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STANDARD TEST CASE RUNS FOR THE EMPULSE
MONOPOLE FIELDSOLVER AND CONDUCTIVITY
GENERATION MODEL

Frank W. Chambers
David M. Cox

March 2, 1981

Lawrence
Livermore
Laboratory

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STANDARD TEST CASE RUNS FOR THE
EMPULSE MONOPOLE FIELDSOLVER AND
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David M. Cox

March 2, 1981

DISCLAIMER

Abstract

The physical models for the conductivity generation and fieldsolver used in several LLNL beam propagation codes are presented. A generalized beam profile is presented and four standard test cases are proposed.

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NOTE

This report was originally prepared and distributed informally in March, 1981. Since that time there have been sufficient referrals to the test cases to indicate the need for a formal reference.

This UCID contains the original text and revised output from the test cases. Several changes were made in the output format. The X development of the test cases was followed only for 100 cm. Plots versus X are now on a logarithmic scale to facilitate extraction of small X results. Snapshot output is now presented at 1.0, 10.0, 20.0, 50.0, and 100.0 cm. in X.

The results for test case B as originally distributed were in error as pointed out by Dr. Keith Brueckner. The X step employed was too large to properly describe the avalanche ionization. Hence, in this report all cases have been run with reduced X steps.

Frank Chambers

September, 1981

I. I. Introduction

At the high current beam propagation workshop (Ref. 1) it was realized that fieldsolver comparisons between working groups should be made for beams with expanded heads such as develop by blowoff and erosion during propagation. To facilitate comparisons of the fieldsolvers while removing the differences due to evolution of the beam during propagation; standard test cases with imposed beam head profiles have been suggested. Hence, unambiguous field and conductivity generation calculation comparisons can be made.

The field equations solved for this report are derived elsewhere (Ref. 2). The plasma generation model includes a direct deposition term, an avalanche ionization term based on experimental data (Ref. 3), and a recombination term. Plasma density is related to a scalar conductivity through the momentum transfer collision frequency. These models have been used by the Beam Research Group at LLNL in the EMPULSE I (Ref. 4), EMPULSE II (Ref. 5), RINGBEARER I (Ref. 6), and RINGBEARER II (Ref. 7) codes. The actual coded fieldsolver used for the results in this report was extracted from the EMPULSE II code. The code PHOENIX was constructed to run this fieldsolver and generate the appropriate diagnostic output.

Standard test cases are proposed where the beam current density is prescribed at all points in space. This is accomplished using a simple parameterized profile which can represent a cylindrical beam or one with an eroded nose. Four test cases are proposed; PHOENIX results for these cases are presented. In this report almost all quantities are in cgs units; beam "temporal" parameters such as rise time (length) are always given in centimeters.

II. Modelling

Coordinate System - Z, X, r, θ :

Z - distance of propagation of a beam segment - since beams are not propagated in the test cases Z = 0.

X - distance back from the beam head.

r, θ - transverse coordinates in the cylindrical geometry - since only monopole fields are calculated all quantities are θ independent.

Field Equations:

$$\frac{1}{r} \frac{\partial}{\partial r} r \frac{\partial}{\partial r} (A + \varphi) = - \frac{4\pi}{c} (J_{BZ} - \sigma \frac{\partial A}{\partial X}) \quad (1)$$

$$\frac{1}{r} \frac{\partial}{\partial r} r \frac{\partial^2 A}{\partial X^2} = \frac{1}{r} \frac{\partial}{\partial r} r \frac{4\pi\sigma}{c} \frac{\partial A}{\partial r} \quad (2)$$

Boundary Conditions:

$$\frac{\partial A}{\partial r}(r=0) = \frac{\partial \varphi}{\partial r}(r=0) = 0 \quad (3)$$

$$A(r=b) = \varphi(r=b) = 0 \quad (4)$$

A and ψ are the usual monopole field potentials, σ is the plasma conductivity, and J_{gz} is the Z directed component of the beam current. The parameter b is the radius at which there is assumed to be a metal wall. A term of the form $(\partial^2 A / \partial x^2)$ has been dropped in equation (1), except in the RINGBEARER I code where this term is retained. The RINGBEARER I code uses a field equation obtained by combining equations (1) and (2) and using r^2 as the independent variable in the radial direction. In this case the boundary condition on A at $r = 0$ is modified (Ref. 6).

