THE PROPOSED WISCONSIN RFP

R.N. Dexter
D.W. Kerst
T.W. Lovell
S .C. Prager
J.C. Sprott

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Plasma Studies

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WISCO

UNIVERSITY OF WISCONSIN • MADISON, WISCONSIN

PLASMA PHYSICS

Abstract

PLP

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The Proposed Wisconsin RFP.* R.N. DEXTER, D.W. KERST, T.W. LOVELL, S.C. PRAGER, and J.C. SPROTT, University of Wisconsin-Madison--The University of Wisconsin is proposing to construct a moderately-sized, 400 kA, reversed field pinch device to investigate the boundary condition requirement. The device would feature interchangeable conducting shells of various thickness and spatial structure, with minor radii up to ~30 cm. An attempt would also be made to achieve an RFP state with no shell (material limiter) and with a poloidal divertor separatrix (magnetic limiter). The subsequent addition of a larger (~6 kG) toroidal field would allow a comparison of the members of the family of axisymmetric, current-carrying, toroidal devices which includes RFP's, non-reversed pinches, and tokamaks. The scientific goals and conceptual design of the device will be described.

*This work is supported by the U.S.D.O.E.

Physics Goals

1) Boundary Condition Studies

Goal: determine shell effect on RFP sustainment, stability, and transport

Note: shell believed essential for EXISTENCE of RFP minimum energy state and linear MHD stability

Also, shell influences m=1 mode evolution, boundary fluctuations, and curvature driven modes

2) q – Scaling Studies

Goal:

- ⁂ attain comparative understanding of the RFP
- ⁂ attain unified picture of axisymmetric toroidal confinement

Method:

- ⁂ in one device vary from RFP to nonreversed pinch to tokamak
- ⁂ track MHD activity, fluctuations, τ_e, resistance vs. configuration

3) large, take–apart, circular vacuum chamber guarantees capability to respond to ≅ any RFP issue

Method:

※ vary shell 'temporal' properties

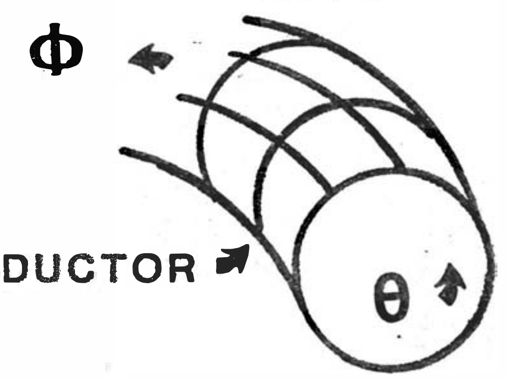
(thickness)

related to ω spectrum of instabilities

※ vary shell 'spatial' properties

(θ, ϕ, structures)

birdcage shell



related to k spectrum of instabilities

※ measure gross parameters,

sustainment time, fluctuations, τ_e

Parameter Goals

major radius:	R_o = 165 cm
minor radius:	a = 32 cm
toroidal plasma current:	I = 350 kA
toroidal loop voltage:	V_l = 22.5 volts
ohmic heating power:	P_{OH} = 7.9 MW
electron temperature:	T_{eo} = 350 ev
electron density:	n = 3 x 10^{13} cm^{-3}
confinement time:	τ_E = 2.0 msec
plasma inductance:	L_p = 2.6 μH
poloidal flux:	Φ = 0.91 volt–sec
poloidal field energy:	U_M = 160 kJ
pulse length:	T = 40 msec
toroidal field at wall:	B_T = 300 G

Conceptual Design

* large vacuum tank with circular cross section and removable lid

* B_T by currents through tank wall – low field ripple and excellent diagnostic access

* internal shell systems – "easily" interchanged and centered on tank flux surfaces

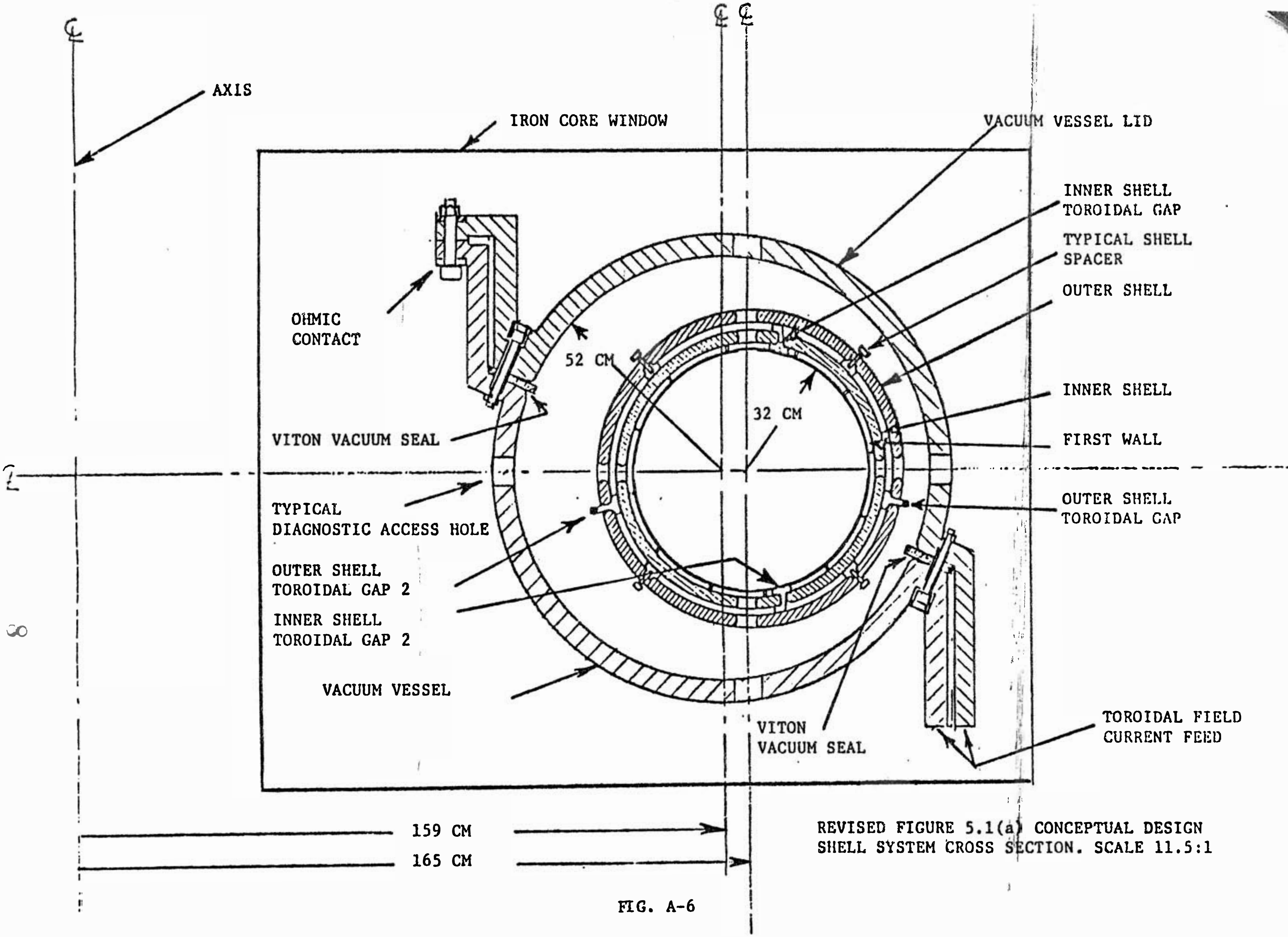
- first wall / liner
  need not hold off vacuum

- all gaps with nearby plasma
  - a problem being
    studied currently

- field errors reduced
  - small holes for pumping
    and diagnostics
  - flanged gaps and
    continuity windings

