NUMERICAL SIMULATION

OF MULTIPOLE PLASMA CONFINEMENT

by

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This paper describes a computer program (SIMULT) that calculates the time dependent, spatially averaged density, electron temperature and ion temperature in a toroidal multipole. The program is an adaptation of one developed to simulate confinement in the ELMO Bumpy Torus at Oak Ridge. The program is zero-dimensional in the sense that it predicts only spatially averaged quantities. It has been used mostly to study cw microwave heated plasmas, but pulsed microwave and gun injected plasmas can also be studied. The numerical predictions and comparisons with experimental results will be described in detail in a subsequent paper.

The numerical method consists of solving three coupled, time dependent, non-linear, first order, ordinary differential equations, one for the particle density, one for the electron energy density, and one for the ion energy density:

$$\frac{dn}{dt} = \frac{\partial n}{\partial t}(n, n_o, T_e)\Big|_{\text{ionization}}$$

$$- \frac{\partial n}{\partial t}(n, n_o, T_e, T_i, B, a)\Big|_{\text{diffusion}}$$

$$- \frac{\partial n}{\partial t}(n, T_e, T_i, a, L, A_o)\Big|_{\text{obstacles}}$$

$$- \frac{\partial n}{\partial t}(n, B, \dot{B})\Big|_{\text{field decay}}$$

$$\frac{dU_e}{dt} = \frac{\partial U_e}{\partial t}(P, n, a, L, f, Q, B)\Big|_{\text{microwaves}}$$

$$- \frac{\partial U_e}{\partial t}(n, n_o, T_e)\Big|_{\text{excitation}}$$

$$- \frac{\partial U_e}{\partial t}(n, T_e, T_i)\Big|_{\text{ion collisions}}$$

$$- \frac{\partial U_e}{\partial t}(n, T_e)\Big|_{\text{bremsstrahlung}}$$

$$- \frac{\partial U_e}{\partial t}(n, T_e, B)\Big|_{\text{synchroton}}$$

$$- \frac{\partial U_e}{\partial t}(n, n_o, T_e, T_i, B, a, L, A_o)\Big|_{\text{thermal conduction}}$$

$$\frac{dU_i}{dt} = \frac{\partial U_i}{\partial t}(n, T_e, T_i)\Big|_{\text{electron collisions}}$$

$$- \frac{\partial U_i}{\partial t}(n, n_o, T_i)\Big|_{\text{charge exchange}}$$

$$- \frac{\partial U_i}{\partial t}(n, n_o, T_e, T_i, B, a, L, A_o)\Big|_{\text{thermal conduction}}$$

The symbols and units are as follows:

n = electron (or ion) density (units of 10^9 cm^{-3})

T_e = electron temperature (eV)

T_i = ion temperature (eV)

$U_e = nT_e$

$U_i = nT_i$

n_o = neutral particle density (10^9 cm^{-3})

B = average magnetic field (kG)

$\dot{B}$ = dB/dt (kG/sec)

a = minor radius of plasma (cm)

L = length of plasma ($2\pi R$ for toroid) (cm)

A_o = obstacle (hoop supports and probes) area (cm^2)

P = microwave power (watts)

f = microwave frequency (GHz)

Q = unperturbed microwave cavity Q

t = time (sec)

The three equations are solved by the simplest method of successive iteration using the current values of each parameter. The electron and ion temperatures are incremented according to:

$$\Delta T_e = (\Delta U_e - T_e \Delta n)/n$$

$$\Delta T_i = (\Delta U_i - T_i \Delta n)/n.$$

The iteration step Δt can be adjusted to insure any desired degree of accuracy. The initial conditions (n, T_e, and T_i) can be set arbitrarily. The detailed form of the various terms is given below:

