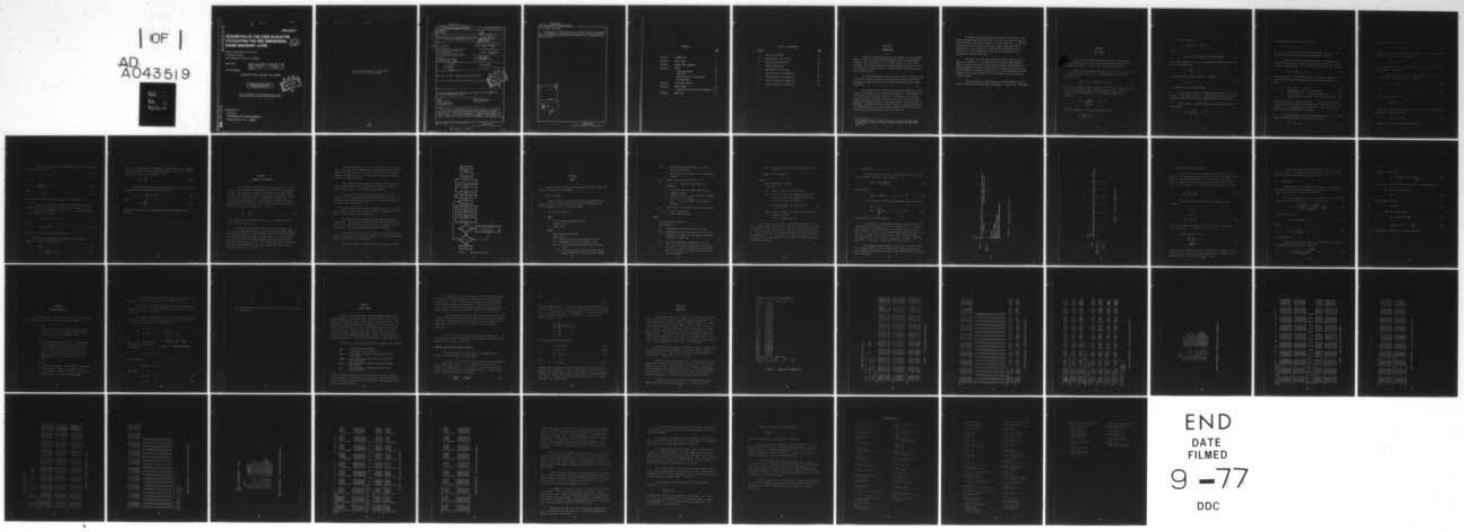
AD-A043 519 MISSION RESEARCH CORP SANTA BARBARA CALIF F/G 20/8
DESCRIPTION OF THE CODE SCALID FOR CALCULATING THE ONE DIMENSIO--ETC(U)
MAY 76 N J CARRON DNA001-76-C-0086
UNCLASSIFIED MRC-R-267 DNA-4237T NL

| OF |
AD
A043519



END
DATE
FILMED
9-77
DDC

DNA 4237T

DESCRIPTION OF THE CODE SCALID FOR CALCULATING THE ONE DIMENSIONAL SGEMP BOUNDARY LAYER

Mission Research Corporation
735 State Street
Santa Barbara, California 93101

May 1976

Topical Report

CONTRACT No. DNA 001-76-C-0086

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

THIS WORK SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE B323076464 R99QAXEB06964 H2590D.

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, D. C. 20305

Destroy this report when it is no longer needed. Do not return to sender.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: DNA 4237T	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE *(and Subtitle)*: DESCRIPTION OF THE CODE SCALID FOR CALCULATING THE ONE DIMENSIONAL SGEMP BOUNDARY LAYER.	5. TYPE OF REPORT & PERIOD COVERED: Topical Report.
6. PERFORMING ORG. REPORT NUMBER: MRC-R-267	
7. AUTHOR(s): N. J. Carron	8. CONTRACT OR GRANT NUMBER(s): DNA 001-76-C-0086
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Mission Research Corporation, 735 State Street, Santa Barbara, California 93101	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Subtask R99QAXEB069-64
11. CONTROLLING OFFICE NAME AND ADDRESS: Director, Defense Nuclear Agency, Washington, D.C. 20305	12. REPORT DATE: May 1976 13. NUMBER OF PAGES: 50
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*: 47p.	15. SECURITY CLASS *(of this report)*: UNCLASSIFIED 15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B323076464 R99QAXEB06964 H2590D.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

SGEMP
Photo Emission
X-ray Photo Effect
Prescribed Current
SGEMP Boundary Layer
Electron Emission

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report is a description of, and a user's manual for, the FORTRAN code SCALID which computes the time dependent electron emission SGEMP boundary layer in one Cartesian dimension. It assumes no skin currents flow on the surface. The code solves the nonlinear Newton's laws for particle motion in the electric field produced by all electrons in the boundary layer.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

406 548

AB

20. ABSTRACT (Continued)

Charge density, current density, field strength, potential, dipole moment, etc., are computed as a function of position and time. The code calculates with the scaled dimensionless equations of motion, assuring adequate time and space resolution.

CONTENTS

LIST OF ILLUSTRATIONS

SECTION 1

INTRODUCTION

SCAL1D is a particle moving code that computes the time dependent dynamics of the electron emission SGEMP boundary layer in one Cartesian dimension. The calculation is self-consistent in that it is the correct solution to the nonlinear equations of motion using the local electric field to accelerate the electrons, but it is assumed that no skin currents flow on the target surface.

The code will accept as input an arbitrary fluence, arbitrary X-ray time history, and an arbitrary electron energy spectrum which can be read in either as a normal spectrum or as the spectrum assuming a $\cos\theta$ angular distribution.

As the name implies, SCAL1D computes with the dimensionless scaled equations of motion which were discussed in Reference 1. The advantage of this is that the dimensionless variables are independent of the separate quantities fluence, pulse width, material yield, etc. so that the numbers computed and handled internally by the code are always of the same order of magnitude. Consequently the user need not decide on a different time step and a different cell size for each problem, thereby simplifying the use of the code and assuring a uniform accuracy and resolution.