- effective utilization of
  existing core and capacitor
  banks

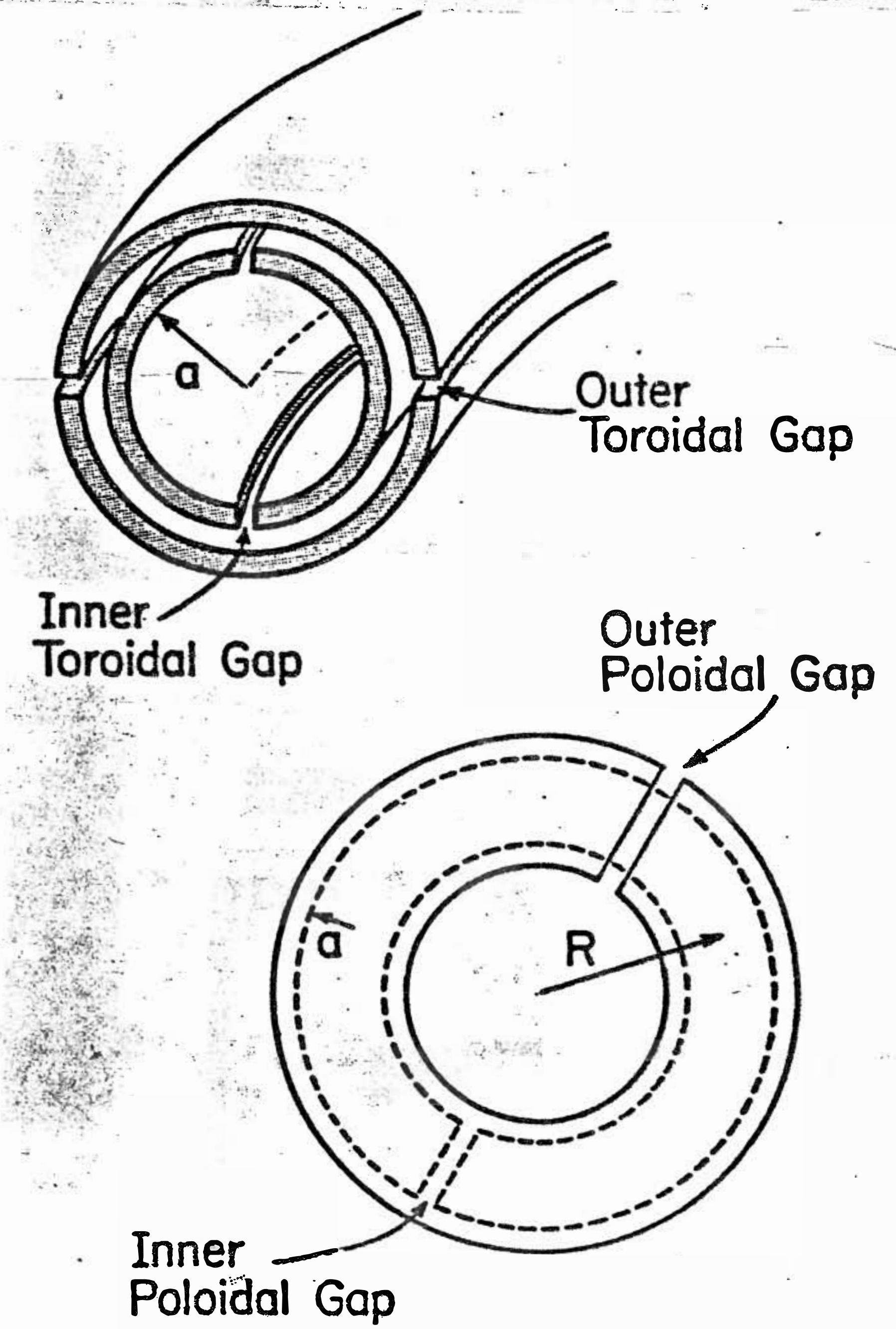
- very general and versatile
  configuration for response to
  many RFP issues



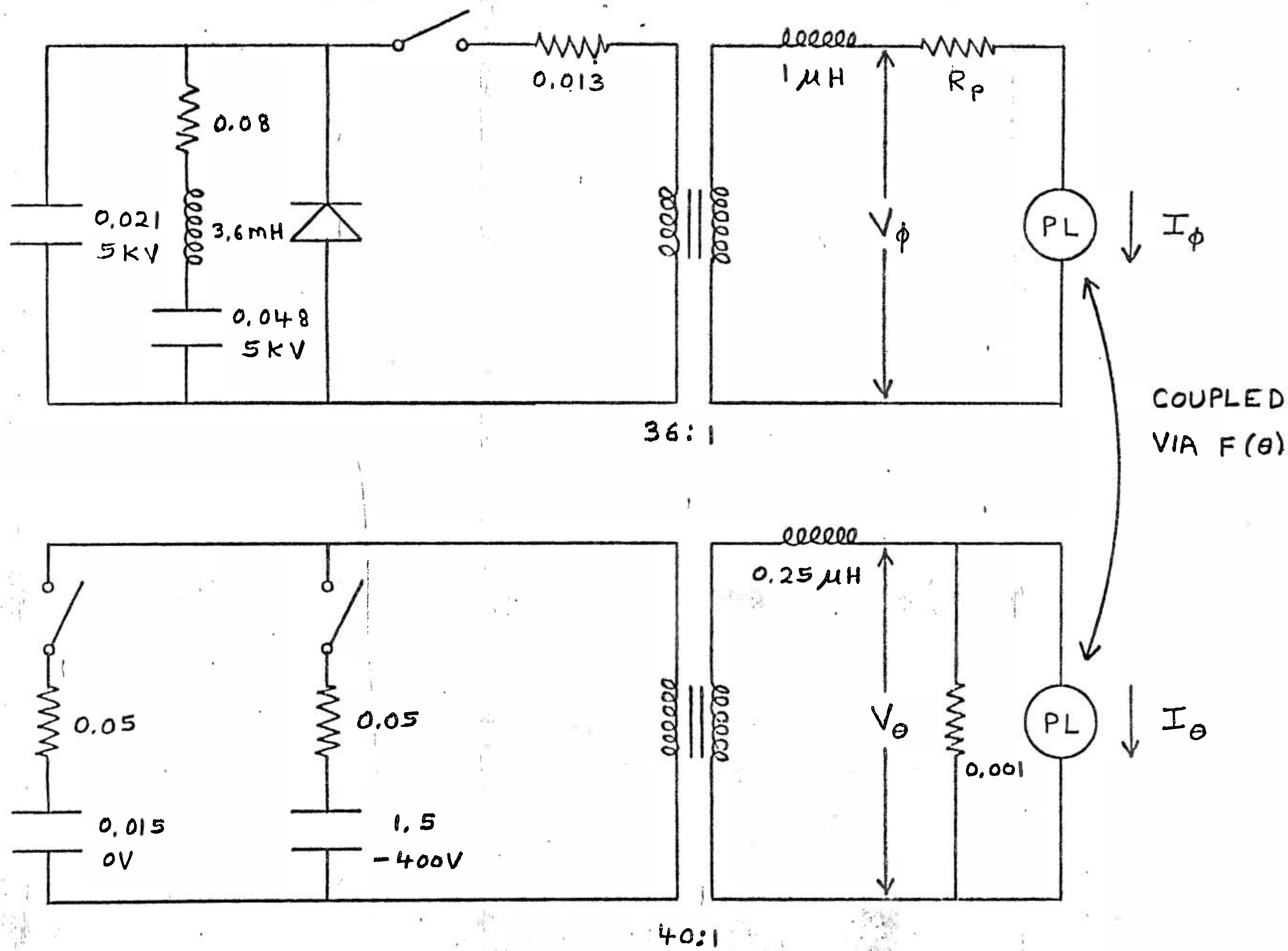
REVISED FIGURE 5.1(a) CONCEPTUAL DESIGN SHELL SYSTEM CROSS SECTION. SCALE 11.5:1