Magnetic field: Any time dependent magnetic field can be specified. For the small octupole we use:

$$B = B_o e^{-t/\tau} \sin \omega t,$$

where $\omega = 200\pi$ sec $^{-1}$ and $\tau = 10^{-2}$ sec. The magnetic field is corrected for finite beta as follows:

$$B = \sqrt{B_{VAC}^2 - 4.05 \times 10^{-8} n(T_e + T_i)} \quad .$$

Microwave power: Any time dependent microwave power pulse can be specified. For the small octupole we use (PLP 494):

$$P = P_o \max [0, 2B/B_o - 1].$$

Neutral density: The neutral (hydrogen) density is calculated at each time step from the pressure (p) as follows:

$$n_o = 322p \exp\left[-3.07 \times 10^{-4} \frac{na}{T_e^{1/8}} e^{-17/T_e}\right]$$

$$+ 12.88p \exp\left[-1.7 \times 10^{-5} \frac{na}{T_e^{1/8}} e^{-17/T_e}\right]$$

where the first term is for thermal (0.025 eV) neutrals and the second term is for Franck-Condon (7 eV) neutrals. The exponential factors account for the finite penetration depth of the neutrals into the plasma. When the neutral density is increasing in time, the rate of increase of each component is limited to:

$$\frac{dn_{TH}}{dt} \leq \frac{1.9 \times 10^{-5} n_{TH}}{a}$$

$$\frac{dn_{FC}}{dt} \leq \frac{3.4 \times 10^{6} n_{FC}}{a}$$

representing the transit time of a neutral from the edge to the center of the plasma.

Ionization: The ionization rate for a maxwellian electron distribution is approximated by an analytic function:

$$\left.\frac{\partial n}{\partial t}\right|_{\text{ionization}} = 50.4 \frac{n n_o}{T_e^{18}} e^{-17\ T_e} \quad .$$

Diffusion: Classical diffusion due to electron-ion and electron-neutral collisions can be written as:

$$\left.\frac{\partial n}{\partial t}\right|_{\text{diffusion}} = 0.33 \frac{n^2}{B^2 a^2 T_e^{1/2}} + 10^{-3} \frac{n n_o T_e}{B^2 a^2}$$

The ambipolar electric field has been considered, but ion-neutral collisions have been neglected since they amount to only a 1.2% correction to the diffusion rate.

Obstacles: Hoop supports and probes which intercept the plasma are assumed to collect particles at a rate given by the ion saturation current for an isotropic plasma:

$$\left.\frac{\partial n}{\partial t}\right|_{\text{obstacles}} = 2 \times 10^5 \frac{n A_o \sqrt{\max(T_e, T_i)}}{a^2 L} ,$$

where in practice A_o is an effective obstacle area calculated from lifetime measurements of ions and hot electrons. For the small octupole we use 90 cm^2, which is somewhat greater than the geometric area.

Field decay: When $\frac{dB}{dt}$ is negative field lines are leaving the machine, and plasma is assumed to leave also at a rate given by:

$$\left.\frac{\partial n}{\partial t}\right|_{\text{field decay}} = -\min[0, \frac{n}{B} \dot{B}]$$

Microwave heating: The microwave heating rate is given by:

$$\left.\frac{\partial U_e}{\partial t}\right|_{\text{microwaves}} = \frac{2 \times 10^9 P}{(1 + n_c/n) a^2 L} ,$$

where n_c is the density above which the microwaves are totally absorbed. From PLP 282, n_c can be estimated from:

$$n_c = \frac{f^2}{Q} [4.5 \times 10^{-3} (f/B)^4 + 37.2 + 123 (B/f)^{2.3}].$$

Excitation: Energy lost by inelastic collisions with neutrals is estimated by assuming that each electron loses 30 eV per ionization:

$$\left.\frac{\partial U_e}{\partial t}\right|_{\text{excitation}} = 30 \left.\frac{\partial n}{\partial t}\right|_{\text{ionization}} .$$

Ion collisions: Classical electron-ion collisions result in an energy loss given by (Spitzer, page 135):

$$\left.\frac{\partial U_e}{\partial t}\right|_{\text{ion collisions}} = \frac{61 n^2 (T_e - T_i)}{T_e^{2/3}} .$$

Bremsstrahlung: Electron-ion Bremsstrahlung losses are given by (Rose and Clark, page 233):

$$\left.\frac{\partial U_e}{\partial t}\right|_{\text{bremsstrahlung}} = 10^{-4} n^2 T_e^{\frac{1}{2}}$$

Synchrotron radiation: Electron synchrotron radiation, neglecting reabsorption, is given by (Rose and Clark, page 25):

$$\left.\frac{\partial U_e}{\partial t}\right|_{\text{synchrotron}} = 3.87 \times 10^{-3} n B^2 T_e (1 + T_e/2.04 \times 10^5).$$