Conductivity Calculation:

The simplified air chemistry models and optional features originated by E. Lee (Ref. 4,5) are described in the following section. Several minor changes have been made in the recombination and collision frequency models to allow the extraction of a single electron temperature parameter and to simplify the analytic forms. These changes will not affect computed conductivities. The field dependent recombination and collision frequency models are included for completeness since they have been used in the past. However, current understanding of the air chemistry indicates better models are needed which retain the simplicity and utility of these models but with increased accuracy. Hence, we are not advocating the use of these models. In the standard cases reported herein recombination is omitted and the high electron temperature limit of the collision frequency is used.

The generation of electron density, n_e , is given by:

$$\frac{\partial n_e}{\partial X} = K' J_{BZ} + \frac{\nu_i}{c} n_e - \frac{\alpha}{c} n_e^2 \quad (5)$$

where:

$$K' = \frac{(dE/dX) \rho}{\Delta E e c} \quad (6)$$

Here $e = 4.803 \cdot 10^{-10}$ esu and $c = 2.9979 \cdot 10^{10}$ cm/s. Typically,

$$dE/dX = 2.52 \text{ MeV cm}^2/\text{gm} \quad (7)$$

$$\rho = 1.29 \cdot 10^{-3} \text{ gm/cm}^3 \quad (\text{air: } p = 760 \text{ torr, } T = 0^\circ\text{C}) \quad (8)$$

$$\Delta E = 33.73 \text{ eV/ion pair} \quad (9)$$

The value of K' used in these runs is:

$$K' = 6.69 \quad (10)$$

To compute avalanche ionization, ν_i , a fit to experimental data (Ref. 3) is used:

$$\nu_i (\text{s}^{-1}) = \frac{A \rho S^3}{1 + B S + C S^2 + D S^3} \quad (11)$$

$$A = 1.423 \cdot 10^{-4}$$

$$B = 9.179 \cdot 10^{-6}$$

$$C = 2.656 \cdot 10^{-10}$$

$$D = 2.820 \cdot 10^{-17}$$

$$S = \frac{E^2}{\bar{\rho}^2} \quad (12)$$

where E is the magnitude of the electric field in statvolts/cm and $\bar{\rho}$ is the gas density normalized to that at 273°K and one atmosphere.

For the computation of the recombination rate, α , and the momentum transfer collision frequency, ν_m , an electron temperature, T_e , is calculated from $E/\bar{\rho}$. Temperature is assumed to vary linearly with $E^2/\bar{\rho}^2$ due to ohmic dissipation; when $E = 0$ the electron temperature is the gas temperature.

$$T_e(\text{eV}) = T_g(\text{eV}) + \kappa (E^2/\bar{\rho}^2) \quad (13)$$

The value of κ is determined in slightly different manners for the recombination and collision frequency calculations. The intent in computing T_e is as a parameter for computing $\nu_m(E/\bar{\rho})$ and $\alpha(E/\bar{\rho})$; and T_e is not intended to accurately indicate the electron temperature for all $E/\bar{\rho}$. Since the formula for ν_m asymptotes above $T_e \sim 2$ eV and above this temperature α is quite small equation (13) is an adequate approximation.

Recombination, when included, is a function of $E/\bar{\rho}$:

$$\alpha(\text{cm}^3/\text{s}) = \frac{2.10 \cdot 10^{-7}}{(T_e(\text{eV})/.02586)^{-7}} = \frac{2.10 \cdot 10^{-7}}{(T_e(^{\circ}\text{K})/300.)^{-7}} \quad (14)$$

$$\kappa = 4.6774 \cdot 10^{-3}$$

This value of κ was determined by requiring that $T_e = 2/3$ eV when $T_g = .02586$ and $E^2/\bar{\rho}^2 = 137.0$. This recombination rate is due to the presence of O_2^+ and was suggested by Bob Johnston (Ref. 8). For the

standard case results thus far computed recombination has been omitted.