FIG. A-6

DOUBLE SHELL SYSTEM TO REDUCE FIELD ERRORS

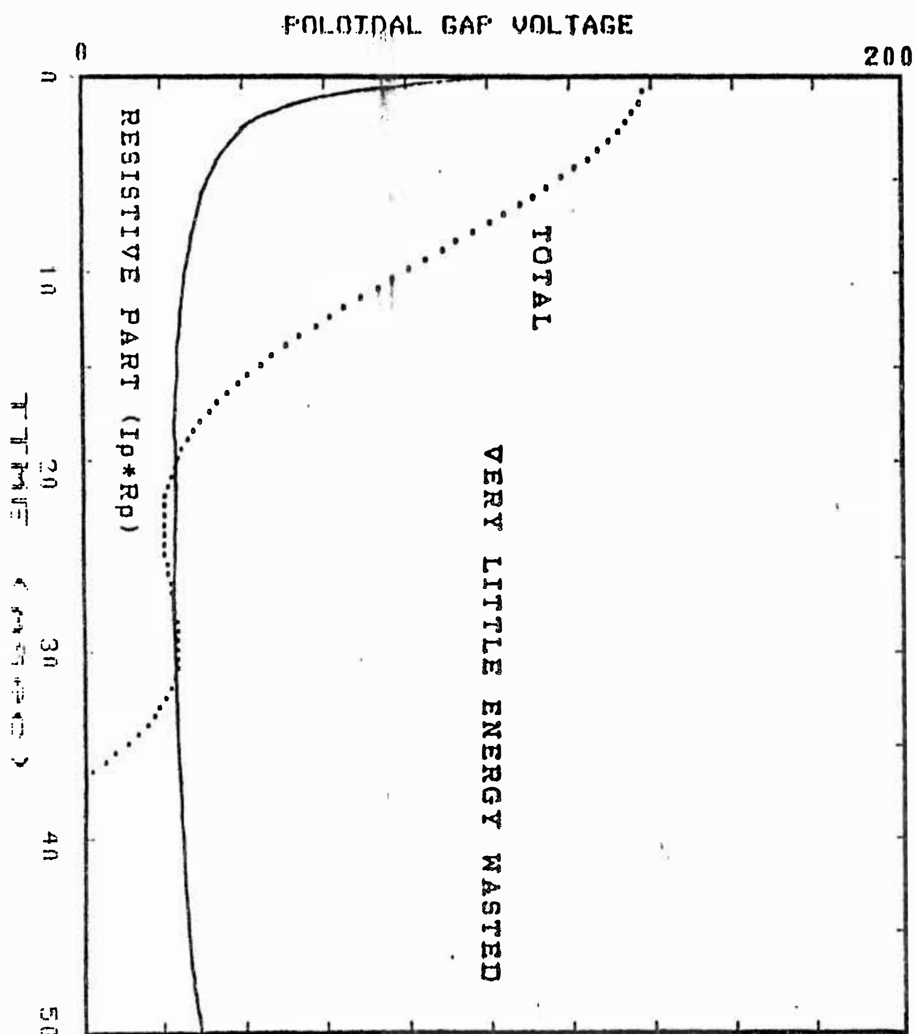


Circuit Modeling

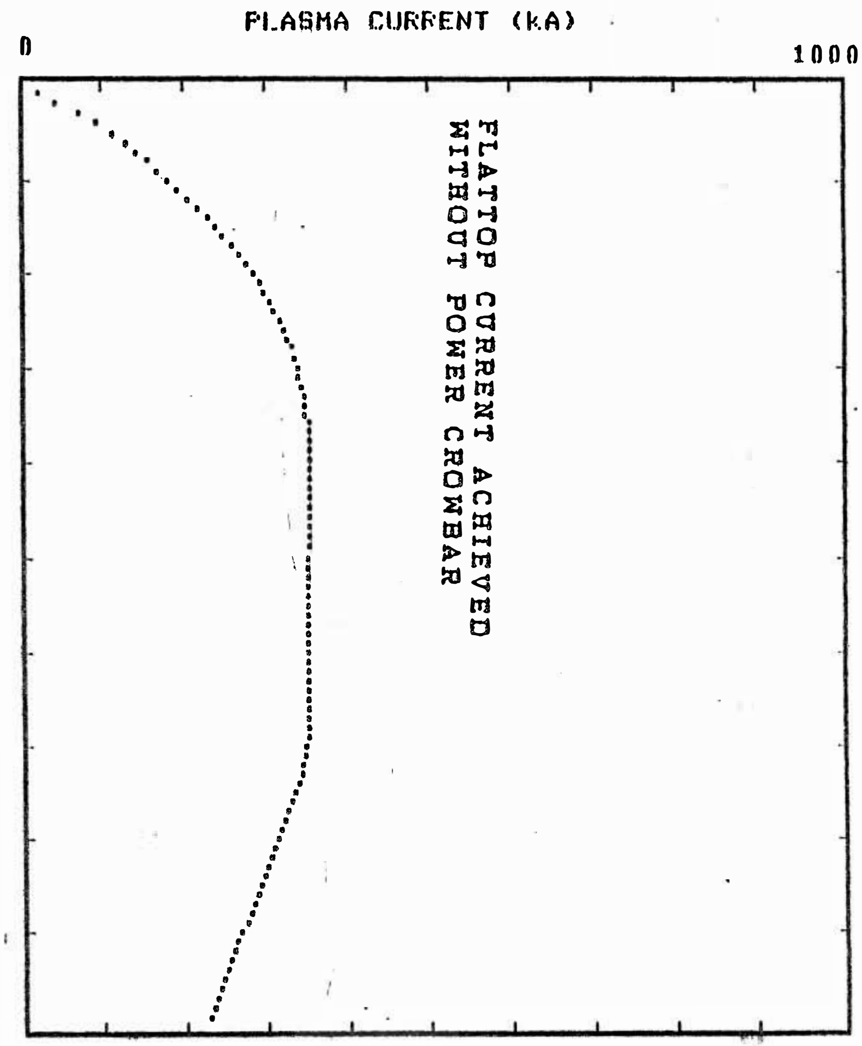


0.013
1 μH
R_P
0.08
0.021
5KV
3.6mH
0.048
5KV
V_ϕ
PL
I_ϕ
36:1
COUPLED
VIA F(θ)
0.25 μH
0.05
0.05
0.015
0V
1.5
-400V
V_θ
0.001
PL
I_θ
40:1