Electron thermal conduction: Heat conduction due to classical collisions and to obstacle losses (Huddlestone and Leonard, page 98) is given by:

$$\left.\frac{\partial U_e}{\partial t}\right|_{\text{thermal conduction}} = 2.5 T_e \left.\frac{\partial n}{\partial t}\right|_{\text{diffusion}} + 5.54 T_e \left.\frac{\partial n}{\partial t}\right|_{\text{obstacles}} .$$

Electron collisions: Ions are heated by classical collisions with electrons (Spitzer, page 135):

$$\left.\frac{\partial U_i}{\partial t}\right|_{\text{electron collisions}} = \frac{61 n^2 (T_e - T_i)}{T_e^{3/2}} .$$

Charge exchange: Charge exchange losses are represented by an approximate analytic form:

$$\left.\frac{\partial U_i}{\partial t}\right|_{\text{charge exchange}} = \frac{0.0186 n n_o T_i^3}{T_i + 100} \quad .$$

Ion Thermal conduction: Heat conduction due to classical collisions and to obstacle losses (Huddlestone and Leonard, page 98) is given by:

$$\left.\frac{\partial U_i}{\partial t}\right|_{\text{thermal conduction}} = 2.5 T_i \left.\frac{\partial n}{\partial t}\right|_{\text{diffusion}} + 2 T_i \left.\frac{\partial n}{\partial t}\right|_{\text{obstacles}} \quad .$$

