DOE/ET/53088-77 IFSR #77

PROCEEDINGS OF

US-JAPAN WORKSHOP
"HOT ELECTRON PHYSICS"

JANUARY 10-14, 1983

AUSTIN, TEXAS

CONTENTS

1. INTRODUCTION

INTRODUCTION

J.W. Van Dam and T. Watanabe

Description of the Meeting

A miniworkshop on "Hot Electron Physics" was held at the Institute for Fusion Studies of the University of Texas at Austin during the week of January 10-14, 1983. This workshop was conducted under the auspices of the US-Japan Joint Institute for Fusion Theory.

Although one in a continuing series of US-Japan workshops, this was the first to employ a "working group" format. This meeting was a miniworkshop, quite informal and restricted in size. A relatively small number of specialists were invited to participate, and the meeting itself was focused on a few specific problems. These problem areas were determined to be (a) the equilibrium and stability of hot electron plasmas and (b) the heating of hot electrons - both with application primarily to bumpy torus and tandem mirror devices.

The purpose of this miniworkshop was likewise twofold. Its intention was, first, to report on recent developments in these two specific areas of hot electron physics and, also, to initiate or continue research collaborations among the Japanese and American participants. To these ends, informal presentations involving a blend of theory, computation, and experiment, as well as small-group working sessions, were scheduled. A copy of the agenda for the meeting may be found on pp. 9. The success of this miniworkshop format may be judged from the vigorous dialogue between speakers and audience during the scheduled presentations and from the variety of individual scientific interactions during the afternoon free sessions.

The topic of hot electron physics has received considerable attention recently. By hot electron physics is meant the physics of plasmas containing a highly energetic electron component whose magnetic drift frequency can exceed the frequency of typical fluctuations of interest. This was a timely subject for a workshop, in view of the impact that hot electron stability theory has had on the bumpy torus program and in view of the utilization of hot electrons in tandem mirrors for confinement by thermal barriers and possibly for stability with axisymmetric end cells. The U.S. and Japan both have bumpy torus and mirror programs; representatives from each were included as workshop participants.

A total of 22 persons participated in the miniworkshop: 3 coming from Japan, 8 from the Institute for Fusion Studies, and 11 from other U.S. institutions. A complete list of attendees is on pp. 394, with a group photograph on p. 388.

For the benefit of the participants, the transparencies presented by the workshop speakers are reproduced in this proceedings report. Viewgraphs from the discussion session on Friday morning are also included; however, since some of these are rather sketchy and their content important, a brief summary is given here.

Synopsis of the Discussion Session

Sanuki reviewed the results of his calculation concerning the effects of ambipolar potential on bumpy torus stability. His theory indicates that electrostatic flute modes can be stabilized by an applied rf electric field, as well as by high-beta hot electron rings. When the ambipolar potential is positive (as in the NBT-1 device), a stronger applied field or higher ring beta is required for stability, and finite ion Larmor radius has less of a stabilizing effect, than when the potential is negative (as in NBT-1M and the EBT experiments). He recommended more theoretical and experimental study of the detailed relationship between fluctuations and the potential profile. He also described the operational parameters of the new NBT-1M machine and the experimental plans of the Nagoya group.

Antonsen commented that his ballooning mode theory had addressed geometrical effects. Several effects (field line bending, circulating hot electrons, core plasma dissipation) lead to shrinking of the stability region, although this can be tolerated with the inclusion of hot electron gyroradius effects. Whether finite Larmor radius (FLR) effects are truly important for experimental stability now and in future devices must be decided. If they are, then hot ion rings become attractive. Particle simulation codes could be useful for determining the effect of FLR on linear instabilities and their nonlinear saturation. The behavior of modes driven unstable by resonance, such as the resonant compressional mode, could also be studied with simulations. In addition to curvature, he suggested that other sources of free energy be investigated, such as the density gradient and the parallel gradient of the $E\times B$ drift.

Quon described how experiments are able to provide detailed information about hot electron properties such as the parallel and perpendicular pressure profiles, as well as the magnetic field and also geometrical information for scaling up to larger size, higher magnetic field devices. Experimentally, the hot electron density, temperature, beta value, and anisotropy can be controlled. The a.c. characteristics of a hot electron plasma should be examined in order to obtain experimental validation of theories. This would involve identification of unstable modes and observation of stability boundaries (e.g., the core beta limit). Current experiments should be able to check the theoretical hot electron decoupling condition and the predicted effect of FLR, the latter by making thicker rings with multi-frequency heating. For new ideas to explore, he suggested using line tying to anchor the rings and using a surface blanket of heavy ions to achieve decoupling, since the parameter that measures decoupling is proportional to the ion mass. An ion blanket would slow down the impedance of the system and may also enhance the stabilizing effect of ion FLR.

Spong further discussed the hot plasma decoupling condition and its implications. After describing how the decoupling parameter scales, he pointed out that a bumpy torus reactor could have difficulty satisfying this condition. In present experiments, taking into account decoupling may make the interacting interchange mode easier to observe. For this, good profile measurements within the ring region are necessary. The use of hot ion rings could possibly lower the power requirements without reducing the ring temperature. He also posed the question as to whether the equilibrium vacuum magnetic field configuration for the bumpy torus could be improved for the purpose of stability. One idea is to locate the rings in regions of large curvature. Toroidally linked minimum-B mirrors have been studied previously; this system relies on the vacuum field design for stability but has poor volume utilization, whereas EBT relies on hot electron ring stabilization and uses volume well. An analogy was drawn with ARE coils, which do not greatly alter the magnetic field but which improve transport significantly.

Watanabe outlined the present and future status for computational analysis of plasma behavior from a kinetic point of view. Two-dimensional equilibrium calculations for axisymmetric bumpy torus, tandem mirror, cusp plasma, tokamak, field reversed mirror, and ion ring devices are now possible, with relativistic and trapped particle effects to be included next. Three-dimensional numerical schemes will be tested with MHD and Vlasov-type models. Stability and wave propagation problems in one or more dimensions are also feasible. Phenomena such as collisions, non-adiabaticity, rf heating, and anomalous transport can be studied with numerical schemes that allow for development in time.

Berk interpreted the various experimentally observed fluctuations listed in chart form by Hiroe as follows: 10 KHz, ion diamagnetic frequency mode or Kelvin-Helmholtz electrostatic potential gradient-driven mode; 20-100 KHz, local interchange of the surface plasma outside the ring; 100-150 KHz, low-frequency hot electron interchange; 10 MHz, high-frequency hot electron interchange (well correlated with the predicted threshold for hot-electron-to-ion density ratio); 100 MHz, magnetic compressional mode coupled to a precessional wave; 10 GHz, whistler (or perhaps electron-plasma oscillation interacting with the hot electron loss cone).

Also, he emphasized that the long-wavelength layer modes give the most pessimistic stability condition for the decoupling problem, with significant consequences for reactor studies. A recent calculation that designed a bumpy torus reactor to operate slightly below the critical core beta value was based on the decoupling condition for the short-wavelength modes. The same condition for the layer modes requires an additional factor of 20-100 in the density ratio for stability. If this factor is 100, the stable operating regime for a reactor disappears; if 10, it still exists but is smaller. Several ways to improve the accuracy of the decoupling prediction are: to calculate line-averaged profiles; to include bending on the magnetic perturbations; to study the radial mode equation at ring beta values on the order of unity; to check whether low ring beta might have better stability properties, even though high beta affords a convenient expansion parameter for the non-resonant modes; and to generalize the theory to frequencies near the ion cyclotron frequency. He proposed examining the possibility of using axis-encircling ions ("Astron Bumpy Torus"), hot enough to reverse the magnetic drift, but not necessarily the field, and to satisfy strongly the decoupling condition with core beta near the critical value, assuming that a similar decoupling parameter is applicable for this system.

Other theoretical problems that remain to be studied are: to obtain quantitative ballooning stability criteria; to calculate allowable radial profiles by solving the ballooning mode problem within and to the inside of the annulus; to examine the spread in bounce frequency; to investigate the effect of ambipolar field on transport and low-frequency fluctuations during reversed potential operation; to see if whistlers influence transport; to optimize heating mechanisms; to study distribution functions produced in tandem mirrors; and to link together equilibrium and transport codes.

Finally, the Gamma-10 device, because it has a thermal barrier on the outside and quadrupole anchor on the inside, appears not to be susceptible to trapped particle instabilities.

Acknowledgments

The co-organizers of the workshop, T. Watanabe and J.W. Van Dam, express their appreciation to Profs. K. Nishikawa, M.N. Rosenbluth, and C.W. Horton for having proposed hot electron physics as the topic for a US-Japan workshop; to Profs. Horton and H.L. Berk for their advice in organizing the workshop; to Prof. Berk for moderating the discussion session and for his scientific leadership throughout the meetings; and to Mrs. Carolyn Valentine and Mrs. Saralyn Stewart for their efficient and indispensable assistance in running the workshop.

This workshop was supported by the U.S. Department of Energy and by the Ministry of Education of Japan.

2. AGENDA

HOT ELECTRON PHYSICS MINIWORKSHOP

JANUARY 10-14, 1983
INSTITUTE FOR FUSION STUDIES
AUSTIN, TEXAS

SPONSORED BY
US-JAPAN JOINT INSTITUTE FOR FUSION THEORY

AGENDA

MONDAY, JANUARY 10, 1983

1:00 PM	REGISTRATION
2:00 PM	OPENING REMARKS: C.W. HORTON, T. WATANABE, J.W. VAN DAM
2:30 PM	T. WATANABE, "EQUILIBRIUM OF VLASOV PLASMA IN AN AXISYMMETRIC SYSTEM"
	T.M. ANTONSEN, "STABILITY OF BALLOONING MODES AND LOW-M MODES IN HOT ELECTRON PLASMAS"
	S. HIROE, "FLUCTUATION MEASUREMENTS IN EBT"

TUESDAY, JANUARY 11, 1983

9:00 AM	H. SANUKI, "EFFECTS OF AN AMBIPOLAR FIELD ON THE STABILITY OF ELECTROSTATIC FLUTE MODES IN A BUMPILESS CYLINDER"
	D.A. SPONG, "RADIAL MODE STRUCTURE OF CURVATURE-DRIVEN INSTABILITIES IN EBT"
	H.L. BERK, "LONG WAVELENGTH MODES WITH FLR EFFECTS"
	B.H. QUON, "HOT ELECTRON RING AND DISK FORMATION IN SYMMETRIC MIRROR FACILITY"
12:00 NOON	LUNCH
1:30 PM	WORKING SESSION

PROGRAM OF US-JAPAN MINIWORKSHOP - JANUARY 10-14, 1983

WEDNESDAY, JANUARY 12, 1983

9:00 AM	Y. KIWAMOTO, "PHYSICS OF HOT ELECTRON HEATING IN TANDEM MIRROR"
	W.M. NEVINS, "CONTROL OF HOT ELECTRON ENERGY IN THERMAL BARRIER CELLS"
	R.J. KASHUBA, "THEORY OF WAVE DAMPING NEAR THE ELECTRON CYCLOTRON FREQUENCY"
	T. WATANABE, "KINETIC STABILITY OF AXISYMMETRIC TANDEM MIRRORS AND EFFECTS OF AXIAL TANDEM POTENTIALS"
12:00 NOON	GROUP PHOTOGRAPH
12:15 PM	LUNCH
1:30 PM	WORKING SESSION
7:00 PM	BANQUET DINNER OLD PECAN STREET CAFE (TRANSPORTATION PROVIDED)

THURSDAY, JANUARY 13, 1983

9:00 AM	Y. OHSAWA, "PARTICLE SIMULATION OF EBT STABILITY"
	N.T. GLADD, "RELATIVISTIC EFFECTS ON THE WHISTLER INSTABILITY"
	A.M. EL-NADI, "TOPICS IN EBT STABILITY THEORY"
12:00 NOON	LUNCH
1:30 PM	WORKING SESSION

FRIDAY, JANUARY 14, 1983

9:00 AM	DISCUSSION SESSION: H.L. BERK
12:00 NOON	CLOSING

3. PRESENTATIONS

VLASOV EQUILIBRIUM OF AXISYMMETRIC SYSTEMS

T. Watanabe, K. Hamamatsu, J. W. Van Dam*, and K. Nishikawa

Institute for Fusion Theory, Hiroshima University

*Institute for Fusion Studies, University of Texas

VLASOV EQUILIBRIUM

of

AXISYMMETRIC SYSTEMS

by

T. Watanabe

K. Hamamatsu

[*] J. W. Van Dam

and

Kyoji Nishikawa

Institute for Fusion Theory,

Hiroshima University

[*]Institute for Fusion Studies,

University of Texas

Most previous workes for studying plasma equilibrium are based on MHD equations.

Recent progress in fusion plasma has revealed a variety of new problems:

effects of finite gyroradius of particles,
mirror trapping effects,
resonant wave particle interactions,
effects of ambipolar potentials.

These effects cannot be treated within the framework of MHD theory, and requires of an analysis based on the Vlasov-Maxwell system of equations.

1. Equilibrium distribution function and basic equations

2. Numerical method

3. Applications

   a) Bumpy cylinder with hot rings

   b) Bumpy cylinder with hot electrons producing revers field configurations

   c) Thermal barrier with sloshing ions and hot electrons

   d) High-β double cusp system

1. Equilibrium distribution function and basic equations

assumption:	axisymmetry
	no B_θ
	(conservation of magnetic moment)

constants of motion

$$E = m\tilde{v}^2/2 + q\Phi$$

$$p_\theta = r m v_\theta + q\psi/c$$

$$(\ \mu = m v_\perp{}^2/2B\ )$$

$$f_j(\mathbf{x},\mathbf{v}) = N_{0j}\left(\frac{m_j}{2\pi T_j}\right)^{3/2}\exp\left[-\frac{E}{T_j}-\frac{(P_\theta-\frac{q}{c}\psi_{0j})^2}{2m_jT_j\lambda_j^2}\right]$$

$$\times\left[\exp\left(-\alpha_{1j}\frac{B_0}{T_j}\mu\right)-\delta_j\exp\left(-\alpha_{2j}\frac{B_0}{T_j}\mu\right)\right]$$

$$n_j = N_{1j} - N_{2j}$$

$$\mathbf{J} = \left(0,\ r(I_{1j}-I_{2j}),\ 0\right)$$

$$N = \frac{N_0}{(1+\alpha B_0/B)^{1/2}(1+\alpha B_0/B + r^2/\lambda^2)^{1/2}}$$

$$\times\exp\left[-\frac{q}{T}\Phi-\frac{q^2(\psi-\psi_0)^2}{2Tm\lambda^2c^2}\,\frac{1+\alpha B_0/B}{1+\alpha B_0/B+r^2/\lambda^2}\right]$$

$$I = -\frac{q^2}{\lambda^2 mc}\,\frac{\psi-\psi_0}{1+\alpha B_0/B+r^2/\lambda^2}N$$

$$B = \frac{1}{r}|\nabla\psi|$$

Φ and ψ are determined by

Poisson and Amper's equations.

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial\Phi}{\partial r}\right)+\frac{\partial^2\Phi}{\partial z^2} = -4\pi\rho(\Phi,\psi,|\nabla\psi|)$$

$$\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial\psi}{\partial r}\right)+\frac{1}{r}\frac{\partial^2\psi}{\partial z^2} = -\frac{4\pi}{c}J_\theta(\Phi,\psi,|\nabla\psi|)$$

$$\rho = \sum_j q_j (N_{1j} - N_{2j})$$

$$J_\theta = r\sum_j (I_{j1} - I_{j2})$$

2. Numerical method

We have solved the coupled nonlinear boundary value problem by combined use of the shooting method and Newton's iteration method.

This method have been proved to be

highly accurate,

highly efficient, and

highly flexible

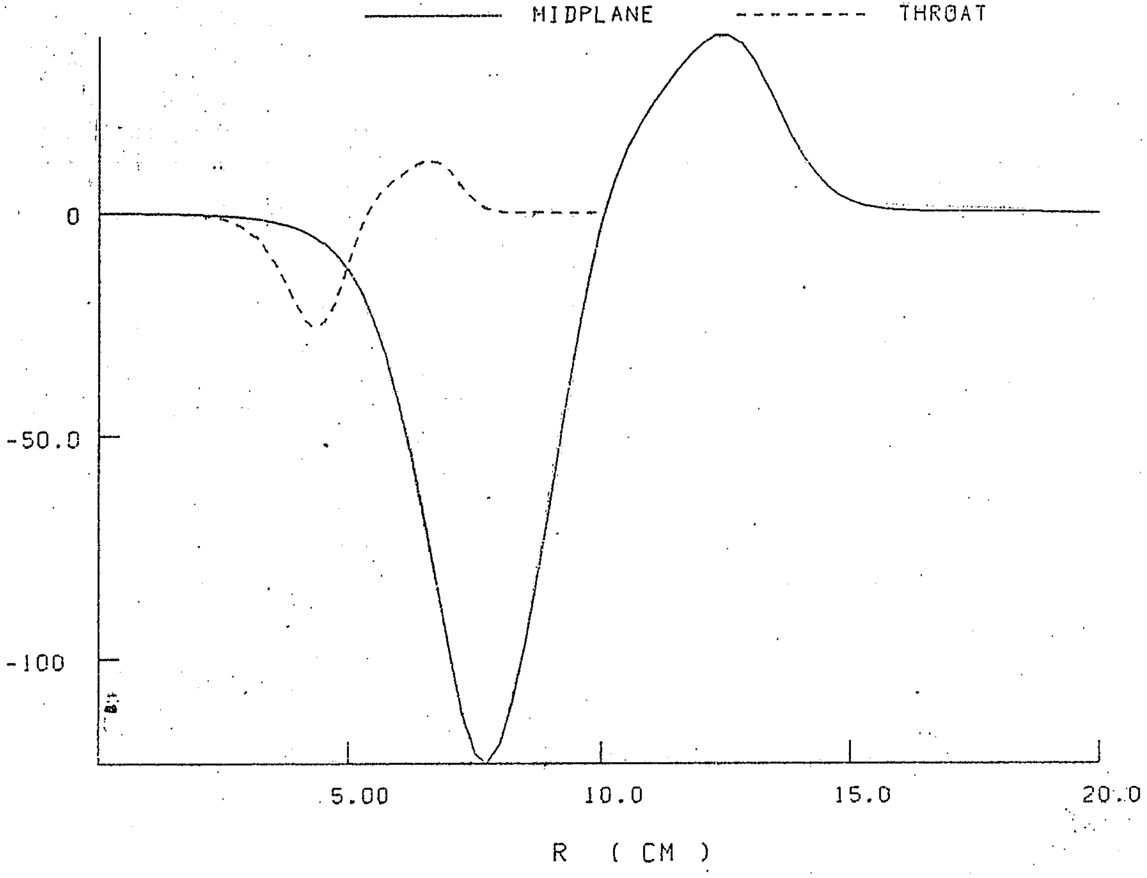
through the following applications.