Assuming a scalar conductivity, σ is related to n_e by:

$$\sigma = \frac{n_e e^2}{m \nu_m} \quad (15)$$

$m = 9.11 \cdot 10^{-28}$ grams is the electron mass; ν_m is the momentum transfer collision frequency:

The momentum transfer collision frequency is modelled as a function of E/ρ as:

$$\nu_m (s^{-1}) = 4.86 \cdot 10^{12} \rho \frac{A + T_e}{B + T_e} \quad (16)$$

$$\kappa = 4.8662 \cdot 10^{-3}$$

$$A = 2.35835 \cdot 10^{-3}$$

$$B = .561026$$

This value of κ was determined by requiring $T_e = 2/3$ eV when $T_g = 0$ and $E^2/\rho^2 = 137.0$. This formula was determined by requiring agreement with tables (Ref. 9) at $T_e = .0235$ eV, $2/3$ eV, and as $T_e \rightarrow \infty$. In the standard case results the high temperature limit ($T_e > 2$ eV) was used; namely,

$$\nu_m (s^{-1}) = 4.86 \cdot 10^{12} \rho \quad (17)$$

When recombination is ignored and ν_m is constant $n_e \sim \sigma$ and the conductivity can be calculated directly using:

$$\frac{\partial \sigma}{\partial X} = KJ_B + \frac{\nu_1}{c} \sigma \quad (17)$$

in this case for the previously given K' value:

$$K = 3.48 \cdot 10^{-4} \quad (18)$$

Plots of ν_1 , ν_m , and α versus E with $\bar{\rho} = 1.0$ are given in figures 1, 2, 3, and 4.

III. Standard Case Definitions, Parameters, and Output

Beam Profile:

$$I_B(X) = I_{B0} \tanh(X/L_R)$$

I_{B0} - Beam current at $X = \infty$

L_R - rise length in centimeters

$$J_B(r, X) = \bar{J}_B(r/R(X)) I_B(X)/(\pi R^2(X))$$

$$R(X) = ROMIN + (ROMAX-ROMIN)/2.0 (1 - \tanh((X-XLOC)/XWDTH))$$

ROMIN - Beam radius as $X \rightarrow \infty$

ROMAX - Beam radius as $X \rightarrow -\infty$

XLOC - Location of "midpoint" of neck

XWDTH - Width of neck region

Gaussian - $\bar{J}(r/R) = e^{-r^2/R^2}$

Bennett - $\bar{J}(r/R) = 1/(1+r^2/R^2)^2$

Gas: 760 torr (1 atm) air and 76 torr (.1 atm) air

ν_m constant

$\alpha = 0$

Numerical:

$$XMAX = 200.0 \text{ cm.}$$

Output:

Snapshot profiles in r of:

$$J_B, J_{NET}, -J_{RET}; \sigma; \nu_1; c/L_1;$$

$$A; \phi; E_R; E_Z$$

$$\text{at: } X = 10., 20., 40., 100., 200. \text{ cm.}$$

History profiles in X of:

$$I_B; R_X; I_B, I_{NET}, I_{RET}, I_{EFF}; E_Z(r=0); \sigma(r=0); \nu_1(r=0)$$

Contour plots in X, r of:

$$A(X, r); \nu_1(X, r)$$

IV. Standard Cases

A. 10 kA, Standard Case

A 10 kA Bennett beam into full atmosphere at injection - beam is cylindrical with no eroded head.

I_{B0}	= 10000.0 A	ROMIN	= .5 cm
L_{RISE}	= 10.0 cm	ROMAX	= .5 cm
γ	= 100.0	XLOC	= 15.0 cm
p	= 760 torr	XWIDTH	= 15.0 cm

B. 10 kA, Reduced Pressure

A 10 kA Bennett beam into one tenth atmosphere; at injection - beam is cylindrical with no eroded head.

I_{B0}	= 10000.0 A	ROMIN	= .5 cm
L_{RISE}	= 10.0 cm	ROMAX	= .5 cm
γ	= 100.0	XLOC	= 15.0 cm
p	= 76 torr	XWIDTH	= 15.0 cm

C. 100 kA, Broad Nose

A 100 kA Bennett beam with an imposed eroded head but with a broad nose.

I_{B0}	= 100000.0 A	ROMIN	= .2 cm
L_{RISE}	= 30.0 cm	ROMAX	= 40.0 cm
γ	= 100.0	XLOC	= 15.0 cm
p	= 760 torr	XWIDTH	= 15.0 cm

D. 100 kA, Narrow Nose

A 100 kA Bennett beam with an eroded head with radius parameters fitted to an SAI run.