The following pages give a FORTRAN listing of the code and typical output.

```
      C     PROGRAM SIMULT - JAN 25, 1973
            DIMENSION T(101),DE(101),TE(101),TI(101)
            DIMENSION BP(101),PP(101),SJ(101)

      C     DEFINE FUNCTIONS
      C     D1 IS DN/DT DUE TO IONIZATION
            D1(DENS,DNEUT,TE)=50.4*DENS*DNEUT*EXP(-17.0/(TE+0.3))/TE**0.125
      C     D2 IS DN/DT DUE TO DIFFUSION
            D2(DENS,TE)=DENS*(0.33*DENS/SQRT(TE)+1.7*DNEUT*TIA)/B/B/A/A
      C     D3 IS DN/DT DUE TO OBSTACLE LOSSES
            D3(DENS,TE)=2.0E5*DENS*A0*SQRT(AMAX1(TE,TIA))/A/A/AL
      C     PE1 IS DUE/DT DUE TO MICROWAVES
            PE1(P)=2.0E9*P/(1.0+DE0/DEA)/A/A/AL
      C     PE2 IS DUE/DT DUE TO ION COLLISIONS
            PE2(DENS,TE,TI)=61.0*DENS*DENS*(TE-TI)/TE**1.5
      C     PE4 IS DUE/DT DUE TO BREMSSTRAHLUNG
            PE4(DENS,TE)=1.0E-4*DENS*DENS*SQRT(TE)
      C     PE5 IS DUE/DT DUE TO SYNCHROTRON RADIATION
            PE5(DENS,TE)=3.87E-3*DENS*B*B*TE*(1.0+TE/2.04E5)
      C     PE6 IS DUE/DT DUE TO THERMAL CONDUCTION
            PE6(DENS,TE)=2.5*TE*D2(DENS,TE)+5.54*TE*D3(DENS,TE)
      C     PI3 IS DUI/DT DUE TO CHARGE EXCHANGE
            PI3(DENS,DNEUT,TI)=0.0186*DENS*DNEUT*TI**3/(TI+100.0)
      C     PI6 IS DUI/DT DUE TO THERMAL CONDUCTION
            PI6(DENS,TE,TI)=2.5*TI*D2(DENS,TE)+2.0*TI*D3(DENS,TE)

      C     SPECIFY PARAMETERS
      C     PO IS PEAK MICROWAVE POWER IN WATTS
            PO=10.0
            IPWR=1
      200   CONTINUE
      C     IIMAX IS NUMBER OF ITERATIONS
      C     DEA IS INITIAL DENSITY IN 10**9/CC
      C     TEA IS INITIAL ELECTRON TEMPERATURE IN EV
      C     TIA IS INITIAL ION TEMPERATURE IN EV
      C     A IS RADIUS IN CM
      C     AL IS LENGTH IN CM
      C     AO IS OBSTACLE AREA IN SQ CM
      C     PRES IS NEUTRAL PRESSURE IN 10**-5 TORR
      C     BO IS FIELD AT OUTER WALL IN KGAUSS
      C     F IS MICROWAVE FREQUENCY IN GHZ
      C     Q IS THE MICROWAVE CAVITY Q
      C     TMAX IS DURATION OF EXPERIMENT IN SECONDS
            IIMAX=4000
            DEA=0.001
            TEA=0.1
            TIA=0.025
            A=18.0
            AL=270.0
            AO=90.0
            PRES=5.0
            BO=1.0
            F=2.45
            Q=2000.0
            TMAX=0.005
```

```
C       SPECIFY INITIAL CONDITIONS
        IPRINT=IIMAX/100
        DT=TMAX/FLOAT(IIMAX)
        B=1.0E-5
        II=0
        TIME=0.0
        DNT=322.0*PRES
        DFC=12.88*PRES
        DEMAX=DEA
        TEMAX=TEA
        TIMAX=TIA
        DNMIN=335.0*PRES
        BPMAX=0.1*B0
        PPMAX=0.1*P0
        SJMAX=0.104*DEA*SQRT(TEA)

C       RECORD VALUES
        WRITE(6,440)
 440    FORMAT(1H1,'      STEP       TIME      DENSITY      TE
     2      TI          DNEUT        FIELD       POWER      JSAT')
 450    CONTINUE
        BOLD=B
        B=B0*SIN(3.14159*TIME/TMAX)*EXP(-0.5*TIME/TMAX)/0.7687+1.0E-5
        B=SQRT(ABS(B*B-4.056-8*DEA*(TEA+TIA)))
        DEO=F*F*(0.0045*(F/B)**4+37.2+123.0*(B/F)**0.66667)/Q
        P=AMAX1(0.0,2.0*P0*(B/B0-0.5))
        SJI=0.104*DEA*SQRT(AMAX1(TEA,TIA))
        DNTO=DNT
        DFCO=DFC
        DNT=322.0*PRES*EXP(-3.07E-4*DEA*A*EXP(-17.0/(TEA+0.3))/TEA**0.125)
        DFC=12.88*PRES*EXP(-1.70E-5*DEA*A*EXP(-17.0/(TEA+0.3))/TEA**0.125)
        IF(DNT.GT.DNTO) DNT=DNT+(DNTO-DNT)*EXP(-1.9E5*DT/A)
        IF(DFC.GT.DFCO) DFC=DFC+(DFCO-DFC)*EXP(-3.4E6*DT/A)
        DNEUT=DNT+DFC
        DEMAX=AMAX1(DEMAX,DEA)
        TEMAX=AMAX1(TEMAX,TEA)
        TIMAX=AMAX1(TIMAX,TIA)
        DNMIN=AMIN1(DNMIN,DNEUT)
        BPMAX=AMAX1(BPMAX,B)
        PPMAX=AMAX1(PPMAX,P)
        SJMAX=AMAX1(SJMAX,SJI)
        IF(MOD(II+1,IPRINT).NE.1) GO TO 480
        WRITE(6,460) II,TIME,DEA,TEA,TIA,DNEUT,B,P,SJI
 460    FORMAT(1H ,I13,8F13.4)
        I=II/IPRINT+1
        T(I)=TIME
        DE(I)=DEA
        TE(I)=TEA
        TI(I)=TIA
        BP(I)=B
        PP(I)=P
        SJ(I)=SJI
 480    CONTINUE
        IF(II.GE.IIMAX) GO TO 640

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```
112.      C      INCREMENT DENSITY
113.             DDENS=D1(DEA,DNEUT,TEA)*DT
114.            2=D2(DEA,TEA)*DT
115.            3=D3(DEA,TEA)*DT
116.            4+2.0*DEA*AMIN1(0.0,B=BOLD)/BOLD
117.             IF(ABS(DDENS).GT.0.5*DEA) DDENS=SIGN(0.5*DEA,DDENS)
118.             DEA=DEA+DDENS
119.
120.      C      INCREMENT ELECTRON TEMPERATURE
121.             DUE=PE1(P)*DT
122.            2=30.0*D1(DEA,DNEUT,TEA)*DT
123.            3=PE2(DEA,TEA,TIA)*DT
124.            4=PE4(DEA,TEA)*DT
125.            5=PE5(DEA,TEA)*DT
126.            6=PE6(DEA,TEA)*DT
127.             DTE=(DUE=TEA*DDENS)/DEA
128.             IF(ABS(DTE).GT.0.5*TEA) DTE=SIGN(0.5*TEA,DTE)
129.             TEA=TEA+DTE
130.
131.      C      INCREMENT ION TEMPERATURE
132.             DUI=PE2(DEA,TEA,TIA)*DT
133.            2=PI3(DEA,DNEUT,TIA)*DT
134.            3=PI6(DEA,TEA,TIA)*DT
135.             DTI=(DUI=TIA*DDENS)/DEA
136.             IF(ABS(DTI).GT.0.5*TIA) DTI=SIGN(0.5*TIA,DTI)
137.             TIA=TIA+DTI
138.
139.      C      INCREMENT TIME
140.             II=II+1
141.             TIME=DT*FLOAT(II)
142.             GO TO 450
143.       640   CONTINUE
144.
145.      C      RECORD MAXIMUM VALUES
146.             WRITE(6,700) DEMAX,TEMAX,TIMAX,DNMIN,BPMAX,PPMAX,SJMAX
147.       700   FORMAT(1HO,'              MAXIMUM  VALUES',7F13.4)
148.
149.      C      GRAPH OUTPUT
150.             DO 820 I=1,101
151.             T(I)=6.0*T(I)/TMAX
152.             DE(I)=6.0*DE(I)/DEMAX
153.             TE(I)=6.0*TE(I)/TEMAX
154.             TI(I)=6.0*TI(I)/TIMAX
155.             BP(I)=6.0*BP(I)/BPMAX
156.             PP(I)=6.0*PP(I)/PPMAX
157.             SJ(I)=6.0*SJ(I)/SJMAX
158.       820   CONTINUE
159.             CALL GRAPH2(T,'R',DE,'R',101,'6X6','NONE','MULTIPOLE SIMULATION.'
160.            2,'TIME.','DENSITY AND TEMP (NORMALIZED).','D')
161.             CALL GRPH2V(T,'R',TE,'R',101,'NONE','E')
162.             CALL GRPH2V(T,'R',TI,'R',101,'NONE','I')
163.             CALL GRAPH2(T,'R',BP,'R',101,'6X6','NONE','MULTIPOLE SIMULATION.'
164.            2,'TIME.','FIELD AND POWER (NORMALIZED).','B')
165.             CALL GRPH2V(T,'R',PP,'R',101,'NONE','P')
166.             CALL GRPH2V(T,'R',SJ,'R',101,'NONE','J')
167.             CALL GRPHND
168.             IPWR=IPWR+1
169.       860   P0=10.0*P0
170.             IF(IPWR.LE.4) GO TO 200
171.             STOP
172.             END
```