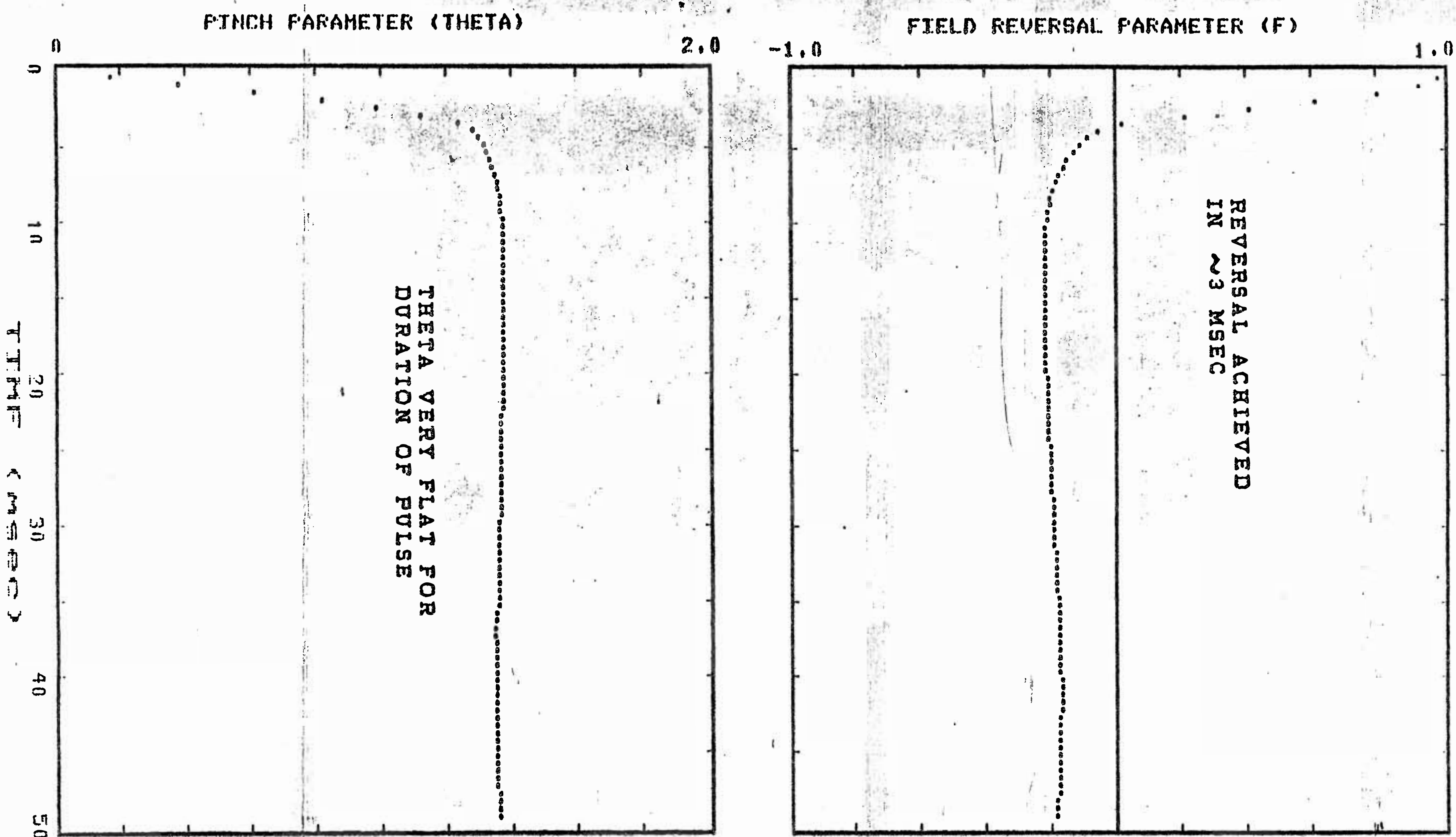
FIG. A-1



PROPOSED RFP WITH N = 36 TURNS, C = .021 FARADS, 50 MSEC FULL SCALE
INITIAL CAPACITOR VOLTAGE = 5000 VOLT-SECONDS CONSUMED = 1.88752
CORE BIAS = 15 KG (16975.4 AMP-TURNS) PRIMARY RESISTANCE = .013 OHMS
INITIAL PLASMA RESISTANCE = .02 OHMS CROWBAR VOLTAGE = 0
PEAK POLOIDAL GAP VOLTAGE = 137.826

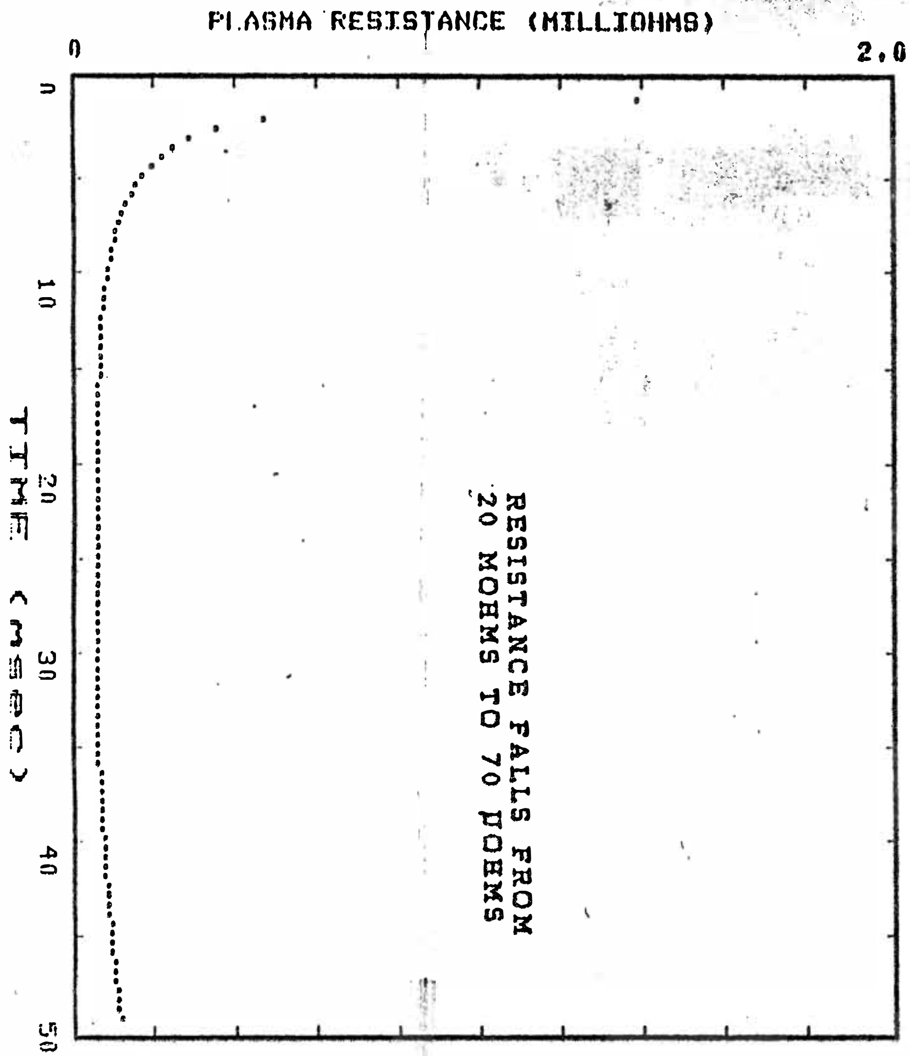


PROPOSED RFP WITH N = 36 TURNS, C = .021 FARADS, 50 MSEC FULL SCALE
INITIAL CAPACITOR VOLTAGE = 5000 VOLT-SECONDS CONSUMED = 1.88752
CORE BIAS = 15 KG (16975.4 AMP-TURNS) PRIMARY RESISTANCE = .013 OHMS
INITIAL PLASMA RESISTANCE = .02 OHMS CROWBAR VOLTAGE = 0
PEAK PLASMA CURRENT (KA) = 353.059



PROPOSED RFP WITH N = 36 TURNS, C = .021 FARADS, 50 MSEC FULL SCALE
INITIAL CAPACITOR VOLTAGE = 5000 VOLT-SECONDS CONSUMED = 1.88752
CORE BIAS = 15 KG (16975.4 AMP-TURNS) PRIMARY RESISTANCE = .013 OHMS
INITIAL PLASMA RESISTANCE = .02 OHMS CROWBAR VOLTAGE = 0
PEAK) = 1.37324

PROPOSED RFP WITH N = 36 TURNS, C = .021 FARADS, 50 MSEC FULL SCALE
INITIAL CAPACITOR VOLTAGE = 5000 VOLT-SECONDS CONSUMED = 1.88752
CORE BIAS = 15 KG (16975.4 AMP-TURNS) PRIMARY RESISTANCE = .013 OHMS
INITIAL PLASMA RESISTANCE = .02 OHMS CROWBAR VOLTAGE = 0
PEAK FIELD REVERSAL PARAMETER (F) PINCH PARAMETER (THETA