Plasma Parameters:

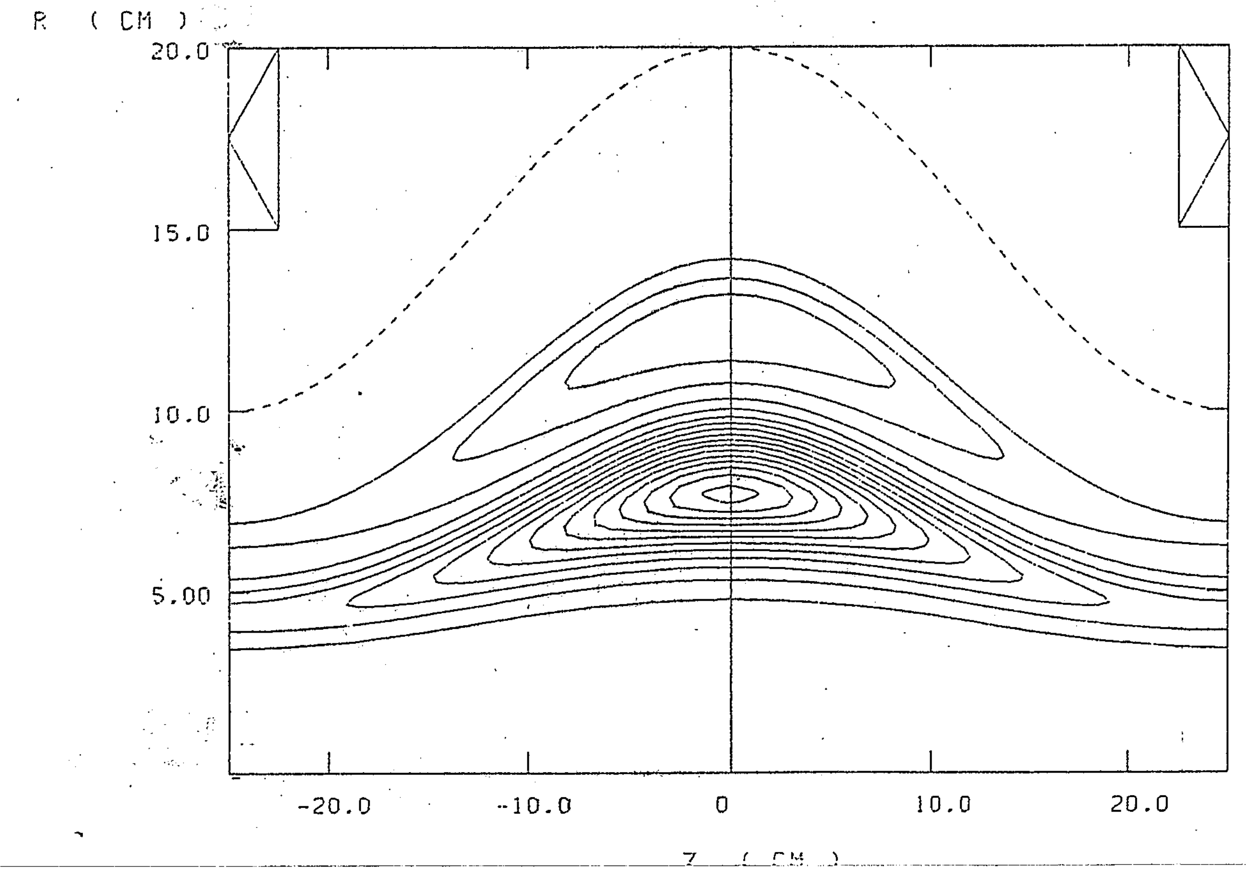
	$n\,(cm^{-3})$	$T_{\parallel}\,(ev)$	$T_{\parallel}/T_{\perp}$
Hot Electron Ring	3×10^{12}	10^{5}	$\simeq 1/2$
Core Electron	3×10^{13}	10^{3}	1
Core Ion	3×10^{13}	500	1
Surface Electron	10^{11}	10^{3}	1
Surface Ion	10^{11}	500	1

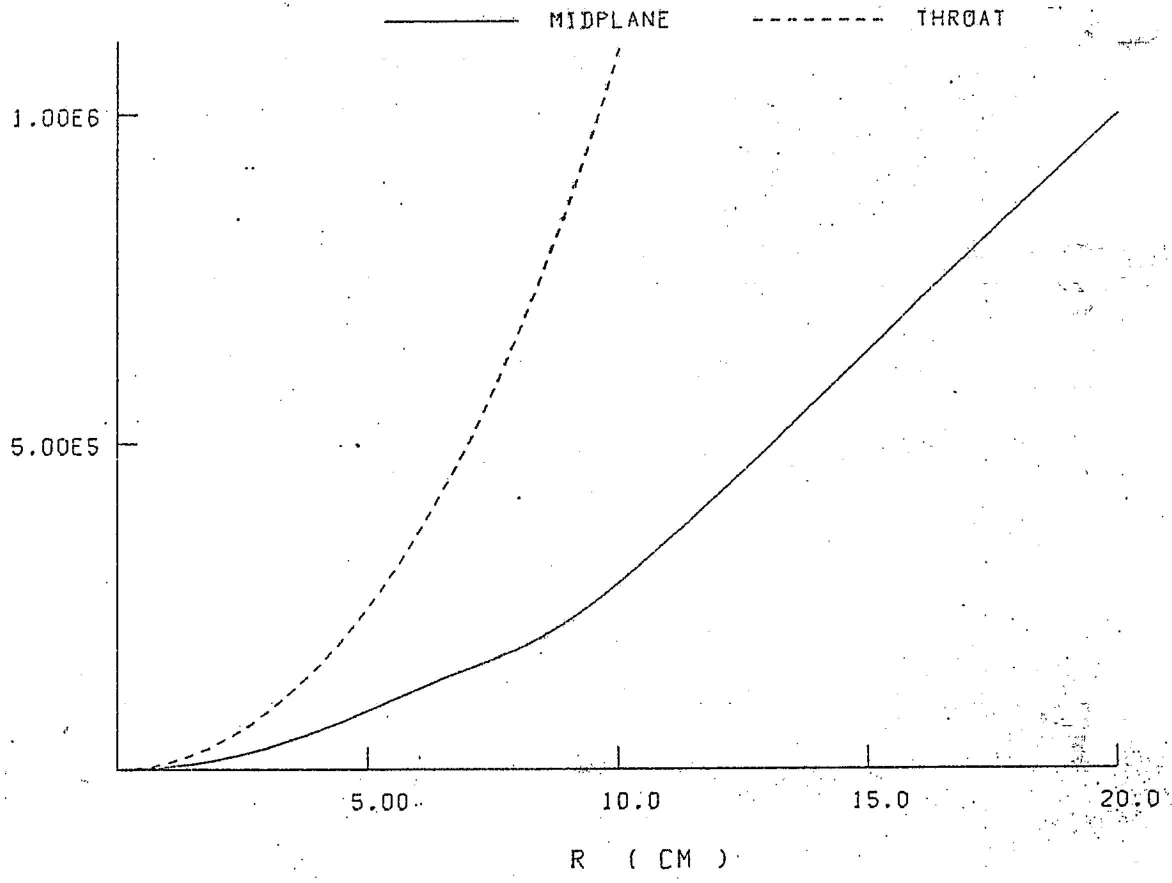
82-06-05 11 18 4

POTENTIAL VS. RADIUS

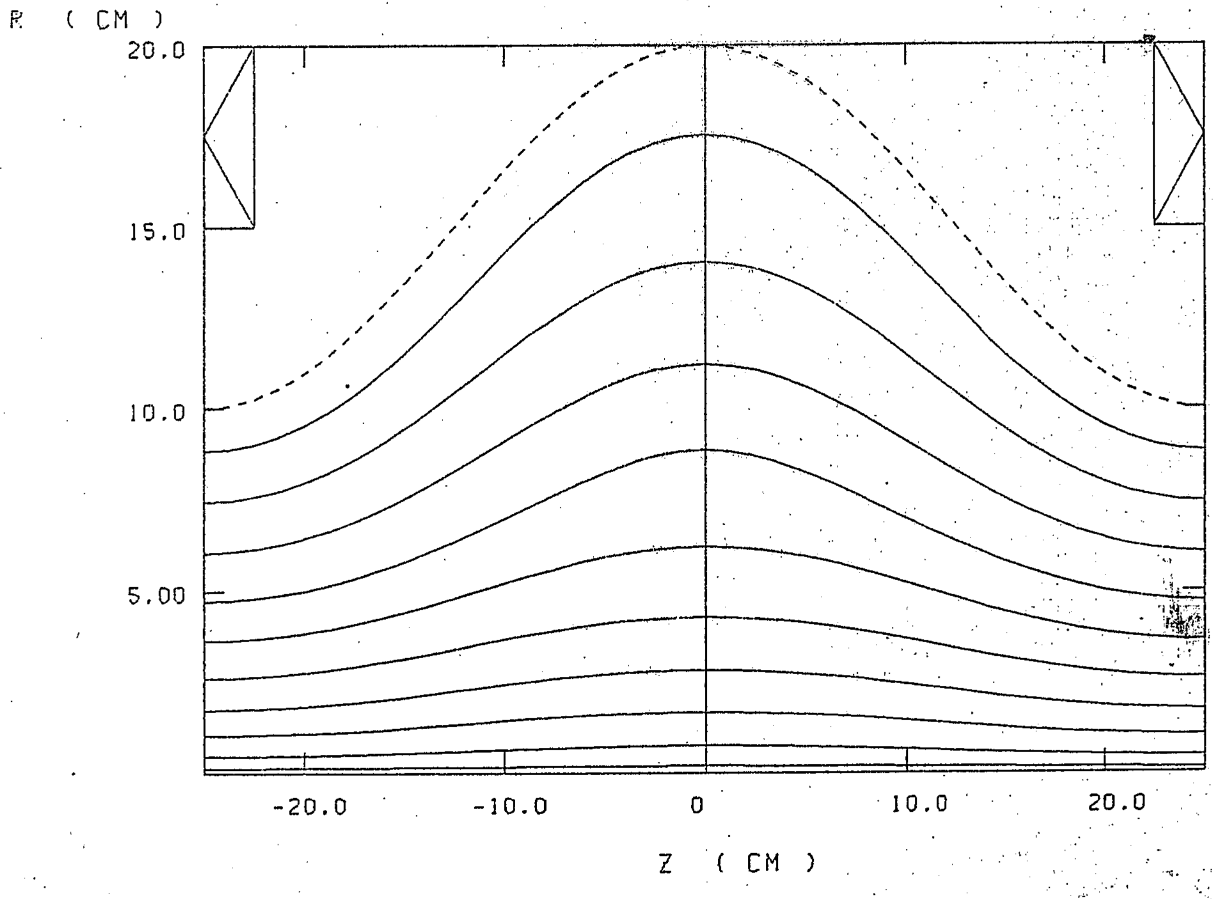


CONTOURS OF POTENTIAL



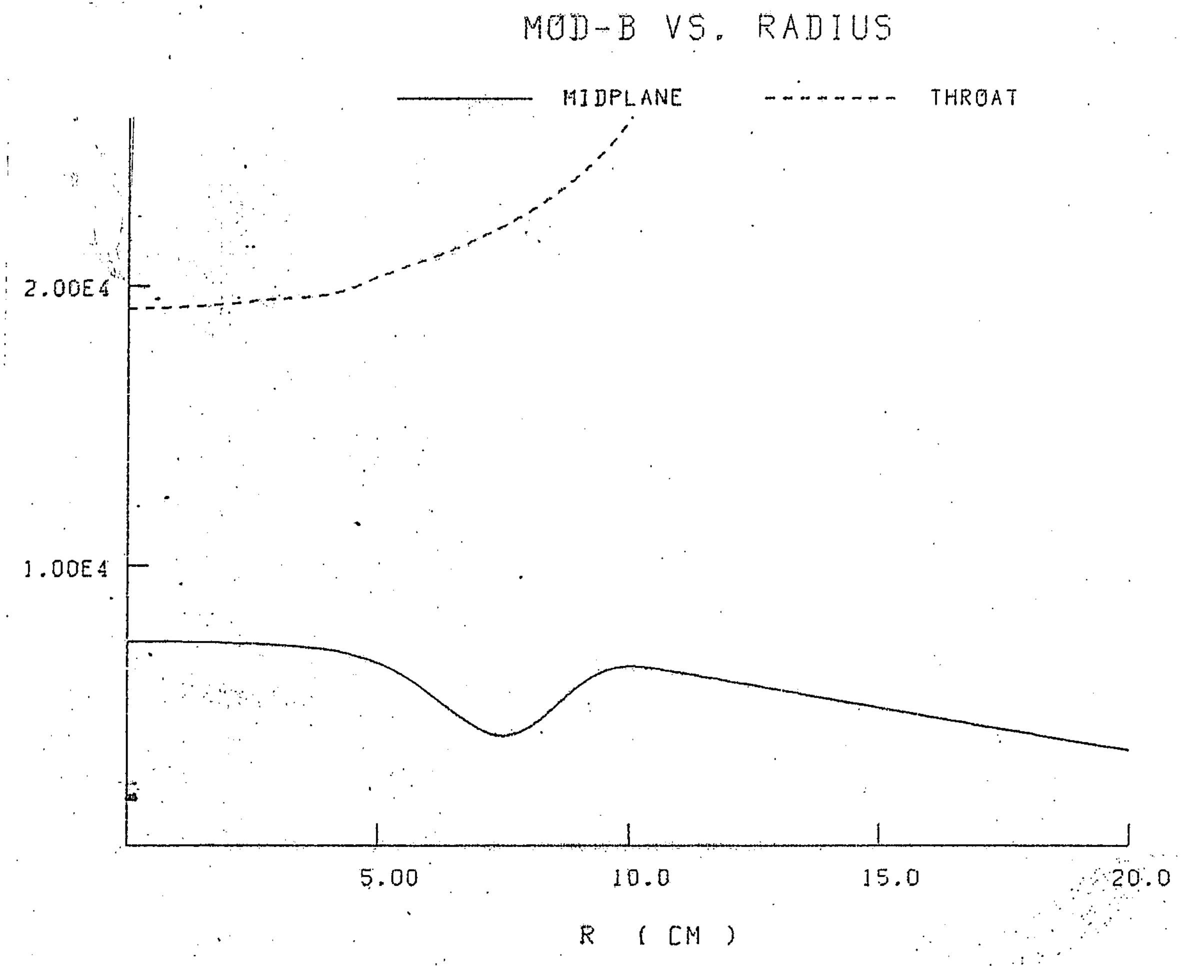


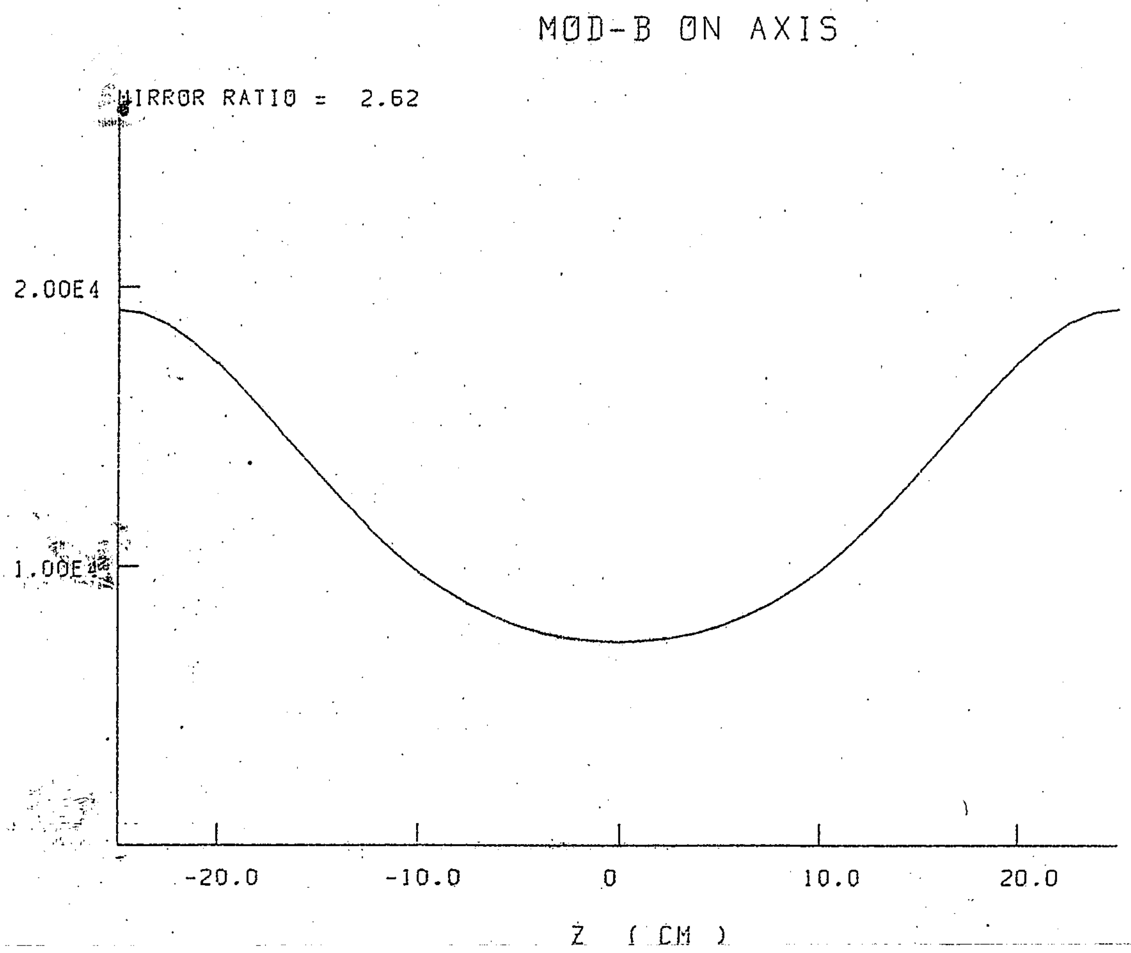
FLUX VS. RADIUS



MAGNETIC FIELD LINES

82-06-05 11 18 5





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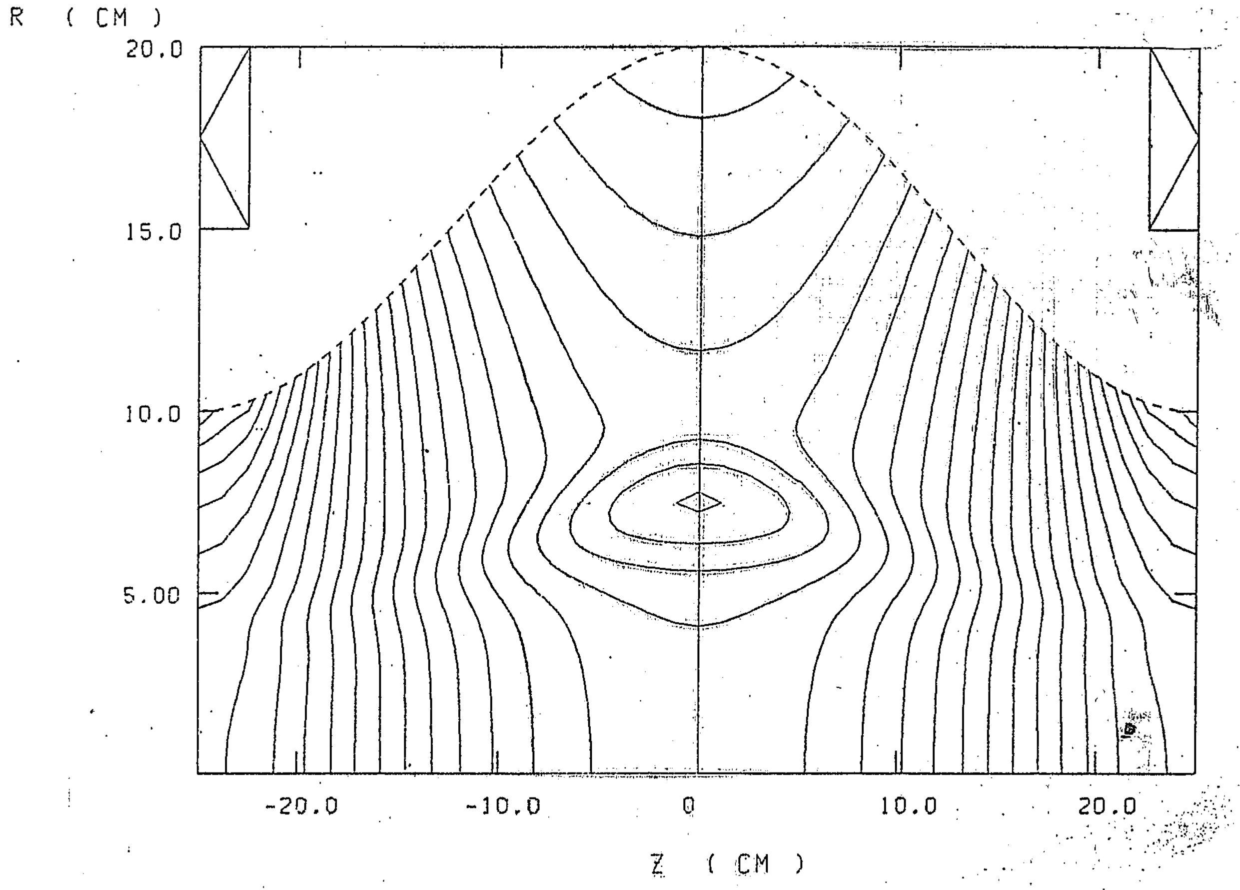
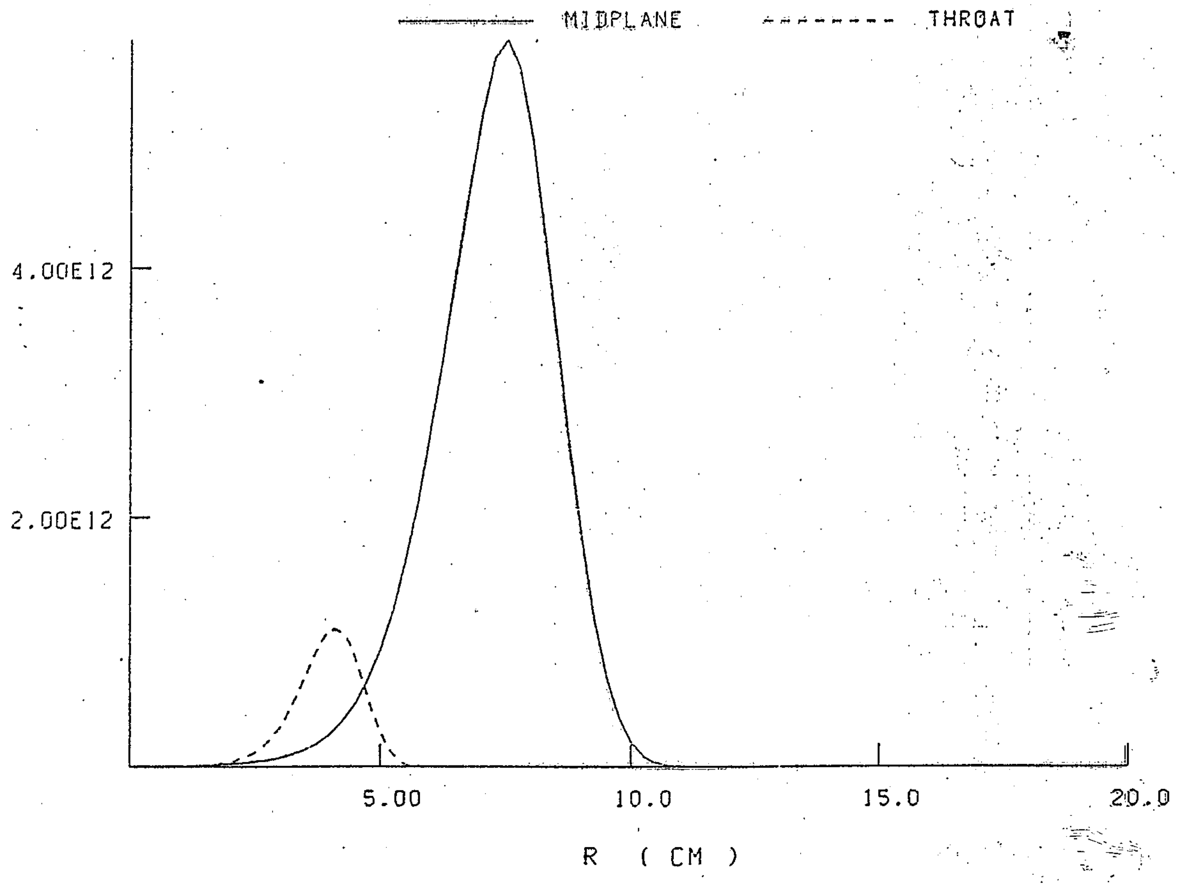
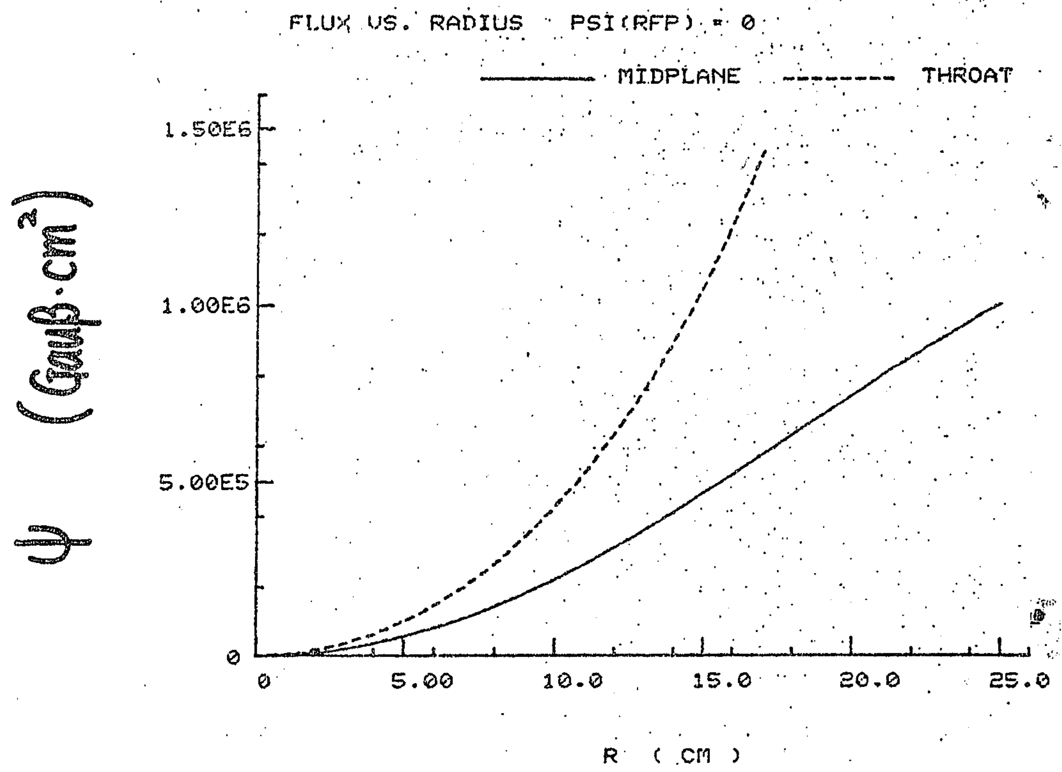