---

[1] C.L. Longmire, and N.J. Carron, "Scaling of the Time Dependent SGEMP Boundary Layer", Mission Research Corporation, MRC-R-262, DNA 3975T, April 1976.

The outputs are the dimensionless electric field, potential, dipole moment, and charge and current densities as a function of position, and the spatial integral of the current density, all at selected times. In addition, the physical units of electric field, time, length, charge and current densities, etc., are printed out (in both MKS and Gaussian ESU units) so that physically correct quantities can be obtained by multiplying the dimensionless output by these units.

The results give the electron emission current in the absence of target skin currents, i.e., in the absence of any target SGEMP response. Hence, if the user inputs the correct electron emission spectrum from the material surface into vacuum, the electron space currents calculated in the code are good for a conducting target only if it can be shown that the target response (such as skin current) does not significantly alter the emission electron dynamics.

Persons interested in obtaining the code SCALID should direct the request to the Defense Nuclear Agency, Washington, DC 20305, ATTN: RAEV/SGEMP.

SECTION 2

BASIC IDEAS

The physical principles leading to the scaling of the boundary layer equations to obtain scaling laws and dimensionless equations were discussed in Reference 1. Here we only sketch the relevant ideas.

When X-rays are normally incident with a flux $F(t)$ (cal cm^{-2} sec^{-1}) on a flat plate with material yield Y (electrons/cal), electrons are ejected at a rate

$$r_0(t) = Y\,F(t) \quad \text{electrons } cm^{-2}\ sec^{-1} \quad . \tag{1}$$

Let v be the normal velocity component of the electrons. Then the emission angular distribution and energy spectrum determine dn/dv (electrons $(cm/sec)^{-1}$), the distribution of v. The normalized normal velocity spectrum is

$$g(v) = \frac{dn/dv}{\int_0^\infty \frac{dn}{dv}\,dv} \quad (cm/sec)^{-1} \tag{2}$$

such that $\int g(v)dv = 1$. The average normal velocity is

$$\bar{v} = \int_0^\infty v\ g(v)\ dv. \tag{3}$$

Let the fluence be

$$\phi = \int_0^\infty F(t)\, dt \qquad \text{cal/cm}^2 \quad , \tag{4}$$

and let

$$T_h = \text{pulse full width at half maximum (FWHM).} \tag{5}$$

be the FWHM in seconds. Then T_h is a naturally occurring characteristic time in the problem, and

$$N_1 = \frac{Y\phi}{\bar{v}\, T_h} \qquad \text{cm}^{-3} \quad , \tag{6}$$

is a naturally occurring number density. Similarly,

$$L_1 = \bar{v}\, T_h \qquad \text{cm} \tag{7}$$

is a naturally occurring unit of length.

Thus the source specifies a characteristic velocity $\bar{v}$, time T_h, length L_1, and number density N_1. These quantities can serve as units in terms of which one can measure all dimensioned dynamical variables.

However, there is another naturally occurring unit of time, the plasma period

$$T_p = \sqrt{\frac{m}{4\pi\, e^2\, N_1}} \qquad \text{sec} \tag{8}$$

and a corresponding distance, the Debye length

$$\ell_D = \bar{v}\, T_p \quad \text{cm} . \tag{9}$$

T_h is the time scale for the emission rate to change, while T_p is the time scale for the internal electron plasma dynamics to change.

In any particle moving code that calculates the boundary layer structure, the time step Δt must be small compared to both T_h and T_p. In SCALID, the unit of time, UT, is chosen as the smaller of T_p and T_h,

$$UT = MIN(T_p, T_h) \quad \text{sec.} \tag{10}$$

and the time step is a small fraction of UT. Real time is measured as a multiple of UT, thereby defining dimensionless time, denoted here by a prime, t':

$$\text{Real time} = UT \cdot t' \tag{11}$$

$$\text{Dimensionless Time} = t' = \text{Real time}/UT \tag{12}$$

$$\text{Real time step} = \Delta t = \text{small fraction of UT} \tag{13}$$

$$\text{Dimensionless time step} \equiv \Delta t' = \text{small fraction of unity} \tag{14}$$

The time in the code is dimensionless time t', and the time step is $\Delta t'$ (called DT in the code) and is small compared to 1. Typically, $DT = \Delta t' \approx 0.025$ is used. UT is calculated in the code, but DT is user supplied. DT usually need not vary from problem to problem.

Since the problem has only one characteristic velocity, $\bar{v}$, once a unit of time has been chosen (UT) the unit of length is

$$UL = \bar{v} \cdot UT \quad \text{cm.} \tag{15}$$

The unit of velocity is, of course,

$$UV = \bar{v} \ . \qquad \text{cm/sec} \tag{16}$$

If the X-ray pulse is not simply a power of time, T_h exists, and the unit of number density UN is N_1 of Equation (6),

$$UN = N_1 \quad \text{cm}^{-3} \tag{17}$$

If the pulse continues to rise as a power of time, T_h does not exist and UN is computed as in Section 4D.

The unit of emission rate is therefore determined to be $N_1\bar{v}$. The dimensionless time history $F'(\tau)$ is defined by

$$F(t) = \frac{\Phi}{T_h} \ F'(\tau) \ . \tag{18}$$

where

$$\tau = t/T_h \ . \tag{19}$$

It is normalized to unity,

$$\int_0^\infty F'(\tau) \ d\tau = 1 \tag{20}$$

and the full width at half maximum of $F'(\tau)$ is unity. The emission rate Equation (1), can now be written

$$r_0(t) = N_1 \ \bar{v} \ F'(\tau) \tag{21}$$

so that $F'(\tau)$ is the dimensionless emission rate.

With $g(v)$ the normalized spectrum of Equation (2), a dimensionless spectrum can be defined as

$$g'(v') = \bar{v}\, g(v) \quad , \tag{22}$$

so that

$$\int_0^\infty g'(v')dv = 1 \ , \tag{23}$$

where

$$v' = \frac{v}{\bar{v}} \tag{24}$$

is the normal component of velocity measured as a multiple of $\bar{v}$.