STEP	TIME	DENSITY	TE	TI	DNEUT	FIELD	POWER	JSAT
0	.0000	.0010	.1000	.0250	1674.4000	.0000	.0000	.0000
40	.0000	.0004	.0366	.0092	1674.4000	.0396	.0000	.0000
80	.0001	.0004	.0362	.0092	1674.4000	.0788	.0000	.0000
120	.0001	.0004	.0359	.0092	1674.4000	.1176	.0000	.0000
160	.0002	.0004	.0356	.0092	1674.4000	.1558	.0000	.0000
200	.0002	.0004	.0352	.0091	1674.4000	.1935	.0000	.0000
240	.0003	.0004	.0349	.0091	1674.4000	.2306	.0000	.0000
280	.0003	.0004	.0346	.0091	1674.4000	.2671	.0000	.0000
320	.0004	.0004	.0343	.0091	1674.4000	.3030	.0000	.0000
360	.0004	.0004	.0340	.0091	1674.4000	.3382	.0000	.0000
400	.0005	.0004	.0337	.0091	1674.4000	.3727	.0000	.0000
440	.0005	.0004	.0334	.0091	1674.4000	.4065	.0000	.0000
480	.0006	.0004	.0331	.0091	1674.4000	.4396	.0000	.0000
520	.0006	.0004	.0328	.0090	1674.4000	.4719	.0000	.0000
560	.0007	.0004	.1649	.0090	1674.4000	.5034	6.7238	.0000
600	.0007	.0012	70.2993	.0027	1674.3951	.5340	68.0722	.0010
640	.0008	.0075	162.0977	.0003	1674.3681	.5639	127.7347	.0099
680	.0008	.0459	228.7121	.0000	1674.2074	.5928	185.6676	.0721
720	.0009	.2748	205.6915	.0000	1673.2410	.6209	241.8280	.4099
760	.0009	1.7228	90.8089	.0001	1667.1611	.6481	296.1761	1.7074
800	.0010	8.8943	21.6138	.0016	1649.7268	.6743	348.6827	4.3004
840	.0010	20.3578	9.9443	.0103	1648.6585	.6997	399.3105	6.6765
880	.0011	32.1965	8.0153	.0283	1646.0018	.7240	448.0231	9.4798
920	.0011	45.1408	7.1114	.0554	1642.9339	.7474	494.7929	12.5193
960	.0012	59.1636	6.5389	.0926	1640.0364	.7698	539.5921	15.7340
1000	.0012	74.1577	6.1316	.1405	1637.3359	.7912	582.3954	19.0975