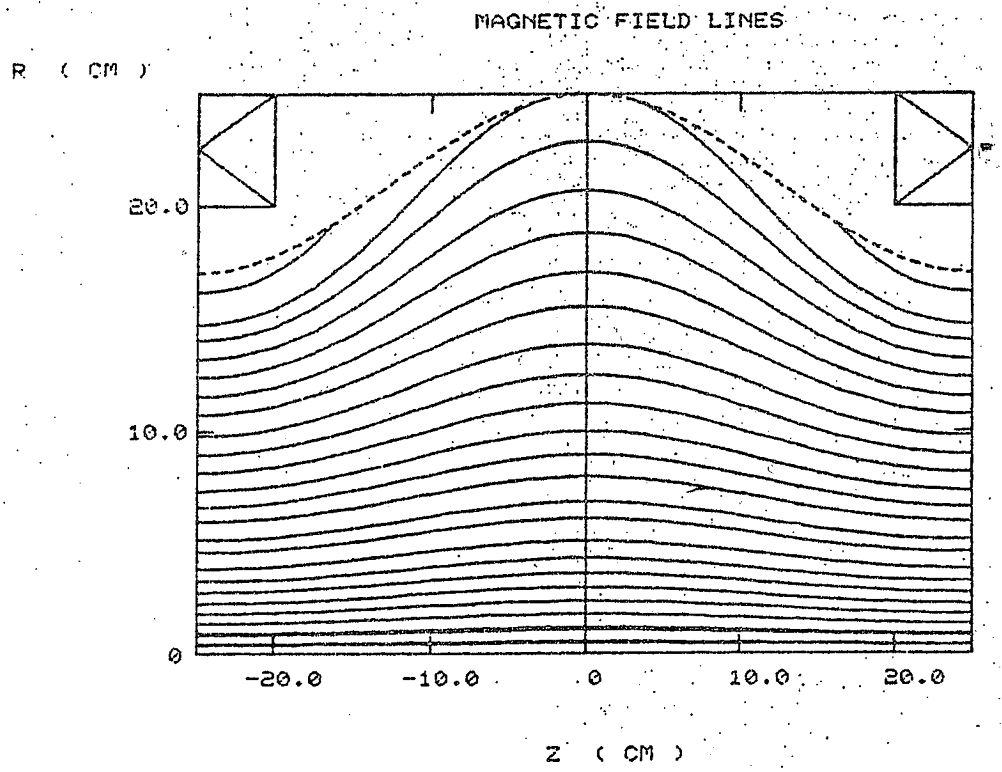
DENSITY VS. RADIUS

COMPONENT (1)

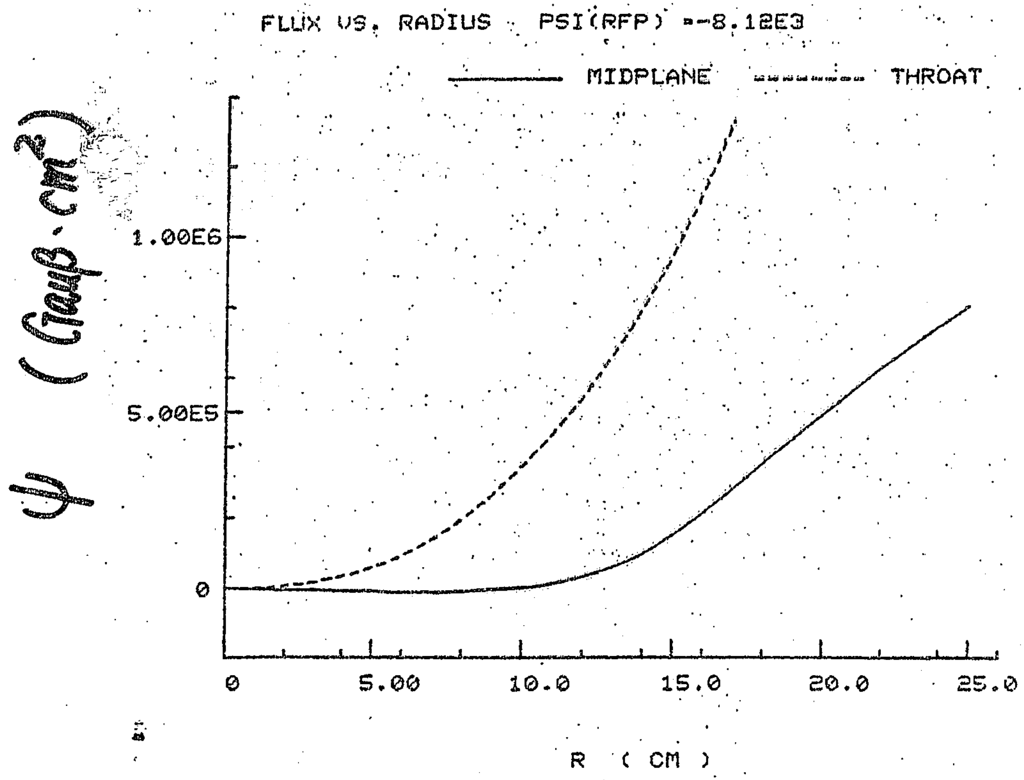


VACUUM SOLUSION





Coil Current : 5 KA/cm²


FLUX VS. RADIUS PSI(RFP) =-8.12E3
MIDPLANE
THROAT
ψ (Gauß·cm²)
1.00E6
5.00E5
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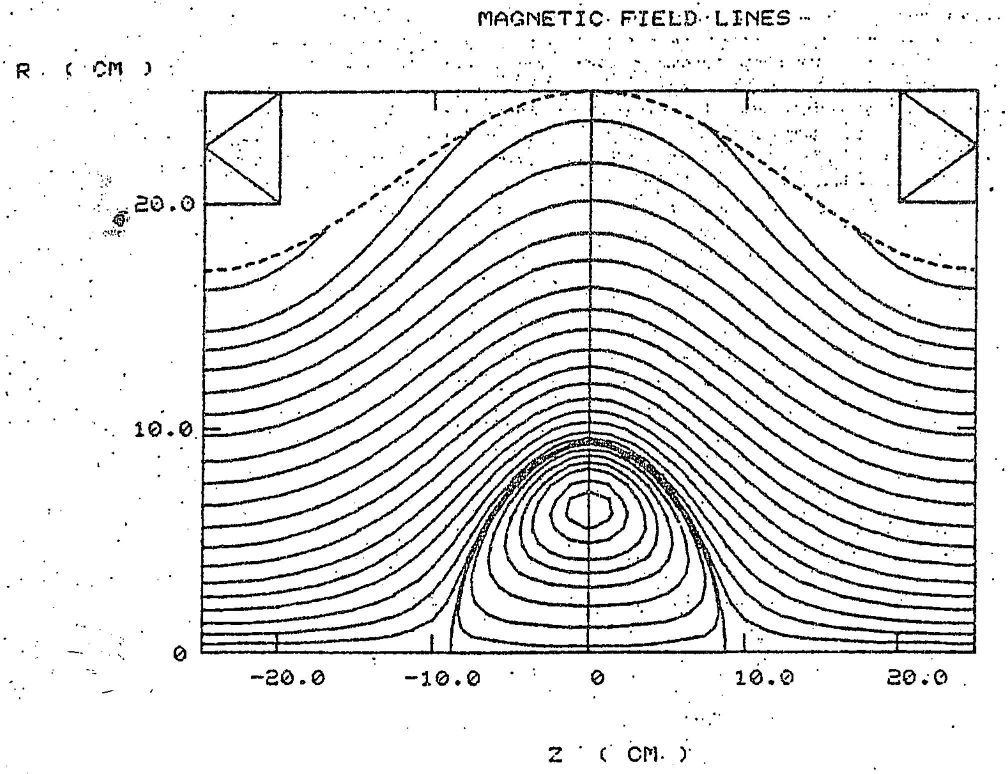
0
5.00
10.0
15.0
20.0
25.0
R (CM)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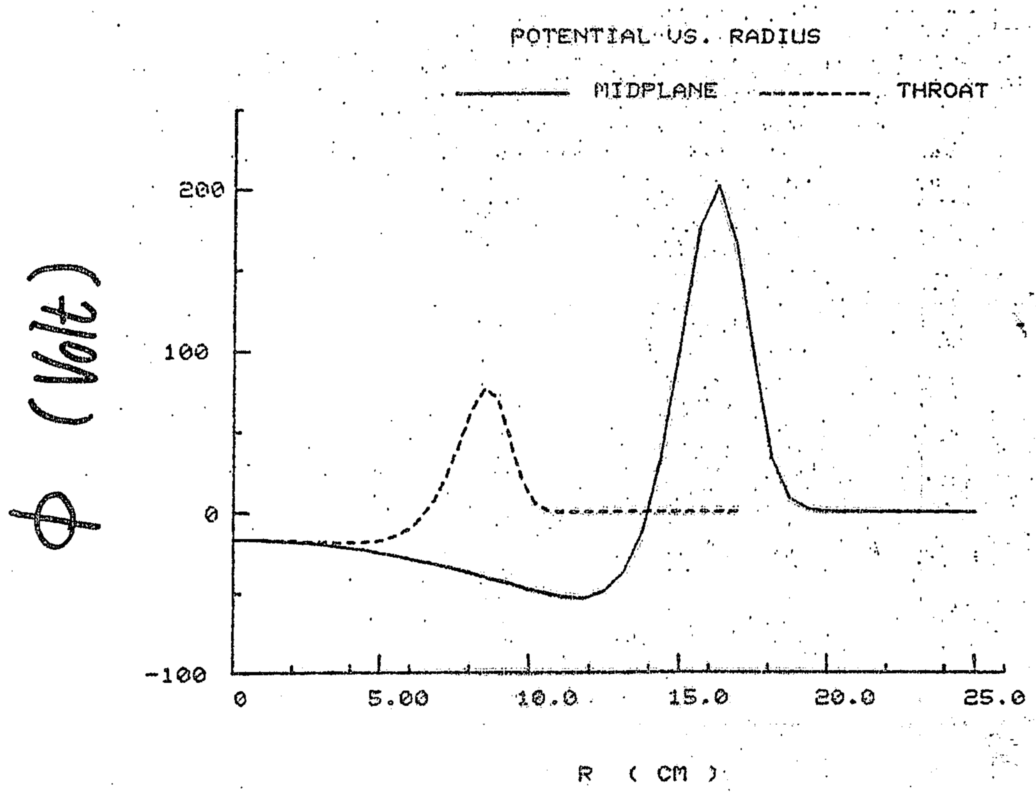
R (CM)
20.0
10.0
0
-20.0
-10.0
0
10.0
20.0
Z (CM)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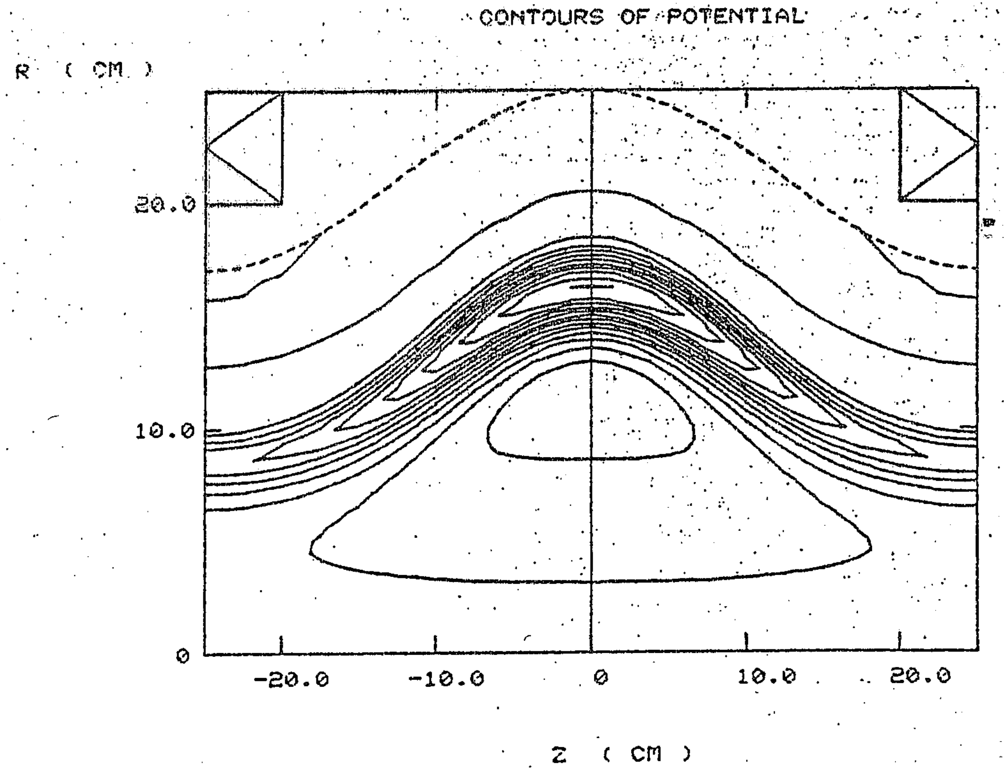
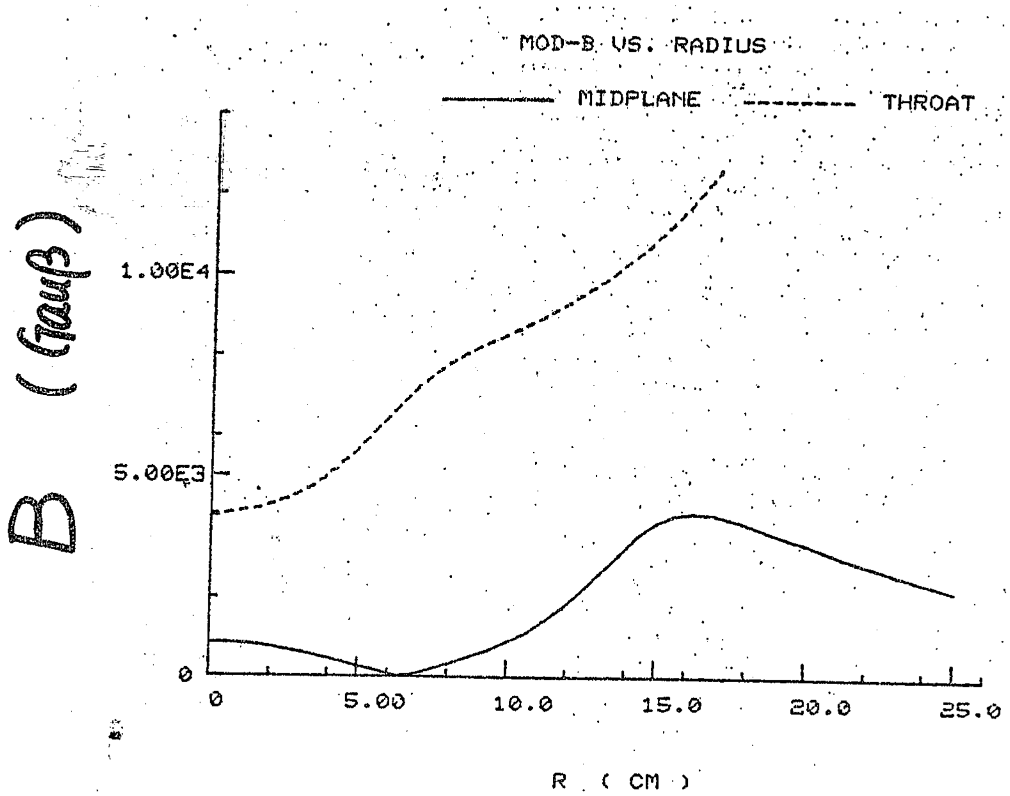
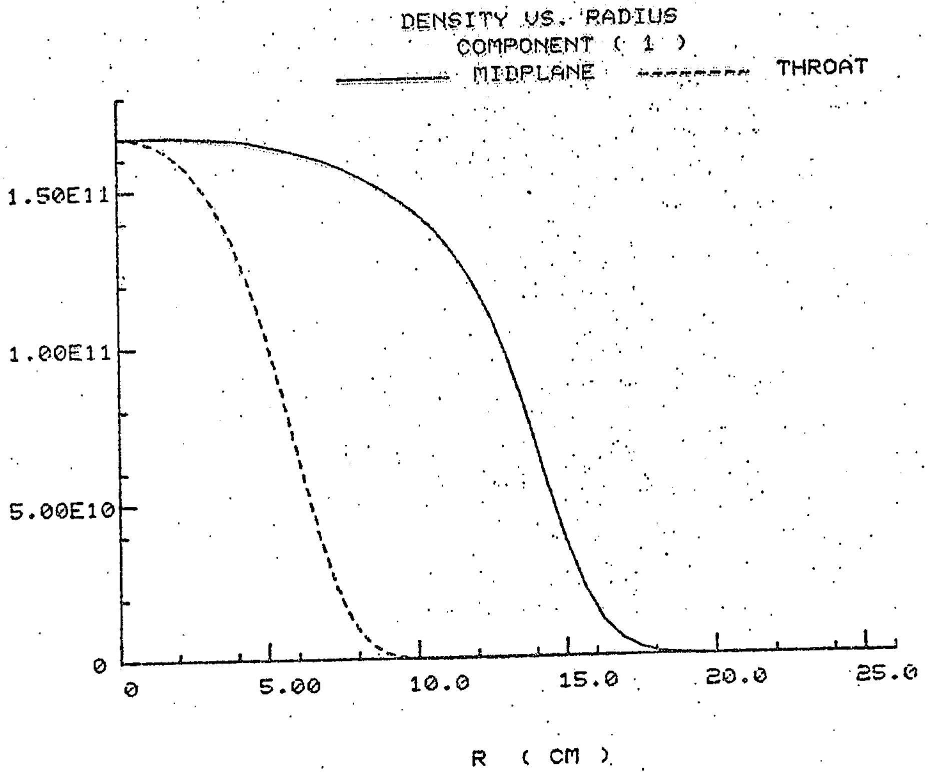
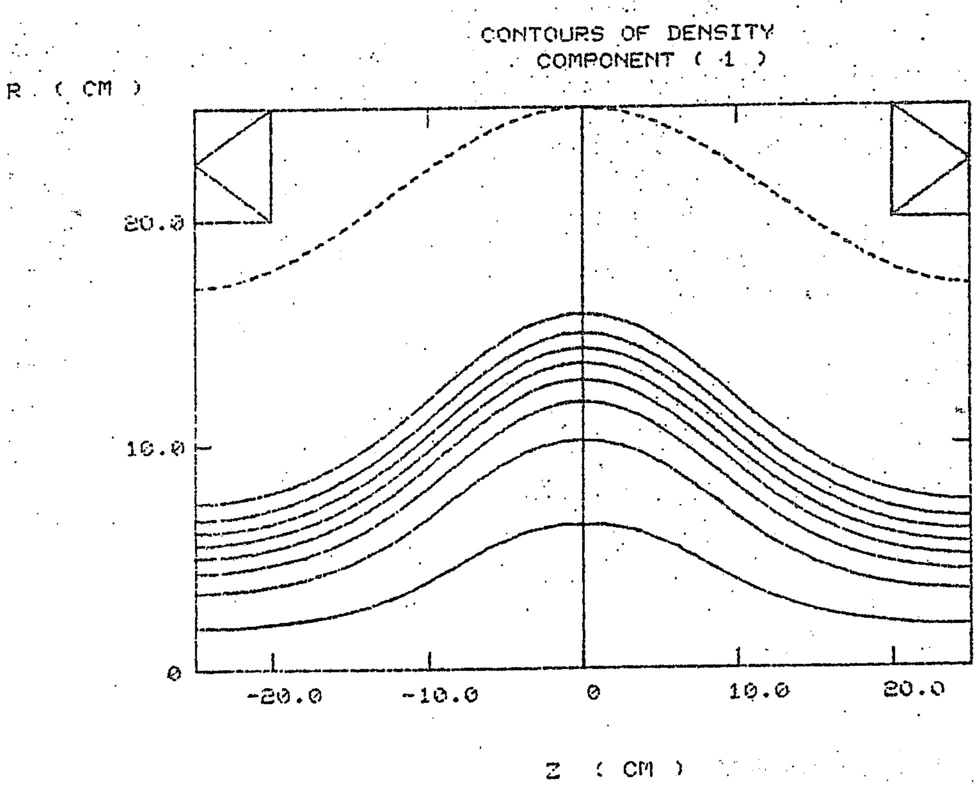