In a particle moving code, each particle on emission represents the charge emitted by all electrons with velocity, say, between v' and $v' + \Delta v'$ and during time between t' and $t' + \Delta t'$. The weight attributed to such a particle is therefore

$$\Delta W = g'(v')\ F'(\tau)\ \Delta v'\ \Delta t' \quad , \tag{25}$$

with

$$\tau = \frac{t}{T_h} = \frac{UT}{T_h}\ t' \ . \tag{26}$$

Equation (25) is the weight of an emitted particle.

Once emitted, the particles are moved by the dimensionless equations of motion derived in Reference 1:

$$\frac{dv'}{dt'} = a' \tag{27}$$

$$a' = -\alpha^2 \int_{x'}^{\infty} n'(x',t')dx' \quad . \tag{28}$$

Here n' is the dimensionless number density (number density/N_1). Equation (28) is the correct expression for the dimensionless electric field if the unit of time $UT = T_h$, as in Reference 1, and

$$\alpha^2 = \frac{T_h^2}{T_p^2} \quad . \tag{29}$$

In SCALID, the unit of time is given by Equation (10), and instead of Equation (28), the dimensionless field is given by

$$a' = - A \int_{x'}^{\infty} n'(x',t')dx' \quad , \tag{30}$$

where

$$A = \frac{(UT)^2}{T_p^2} \quad . \tag{31}$$

Equations (27) and (30) are the dimensionless equations of motion used in the code.

SECTION 3

GENERAL CODE STRUCTURE

After all input quantities are read in, the space grid is set up. The space grid is used for calculating the electric field as a function of position. Since dynamical quantities are expected to vary more rapidly near the surface than farther away, the space grid has logarithmic spacing, with each cell a constant factor ξ thicker than the previous one. If many cells are used (one may use up to 500 cells), ξ must not be much larger than unity. If there are NC cells, the ratio of the thickness of the last cell, ℓ_{NC}, to the first cell, ℓ_1, is

$$\frac{\ell_{NC}}{\ell_1} = \xi^{NC-1} \quad . \tag{32}$$

If NC = 500, this will be unwieldly large if ξ is greater than about 1.005, for which $\ell_{NC}/\ell_1 \approx 12$.

The first cell nearest the surface will be the thinnest. The first few cells should not be made too thin. They should be small compared to a Debye length (that is, small compared to unity in the code's dimensionless variables) but large enough to contain on the order of 100 particles per cell for good statistics when computing charge and current densities. (The number of particles per cell is also affected, of course, by the number NV of particles emitted every time step.) We find good results if the first cell thickness is ~ 0.05 to 0.1.

The input spectrum is read in as an energy spectrum with energies in keV. The input energy spectrum may be either that for a $\cos\theta$ emission angular distribution (ICN = 0), or it may be the spectrum for the normal component of energy (ICN = 1). If the former, the spectrum is internally converted to a normal spectrum.

The spectrum is then converted to a normal velocity spectrum dn/dv, and the input energies are converted to normal velocities. The average normal velocity $\bar{v}$ and energy are then computed.

The spectrum and velocities are now normalized, velocities (as multiples of $\bar{v}$) are the dimensionless particle emission velocities. If NV energies were originally read in, there are NV particles emitted every time step. They all have weight 1/NV.

Before entering the time loop, the dimensional units of length, time, velocity, electric field strength, potential, charge density, current density, etc., are computed and printed out.

The time loop is then entered, with the new particles being emitted first. Their weight is determined by the time history taken from function FT. Then all particles are moved, using old velocities and old accelerations. New fields are then calculated at cell edges.

If the cycle is a print cycle, quantities of interest that are not needed in the particle moving loop are computed, such as current and charge densities and potentials, and are printed.

The code structure is exhibited in the flow diagram in Figure 1.