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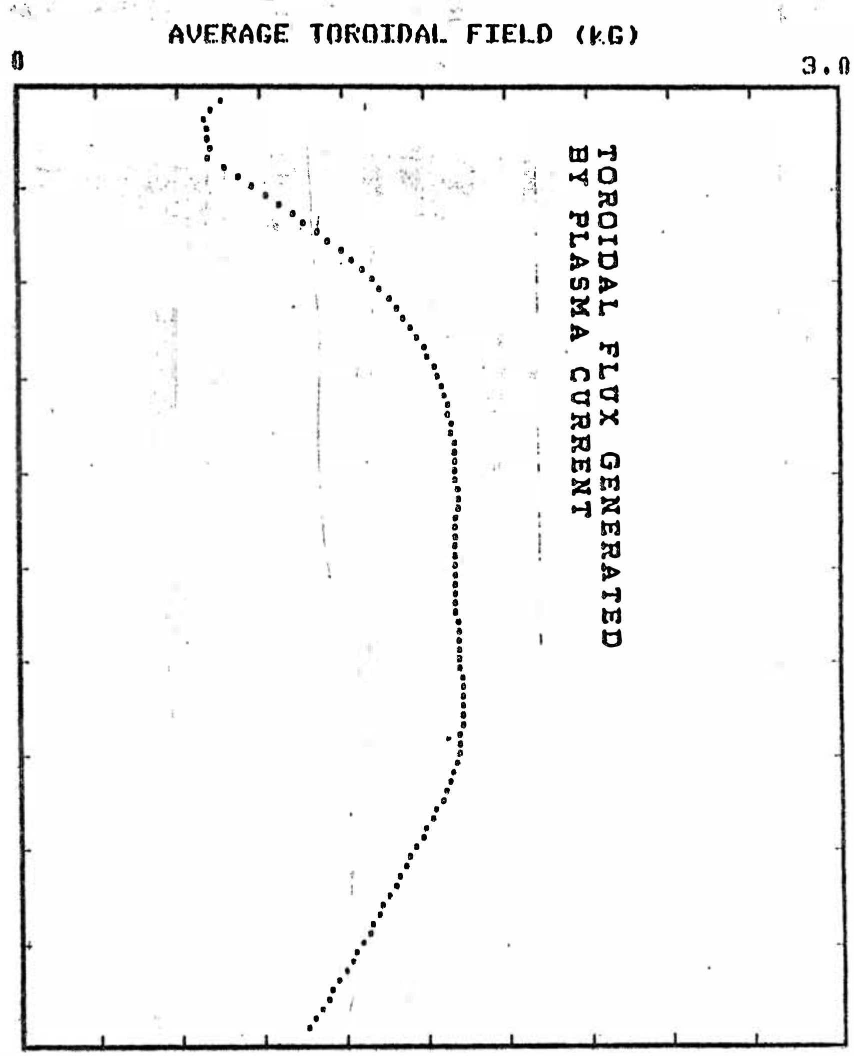
CORE BIAS = 15 KG (16975.4 AMP-TURNS) PRIMARY RESISTANCE = .013 OHMS
INITIAL PLASMA RESISTANCE = .02 OHMS CROWBAR VOLTAGE = 0
PEAK PLASMA RESISTANCE (OHMS) = 3.60664E-03



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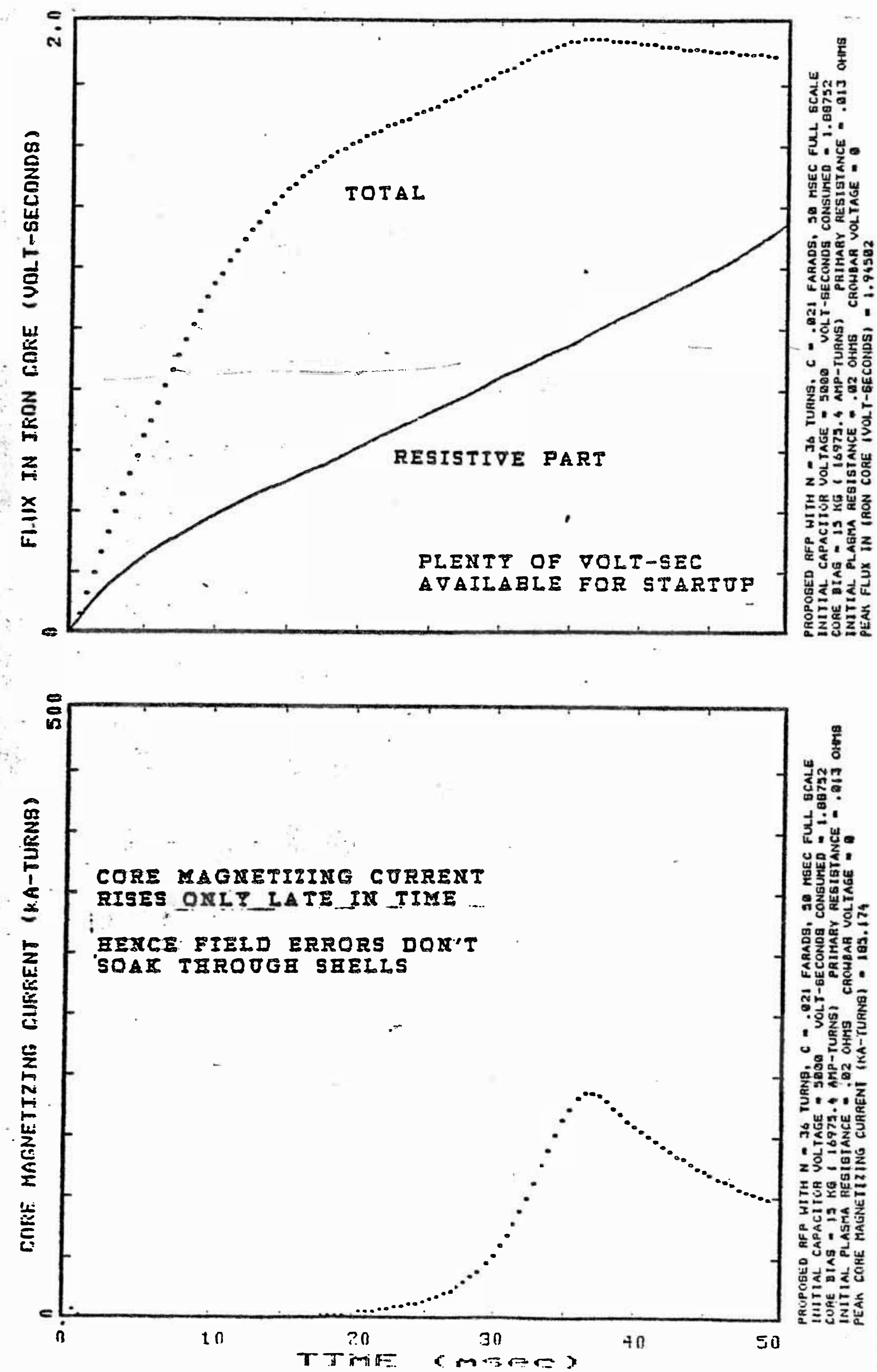
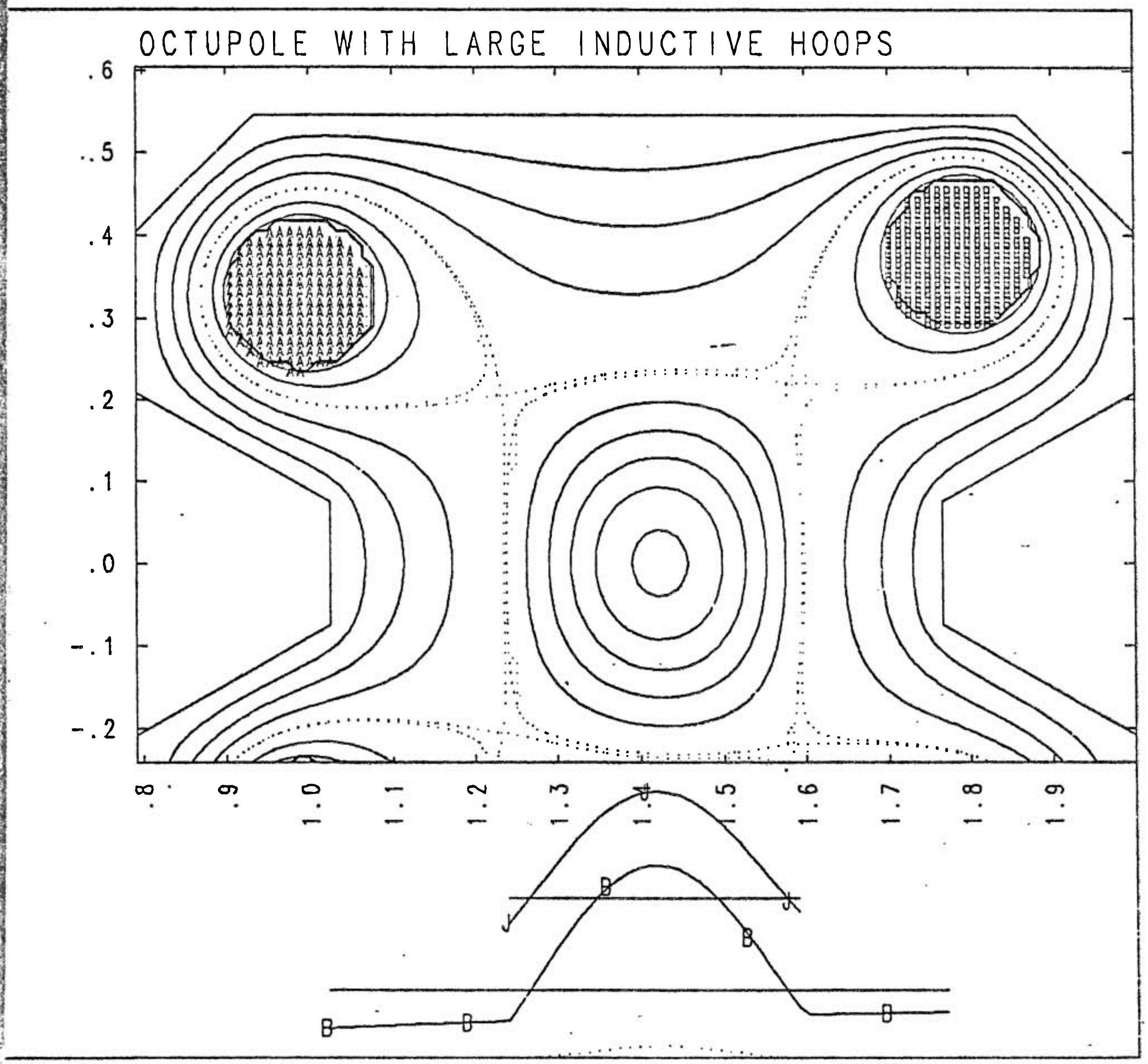
CORE BIAS = 15 KG (16975.4 AMP-TURNS) PRIMARY RESISTANCE = .013 OHMS
INITIAL PLASMA RESISTANCE = .02 OHMS CROWBAR VOLTAGE = 0
PEAK AVERAGE TOROIDAL FIELD (GAUSS) = 1628.93