CONTOURS OF POTENTIAL

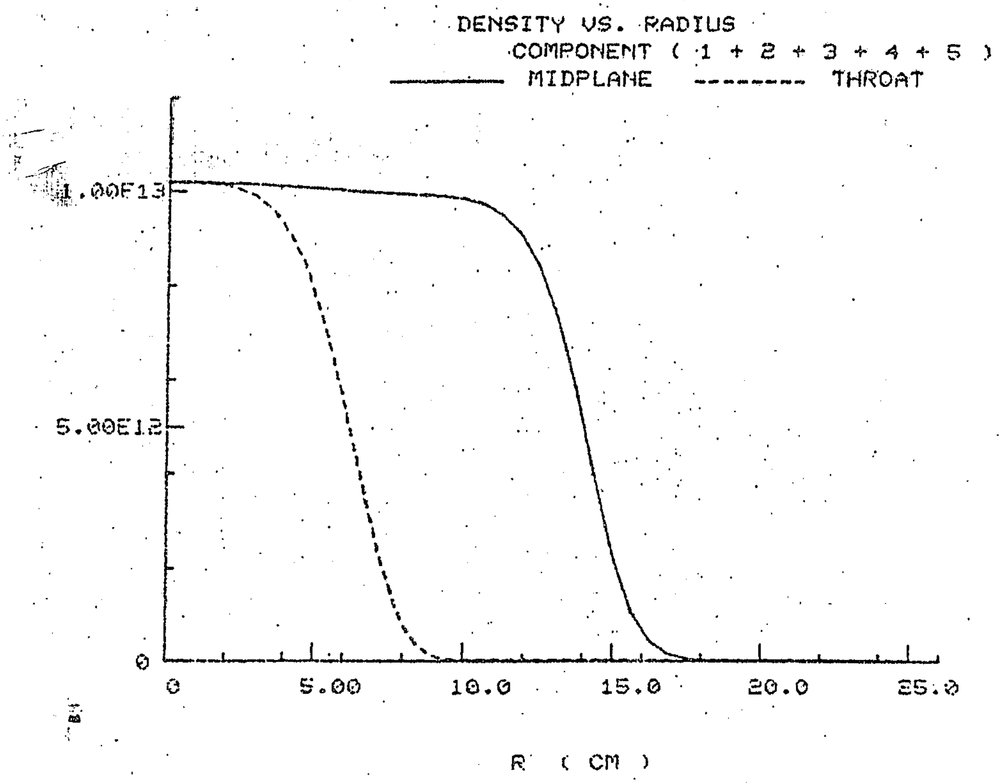

MOD-B VS. RADIUS
MIDPLANE
THROAT
B (Gauß)
1.00E4
5.00E3
0
0
5.00
10.0
15.0
20.0
25.0
R (CM)

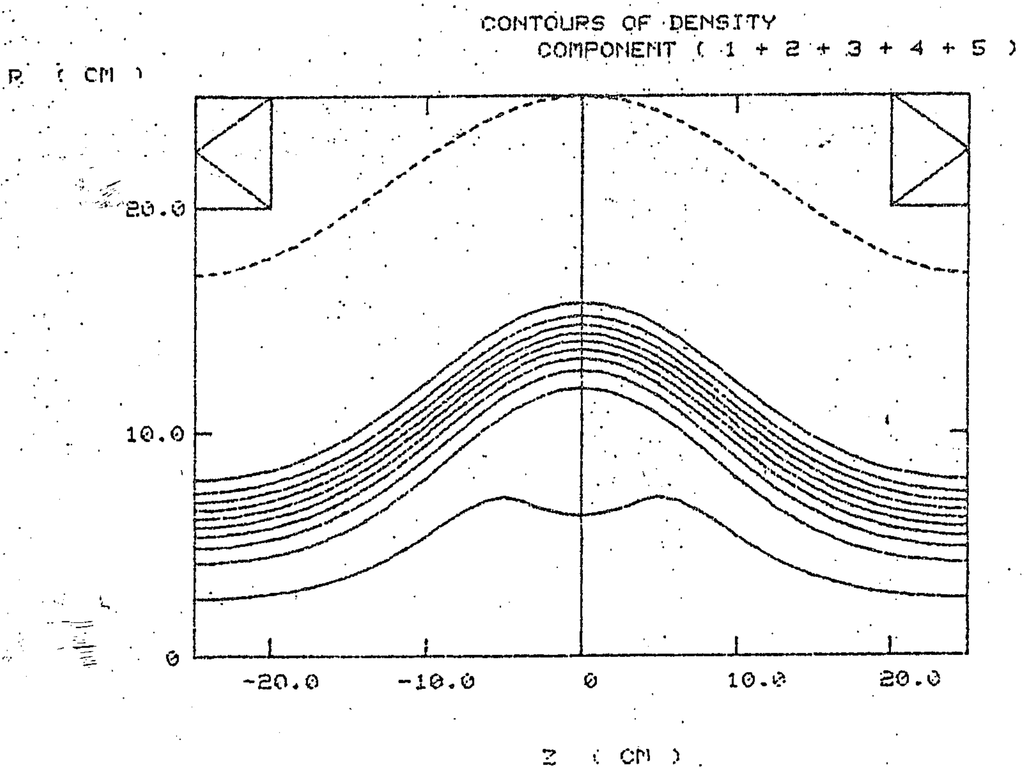
HOT ELECTRON DENSITY
$(1/cm^3)$



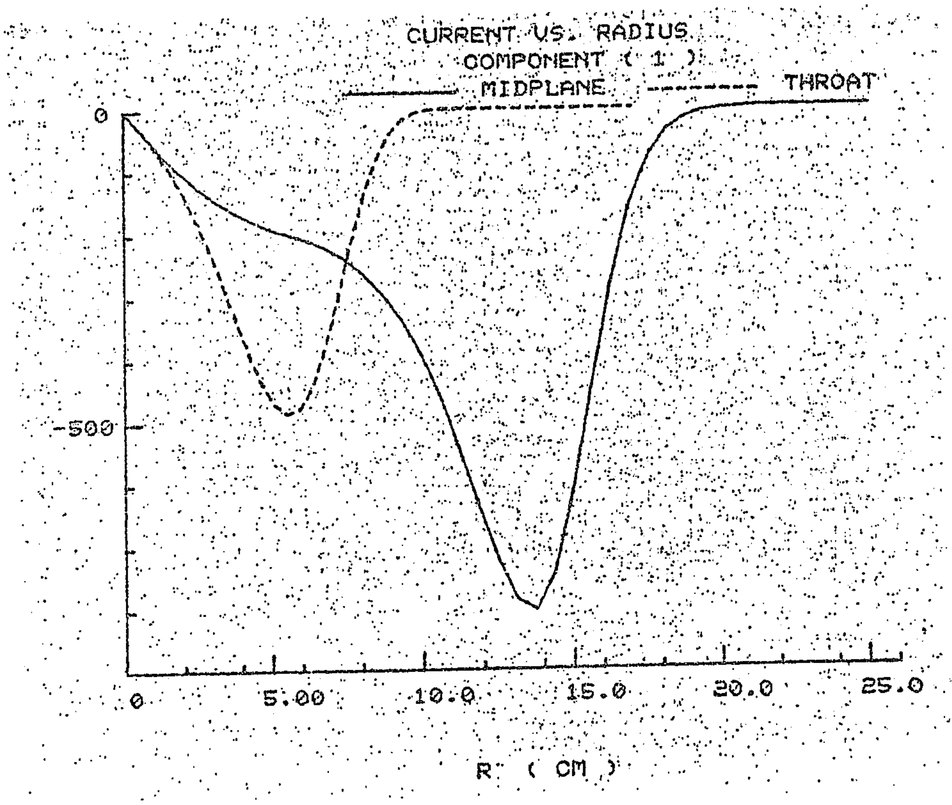


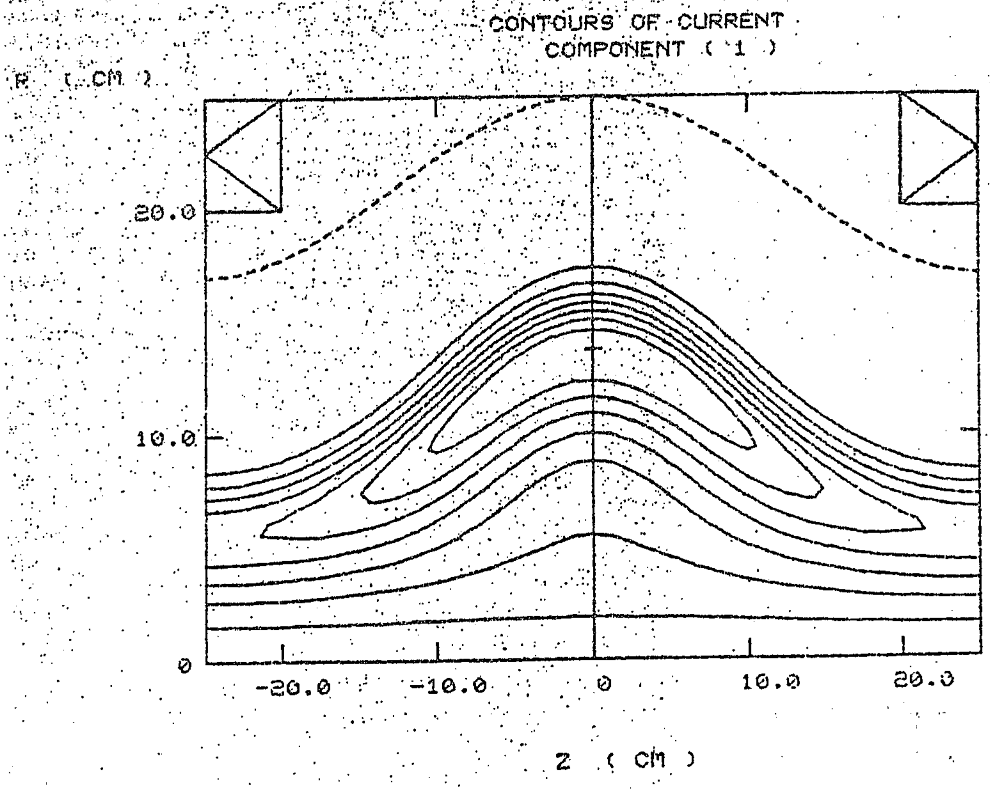
TOTAL DENSITY $(1/cm^3)$





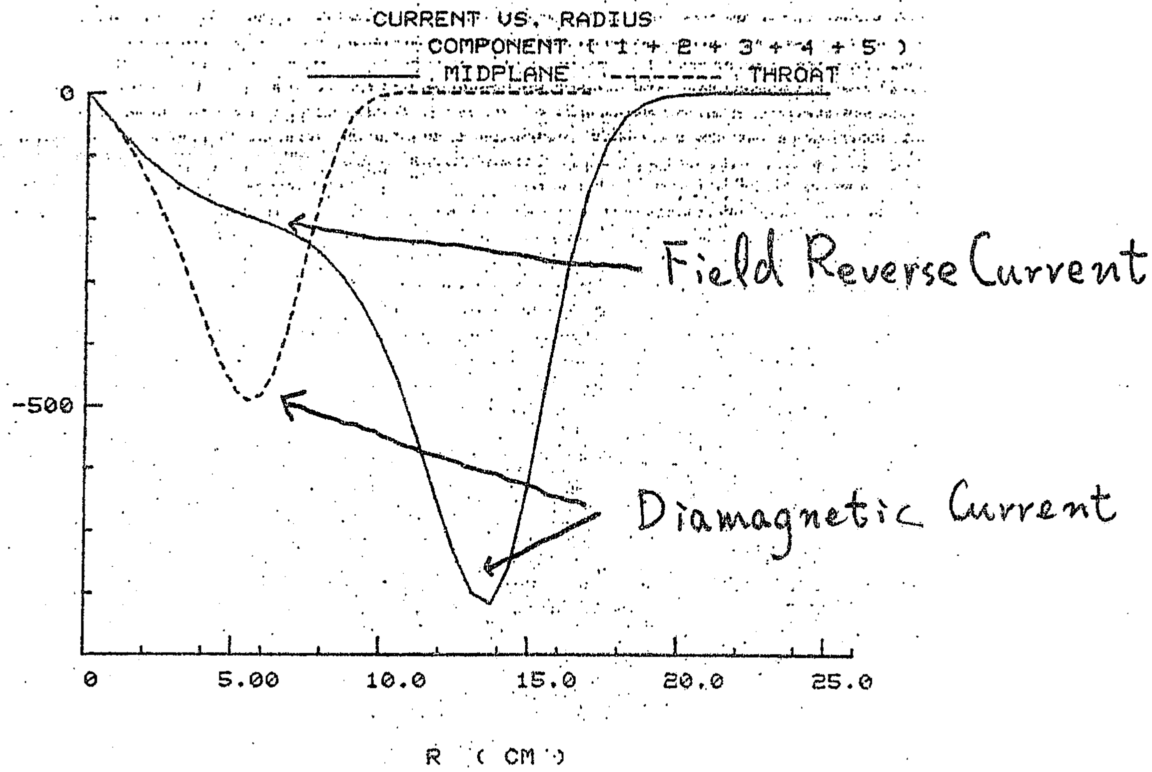
Hot Electron (A/cm²)

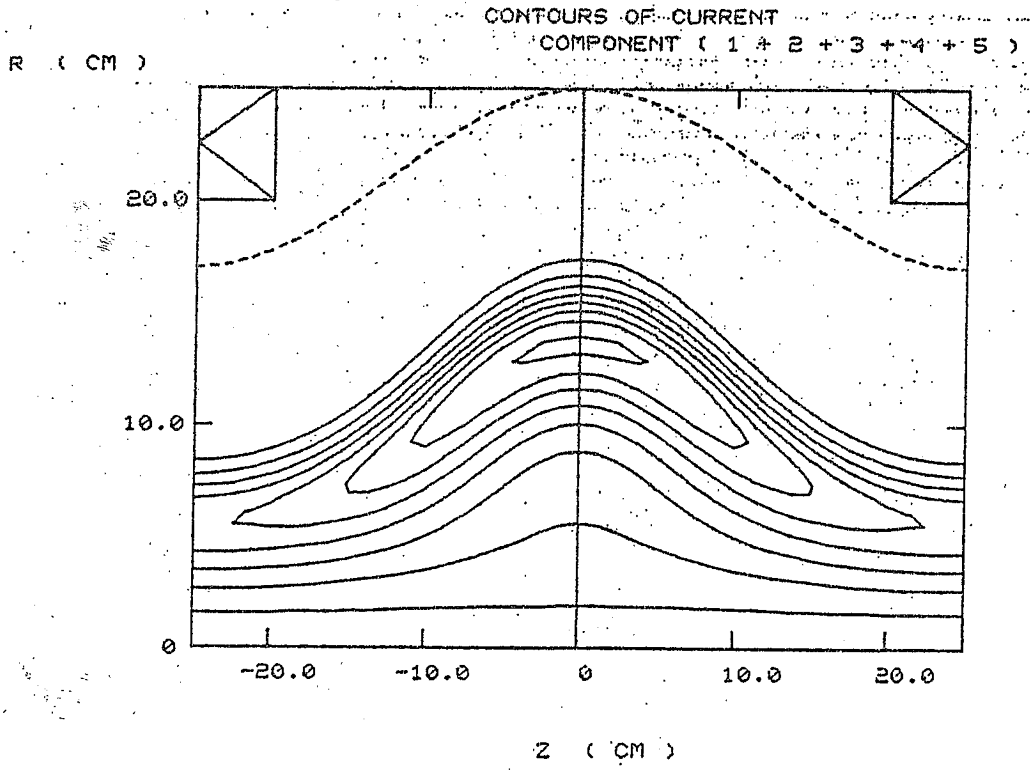




CURRENT DENSITY

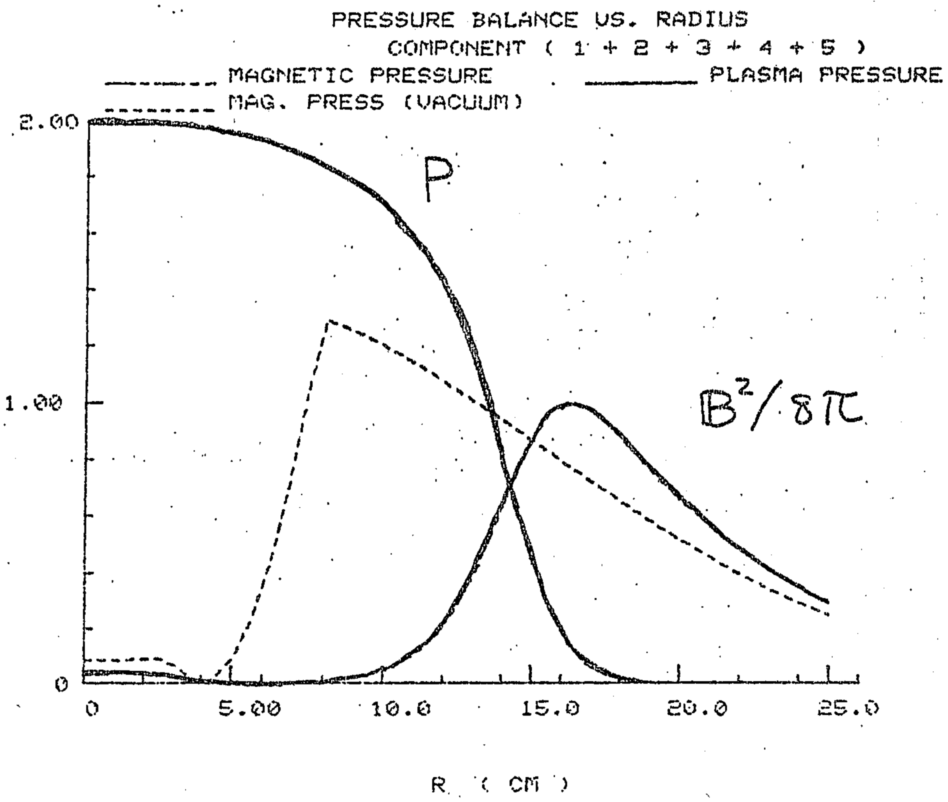
Total (A/cm²)