I_{B0}	= 100000.0 A	ROMIN	= .5 cm
L_{RISE}	= 30.0 cm	ROMAX	= 100.0 cm
γ	= 100.0	XLOC	= 20.0 cm
p	= 760 torr	XWIDTH	= 1.8 cm

V. PHOENIX Output

Frame 1. Input parameters are defined as follows:

```

C-
C-  NAMELIST INPUT FOR THE PHOENIX FIELDSOLVER
C-
C-  NAME          UNITS      DEFAULT    COMMENTS
C-
C-  BEAM PHYSICAL PARAMETERS
C-
C-  IBO           AMPS       10000.0    BEAM CURRENT
C-  LR            CM         30.0       BEAM RISE LENGTH
C-  GAMMAO        100.0      BEAM ENERGY PARAMETER
C-  IPROFILE      1          =1 FOR GAUSSIAN PROFILE
C-                                     =2 FOR BENNETT PROFILE
C-  RMIN          CM         .5         MINIMUM RADIUS AT LARGE X
C-  RMAX          CM         40.0       MAXIMUM RADIUS AT LARGE -X
C-  XLOC          CM         15.0       LOCATION OF NECK REGION
C-  XWIDTH        CM         15.0       WIDTH OF NECK REGION
C-
C-  GAS PARAMETERS
C-
C-  ENDO          CM**-3      1.E4      INITIAL ELECTRON DENSITY
C-  KSCATTER      1.699157E3  SCATTERING PARAMETER
C-                                      $4(C^2/MC^2)(CN/MC^2)$ 
C-  KBEAM         6.69        DIRECT DEPOSITION PARAMETER
C-                                      $(DE/Dx)*ROE/(DELTA E^*C)$ 
C-  LAMBDAO       CM         5.13336E4  RADIATION LENGTH
C-  IFROHAT       1          -1 FOR NO CHANNEL
C-  RHOHATQ       1.00       DENSITY, VARY TO VARY PRESSURE
C-
C-  R GRID
C-
C-  NR            NRMX       NUMBER OF R GRID POINTS
C-  B             CM         10.0       MAXIMUM RADIUS FOR FIELDS
C-  NRLNSTEP      40         =0 PURELY EXPONENTIAL R GRID
C-                                     =NR-1 LINEAR GRID
C-                                     -1, - NR-1: HYBRID GRID
C-  RO            1.0        ORIGINAL BEAM RADIUS
C-  RLNFAC        1.0        FRACTION OF RO TO BE LINEAR
C-
C-  X GRID
C-
C-  NX            NXMX       NUMBER OF X GRID POINTS
C-  NDX           1          NUMBER OF DIFFERENT SIZE STEPS
C-  DXVALUES      CM         .2        ARRAY OF X STEP SIZES
C-  XLIMITS       ARRAY OF SWITCHING PLACES
C-

```

Frames 2-11. Snapshots versus r at several X .

Current densities are J_B , $J_{RET} = \sigma E_z$, and $J_{NET} = J_B + J_{RET}$. Since usually $J_{RET} < 0$, $-J_{RET}$ is plotted.

c/v_i is plotted to indicate the refolding distance in centimeters for the computed avalanche ionization rate.

Frames 12,13. Prescribed beam current and radius profiles.

Frame 14. Neutralization fractions, the plotted quantities are:

$$\text{"B"} \rightarrow I_B(X)/I_{B0}$$

$$\text{"R"} \rightarrow -I_{RET}/I_{B0} = \int_0^b -\sigma E_z \frac{2\pi r dr}{I_{B0}}$$

$$\text{"N"} \rightarrow (I_B + I_{RET})/I_{B0} = I_{NET}/I_{B0}$$

$$\text{"U"} \rightarrow I_{EFF}/I_{B0} = \left(\frac{I_A}{I_B}\right) \int_0^b \frac{\sigma}{\gamma mc^2} \frac{\partial}{\partial r} \frac{2\pi r dr J_B}{I_B}$$

I_{EFF} is the effective current providing the beam pinch force:

if, in the magnetic regime, $I_{RET} = 0$ (and $J_{RET} = 0$) then $I_{EFF} =$

I_B ; if J_{RET} has the identical profile to J_B then $I_{EFF} = I_{NET}$.

Frames 15,16,17. X histories of the on-axis ($r=0$) values of E_z , σ , and v_i .

Frame 18. Contour plot of $A(X,r)$, contours are at .1-.9 A_{max} .

Frame 19. Contour plot of $v_i(X,r)$, contours logarithmically spaced.

NO. OUT AVALANCHE IONIZATION RATE PLOT

Figure 1. Plot of the avalanche ionization rate, ν_i , versus E with $\rho = 1.0$. E is varied from 0 to 1000 statvolts/cm.