FLUX IN IRON CORE (VOLT-SECONDS)
2.0
0
TOTAL
RESISTIVE PART
PLENTY OF VOLT-SEC
AVAILABLE FOR STARTUP
PROPOSED RFP WITH N = 36 TURNS, C = .021 FARADS, 50 MSEC FULL SCALE
INITIAL CAPACITOR VOLTAGE = 5000 VOLT-SECONDS CONSUMED = 1.88752
CORE BIAS = 15 KG (16975.4 AMP-TURNS) PRIMARY RESISTANCE = .013 OHMS
INITIAL PLASMA RESISTANCE = .02 OHMS CROWBAR VOLTAGE = 0
PEAK FLUX IN IRON CORE (VOLT-SECONDS) = 1.94502
CORE MAGNETIZING CURRENT (KA-TURNS)
500
0
CORE MAGNETIZING CURRENT
RISES ONLY LATE IN TIME
HENCE FIELD ERRORS DON'T
SOAK THROUGH SHELLS
PROPOSED RFP WITH N = 36 TURNS, C = .021 FARADS, 50 MSEC FULL SCALE
INITIAL CAPACITOR VOLTAGE = 5000 VOLT-SECONDS CONSUMED = 1.88752
CORE BIAS = 15 KG (16975.4 AMP-TURNS) PRIMARY RESISTANCE = .013 OHMS
INITIAL PLASMA RESISTANCE = .02 OHMS CROWBAR VOLTAGE = 0
PEAK CORE MAGNETIZING CURRENT (KA-TURNS) = 185.174
0
10
20
30
40
50
TIME (MSEC)