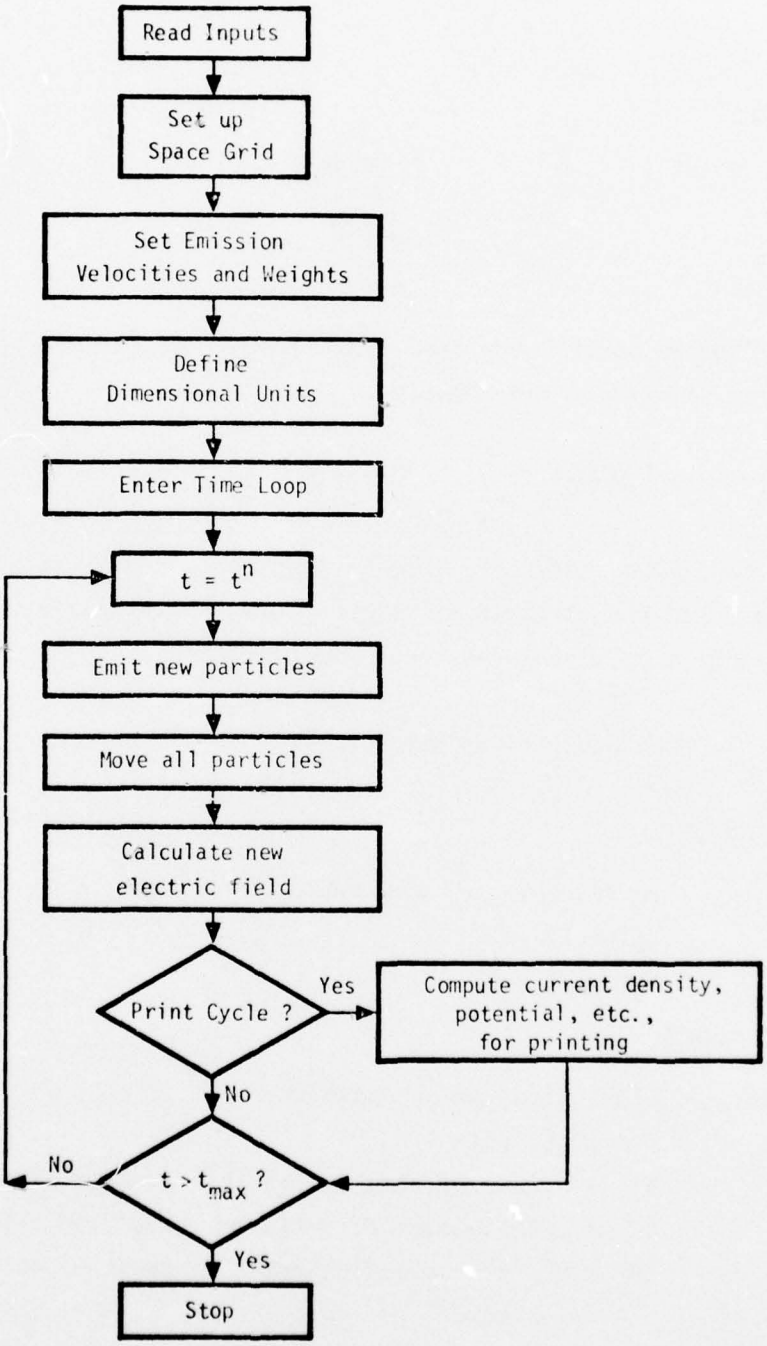


Figure 1. Flow chart of SCAL1D.

SECTION 4

INPUT

Here we discuss the input card format and the way the space grid and emission velocities are computed.

A. INPUT CARD FORMAT

Four basic cards are read in per problem, plus an additional NV cards specifying the electron emission spectrum if it differs from the previous problem or if this is the first problem.

The four basic cards are:

CARD 1

An 80 character alphanumeric title.
TITLE(I), I = 1,8
Format (8A10)

CARD 2

Eight fixed point parameters.
Format (14I5)
NT = number of time cycles this problem is to run
NC = total number of cells in space grid, ≤ 500
IR = 0 - Read electron emission spectrum on following cards
= 1 - Use same spectrum as previous problem (IR can equal 1 only if this is not the first problem)

ICN = 0 - the electron energy spectrum is for a $\cos\theta$ angular distribution

= 1 - the electron energy spectrum is the normal energy spectrum

NV = number of spectrum points read in, ≤ 100

IT = 1, 2, 3, ... = choice of time histories, see FUNCTION FT

= 1 - X-ray pulse rises as a power (POW) of time

= 2 - symmetric triangle

= 3 - asymmetric triangle. Rises to peak in 0.5*FWHM, falls to zero at 2.0*FWHM

= 4, 5, 6, ... - user must define a time history in FUNCTION FT

IP = print cycles. A printout will occur every IP cycles.

LP = 0 - this is last problem

= 1 - another problem follows

CARD 3

Five floating point variables.
Format (8E10.3)

DT = dimensionless time step (typically DT $\approx$ 0.025)

XMAX = dimensionless distance from surface to end of grid. Essentially the number of Debye lengths in the grid. (Typically $20 \lesssim$ XMAX $\lesssim 100$)

XI = Space grid logarithmic spacing ratio, ≥ 1.0. If XI = 1.0 all cells are the same size. If XI > 1.0 , each cell is a factor XI thicker than the preceeding one. If NC is large, XI must not be too large for practical purposes.

POW = power of time of X-ray time history (used only if IT = 1)

PROBNO = problem number

CARD 4

Three floating point variables.
Format (8E10.3)

YIE = material yield in electrons/calorie

FLU - If IT ≠ 1, FLU = X-ray fluence in calories/cm^2

- If IT = 1, FLU is the coefficient determined (by the user) from the equation

$$\text{X-ray flux}\left(\frac{\text{cal}}{\text{cm}^2\ \text{sec}}\right) = \text{FLU}\ (\text{time(sec)})^{\text{POW}} . \qquad (33)$$

FWHM - If IT ≠ 1, FWHM = X-ray pulse full width at half maximum in seconds.

- If IT = 1, FWHM is not used.

These four cards are read for each problem. In addition, if IR = 0, NV more cards are read in which specify the electron energy spectrum in format 2E10.3. The first number on each card is the electron energy in keV. The second number is the value of the energy spectrum at that energy, in arbitrary units. The energy spectrum is normalized within the code, so no special units need be used on input. The correct normalization information is contained in YIE.

B. SPACE GRID

The space grid is set up first. The thickness of the I-th cell is called XB(I). The first cell is given by

$$XB(1) = XMAX \frac{(XI-1.)}{(XI^{NC}-1.)} \tag{34}$$

and thereafter,

$$XB(I) = XI*XB(I-1) , \quad I = 2, 3, \ldots, NC. \tag{35}$$

An array SL(J) is defined as the distance to the J-th cell, by

$$SL(1) = 0.$$

$$SL(J) = \sum_{I=1}^{J-1} XB(I) , \quad J = 2, 3, \ldots NC+1. \tag{36}$$

The space grid is sketched in Figure 2.

Since the grid is logarithmically spaced, the bins fall at inconvenient locations for printing quantities as a function of x. Instead, output quantities are computed every 0.1 length units using an array K10(I) defined as follows. Mark every tenth length unit on the grid, as in Figure 3. Each mark will fall in some bin. K10(I) is the bin number in which the mark for x = 0.1*J falls. For example, in Figure 3, K10(7) = 6, and K10(2) = 3, meaning 0.7 length units falls in bin 6, etc.

When computing output quantities, array K10 is used to locate the bin corresponding to every 0.1 length units. Output quantities are then computed by averaging over that bin and two adjacent bins, as discussed later in Section 6.