OUTPUT AVALANCHE IONIZATION RATE PLOT

Figure 2. Plot of the avalanche ionization rate, ν_i , versus E with $\rho = 1.0$. E is varied from 0 to 10000 statvolts/cm. Note that ν_i is reaching the asymptotic value, $\nu_i = 5.05 \times 10^{12}$.

NU1OUT

MOMENTUM TRANSFER COLLISION FR

TIME, DATE:
13:52:33
U 03/11/81

Figure 3. Plot of the momentum transfer collision frequency, ν_m , versus E with $\bar{\rho} = 1.0$. The lower trace is with $T_g = .0235$ eV, the upper trace is with $T_g = .5$ eV.

NU10UT

RECOMBINATION RATE ALPHA

Figure 4. Plot of recombination rate, α , versus $E/\bar{\rho}$. E field values given on the horizontal axis are for $\bar{\rho} = 1.0$.

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VERSION RB9MEM08

ENDTEXT

PHOENIX

BEAM PARAMETERS

IBO(AMPS)	1.000E+04	LR(CM)	= 1.000E+01
GAMMA0	1.000E+02	IPROFILE	= 2
RDMIN(CM)	5.000E-01	ROMAX(CM)	= 5.000E-01
XLOC(CM)	1.500E+01	XWDTH(CM)	= 1.500E+01
ISIGMOD	0		

GAS PARAMETERS

PROD(CM**3)	1.000E+04	KSCATTER	= 1.699E+03
KHEAM	6.690E+00	LAMBDA0	= 3.133E+04
IRHOHAT	1	RHOHAT0	= 1.000E+00

NUMERICAL PARAMETERS

NR	220	B(CM)	= 1.000E+01
NRINSTEP	40	RO(CM)	= 1.000E+00
RINIAC	1.000E+00	NX	= 2500
NDX	1	DXVALUES(1) CM	= 4.000E-02

CASE: A FRAME: 1

SNAPSHOT 1 1 00, X STEP NO 25

CASE A FRAME 2

SNAPSHOT 1 1 00, X STEP NO 25

CASE A FRAME 3

SNAPSHOT 10.00, K STEP NO. 250

CASE A FRAME 4

SNAPSHOT 10.00, K STEP NO. 250

CASE A FRAME 5

SNAPSHOT $t = 20.00$, x STEP NO. 500

CASE A FRAME 6

SNAPSHOT $t = 20.00$, x STEP NO. 500

CASE A FRAME 7

SNAPSHOT * : 50 00, # STEP NO 1250

CASE A FRAME 8

SNAPSHOT * : 50 00, # STEP NO 1250

CASE A FRAME 9

SNAPSHOT # = 100 00, X STEP NO 2500

CASE A FRAME 10

SNAPSHOT # = 100 00, X STEP NO 2500

CASE A FRAME 11

PHOENIX FIELD SOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13 36 58
09/22/81

IBEAM =
9.993E+03
IRISE =
1.000E+0
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

CASE A FRAME 12

PHOENIX FIELD SOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13 36 58
09/22/81

IBEAM =
9.993E+03
IRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

CASE A FRAME 13

PHOTO 10

FIELDSCALPER WITH FIXED LB PLY
PLOT VERSUS X

TIME DATE
13 56 58
09/22/81

BEAM
9.9931+03
LP 1E
1.000E+01
DOM 1
5.000E+01
HOM 1
5.000E+01
+L 1
1.000E+01
+R 1
1.000E+01

CASE 10000000

PHOTO 11

FIELDSCALPER WITH FIXED LB PLY
PLOT VERSUS X

TIME DATE
14 56 58
09/22/81

BEAM
9.9931+03
LP 1E
1.000E+01
DOM 1
5.000E+01
HOM 1
5.000E+01
+L 1
1.000E+01
+R 1
1.000E+01

CASE 10000000

PROBLEM 1: PLOT OF $\log R$ WITH FIXED SUB, R_0
PLOT VERSUS $\log R_0$

TIME DATE
15 36 08
09-22-81

BLANK
9 99999999
4 54
1 00000000
00000000
1 00000000
00000000
1 00000000
00000000
1 00000000
00000000
1 00000000
00000000

CASE 1: 10000000

PROBLEM 2: PLOT OF $\log R$ WITH FIXED SUB, R_0
PLOT VERSUS $\log R_0$

TIME DATE
15 36 08
09-22-81

BLANK
9 99999999
4 54
1 00000000
00000000
1 00000000
00000000
1 00000000
00000000
1 00000000
00000000
1 00000000
00000000