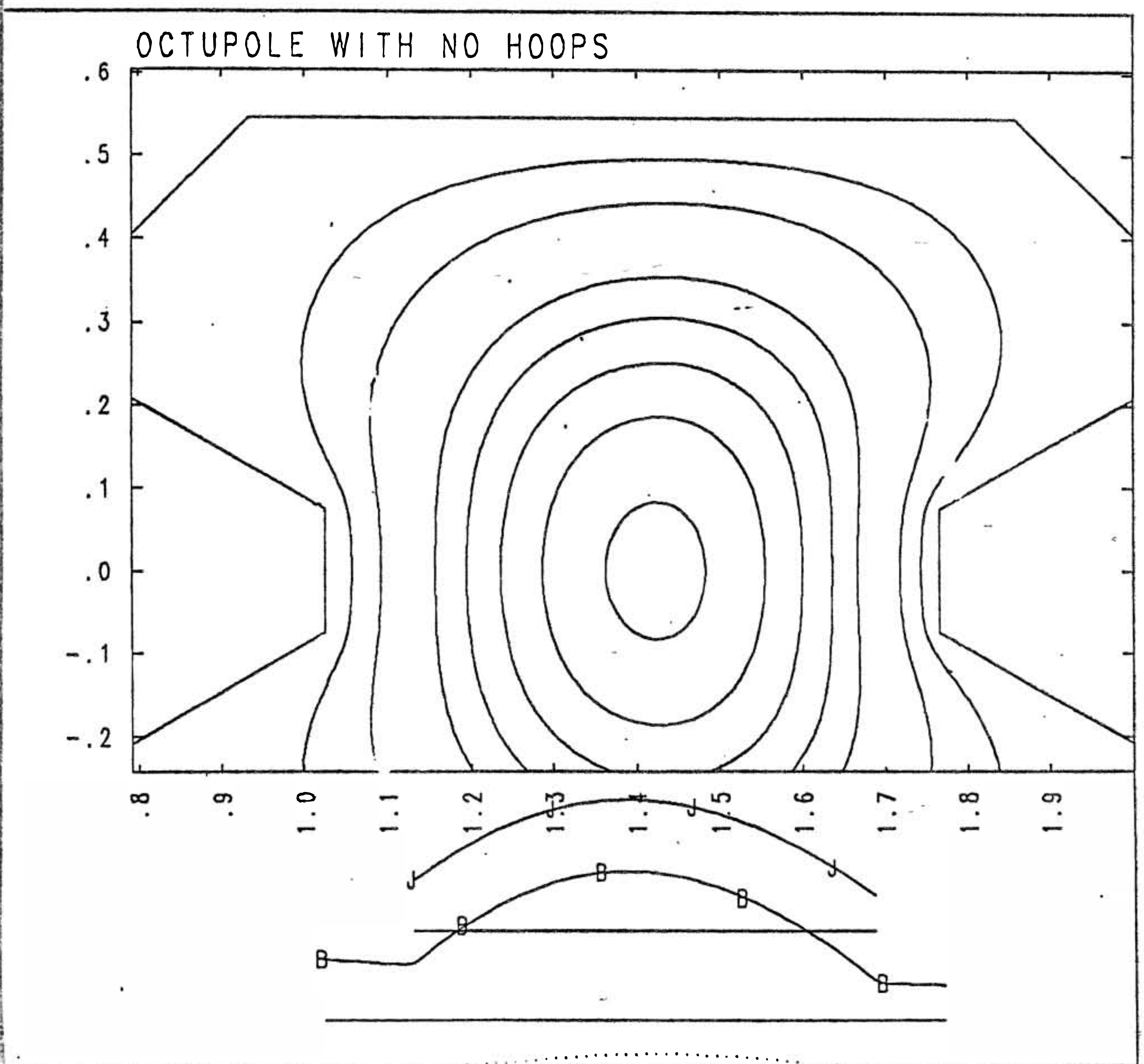
Flux Plots
and
Proposed Schedule

Construction Phase Experiments

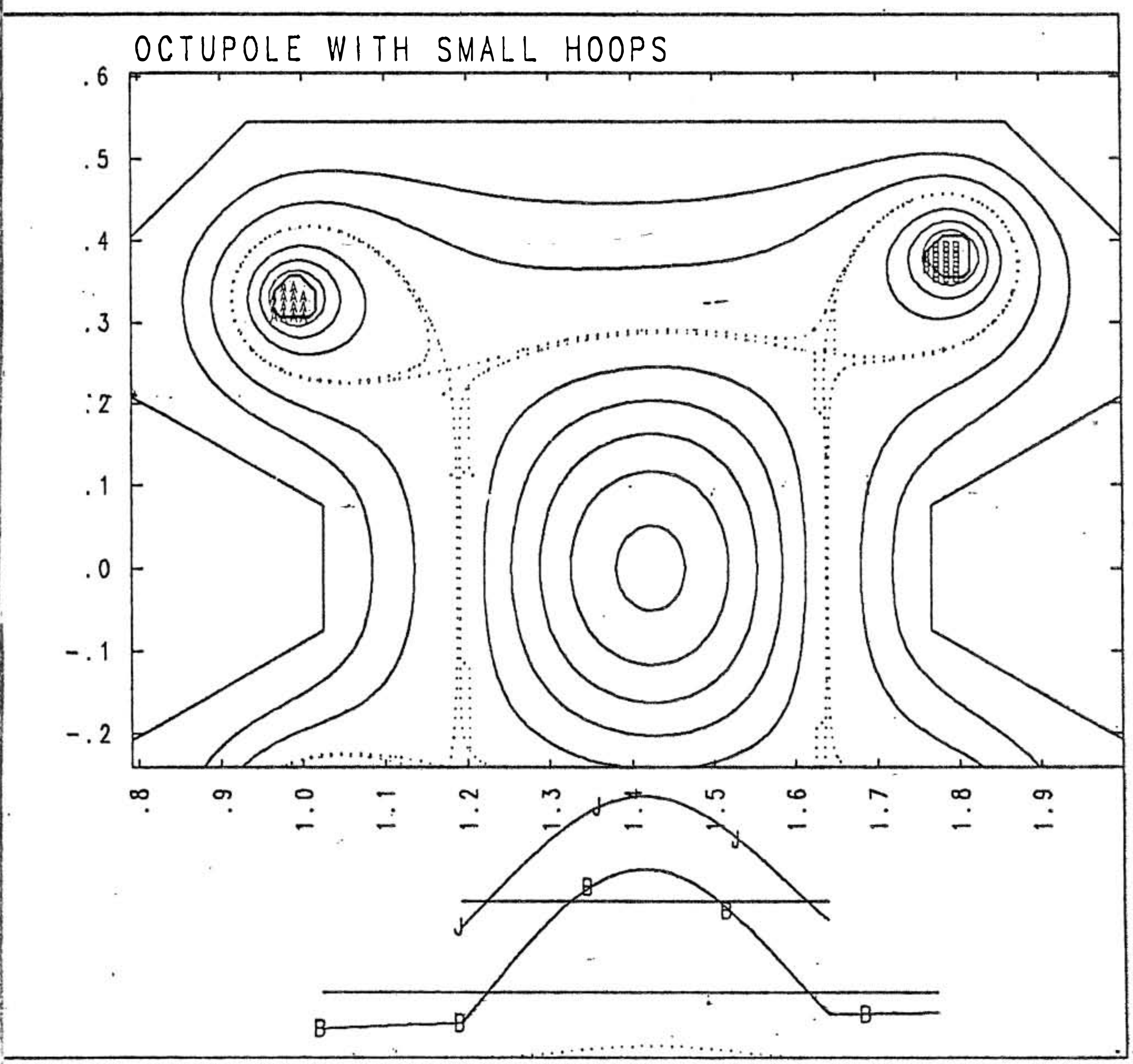
PRESENT


OCTUPOLE WITH LARGE INDUCTIVE HOOPS
.6
.5
.4
.3
.2
.1
.0
-.1
-.2
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
J
B

FIRST YEAR

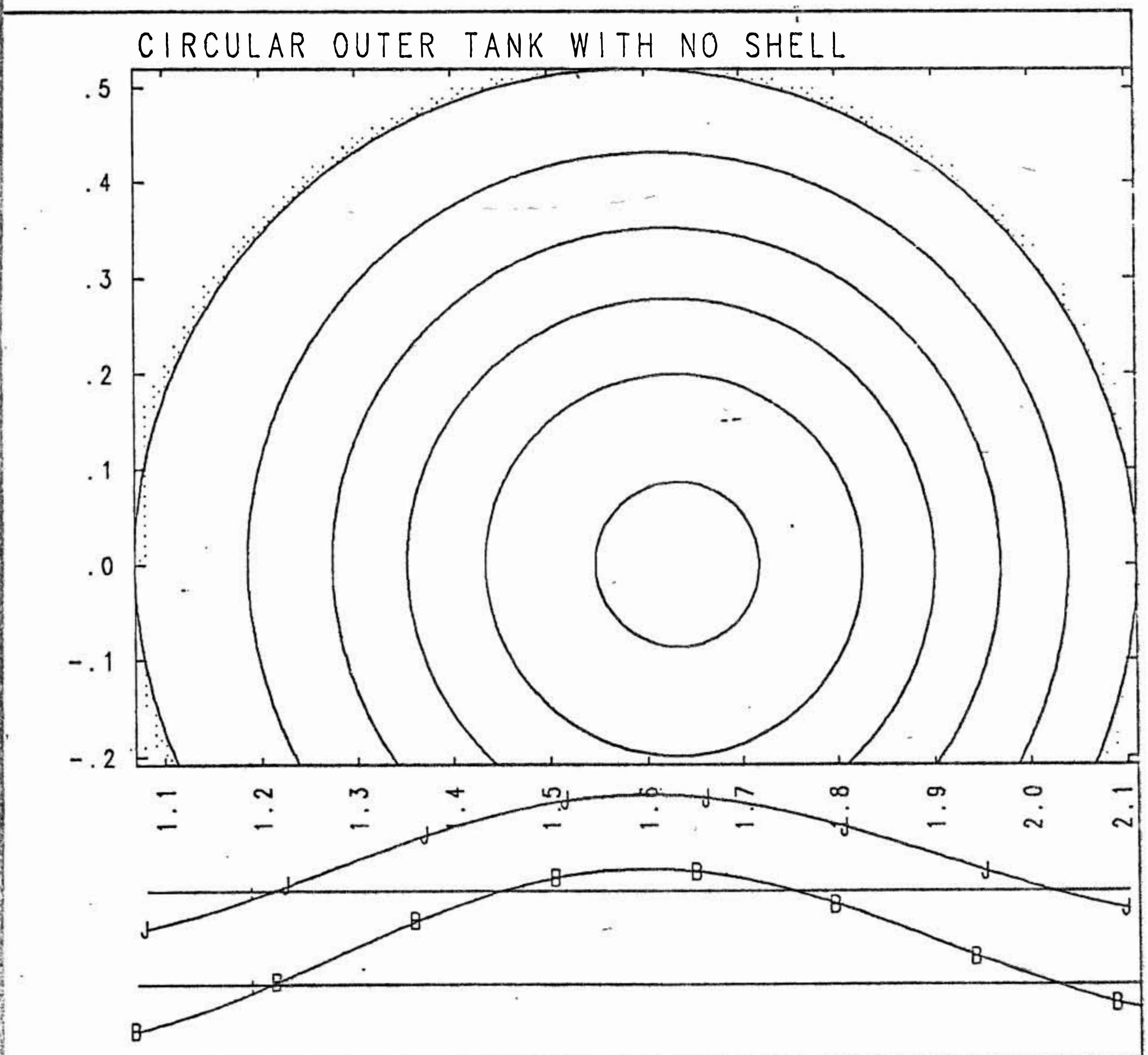

OCTUPOLE WITH NO HOOPS
.6
.5
.4
.3
.2
.1
.0
-.1
-.2
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9

SECOND YEAR



OCTUPOLE WITH SMALL HOOPS
.6
.5
.4
.3
.2
.1
.0
-.1
-.2
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
J
B