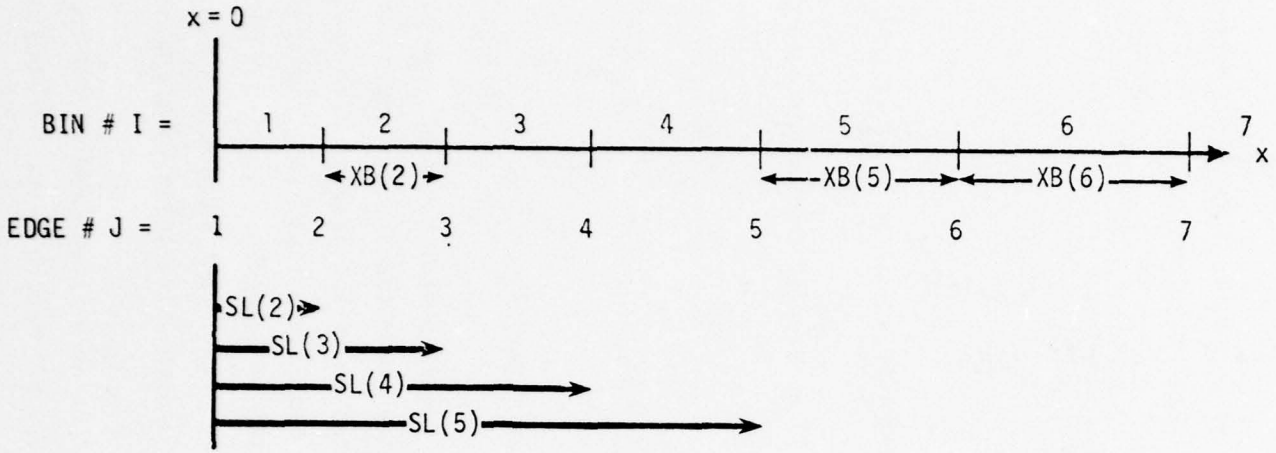


Figure 2. Space grid with XB and SL.

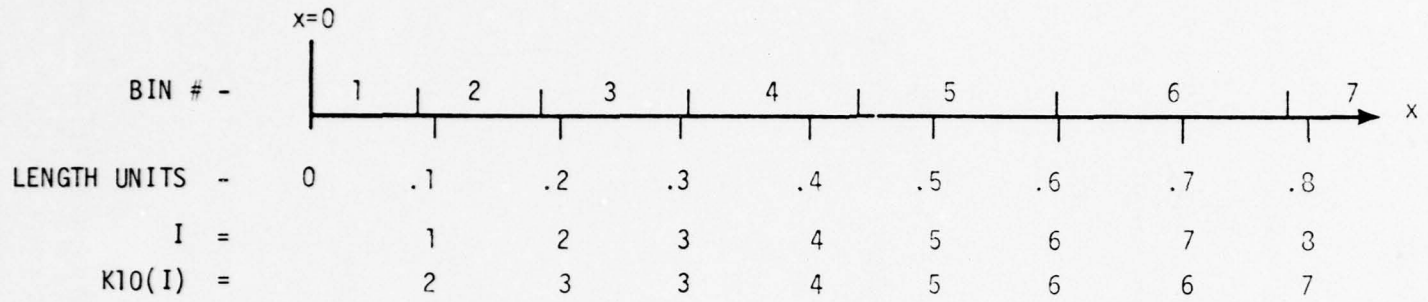


Figure 3. Space grid showing K1O(I).

C. EMISSION VELOCITIES AND WEIGHTS

As read in, the emission spectrum is an energy spectrum with energies in keV and either a normal spectrum (ICN = 1) or the energy spectrum for a $\cos\theta$ angular distribution (ICN = 0). If the latter, the spectrum dn/dE is converted to a normal energy spectrum, dn/dw, where $E=(1/2)mv^2$, and $w = (1/2)mv_x^2$, where v_x is the normal velocity component, according to

$$\frac{dn}{dw} = \int_w^\infty \frac{1}{E} \frac{dn}{dE} dE \quad . \tag{37}$$

This normal energy spectrum is then converted to a velocity spectrum by

$$\gamma = 1 + \frac{w}{mc^2}$$

$$v = c\sqrt{1 - 1/\gamma^2}$$

$$\frac{dn}{dv} = mv\ \gamma^3 \frac{dn}{dw} \tag{38}$$

where we have dropped the subscript x on v. Here γ is the usual relativistic factor $\gamma = (1-v^2/c^2)^{-1/2}$, and $w = (\gamma-1)\ mc^2$.

The average normal velocity

$$v = \frac{\int_0^\infty v \frac{dn}{dv} dv}{\int_0^\infty \frac{dn}{dv} dv} \tag{39}$$

is then computed, and the spectrum is normalized to unit integral, as in Equations 3 and 2. Velocities are now normalized to $\bar{v}$. These velocities are called VE(I), and the spectrum GV(I), I=1,NV.

Finally the spectrum is divided into bins of equal area, and the velocities VE(I) are redefined as the central velocities of those bins. This gives to each emitted particle the weight GV(I) = 1/NV.

D. PHYSICAL UNITS

SCAL1D calculates with dimensionless quantities. To get physical results these numbers must be multiplied by the appropriate dimensional unit. These units are calculated and printed out.

If the pulse does not rise as a power of time (IT ≠ 1) then FWHM exists and the unit of number density is as in Equation (6).

$$UN = \frac{\text{Yield}\left(\frac{\text{elec}}{\text{cal}}\right) \cdot \text{fluence}\left(\frac{\text{cal}}{\text{cm}^2}\right)}{\bar{v}\ (\text{cm/sec}) \cdot \text{FWHM(sec)}} \quad \left(\frac{\text{elec}}{\text{cm}^3}\right) \quad , \tag{40}$$

and the unit of time is

$$UT = MIN(T_p, FWHM) \quad \text{sec}, \tag{41}$$

where

$$T_p = \sqrt{\frac{m}{4\pi\ e^2 \cdot UN}} \quad \text{sec} \quad , \tag{42}$$

is the plasma period.

