THE PROPOSED WISCONSIN RFP

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Abstract
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 \( \sim 30 \) 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 (\( \sim 6 \) 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.

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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, $\tau_e$, 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 $\omega$ spectrum of instabilities

* vary shell 'spatial' properties ($\theta, \phi, \text{structures}$) related to $k$ spectrum of instabilities

* measure gross parameters, sustainment time, fluctuations, $\tau_e$
Parameter Goals

major radius: \( R_o = 165 \) cm
minor radius: \( a = 32 \) cm
toroidal plasma current: \( I = 350 \) kA
toroidal loop voltage: \( V_I = 22.5 \) volts
ohmic heating power: \( P_{OH} = 7.9 \) MW
electron temperature: \( T_{eo} = 350 \) ev
electron density: \( n = 3 \times 10^{13} \) cm\(^{-3}\)
confinement time: \( \tau_E = 2.0 \) msec
plasma inductance: \( L_p = 2.6 \) \( \mu \)H
poloidal flux: \( \phi = 0.91 \) 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
FIG. A-6

REVISED FIGURE 5.1(a) CONCEPTUAL DESIGN SHELL SYSTEM CROSS SECTION. SCALE 11.5:1
DOUBLE SHELL SYSTEM TO REDUCE FIELD ERRORS

Outer Toroidal Gap

Inner Toroidal Gap

Outer Poloidal Gap

Inner Poloidal Gap
Circuit Modeling
PROPOSED RFP WITH N = 36 TURNS, C = 0.021 FARADS, 58 MSEC FULL SCALE
INITIAL CAPACITOR VOLTAGE = 5000 VOLT-SECONDS CONSUMED = 1.08752
CORE BIAS = 15 KG (16975.4 AMP-TURNS) PRIMARY RESISTANCE = 0.013 OHMS
INITIAL PLASMA RESISTANCE = 0.02 OHMS CROWN VOLTAGE = 0
YEAR PLASMA RESISTANCE (OHMS) = 3.68646-03

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PEAK AVERAGE TOROIDAL FIELD (GAUSS) = 1628.93
PLENTY OF VOLT-SEC AVAILABLE FOR STARTUP

CORE MAGNETIZING CURRENT RISES ONLY LATE IN TIME
HENCE FIELD ERRORS DON'T SOAK THROUGH SHELLS
Flux Plots
and Proposed Schedule
Construction Phase Experiments
SECOND YEAR

OCTUPOLE WITH SMALL HOOPS
Boundary Condition Studies
FOURTH YEAR

CIRCULAR OUTER TANK WITH EXTERIOR OF THICK SHE
FIFTH YEAR

CIRCULAR OUTER TANK WITH THIN SHELL CASE STUDY
SIXTH YEAR

BIRDCAGE SHELL

AND

START OF q-SCALING