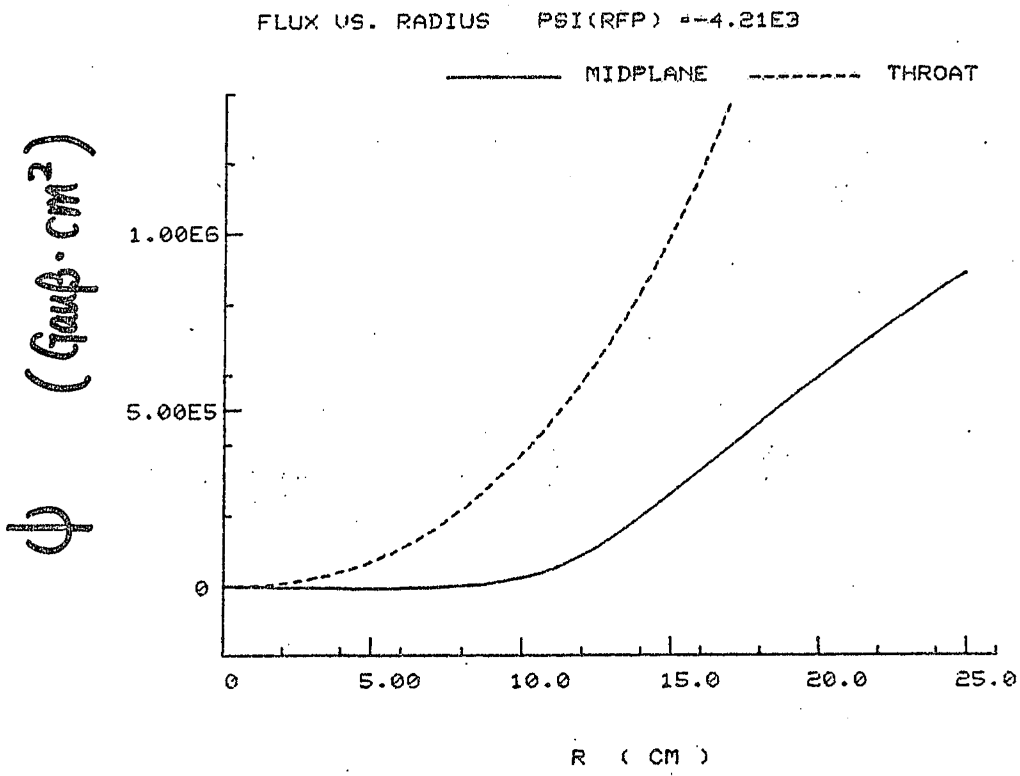


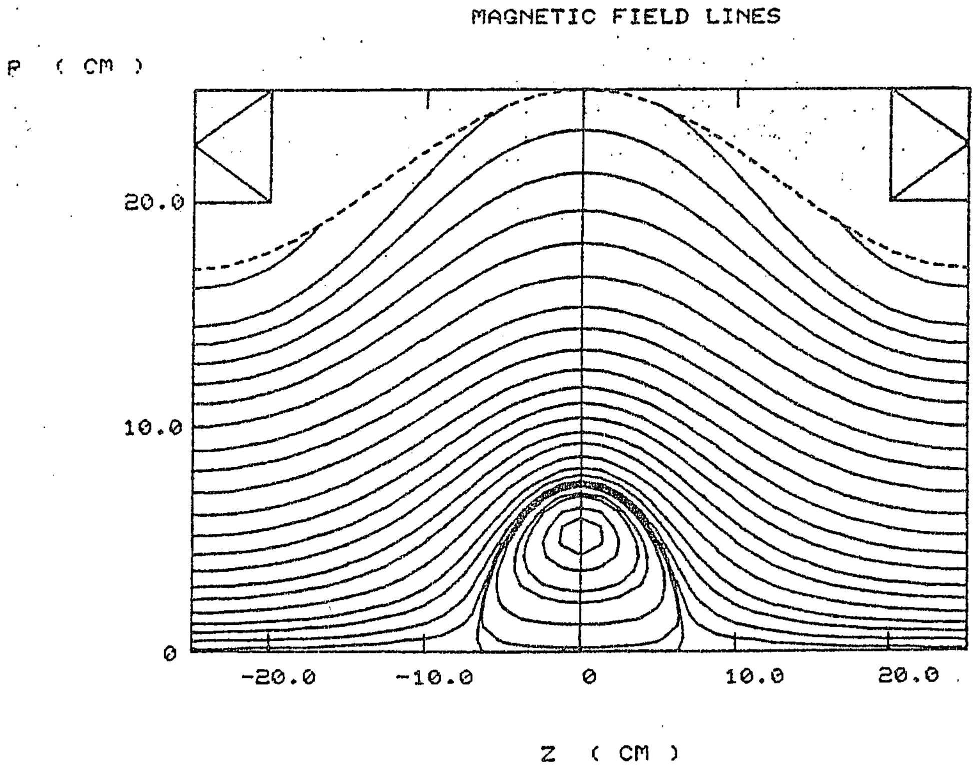


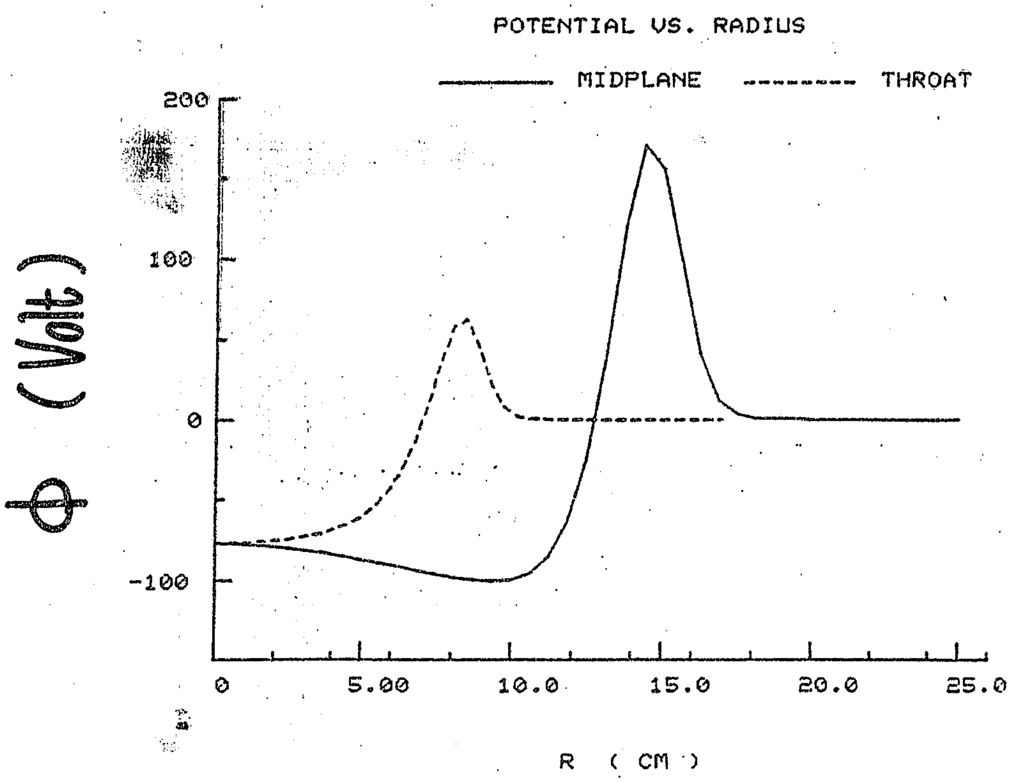
PLASMA PARAMETERS

		T_j (KeV)	N_{0j} ($1/cm^3$)	ψ_{0j} (Gauß·cm^2)	λ_j (cm)
hot electron		200	7.84×10^{11}	-3×10^4	3.67×10
core	electron	1	5×10^{12}	0	1.16×10^3
	ion	1	5×10^{12}	0	2.71×10
surface	electron	.1	1×10^{10}	0	1×10^{29}
	ion	.1	1×10^{10}	0	2.33×10^{27}

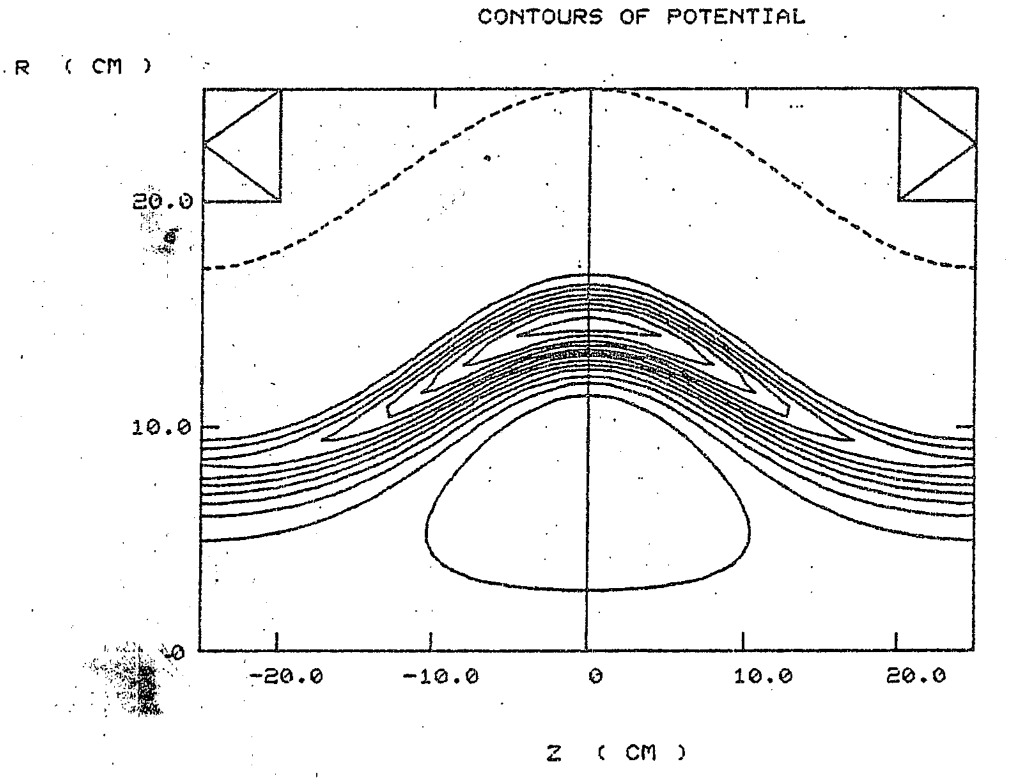

PRESSURE BALANCE VS. RADIUS
COMPONENT (1 + 2 + 3 + 4 + 5)
MAGNETIC PRESSURE
PLASMA PRESSURE
MAG. PRESS (VACUUM)
2.00
1.00
0
P
$B^2/8\pi$
0
5.00
10.0
15.0
20.0
25.0
R (CM)


FLUX VS. RADIUS PSI(RFP) =-4.21E3
MIDPLANE
THROAT
ψ (Gauß · cm²)
1.00E6
5.00E5
0
0
5.00
10.0
15.0
20.0
25.0
R (CM)

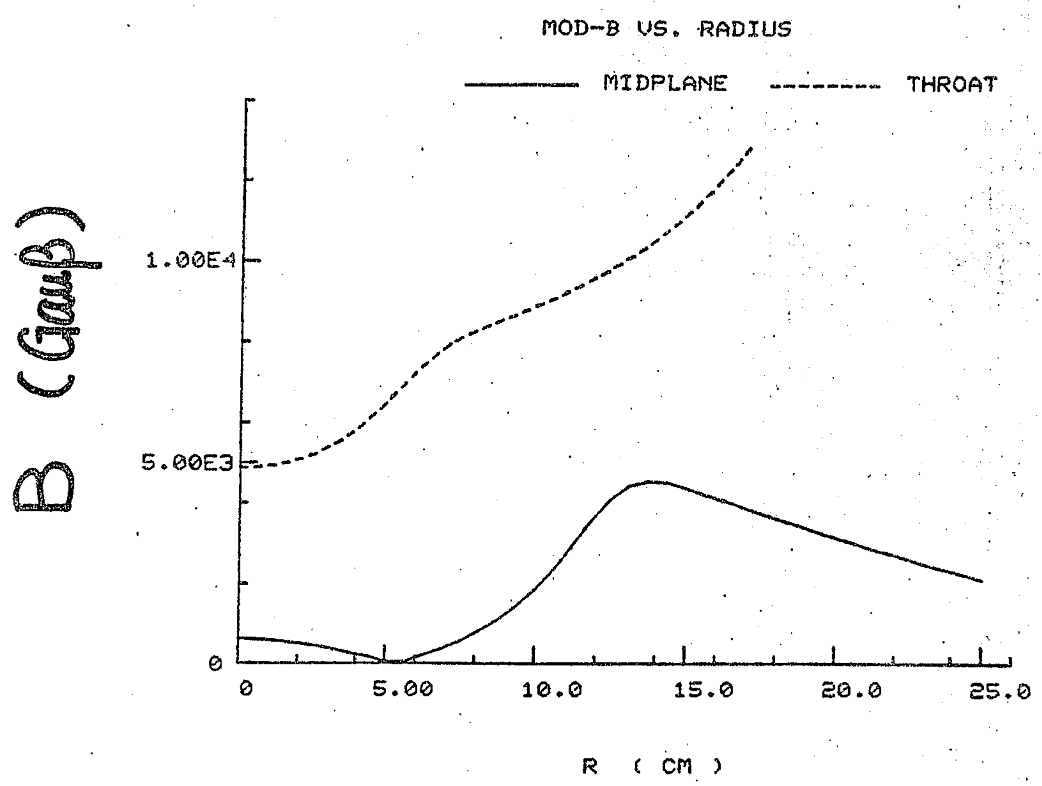

MAGNETIC FIELD LINES
R (CM)
20.0
10.0
0
-20.0
-10.0
0
10.0
20.0
Z (CM)



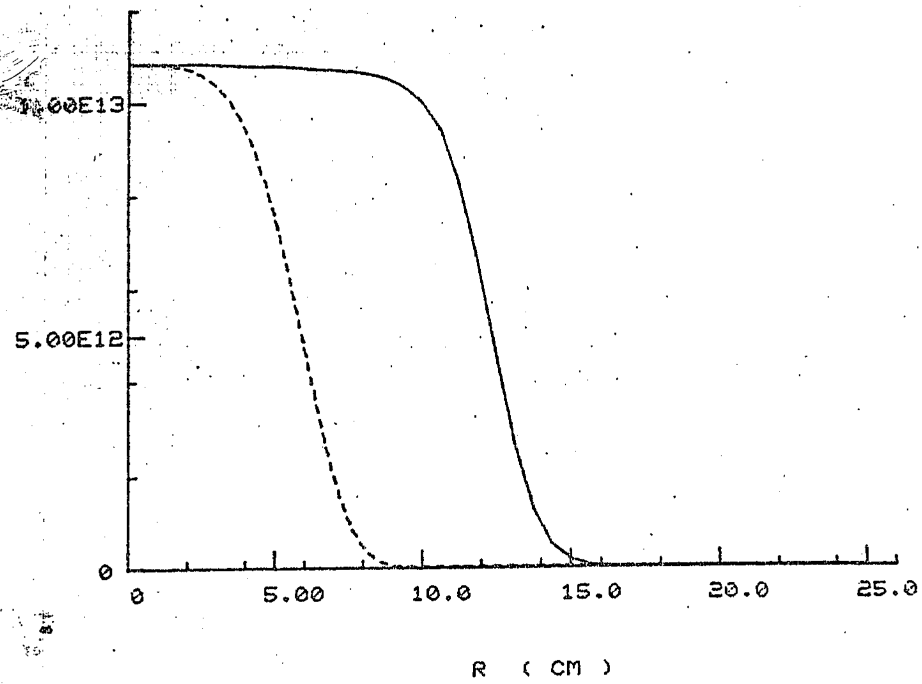
POTENTIAL VS. RADIUS

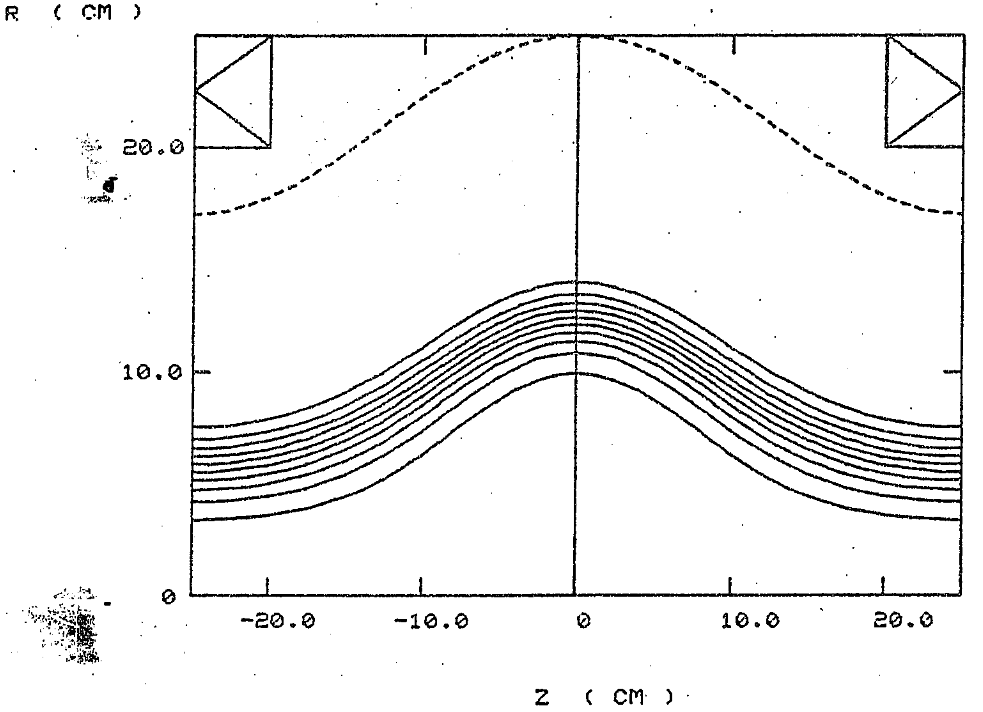


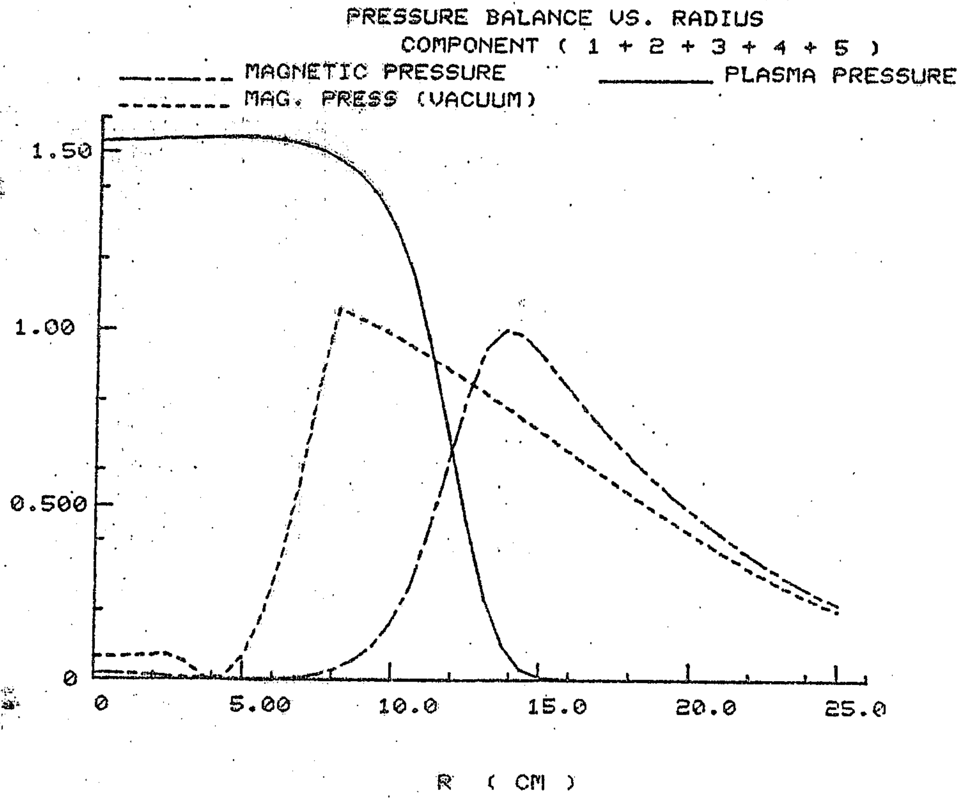
CONTOURS OF POTENTIAL


MOD-B VS. RADIUS
MIDPLANE
THROAT
B (Gauß)
1.00E4
5.00E3
0
0
5.00
10.0
15.0
20.0
25.0
R (CM)

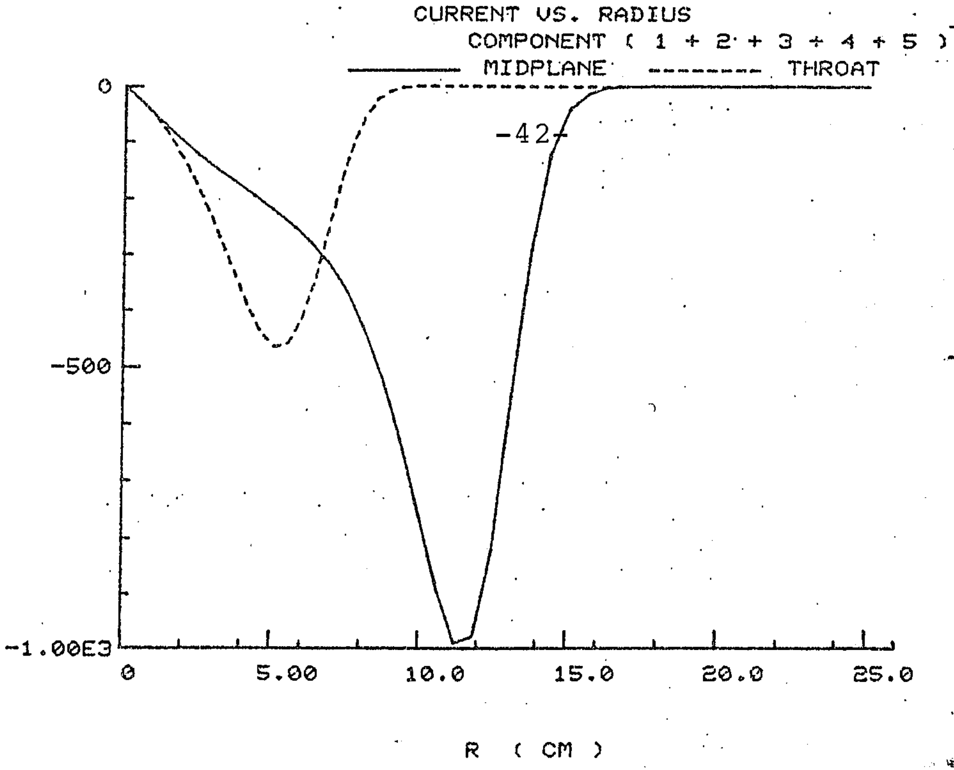
TOTAL DENSITY $(1/cm^3)$

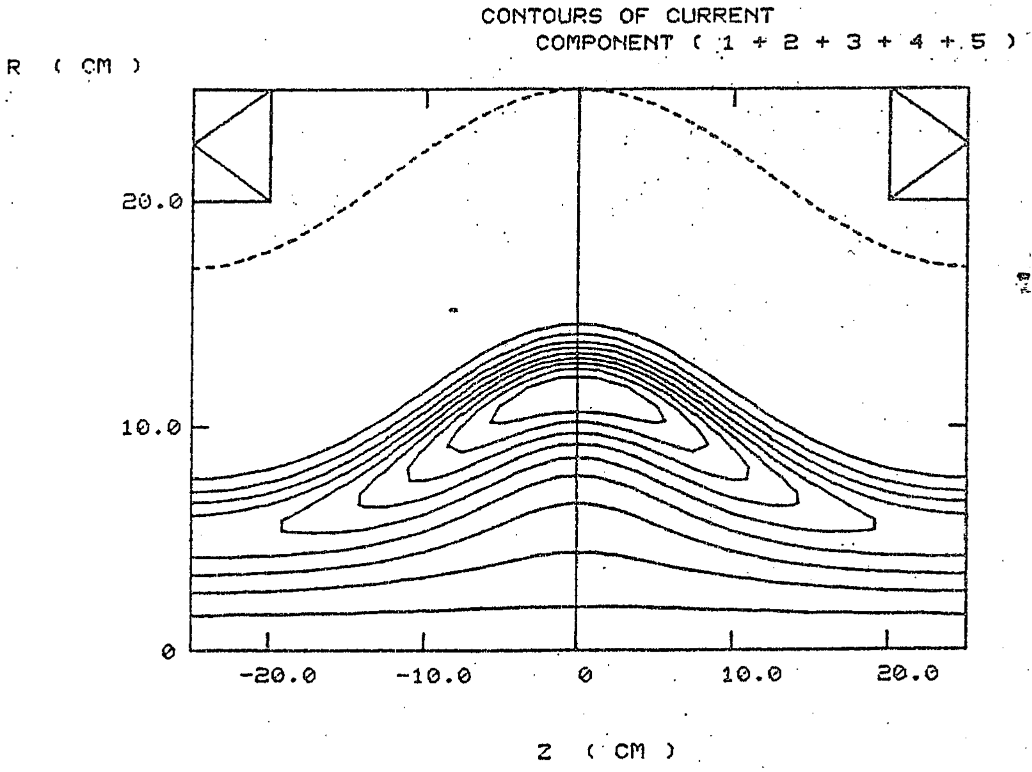

DENSITY VS. RADIUS
COMPONENT (1 + 2 + 3 + 4 + 5)