CASE 1: 10000000

FIGURE 1. FIELD OVER WITH FIXED $UB(R,X)$
CONTOUR PLOT OF $AC(R,X)$

TIME DATE
15 56 58
09 22 81

NAME
1. 1000-01
2. 1000-01
3. 1000-01
4. 1000-01
5. 1000-01
6. 1000-01
7. 1000-01

NO

C1: 1. 1000-01
C2: 2. 1000-01
C3: 3. 1000-01
C4: 4. 1000-01
C5: 5. 1000-01
C6: 6. 1000-01
C7: 7. 1000-01
C8: 8. 1000-01
C9: 9. 1000-01
C10: 10. 1000-01

X (CM)

FIGURE 1. 1000-01

FIGURE 2. FIELD OVER WITH FIXED $UB(R,X)$
CONTOUR PLOT OF $MUSCH(R,X)$

TIME DATE
15 56 58
09 22 81

NAME
1. 1000-01
2. 1000-01
3. 1000-01
4. 1000-01
5. 1000-01
6. 1000-01
7. 1000-01

NO

C1: 1. 1000-01
C2: 2. 1000-01
C3: 3. 1000-01
C4: 4. 1000-01
C5: 5. 1000-01
C6: 6. 1000-01
C7: 7. 1000-01
C8: 8. 1000-01
C9: 9. 1000-01
C10: 10. 1000-01

X (CM)

FIGURE 2. 1000-01

PARAMETERS

BEAM PARAMETERS

B(AMPERE)	1.00E+04	LR(CM)	1.000E+01
AWMAG	1.000E+01	PROF(1)	.
ROMAX(1)(CM)	1.000E+01	ROMAX(CM)	5.000E+01
R(1)(CM)	1.500E+01	XWIDTH(CM)	1.500E+01
R(CM)	1.		

PLASMA PARAMETERS

PHI(1) (METER)	1.000E+04	RSCATTER	1.699E+03
PERAM	1.000E+01	LAMBDAPO	3.133E+04
PHI(2) (METER)	1.	RHOHAT0	1.000E+01

NUMERICAL PARAMETERS

NB	22	B(CM)	1.000E+01
NB(INTER)	4	R0(CM)	1.000E+00
RESIDUAL	1.00E+03	NX	2500
NDX	1	DXVALUES(1) CM	4.000E-02

CASE B FRAME 1

SNAPSHOT: 1.00, STEP NO. 25

CASE B FRAME 2

SNAPSHOT: 1.00, STEP NO. 25

CASE B FRAME 3

SNAPSHOT * * 10 00, * STEP NO 250

CASE B FRAME 4

SNAPSHOT * * 10 00, * STEP NO 250

CASE B FRAME 5

SNAPSHOT $x = 20.00$, STEP NO 500

CASE B FRAME 6

SNAPSHOT $x = 20.00$, STEP NO 500

CASE B FRAME 7

SNAPSHOT : 50.00, STEP NO. 126

CASE B FRAME 8

SNAPSHOT : 50.00, STEP NO. 129

CASE B FRAME 9

SNAPSHOT # = 100 00, # STEP NO 2500

CASE B FRAME 10

SNAPSHOT # = 100 00, # STEP NO 2500

CASE B FRAME 11

PHOENIX

FIELDSOLVER WITH FIXED JB(R,X) PLOT VERSUS X

TIME, DATE
13 52 50
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

CASE B FRAME 12

PHOENIX

FIELDSOLVER WITH FIXED JB(R,X) PLOT VERSUS X

TIME, DATE
13 52 50
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

CASE B FRAME 13

PHOENIX

FIELDSOLVER WITH FIXED JB(R,X) PLOT VERSUS X

TIME, DATE
13:52:50
09/22/81

IBEAM =
9.993E+03
IRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

NEUTRAL

CASE B FRAME 14

PHOENIX

FIELDSOLVER WITH FIXED JB(R,X) PLOT VERSUS X

TIME, DATE
13:52:50
09/22/81

IBEAM =
9.993E+03
IRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

NEUTRAL

CASE B FRAME 15

PHOENIX

IELDSOLVER WITH FIXED JB(R,x) PLOT VERSUS x

TIME, DATE
13 52 50
09/22/81

IBEAM =
9.993E+03
IRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

$S_z(R=0)$

CASE B FRAME 16

PHOENIX

IELDSOLVER WITH FIXED JB(R,x) PLOT VERSUS x

TIME, DATE
13 52 50
09/22/81

IBEAM =
9.993E+03
IRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

$S_z(R=0)$

CASE B FRAME 17

PHOENIX

FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF AO(R,X)