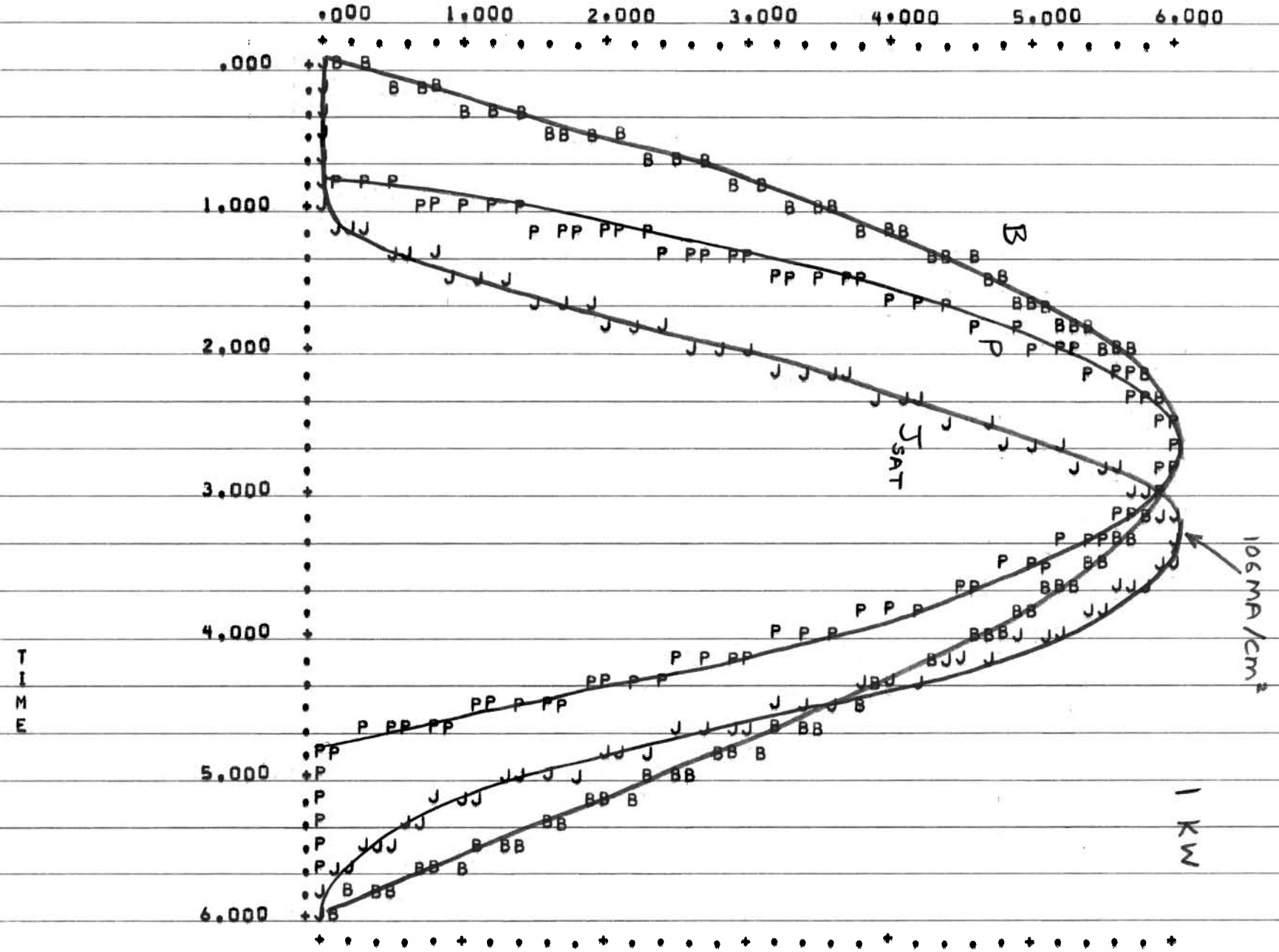
1040	.0013	90.0146	5.8209	.1994	1634.8346	.8116	623.1794	22.5860
1080	.0013	106.6271	5.5723	.2695	1632.5334	.8310	661.9233	26.1769
1120	.0014	123.8907	5.3665	.3506	1630.4320	.8493	698.6083	29.8482
1160	.0014	141.7034	5.1917	.4423	1628.5284	.8666	733.2178	33.5792
1200	.0015	159.9669	5.0403	.5439	1626.8187	.8829	765.7378	37.3500
1240	.0015	178.5872	4.9070	.6544	1625.2970	.8981	796.1561	41.1425
1280	.0016	197.4754	4.7882	.7727	1623.9553	.9122	824.4632	44.9399
1320	.0016	216.5483	4.6813	.8972	1622.7841	.9253	850.6515	48.7271
1360	.0017	235.7292	4.5843	1.0265	1621.7728	.9374	874.7156	52.4909
1400	.0017	254.9479	4.4957	1.1589	1620.9099	.9483	896.6525	56.2193
1440	.0018	274.1406	4.4144	1.2926	1620.1841	.9582	916.4614	59.9022
1480	.0018	293.2501	4.3393	1.4261	1619.5847	.9671	934.1434	63.5307
1520	.0019	312.2249	4.2698	1.5577	1619.1017	.9749	949.7018	67.0970
1560	.0019	331.0186	4.2050	1.6858	1618.7268	.9816	963.1423	70.5941
1600	.0020	349.5894	4.1445	1.8093	1618.4532	.9872	974.4723	74.0159
1640	.0020	367.8988	4.0876	1.9270	1618.2756	.9919	983.7015	77.3565
1680	.0021	385.9114	4.0340	2.0379	1618.1907	.9954	990.8414	80.6102
1720	.0021	403.5935	3.9833	2.1415	1618.1837	.9980	995.9057	83.7716
1760	.0022	420.9125	3.9350	2.2373	1618.2078	.9995	998.9100	86.8353
1800	.0022	437.8367	3.8888	2.3250	1618.2810	.9999	999.8718	89.7957
1840	.0023	453.8995	3.8474	2.4066	1618.4027	.9994	998.8104	92.5923
1880	.0023	468.6471	3.8109	2.4835	1618.5429	.9979	995.7471	95.1470
1920	.0024	482.0444	3.7782	2.5548	1618.7056	.9954	990.7049	97.4455
1960	.0024	494.0532	3.7485	2.6202	1618.9022	.9919	983.7087	99.4798
2000	.0025	504.6380	3.7214	2.6797	1619.1435	.9874	974.7849	101.2431
2040	.0025	513.7675	3.6965	2.7335	1619.4392	.9820	963.9618	102.7293
2080	.0026	521.4147	3.6735	2.7820	1619.7976	.9756	951.2691	103.9333
2120	.0026	527.5578	3.6521	2.8256	1620.2260	.9684	936.7382	104.8508
2160	.0027	532.1799	3.6320	2.8647	1620.7306	.9602	920.4020	105.4788
2200	.0027	535.2701	3.6131	2.8998	1621.3162	.9511	902.2951	105.8150

