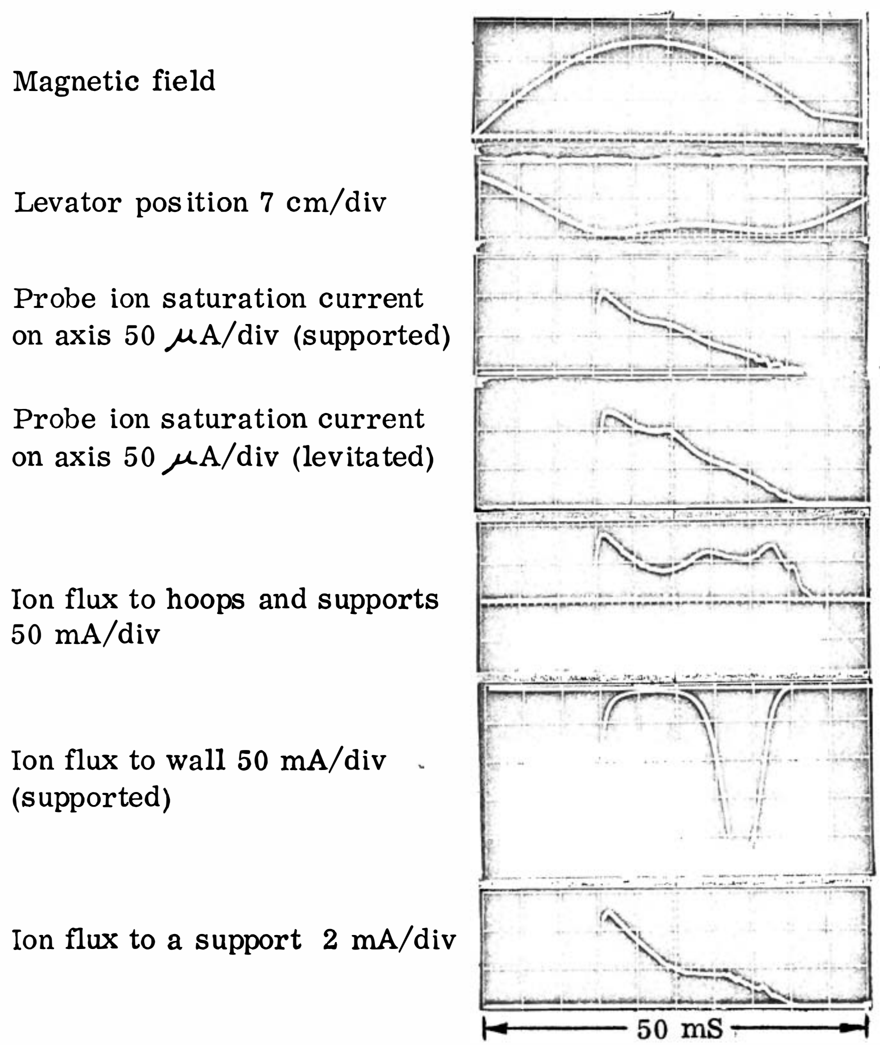


FIGURE 2

The lifetime of energetic electrons in the tail of the nonmaxwellian distribution, produced by pulsed microwave heating of gun injected plasma and measured with a scintillator probe near the edge of the plasma, shows a pronounced increase when the hoops are levitated, indicating that these electrons are lost primarily to the supports as suspected from measurements on the small octupole. The intensity and decay rate of the signal from the scintillator probe depends strongly on pressure even at the lowest pressure attained indicating that ionization losses are an important cooling mechanism for these electrons.

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 $\int dl/B$ stable region, but large ( $\simeq$ 100%) fluctuations in ion saturation current are observed in the flute unstable region near the wall. To get a measure of losses in the machine, and thus of plasma lifetime, the four hoops with their sixteen supports were used as ion collectors. Ion current to the hoops and supports was measured with all four hoops and their supports biased to -45 V relative to the tank wall. Ion current to the wall was measured by biasing the hoops and supports to +45 V. These measurements give a lifetime of $\simeq$ 10-20 msec in agreement with measurements using Langmuir probes and microwave diagnostics.

Ion current to a single support was measured by withdrawing a support a short distance from the hoop and biasing it to -45 V. Ion flux to individual hoops and to hoops with and without supports are being measured to establish the validity of these loss measurements.

Acknowledgment: This work was supported by the U.S. Atomic Energy Commission. Fabrication was done by the staff of the Physical Sciences Laboratory, The University of Wisconsin.