TIME, DATE
15 52 50
09/22/81

PROB
1. 0000E+01
2. 0000E+01
3. 0000E+01
4. 0000E+01
5. 0000E+01
6. 0000E+01
7. 0000E+01
8. 0000E+01
9. 0000E+01
10. 0000E+01

AO
C1 1.0 1.0000E+01
C2 2.0 1.0000E+01
C3 3.0 1.0000E+01
C4 4.0 1.0000E+01
C5 5.0 1.0000E+01
C6 6.0 1.0000E+01
C7 7.0 1.0000E+01
C8 8.0 1.0000E+01
C9 9.0 1.0000E+01
C10 10.0 1.0000E+01

R (CM)

X (CM)

CASE 8 FRAME 18

PHOENIX

FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF NUSUB1(R,X)

TIME, DATE
15 52 50
09/22/81

PROB
1. 0000E+01
2. 0000E+01
3. 0000E+01
4. 0000E+01
5. 0000E+01
6. 0000E+01
7. 0000E+01
8. 0000E+01
9. 0000E+01
10. 0000E+01

NUSUB1
C1 1.0 1.0000E+01
C2 2.0 1.0000E+01
C3 3.0 1.0000E+01
C4 4.0 1.0000E+01
C5 5.0 1.0000E+01
C6 6.0 1.0000E+01
C7 7.0 1.0000E+01
C8 8.0 1.0000E+01
C9 9.0 1.0000E+01
C10 10.0 1.0000E+01

R (CM)

X (CM)

CASE 8 FRAME 19

044-444444

BEAM PARAMETERS

IBD(AMPS)	1.000E+05	IP(CM)	5.000E+01
GAMMA0	1.000E+01	IPROFILE	1
ROMIN(CM)	2.000E+01	PUMAX(CM)	4.000E+01
XLOC(CM)	1.500E+01	KWIDTH(CM)	1.500E+01
YLOC(CM)	0		

GAS PARAMETERS

END0(CM**3)	1.000E+04	KSCATTER	1.699E+03
KRAM	6.690E+00	LAMBDA0	3.133E+04
TERH0AT	1	RHOH0T	1.000E+00

NUMERICAL PARAMETERS

NR	250	B(CM)	1.000E+01
NRNSTEP	40	RO(CM)	1.000E+00
RUNFAC	1.000E+00	NX	2500
NDA	1	DXVALUES(') CM=	4.000E-02

CASE C FRAME

SHARPLOT 1 00 4 STEP NO 25

CASE 0 FRAME 2

SHARPLOT 1 00 4 STEP NO 25

CASE 0 FRAME 3

SAMPLE NO. 1 TO 20 + STIR NG 1.00 CASE 1 NAME 1

SAMPLE NO. 1 TO 20 + STIR NG 1.00 CASE 1 NAME 1

SNAPSHOT - 20.00, # STEP NO. 500

CASE C, FRAME 6

SNAPSHOT - 20.00, # STEP NO. 1000

CASE C, FRAME 10

SNAPSHOT = 50.00 STEP NO. 1250

CASE C FRAME B

SNAPSHOT = 50.00 STEP NO. 1250

CASE C FRAME B

SNAPSHOT # 100 00, # STEP NO 2500

CASE C FRAME 10

SNAPSHOT # 100 00, # STEP NO 2500

CASE C FRAME 11

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13 57 15
09/22/81

IBEAM =
9.993E+04
LR/SE
5.000E+01
ROMIN =
2.000E+01
ROMAX =
4.000E+01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