If the pulse rises as a power of time, t^{POW}, (IT = 1) then there is no FWHM, and the unit of time is taken as[1]

$$UT = \left(\frac{m\bar{v}}{4\pi e^2 \cdot \text{Yield} \cdot \text{FLU}}\right)^{\frac{1}{2+POW}} \quad \text{sec} \quad . \tag{43}$$

The unit of number density is

$$UN = \frac{\text{Yield FLU}}{\bar{v}} \quad (UT)^{POW} \quad \left(\frac{elec}{cm^3}\right) \quad . \tag{44}$$

In Equations (43) and (44), the quantity FLU is that from Equation (33).

The unit of velocity is always

$$UV = \bar{v} \quad , \tag{45}$$

and the unit of length is

$$UL = UV*UT \quad , \tag{46}$$

The unit of charge density is

$$UR = 4.8\times10^{-10} \; UN \; \frac{esu}{cm^3} \quad , \tag{47}$$

or

$$URM = 1.6\times10^{-13} \; UN \quad \frac{coul}{m^3} \quad , \tag{48}$$

in MKS units. Other units are computed similarly.

SECTION 5

PULSE TIME HISTORY

Three time histories are built into SCAL1D. The user chooses one by the value of IT on input. They are contained in FUNCTION FT.

IT = 1

This is for an X-ray pulse that rises in time like a power of t. The power is read in (POW) on card 3. The X-ray flux is given by Equation (33).

IT = 2

A symmetric triangle time history. As computed and used in FUNCTION FT its full width at half maximum is unity, and its integral is also unity. Thus it rises to value 1 at time 1 and falls to zero at time 2. The correct scale of time is taken care of when FUNCTION FT is called, using FWHM read in on card 4.

IT = 3

An asymmetric triangle. In FUNCTION FT its full width at half maximum is 1 as is its integral. It rises to 1 at time 0.5, and falls to zero at time 2.0. Thus the rise time is 1/4 of the full pulse length.

The user chooses one of these time histories by its shape, and reads in the real full width at half maximum as FWHM on card 4.

The coding in FUNCTION FT allows the user to add additional time histories (IT = 4 or 5). As used in FUNCTION FT it must have unit integral and unit full width at half maximum.

For example, if one desires a time history with the shape of the trapezoid in Figure 4, which rises in 0.25 pulse length and stays flat to 0.5 pulse length, one would, in FUNCTION FT, choose

$$t_1 = 0.25\ t_3$$

and

$$t_2 = 0.5\ t_3.$$

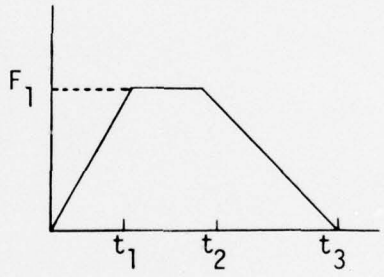


Figure 4. Trapezoid time pulse

Then t_3 and F_1 are chosen by requiring unit full width at half maximum,

$$\frac{1}{2}\,(t_3 + t_2 - t_1) = 1$$

and unit integral,

$$\frac{1}{2}\,F_1(t_3 + t_2 - t_1) = 1\ .$$

These imply

$$t_3 = \frac{8}{5} \tag{49}$$

$$t_2 = \frac{4}{5} \tag{50}$$

$$t_1 = \frac{2}{5} \tag{51}$$

$$F_1 = 1. \tag{52}$$

These numbers specify the trapezoidal time history of Figure 4 as would be used in FUNCTION FT.

SECTION 6

OUTPUT FORMAT

Before the time cycle printout, an initial print shows the fixed problem parameters. The problem number, title, and first input cards are printed followed by some of the XB(I), and SL(I), and all of K10(I). Then the emission velocities, spectrum, and weights are printed, followed by the plasma period (Equation (42) or (43)), the parameter α of Equation (29), A of Equation (31) (called AL in the code), and a quantity DL which is one-half the particle length (finite length particles are used for the computation of charge and current densities). Finally the dimensional units of dynamical quantities are printed in mixed Gaussian esu and in MKS units.

The time cycle output begins with the cycle number and the following:

TIME	=	dimensionless time elapsed
NP	=	total number of live particles
NKILL	=	total number of particles that have been killed since time 0.
NPXMAX	=	total number of particles that have passed XMAX and been killed.
QTOT	=	total dimensionless charge per unit area outside the surface.
QR	=	total dimensionless charge per unit area that has passed XMAX.

Real time elapsed is obtained by multiplying "TIME" by the unit of time in seconds printed out at the end of the initial print. Real charge per unit area is obtained by multiplying QTOT by the unit of charge/unit area printed above, and similarly for QR.

Then the electric field and potential at the surface are printed, followed by the field and potential at every tenth length unit from the surface, out to $x = 10.0$. If fields and/or potentials are desired farther out than this, the print variable NPR3 may be changed in the code. The physical field and potential are obtained by multiplying the dimensionless output numbers by the units printed at the end of the initial printout.

Next, the numbers of particles in the first 100 cells are printed, together with the total charge (per unit area) in each of the first 60 cells. Then follow the charge density, current density and dipole moment every 0.1 length unit, and finally the spatial integral of the current density, $\int_0^\infty j(x,t)dx$.

The field is computed every cycle at the edges between bins. The field printed out every 0.1 length units is obtained by simple linear interpolation from the fields at cell edges.

AVERAGING FOR CHARGE AND CURRENT DENSITIES

The charge density and current density are computed every 0.1 length unit by the following averaging process.