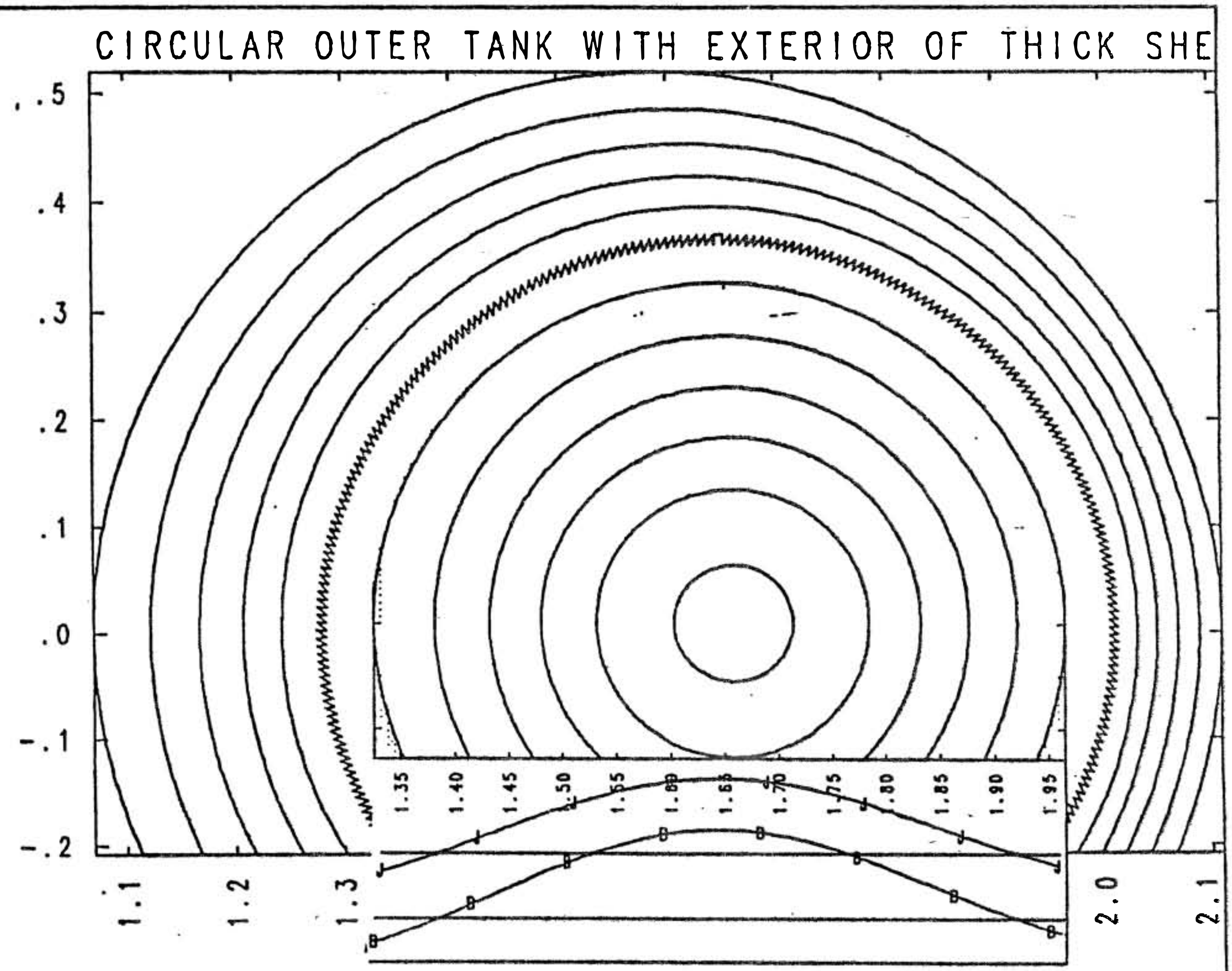
THIRD YEAR



CIRCULAR OUTER TANK WITH NO SHELL
.5
.4
.3
.2
.1
.0
-.1
-.2
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1

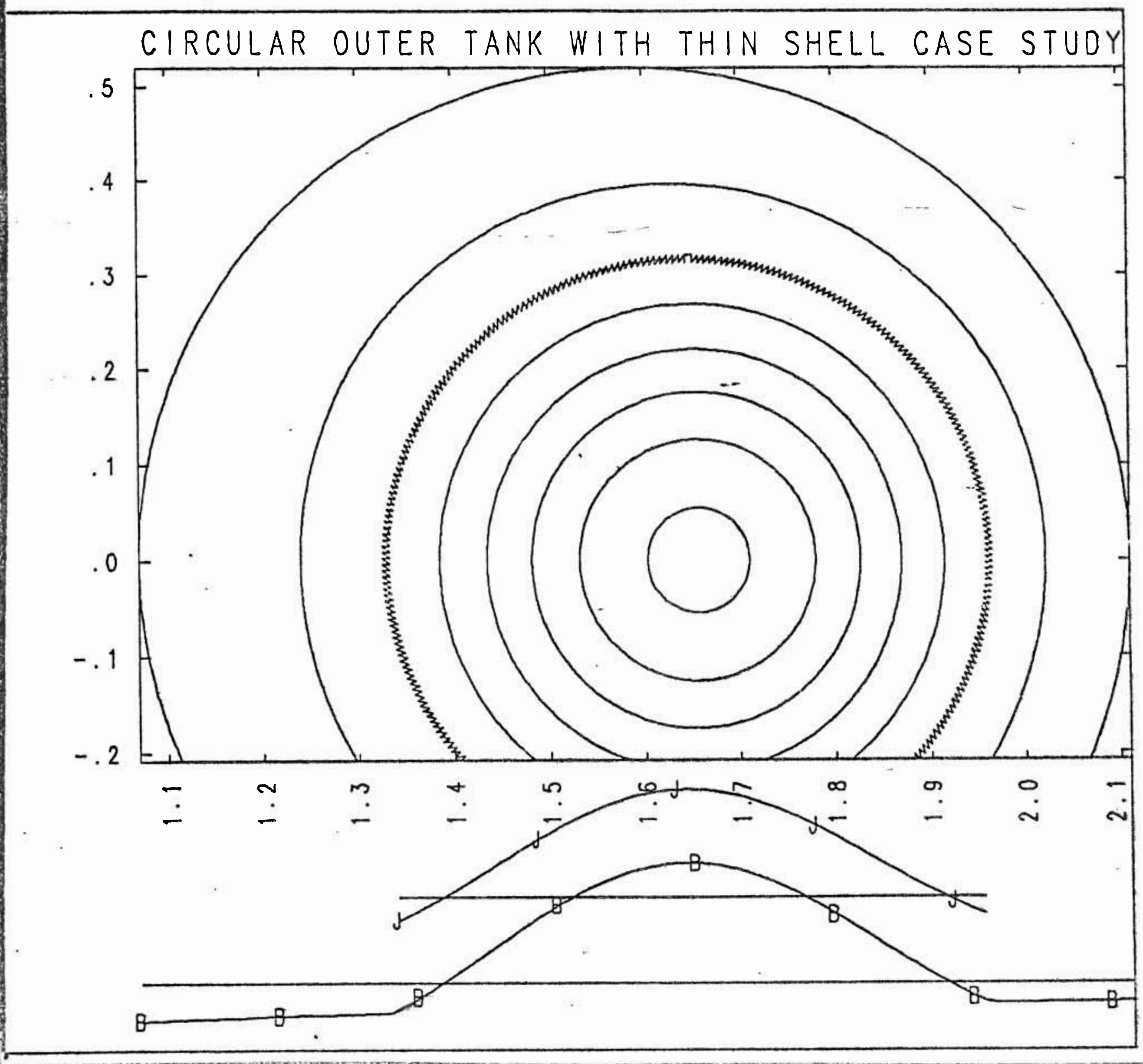
Boundary Condition Studies

FOURTH YEAR



CIRCULAR OUTER TANK WITH EXTERIOR OF THICK SHE
.5
.4
.3
.2
.1
.0
-.1
-.2
1.1
1.2
1.3
2.0
2.1
1.35
1.40
1.45
1.50
1.55
1.60
1.65
1.70
1.75
1.80
1.85
1.90
1.95

FIFTH YEAR



CIRCULAR OUTER TANK WITH THIN SHELL CASE STUDY
.5
.4
.3
.2
.1
.0
-.1
-.2
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1

SIXTH YEAR

BIRDCAGE SHELL

AND

START OF q-SCALING