CASE C FRAME 12

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13 57 15
09/22/81

IBEAM =
9.993E+04
LR/SE
5.000E+01
ROMIN =
2.000E+01
ROMAX =
4.000E+01
XLOC =
1.500E+01
XWIDTH =
1.500E+01

CASE C FRAME 13

PHOENIX

FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13 57 15
09/22/81

IBEAM
9.995E+04
RUSE
5.000E+01
ROMIN
2.000E+01
ROMAX
4.000E+01
KLOC
1.500E+01
KWDTH
1.500E+01

CASE C FRAME 14

PHOENIX

FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13 57 15
09/22/81

IBEAM
9.995E+04
RUSE
5.000E+01
ROMIN
2.000E+01
ROMAX
4.000E+01
KLOC
1.500E+01
KWDTH
1.500E+01

CASE C FRAME 15

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13 57 15
09/22/81

IBLAM =
9.995E+04
LRISI =
5.000E+01
ROMIN =
2.000E+01
ROMAX =
4.000E+01
KLOC =
1.500E+01
XWIDTH =
1.500E+01

CASE C FRAME 16

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13 57 15
09/22/81

IBLAM =
9.995E+04
LRISI =
5.000E+01
ROMIN =
2.000E+01
ROMAX =
4.000E+01
KLOC =
1.500E+01
XWIDTH =
1.500E+01

CASE C FRAME 17

TIME, DATE
13 57 15
04/22/81

[illegible]

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1981	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100																				

2,
14 $\kappa(\text{CM})$

CASE 6 PAGE 18

TIME, DATE
13 51 15
09/22/81

0000
0000
0000
0000
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0000

Age	Sex	Height (cm)	Weight (kg)	Body Fat (%)	Lean Body Mass (kg)
21	M	175	75	15	63.75
22	F	165	60	20	48.00
23	M	180	85	18	70.10
24	F	170	70	22	54.40
25	M	185	90	20	72.00
26	F	160	55	25	41.25
27	M	190	100	22	78.00
28	F	175	75	28	54.00
29	M	180	80	25	60.00
30	F	165	65	30	45.50

25

$\times \{CM\}$

CASE C FRAME '9

PHOENIX

BEAM PARAMETERS

IBO(AMPS)	1.000E+05	LR(CM)	= 3.000E+01
GAMMA0	1.000E+02	IPROFILE	= 2
ROMIN(CM)	5.000E-01	ROMAX(CM)	= 1.000E+02
XLOC(CM)	2.000E+01	XWIDTH(CM)	= 1.800E+01
ISIGMOD	0		

GAS PARAMETERS

FN00(CM**3)	1.000E+04	KSCATTER	= 1.699E+03
KBEAM	6.690E+00	LAMBDA0	= 3.133E+04
IRHOHAT	1	RHOHAT0	= 1.000E+00

NUMERICAL PARAMETERS

NR	220	B(CM)	= 1.000E+01
NRINSTEP	40	RO(CM)	= 1.000E+00
RLNFACT	1.000E+00	NX	= 2500
NDX	1	DXVALUES(1) CM	= 4.000E-02

CASE: D FRAME: 1

SNAPSHOT # = 100, # STEP NO 25

CASE D FRAME 2

SNAPSHOT # = 100, # STEP NO 25

CASE D FRAME 3

SNAPSHOT X = 10.00, Y STEP NO 250

CASE D FRAME 4

SNAPSHOT X = 10.00, Y STEP NO 250

CASE D FRAME 5

SNAPSHOTS # 20 00, # STEP NO 500

CASE D FRAME 8

SNAPSHOTS # 20 00, # STEP NO 500

CASE D FRAME 7

SNAPSHOT# 4 - 50 00, # STEP NO 1250

CASE D FRAME 8

SNAPSHOT# 4 - 50 00, # STEP NO 1250

CASE D FRAME 9

SNAPGAP* * 100.00 * STEP NO. 2500

CASE 2 FORM 10

SNAPGAP* * 100.00 * STEP NO. 2500

CASE 2 FORM 10

ME. LA
4 04 25
09/22/81

BEAM
4 00000000
D 00
5 00000000
00000000
5 00000000
00000000
1 00000000
5 00000000
5 00000000
1 00000000

201 2 1000 1

[illegible]

AS(7 4 2002) 3

PHOTO. 4 FIELD OVER WITH FIXED B(R,X)
R, CT. VERSUS X

TIME DATE
14 04 23
09/22/81

BEAM
9.945E+14
R 0.1
5.000E+11
RPM %
5.000E+11
RPM %
1.000E+11
RPM %
2.000E+11
RPM %
1.000E+11

CASE D FROM 14

PHOTO. 5 FIELD OVER WITH FIXED B(R,X)
R, CT. VERSUS X

TIME DATE
14 04 23
09/22/81

BEAM
9.945E+14
R 0.1
5.000E+11
RPM %
5.000E+11
RPM %
1.000E+11
RPM %
2.000E+11
RPM %
1.000E+11

CASE D FROM 15

• 02

0-100000

• (CM)

1456 2 1 JAN 1951

1991

1. CM.

456 = 202/1