2240	.0028	536.8230	3.5952	2.9315	1621.9869	.9412	882.4531	105.8587
2280	.0028	536.8398	3.5781	2.9601	1622.7457	.9305	860.9134	105.6102
2320	.0029	535.3273	3.5617	2.9861	1623.5949	.9189	837.7146	105.0707
2360	.0029	532.2987	3.5458	3.0099	1624.5362	.9064	812.8965	104.2427
2400	.0030	527.7734	3.5303	3.0319	1625.5706	.8933	786.5002	103.1299
2440	.0030	521.7767	3.5150	3.0524	1626.6988	.8793	758.5680	101.7370
2480	.0031	514.3401	3.4997	3.0718	1627.9209	.8646	729.1433	100.0695
2520	.0031	505.5008	3.4844	3.0903	1629.2371	.8491	698.2705	98.1342
2560	.0032	495.3016	3.4688	3.1084	1630.6469	.8330	665.9953	95.9387
2600	.0032	483.7909	3.4527	3.1262	1632.1500	.8162	632.3641	93.4913
2640	.0033	471.0223	3.4359	3.1441	1633.7457	.7987	597.4241	90.8015
2680	.0033	457.0542	3.4180	3.1623	1635.4332	.7806	561.2237	87.8793
2720	.0034	441.9502	3.3987	3.1813	1637.2116	.7619	523.8118	84.7354
2760	.0034	425.7785	3.3777	3.2013	1639.0797	.7426	485.2382	81.3815
2800	.0035	408.6119	3.3543	3.2228	1641.0365	.7228	445.5533	77.8294
2840	.0035	390.5278	3.3279	3.2462	1643.0802	.7024	404.8081	74.0918
2880	.0036	371.6080	3.2977	3.2720	1645.2092	.6815	363.0541	70.1816
2920	.0036	351.9276	3.2622	3.3006	1647.4223	.6602	320.3437	66.4945
2960	.0037	331.5201	3.2192	3.3324	1649.7275	.6384	276.7292	62.9391
3000	.0037	310.4724	3.1674	3.3679	1652.1237	.6161	232.2637	59.2563