The array K10(I) shows which cell contains the point of interest, say 0.7 length units so that $I = 7$. For example in the space grid of Figure 3, 0.7 length units is in cell $K10(7) = 6$. The two adjacent cells (5 and 7) are also considered. The fractional distance y that the point $x = 0.7$ occupies within cell 6, is computed,

$$y = \frac{x-SL(6)}{XB(6)} = \frac{0.7-SL(6)}{XB(6)} \qquad (53)$$

where

$$0 \leq y < 1. \tag{54}$$

Then the current density at x, j(x), is a weighted average of the current densities C(5), C(6), C(7) in cells 5, 6, and 7, respectively. The weights w_5, w_6, w_7 given to cells 5, 6, and 7 depend on y in such a way that they have the following values when x is at an edge (y = 0 or 1) or at the center of cell 6 (y = 1/2):

y =	0	.5	1
w_5 =	.5	.2	0
w_6 =	.5	.6	.5
w_7 =	0	.2	.5

The weights are given by the formula

$$w_5 = \frac{1}{2}(1 - y)^{p_1} \tag{55a}$$

$$w_7 = \frac{1}{2}\, y^{p_1} \tag{55b}$$

$$w_6 = 1 - w_5 - w_7 \tag{55c}$$

where

$$p_1 = 1.32193 \tag{55d}$$

Equations (55) interpolate between the weights given in the above table. When the point of interest, x, falls at the center of a cell ($y = \frac{1}{2}$), the averaging gives three times the weight to this cell as to either adjacent cell. When x falls at the boundary between two cells (y = 0, or 1) those two cells receive equal weight.

SECTION 7

SAMPLE RUN

We present the results of a sample run consisting of two problems. Both are for a 5 keV blackbody X-ray spectrum incident on aluminum. The first problem has a time history which is a symmetic triangle (IT = 2) with full width at half maximum of 10 ns (FWHM = 1×10^{-8} sec), and a fluence of 2×10^{-4} cal/cm^2. The second problem has a time history which is a continuously linearly rising X-ray flux (IT = 1, POW = 1.0), and hence there is no FWHM or fluence. The parameter FLU in the second problem is chosen from Equation (33) so that the flux is the same as the rising portion of the pulse in the first problem. In this case, FLU = 2.0×10^{12} in units of cal/cm^2/sec^2. In both problems, the yield is YIE = 2.57×10^{12} elec/cal.

The input cards for this run are shown in Figure 5. Figure 6 shows the initial print output for problem 1.0, and Figure 7 shows a sample of the time cycle output. Figure 8 shows the initial print for problem 2.0, and Figure 9 is a sample of its time cycle output.

Referring to Figure 5, we have chosen a space grid out to x = 50.0 length units (essentially 50 Debye lengths), and have used 350 cells with a spacing ratio $\xi = 1.004$. The time step is 0.025 time units (essentially 0.025 plasma periods) and we print every 10 cycles. The first problem will run for 500 cycles, the second for 400 cycles. There are 32 input cards defining the spectrum. 32 particles will be emitted each time step.

In Figure 6 the initial print shows the first four data cards, then various bin sizes XB and distances SL. The full array K10 is

```
SAMPLE PROBLEM ONE.  5 KEV BB ON ALUMINUM
 500  350    0    0   32    2   10    1
 0.025     50.0     1.004      0.0        1.0
  2.57E12    2.0E-4     1.E-8
0.15       5.447E-06
0.45       1.634E-05
1.0        3.631E-05
1.5        9.768E-06
2.0        1.178E-05
2.5        8.724E-06
3.0        9.710E-06
4.0        8.015E-06
5.0        6.562E-06
6.0        5.350E-06
7.0        4.348E-06
8.0        3.535E-06
10.0       2.518E-06
12.0       1.625E-06
14.0       1.048E-06
16.0       6.768E-07
18.0       4.390E-07
20.0       2.850E-07
22.0       1.571E-07
24.0       8.678E-08
26.0       8.286E-08
28.0       4.252E-08
30.0       2.355E-08
33.0       1.235E-08
36.0       6.527E-09
39.0       3.019E-09
42.0       2.728E-09
46.0       1.132E-09
50.0       4.714E-10
55.0       9.353E-11
60.0       3.502E-11
70.0       5.813E-12
SAMPLE PROBLEM TWO.  LINEAR RISE.
 400  350    1    0   32    1   10    0
0.025      50.0      1.004     1.0        2.00
  2.57E12     2.E12  0.
```