CONTOURS OF DENSITY
COMPONENT (1 + 2 + 3 + 4 + 5)


PRESSURE BALANCE VS. RADIUS
COMPONENT (1 + 2 + 3 + 4 + 5)
MAGNETIC PRESSURE
PLASMA PRESSURE
MAG. PRESS (VACUUM)
1.50
1.00
0.500
0
0
5.00
10.0
15.0
20.0
25.0
R (CM)

TOTAL CURRENT DENSITY (A/CM²)


CURRENT VS. RADIUS
COMPONENT (1 + 2 + 3 + 4 + 5)


CONTOURS OF CURRENT
COMPONENT (1 + 2 + 3 + 4 + 5)

		$n_j(cm^{-3})$	$T_j(eV)$	α_{1j}	α_{2j}	δ_j	$\psi_{0j}(G\cdot cm^2)$	$\lambda_j(cm)$
hot ring electron		3.0×10^{12}	1.0×10^{5}	-5.0×10^{-2}	5.0×10^{-2}	1.0	1.8×10^{5}	1.5
core plasma	electron	3.0×10^{13}	5.0×10^{2}	0.0	0.0	0.0	0.0	8.0
	ion	3.0×10^{13}	1.0×10^{3}	0.0	0.0	0.0	0.0	8.0
surface plasma	electron	1.0×10^{11}	2.5×10^{2}	0.0	0.0	0.0	1.0×10^{6}	10.
	ion	1.0×10^{11}	5.0×10^{2}	0.0	0.0	0.0	1.0×10^{6}	10.

	current density	inner diameter	outer diameter	thickness	distance
external magnetic coil	20 KA/cm²	15 cm	20 cm	5 cm	40 cm

Table 1.

		$n_j(cm^{-3})$	$T_j(eV)$	α_{1j}	α_{2j}	δ_j	$\psi_{0j}(G\cdot cm^2)$	$\lambda_j(cm)$
sloshing ion		1.0×10^{13}	5.0×10^{4}	2.0×10^{-1}	4.0×10^{-1}	1.0	0.0	8.0
		-6.8×10^{11}	8.3×10^{3}	-5.0×10^{-2}	6.7×10^{-3}	1.0	0.0	8.0
hot electron		5.0×10^{12}	1.0×10^{5}	-5.0×10^{-2}	1.0×10^{-2}	1.0	0.0	8.0
		-2.8×10^{12}	5.5×10^{3}	-5.0×10^{-2}	0.0	0.0	0.0	8.0
warm electron		7.0×10^{12}	1.0×10^{4}	0.0	0.0	0.0	0.0	8.0
surface plasma	electron	1.0×10^{11}	5.0×10^{2}	0.0	0.0	0.0	3.0×10^{6}	10.
	ion	1.0×10^{11}	5.0×10^{2}	0.0	0.0	0.0	3.0×10^{6}	10.

	current density	inner diameter	outer diameter	thickness	distance
external magnetic coil	70 KA/cm²	12 cm	20 cm	8 cm	80 cm

Table 2.

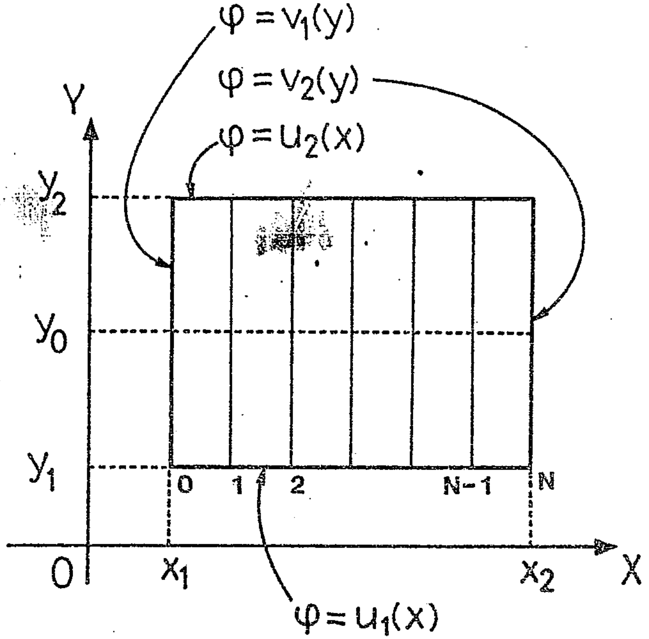


Fig. 1.

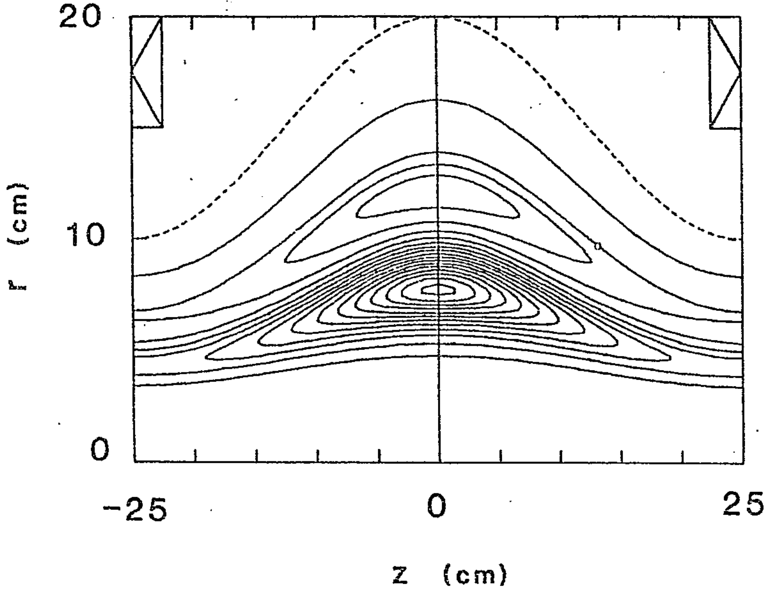


Fig. 2. (b)

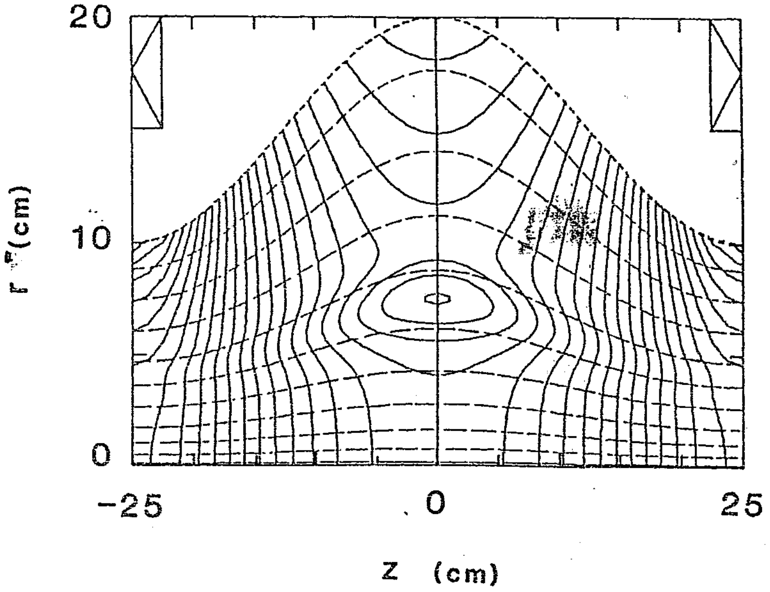


Fig. 2. (a)

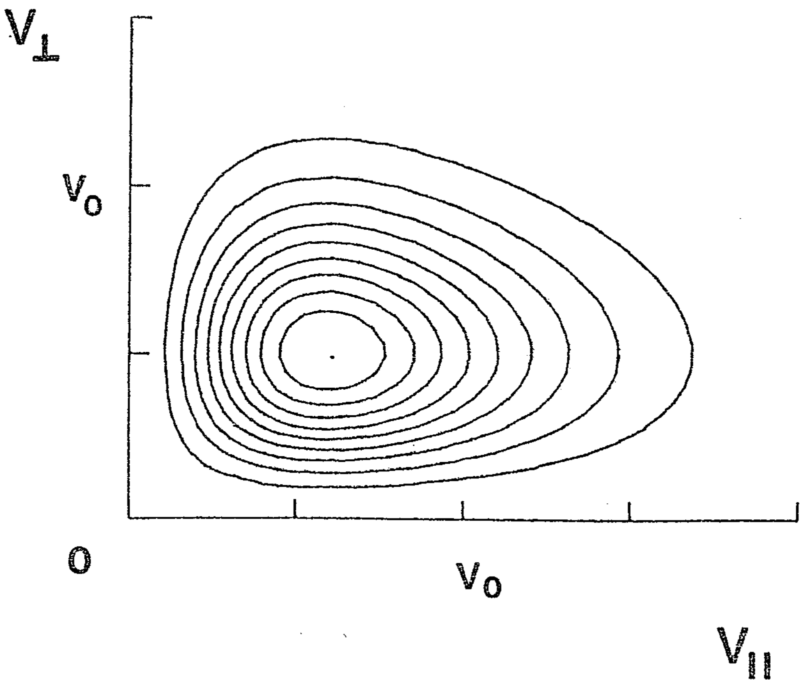


Fig. 3. (a)

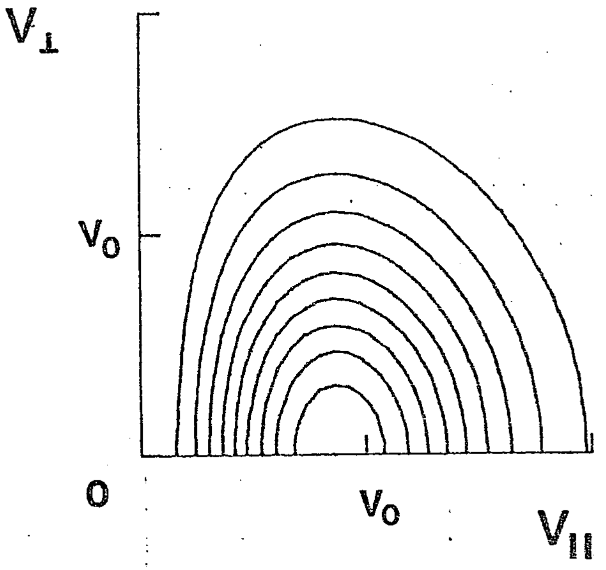


Fig. 3. (b)

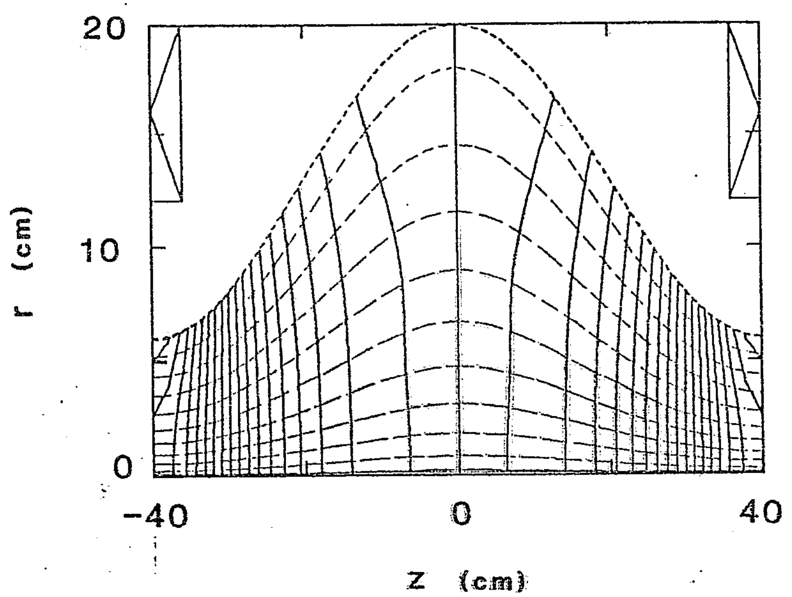


Fig. 3. (c)

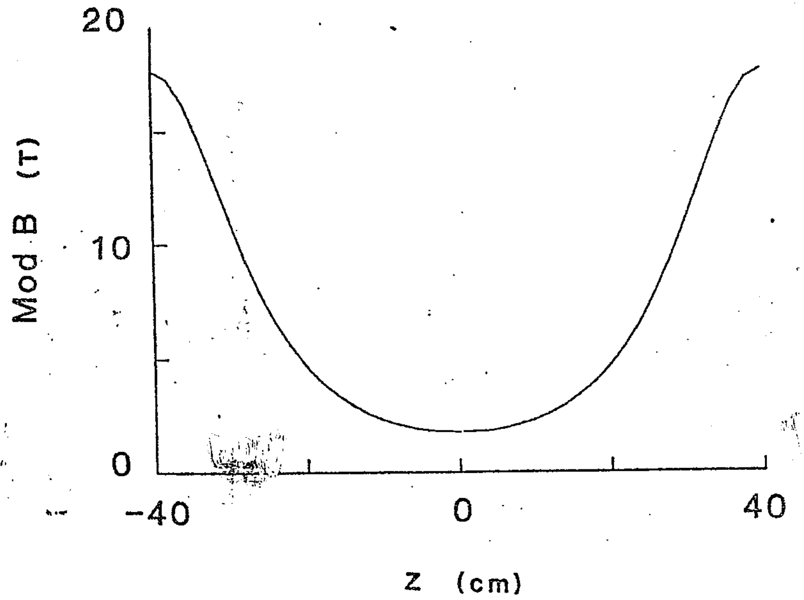


Fig. 3. (d)

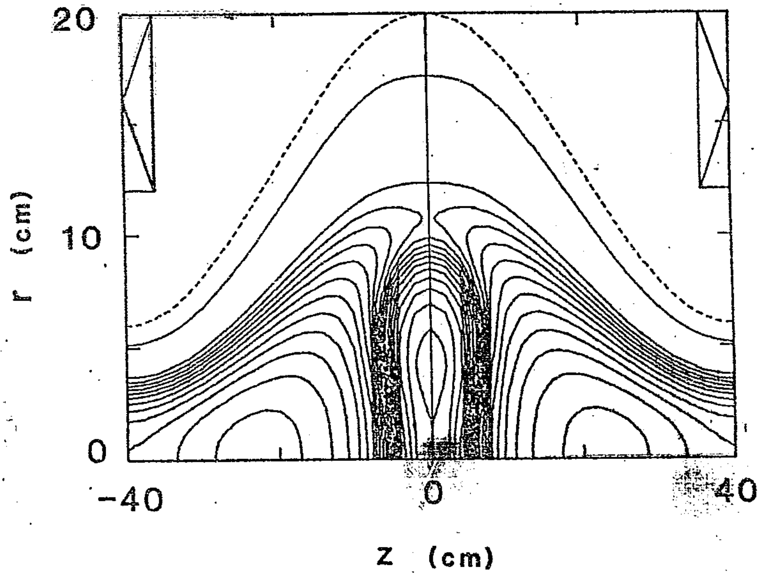


Fig. 3. (e)

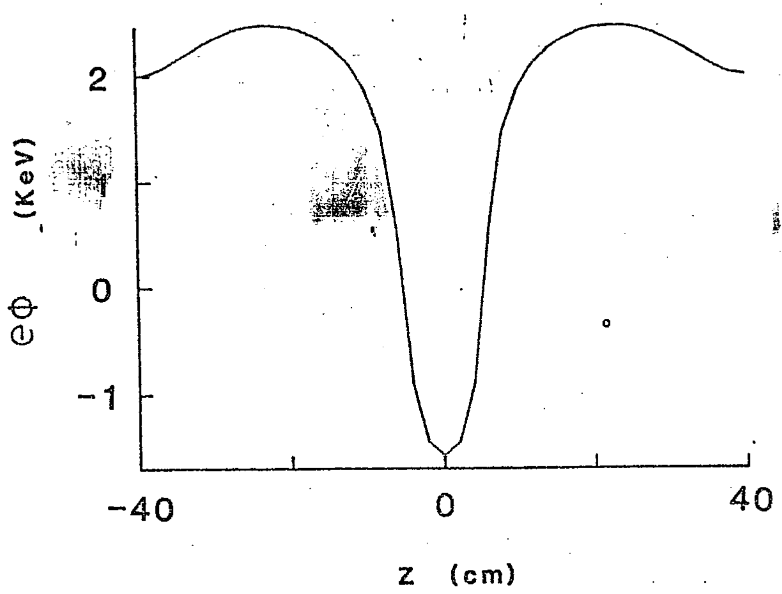


Fig. 3. (f)

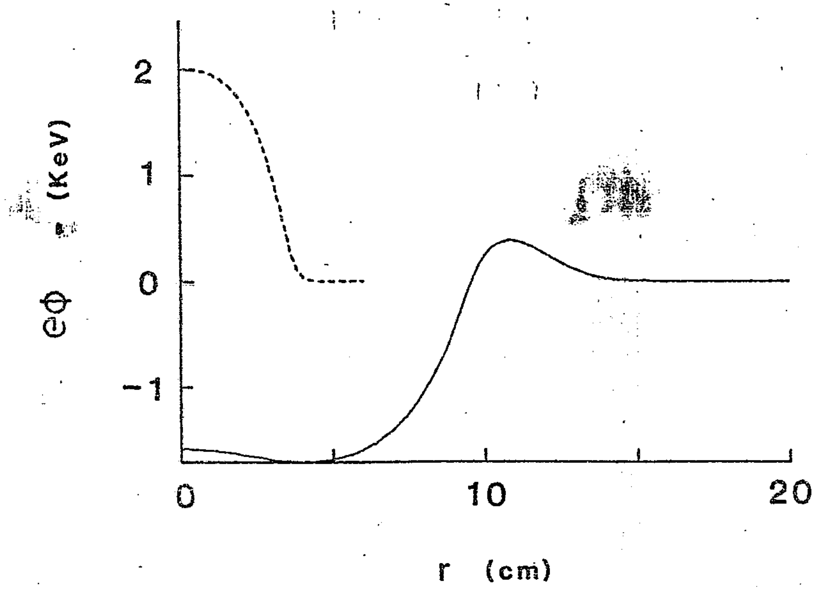


Fig. 3. (g)

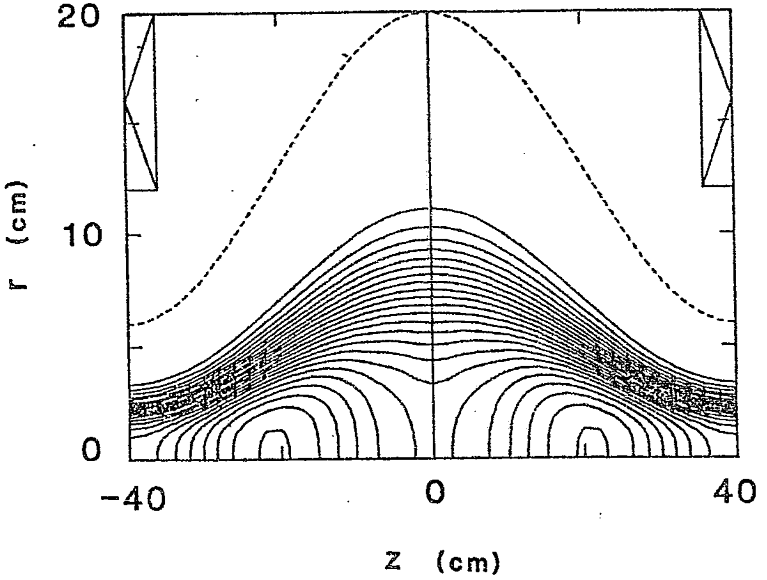


Fig. 3. (h)