3040	.0038	288.8920	3.1039	3.4079	1654.6008	.5935	187.0005	55.4640
3080	.0038	266.8965	3.0246	3.4531	1657.1466	.5705	140.9931	51.5800
3120	.0039	244.6158	2.9233	3.5040	1659.7446	.5471	94.2954	47.6212
3160	.0039	222.1978	2.7899	3.5602	1662.3704	.5235	46.9614	43.6021
3200	.0040	199.8209	2.6081	3.6188	1664.9820	.4995	.0000	39.5328
3240	.0040	177.8405	2.4682	3.6787	1667.3683	.4753	.0000	35.4741
3280	.0041	156.8564	2.4068	3.7554	1669.1782	.4508	.0000	31.6128
3320	.0041	137.1207	2.3777	3.8608	1670.4619	.4262	.0000	28.0204
3360	.0042	118.7159	2.3636	4.0020	1671.3648	.4013	.0000	24.6991
3400	.0042	101.6684	2.3572	4.1850	1672.0100	.3763	.0000	21.6305
3440	.0043	85.9820	2.3547	4.4162	1672.4849	.3512	.0000	18.7917
3480	.0043	71.6500	2.3536	4.7030	1672.8479	.3259	.0000	16.1598
3520	.0044	58.6599	2.3516	5.0536	1673.1369	.3006	.0000	13.7144
3560	.0044	46.9975	2.3464	5.4766	1673.3760	.2752	.0000	11.4384
3600	.0045	36.6489	2.3347	5.9785	1673.5800	.2498	.0000	9.3194
3640	.0045	27.6042	2.3122	6.5589	1673.7575	.2244	.0000	7.3523
3680	.0046	19.8610	2.2723	7.2016	1673.9128	.1990	.0000	5.5430
3720	.0046	13.4267	2.2049	7.8566	1674.0466	.1737	.0000	3.9140
3760	.0047	8.3168	2.0953	8.4147	1674.1579	.1485	.0000	2.5091
3800	.0047	4.5388	1.9235	8.6820	1674.2441	.1234	.0000	1.3909
3840	.0048	2.0485	1.6672	8.3908	1674.3050	.0983	.0000	.6171
3880	.0048	.6846	1.3150	7.3042	1674.3438	.0735	.0000	.1924
3920	.0049	.1340	.8898	5.3997	1674.3671	.0488	.0000	.0324
3960	.0049	.0072	.4517	2.9524	1674.3808	.0243	.0000	.0013
4000	.0050	.0000	.0033	.0229	1674.3889	.0000	.0000	.0000
MAXIMUM	VALUES	537.0231	234.9409	8.6831	1618.1821	.9999	999.8725	105.8767

MULTIPOLE SIMULATION

FIELD AND POWER (NORMALIZED)



MULTIPOLE SIMULATION

DENSITY AND TEMP (NORMALIZED)