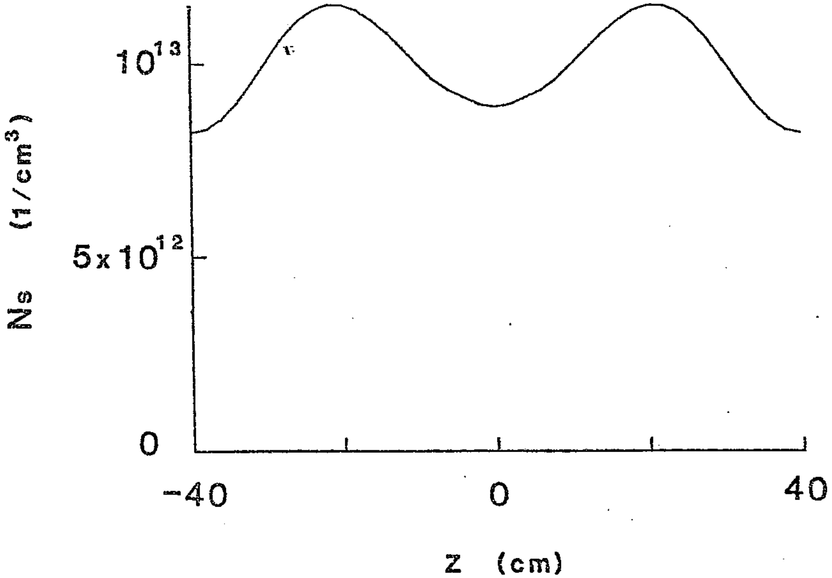


Fig. 3. (i)

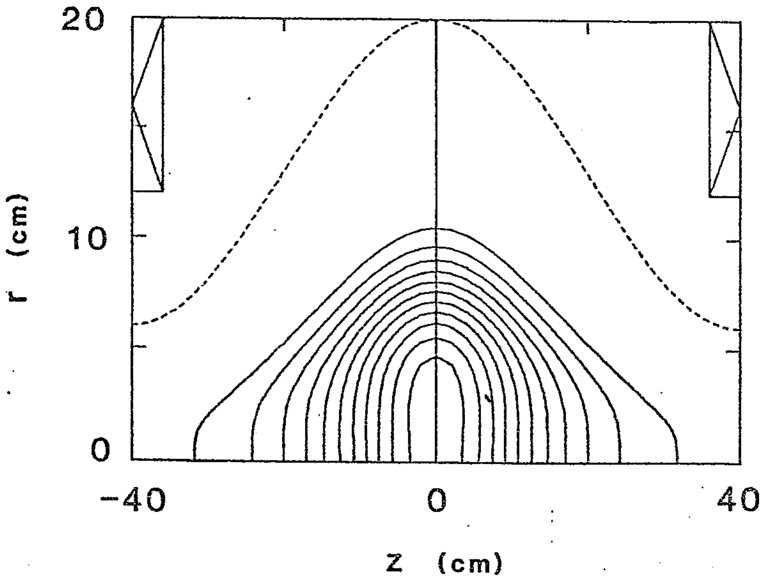


Fig. 3. (j)

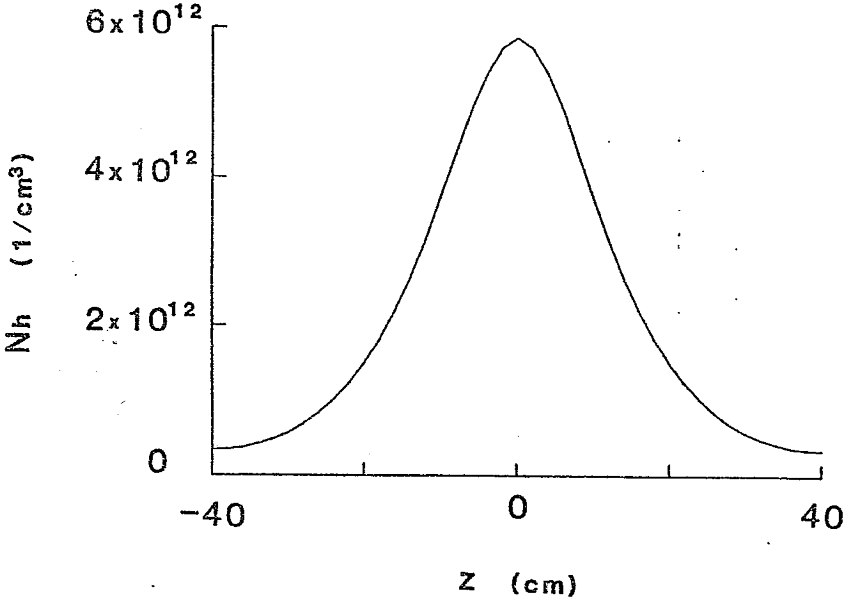


Fig. 3. (k)

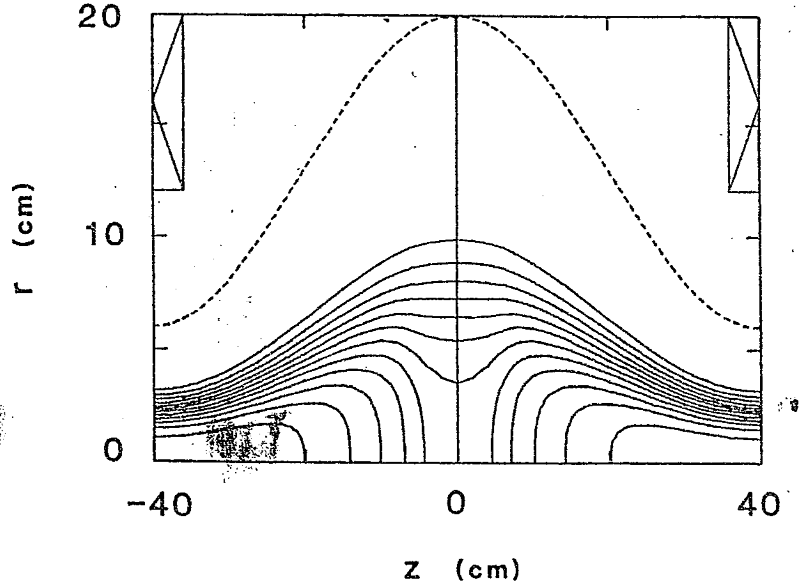


Fig. 3. (l)

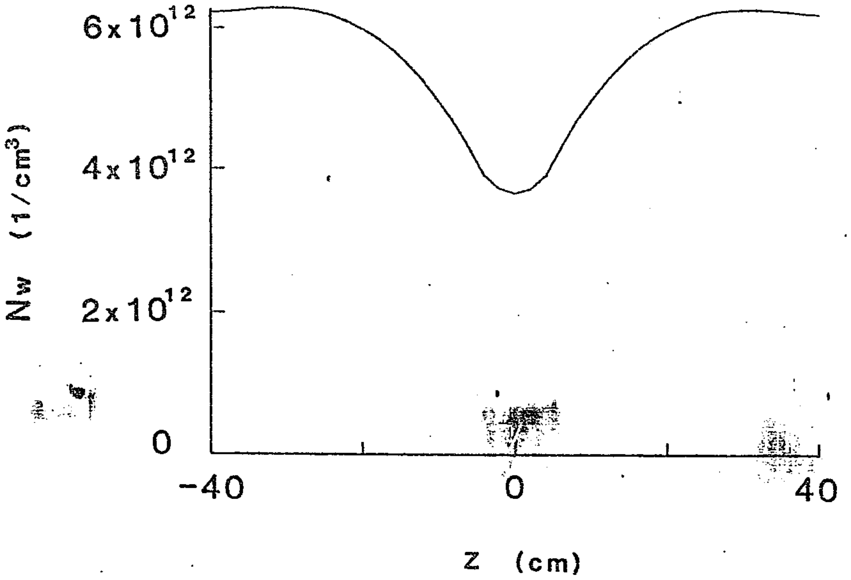


Fig. 3. (m)

Table I. The parameters of equilibrium distribution function.

Plasma $\tilde{\beta}$-value is defined by the following expression:

$$\tilde{\beta} = \frac{\sum_j T_j \, n_j (r=0 \ , \ z=0)}{(B^2 / 8\pi)_{\text{max at midplane}}}$$

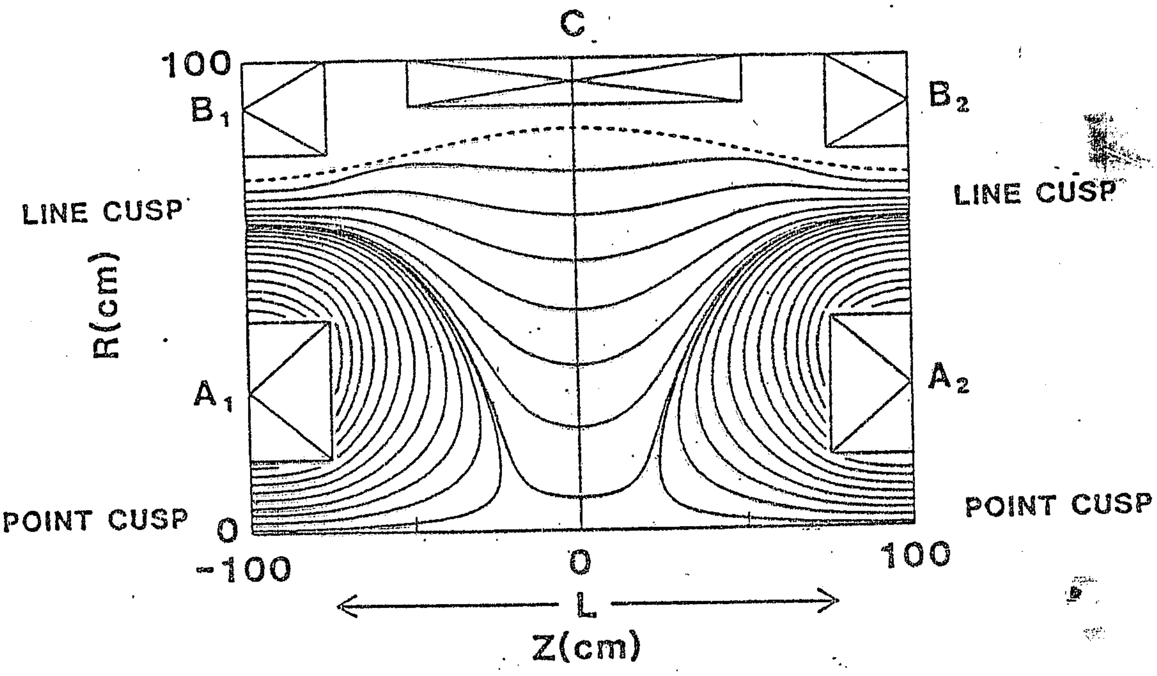
	n_{0j} (cm^{-3})				T_j (KeV)	λ_j (cm)
	Low-β	Mid-β_1	Mid-β_2	High-β		
Hot ion	1.00×10^{13}	3.00×10^{13}	5.00×10^{13}	8.00×10^{13}	10.	8.46×10
Hot electron	7.82×10^{12}	2.34×10^{13}	3.91×10^{13}	6.25×10^{13}	10.	4.59×10^{3}
Cold ion	1.00×10^{12}	1.00×10^{12}	1.00×10^{12}	1.00×10^{12}	0.5	1.04×10^{27}
Cold electron	1.00×10^{12}	1.00×10^{12}	1.00×10^{12}	1.00×10^{12}	0.5	4.47×10^{28}
$\tilde{\beta}$	0.18	0.56	0.83	1.11		

PLASMA PARAMETERS

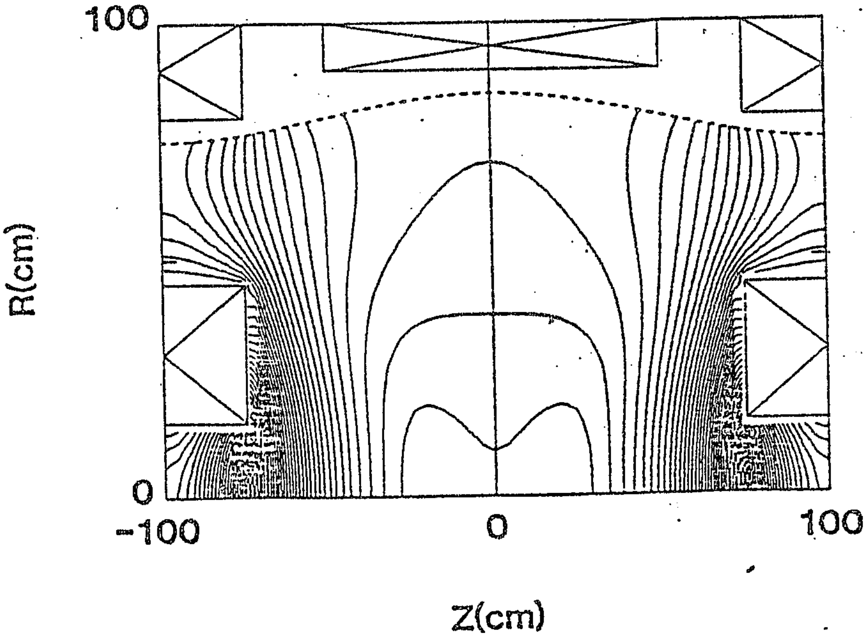
		T_j (KeV)	N_{oj} (1/cm^3)	ψ_{aj} (Gauß·cm^2)	λ_j (cm)
hot	electron	500	1.67×10^{11}	-3×10^4	1.69×10
core	electron	1	5×10^{12}	0	1.16×10^3
	ion	1	5×10^{12}	0	2.71×10
surface	electron	.1	1×10^{10}	0	1×10^{29}
	ion	.1	1×10^{10}	0	2.33×10^{27}

VACUUM FIELD

MAGNETIC FIELD LINES



CONTOURS OF MOD-B



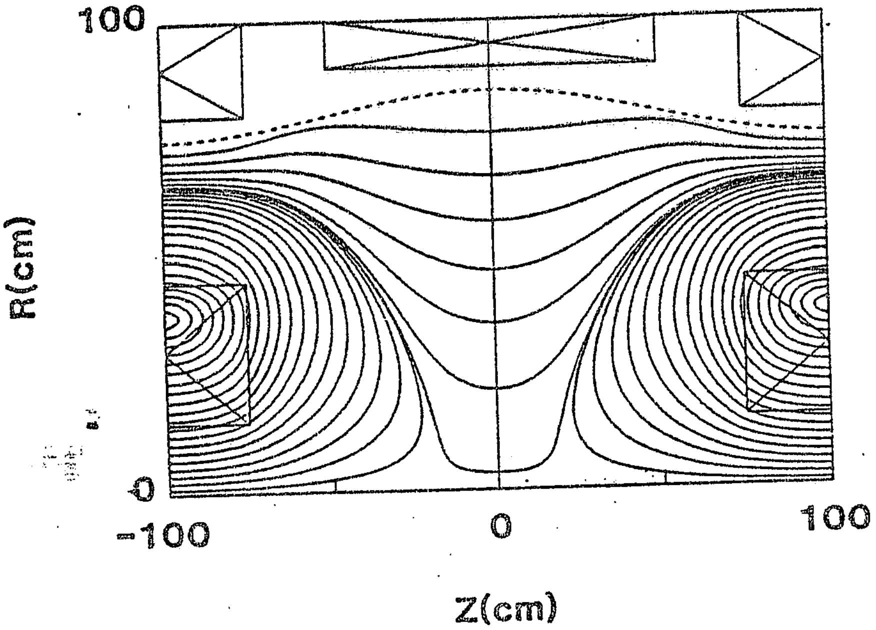
Coil Current A : -5000 A/cm^2

B : 1700 A/cm^2

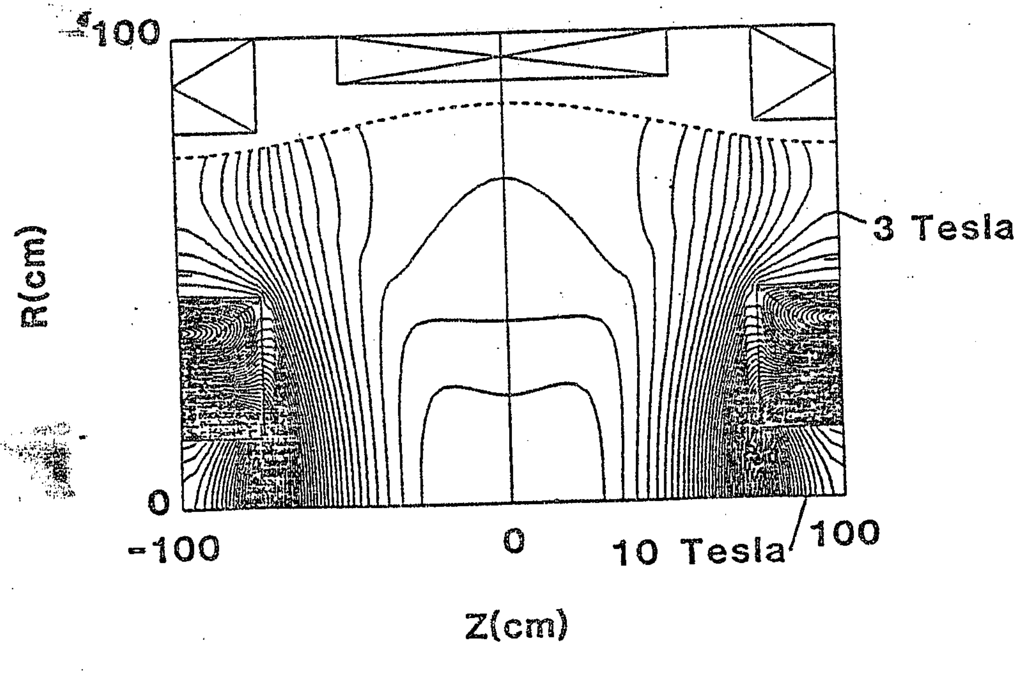
C : 400 A/cm^2

LOW-β EQUILIBRIUM

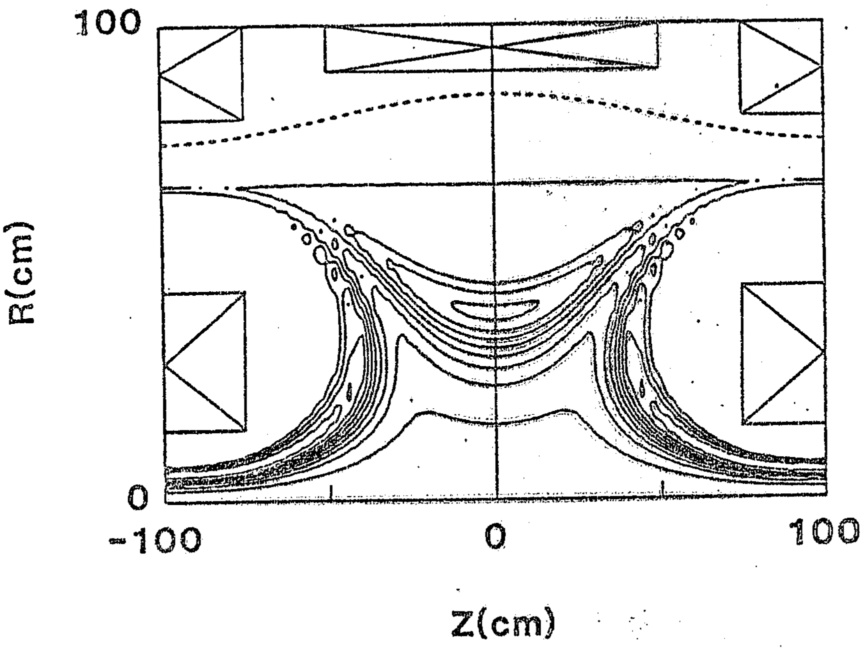
MAGNETIC FIELD LINES

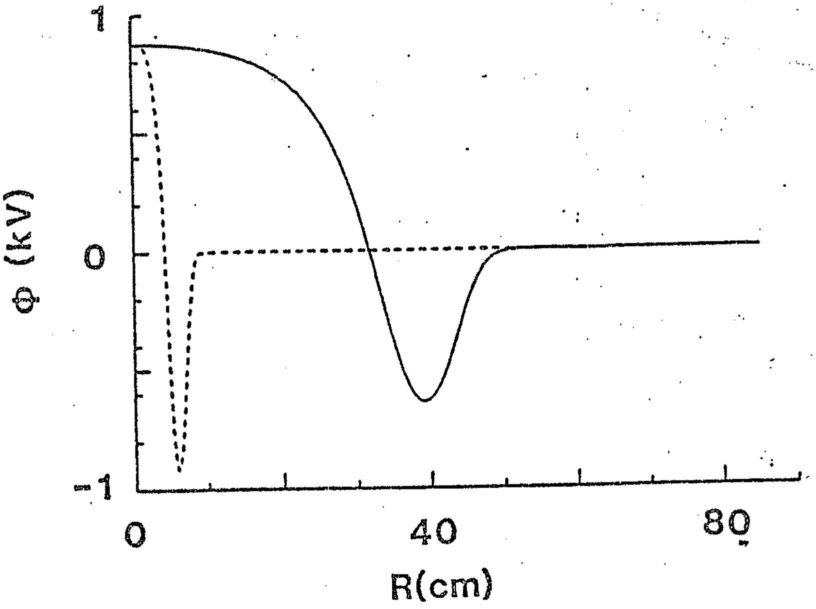


CONTOURS OF MOD-B

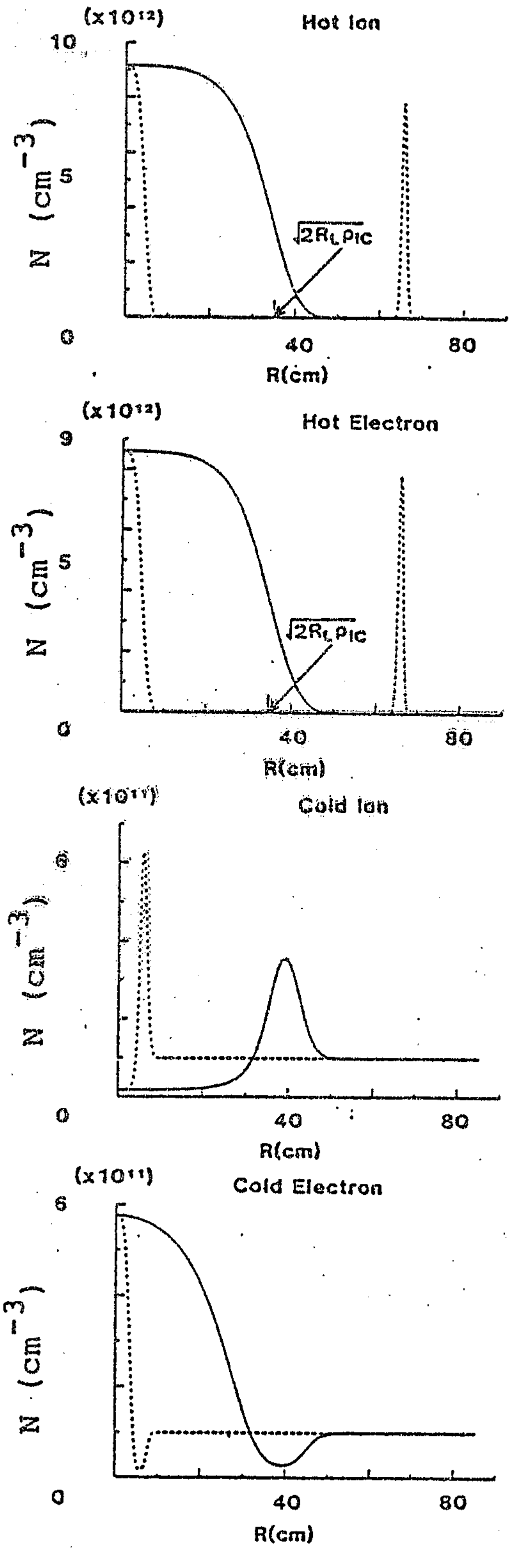


Electrostatic potential

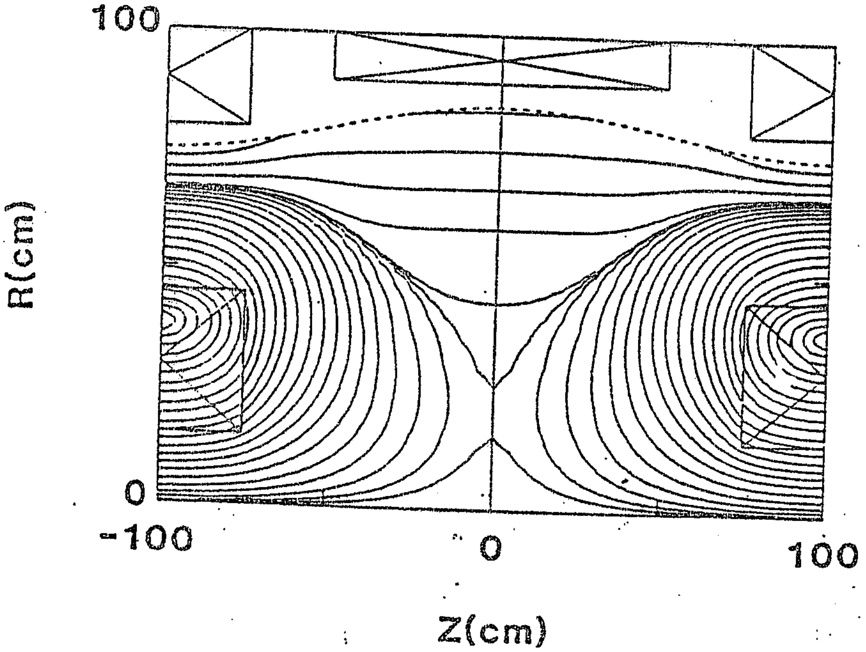


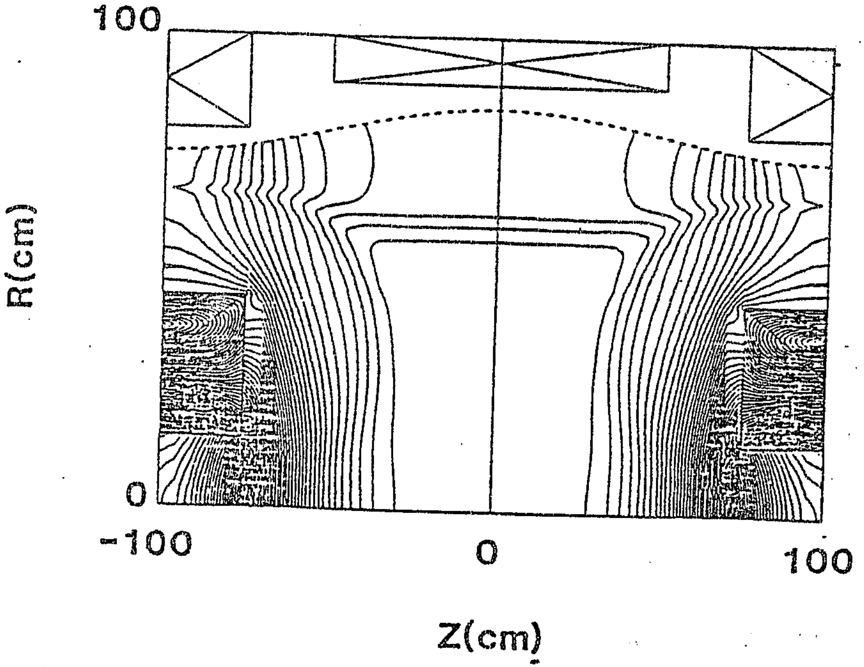


Density profiles

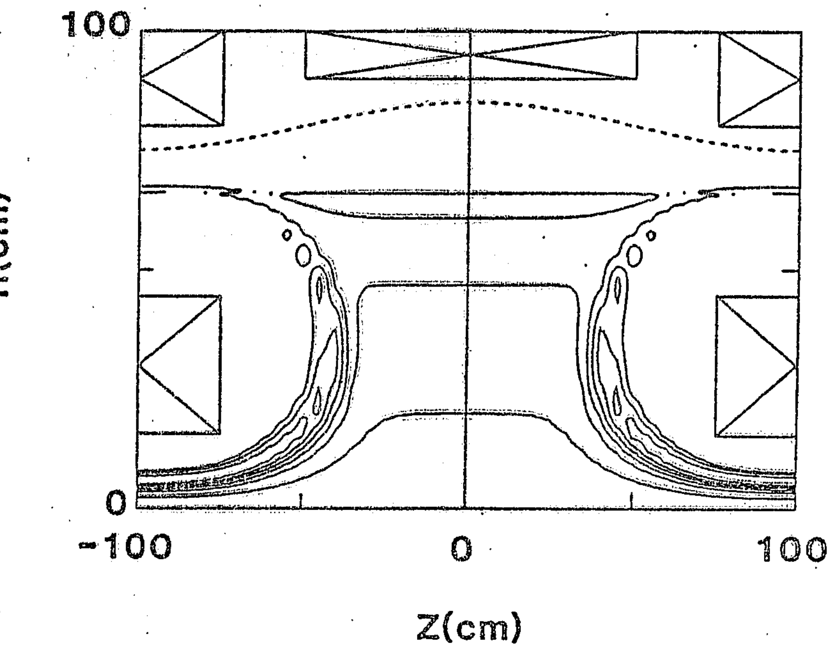


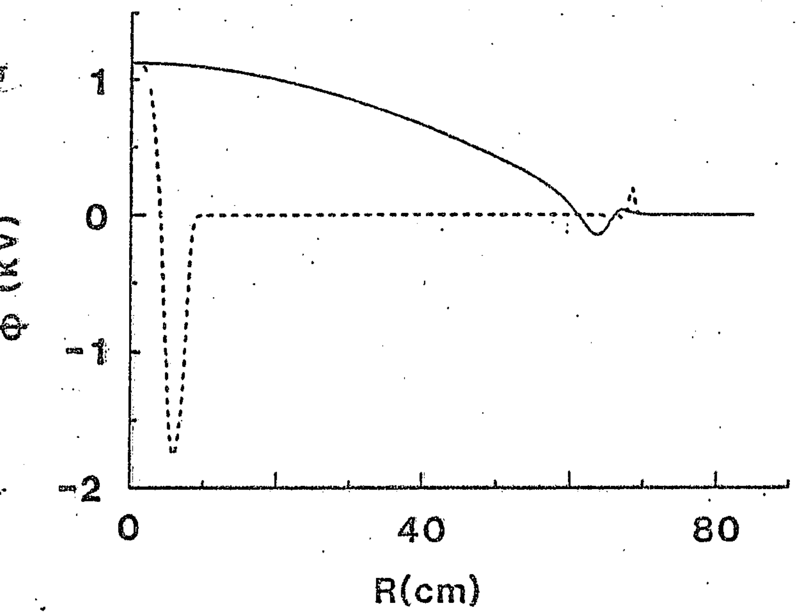
HIGH-β EQUILIBRIUM



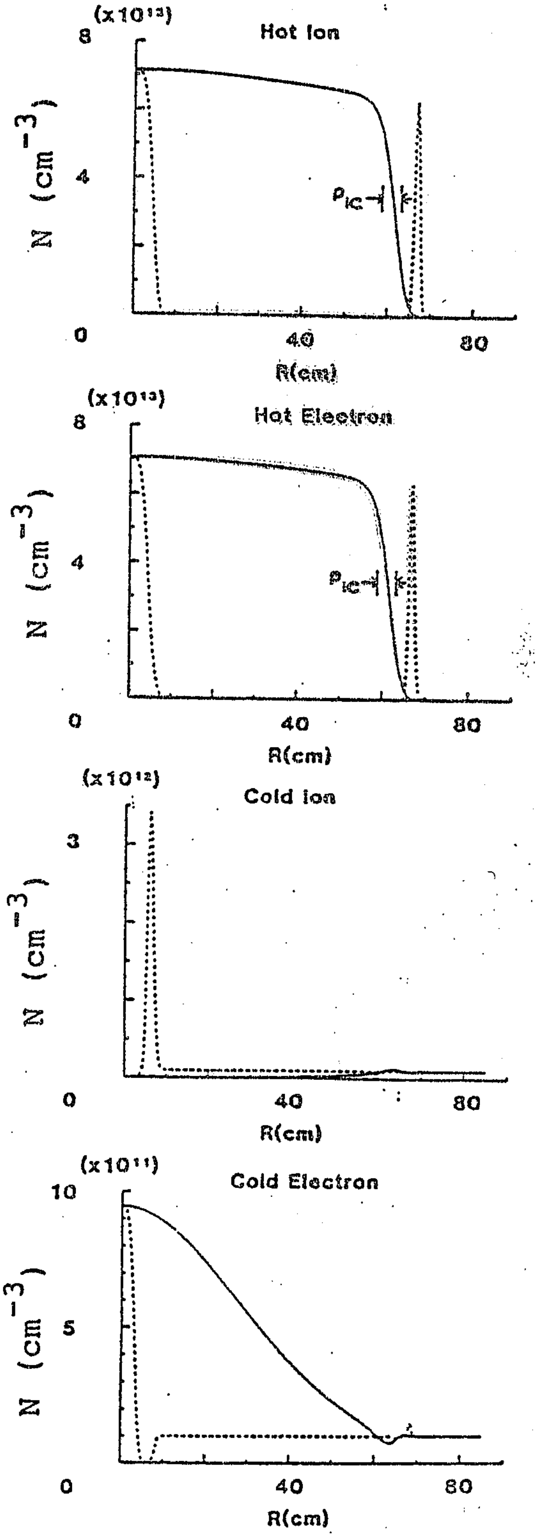


Electrostatic potential



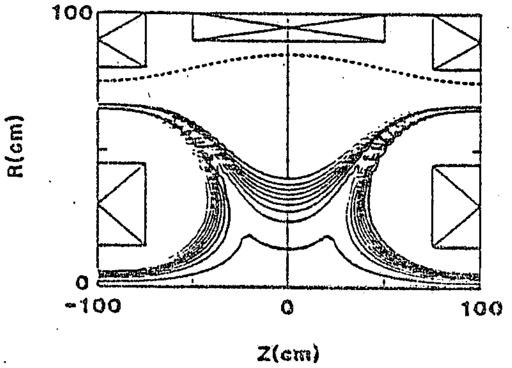


Density profiles

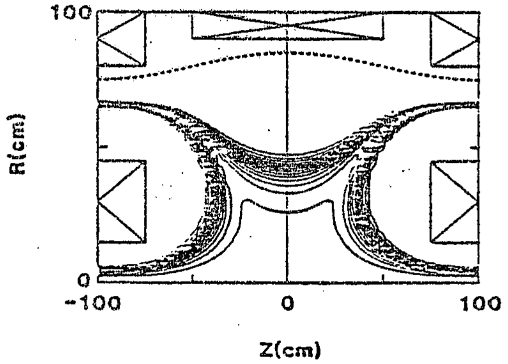


LOW-β ➔ HIGH-β

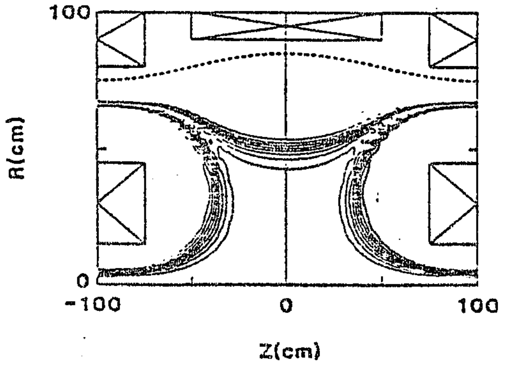
Density profiles


Low-β

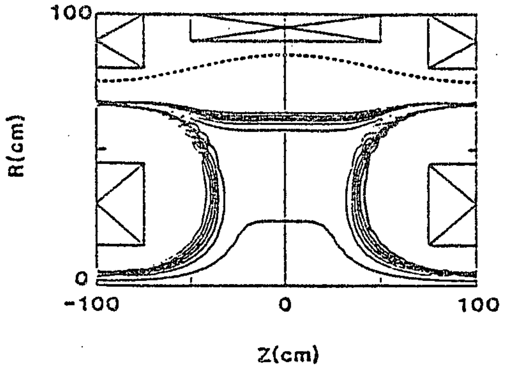
β = .18


Mid-β₁

β = .56

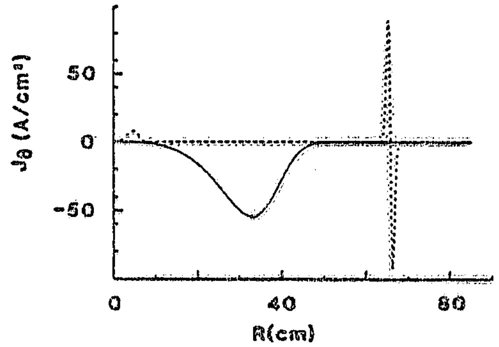

Mid-β₂

β = .83

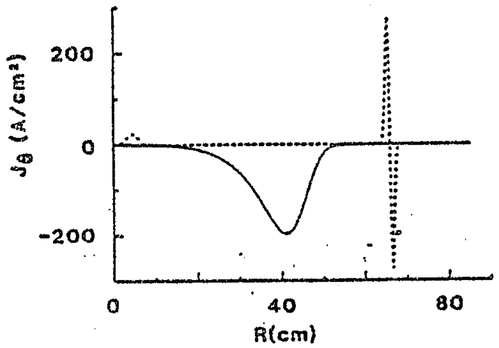

High-β

β = 1.11

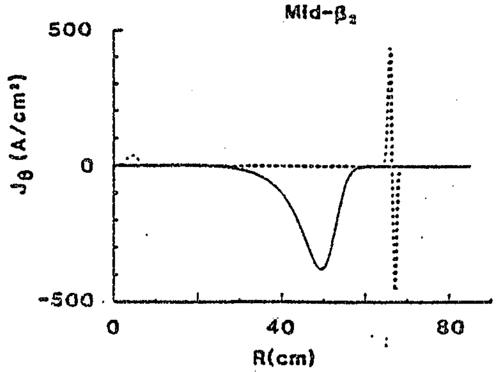
Diamagnetic current


Low-β

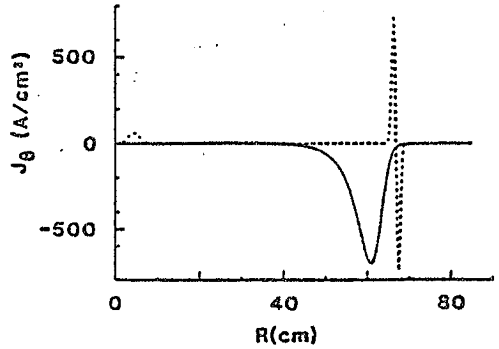
$\beta = .18$


Mid-β_1

$\beta = .56$

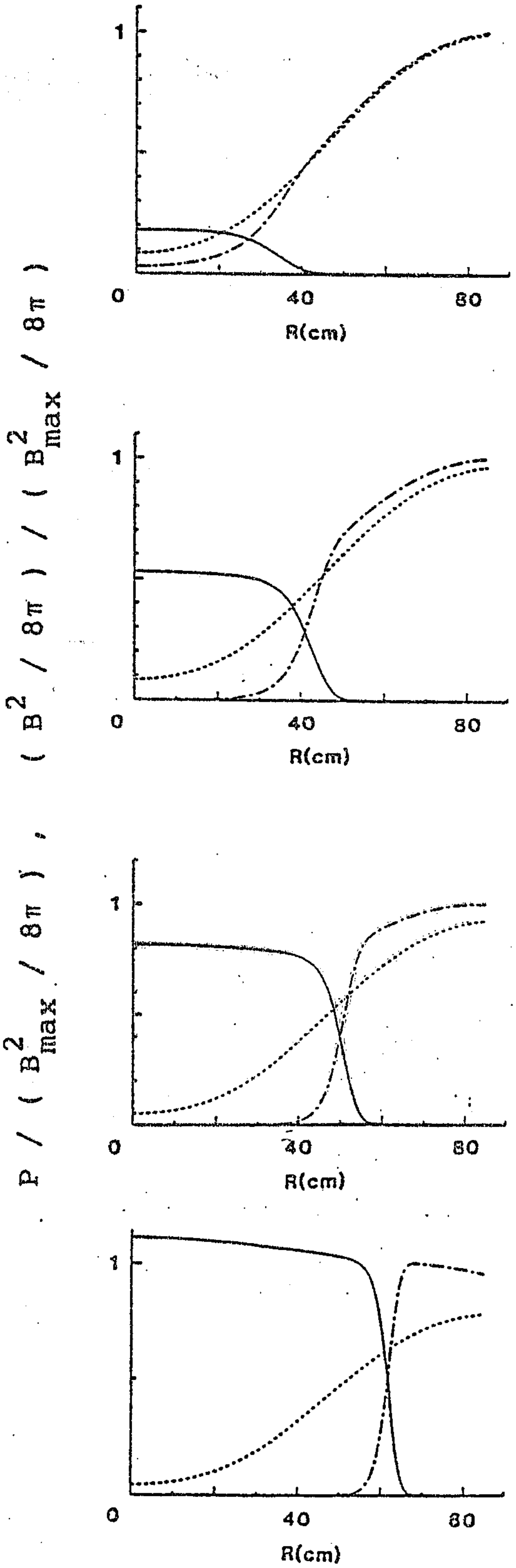

Mid-β_2

$\beta = .83$


High-β

$\beta = 1.11$

Pressure balance



HIGH-N BALLOONING INSTABILITIES IN HOT ELECTRON PLASMAS

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J. W. Van Dam*

LOW-N EIGENMODE EQUATIONS FOR AXISYMMETRIC HOT ELECTRON PLASMAS

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*Institute for Fusion Studies, University of Texas

PART I: HIGH n BALLOONING INSTABILITIES IN HOT ELECTRON PLASMAS

Y.C. LEE, H.L. BERK, M.N. ROSENBLUTH,

J.W. VAN DAM

PART II: LOW n EIGENMODE EQUATIONS FOR AXISYMMETRIC HOT ELECTRON PLASMAS

Y.C. LEE

MAIN CONCLUSIONS (Part I)

1) HOT ELECTRONS ACT AS A RIGID RING FOR FLUTE MODE ONLY. BALLOONING MODE STABILITY IS DETERMINED BY TREATING HOT ELECTRONS AS AN INTERACTING FLUID.

2) A SIGNIFICANT POPULATION OF CIRCULATING HOT ELECTRONS CAN LOWER THE LEE-VAN DAM THRESHOLD.

3) BACKGROUND PLASMA DISSIPATION CAN DESTABILIZE NEGATIVE ENERGY HOT ELECTRON COMPRESSIONAL MODE

4) SUFFICIENT HOT ELECTRON FLR STABILIZES EVERYTHING. (IN EIKONAL LIMIT)

5) FIELD LINE BENDING CAN BE DESTABILIZING FOR SOME PARAMETERS