Figure 5. Data cards for sample run.

```
                    SCALID PROBLEM NUMBER      1.000
                 SAMPLE PROBLEM ONE.  5 KEV BB ON ALUMINUM

   NT   NC   IR  ICN   NV   IT   IP   LP
  500  350    0    0   32    2   10    1

     DT          XMAX          XI          POW         PROBNO
   2.500E-02   5.000E+01   1.000E+00   0.          1.000E+00

     YIE         FLU         FWHM
   2.572E+12   2.000E-04   1.000E-08

FIRST  100 BINS...
XB(I) =
   6.571E-02   6.597E-02   6.623E-02   6.650E-02   6.676E-02   6.703E-02   6.730E-02   6.757E-02   6.784E-02   6.811E-02
   6.838E-02   6.865E-02   6.893E-02   6.921E-02   6.948E-02   6.976E-02   7.004E-02   7.032E-02   7.060E-02   7.088E-02
   7.117E-02   7.145E-02   7.174E-02   7.202E-02   7.231E-02   7.260E-02   7.289E-02   7.318E-02   7.348E-02   7.377E-02
   7.406E-02   7.436E-02   7.466E-02   7.496E-02   7.526E-02   7.556E-02   7.586E-02   7.616E-02   7.647E-02   7.677E-02
   7.708E-02   7.739E-02   7.770E-02   7.801E-02   7.832E-02   7.864E-02   7.895E-02   7.927E-02   7.959E-02   7.992E-02
   8.025E-02   8.058E-02   8.091E-02   8.125E-02   8.159E-02   8.193E-02   8.227E-02   8.262E-02   8.297E-02   8.332E-02
   8.368E-02   8.403E-02   8.439E-02   8.476E-02   8.513E-02   8.550E-02   8.587E-02   8.625E-02   8.663E-02   8.702E-02
   8.740E-02   8.779E-02   8.818E-02   8.858E-02   8.898E-02   8.938E-02   8.979E-02   9.020E-02   9.062E-02   9.104E-02
   9.146E-02   9.189E-02   9.232E-02   9.276E-02   9.320E-02   9.365E-02   9.410E-02   9.456E-02   9.502E-02   9.549E-02
   9.411E-02   9.449E-02   9.486E-02   9.524E-02   9.562E-02   9.601E-02   9.639E-02   9.678E-02   9.718E-02   9.758E-02

SL(I) =
   2.          6.571E-02   1.317E-01   1.979E-01   2.644E-01   3.312E-01   3.982E-01   4.655E-01   5.331E-01   6.009E-01
   6.690E-01   7.374E-01   8.061E-01   8.750E-01   9.442E-01   1.014E+00   1.083E+00   1.153E+00   1.224E+00   1.294E+00
   1.365E+00   1.436E+00   1.508E+00   1.580E+00   1.652E+00   1.724E+00   1.797E+00   1.869E+00   1.943E+00   2.016E+00
   2.090E+00   2.164E+00   2.238E+00   2.313E+00   2.388E+00   2.463E+00   2.539E+00   2.615E+00   2.691E+00   2.767E+00
   2.844E+00   2.921E+00   2.998E+00   3.076E+00   3.154E+00   3.232E+00   3.311E+00   3.390E+00   3.469E+00   3.549E+00
   3.629E+00   3.709E+00   3.790E+00   3.871E+00   3.952E+00   4.033E+00   4.115E+00   4.197E+00   4.279E+00   4.362E+00
   4.444E+00   4.527E+00   4.611E+00   4.695E+00   4.779E+00   4.864E+00   4.950E+00   5.037E+00   5.123E+00   5.209E+00
   5.296E+00   5.383E+00   5.471E+00   5.559E+00   5.646E+00   5.734E+00   5.822E+00   5.911E+00   6.000E+00   6.090E+00
   6.180E+00   6.271E+00   6.362E+00   6.453E+00   6.544E+00   6.636E+00   6.728E+00   6.821E+00   6.914E+00   7.007E+00
   7.101E+00   7.195E+00   7.289E+00   7.385E+00   7.480E+00   7.575E+00   7.671E+00   7.768E+00   7.865E+00   7.962E+00

LAST  100 BINS...
XB(I) =
   1.749E+01   1.752E+01   1.757E+01   1.761E+01   1.766E+01   1.771E+01   1.776E+01   1.781E+01   1.786E+01   1.791E+01
   1.796E+01   1.801E+01   1.806E+01   1.811E+01   1.816E+01   1.821E+01   1.826E+01   1.831E+01   1.836E+01   1.841E+01
   1.846E+01   1.851E+01   1.856E+01   1.861E+01   1.866E+01   1.871E+01   1.876E+01   1.881E+01   1.886E+01   1.891E+01
   1.896E+01   1.901E+01   1.906E+01   1.911E+01   1.916E+01   1.921E+01   1.926E+01   1.931E+01   1.936E+01   1.941E+01
   1.946E+01   1.951E+01   1.956E+01   1.961E+01   1.966E+01   1.971E+01   1.976E+01   1.981E+01   1.986E+01   1.991E+01
   1.996E+01   2.001E+01   2.006E+01   2.011E+01   2.016E+01   2.021E+01   2.026E+01   2.031E+01   2.036E+01   2.041E+01
   2.046E+01   2.051E+01   2.056E+01   2.061E+01   2.066E+01   2.071E+01   2.076E+01   2.081E+01   2.086E+01   2.091E+01
   2.096E+01   2.101E+01   2.106E+01   2.111E+01   2.116E+01   2.121E+01   2.126E+01   2.131E+01   2.136E+01   2.141E+01
   2.146E+01   2.151E+01   2.156E+01   2.161E+01   2.166E+01   2.171E+01   2.176E+01   2.181E+01   2.186E+01   2.191E+01
   2.196E+01   2.201E+01   2.206E+01   2.211E+01   2.216E+01   2.221E+01   2.226E+01   2.231E+01   2.236E+01   2.241E+01
   2.246E+01   2.251E+01   2.256E+01   2.261E+01   2.266E+01   2.271E+01   2.276E+01   2.281E+01   2.286E+01   2.291E+01
   2.296E+01   2.301E+01   2.306E+01   2.311E+01   2.316E+01   2.321E+01   2.326E+01   2.331E+01   2.336E+01   2.341E+01
   2.346E+01   2.351E+01   2.356E+01   2.361E+01   2.366E+01   2.371E+01   2.376E+01   2.381E+01   2.386E+01   2.391E+01
   2.396E+01   2.401E+01   2.406E+01   2.411E+01   2.416E+01   2.421E+01   2.426E+01   2.431E+01   2.436E+01   2.441E+01
   2.446E+01   2.451E+01   2.456E+01   2.461E+01   2.466E+01   2.471E+01   2.476E+01   2.481E+01   2.486E+01   2.491E+01
   2.496E+01   2.501E+01   2.506E+01   2.511E+01   2.516E+01   2.521E+01   2.526E+01   2.531E+01   2.536E+01   2.541E+01
   2.546E+01   2.551E+01   2.556E+01   2.561E+01   2.566E+01   2.571E+01   2.576E+01   2.581E+01   2.586E+01   2.591E+01
   2.596E+01   2.601E+01   2.606E+01   2.611E+01   2.616E+01   2.621E+01   2.626E+01   2.631E+01   2.636E+01   2.641E+01
   2.646E+01   2.651E+01   2.656E+01   2.661E+01   2.666E+01   2.671E+01   2.676E+01   2.681E+01   2.686E+01   2.691E+01
   2.696E+01   2.701E+01   2.706E+01   2.711E+01   2.716E+01   2.721E+01   2.726E+01   2.731E+01   2.736E+01   2.741E+01
   2.746E+01   2.751E+01   2.756E+01   2.761E+01   2.766E+01   2.771E+01   2.776E+01   2.781E+01   2.786E+01   2.791E+01
   2.796E+01   2.801E+01   2.806E+01   2.811E+01   2.816E+01   2.821E+01   2.826E+01   2.831E+01   2.836E+01   2.841E+01
   2.846E+01   2.851E+01   2.856E+01   2.861E+01   2.866E+01   2.871E+01   2.876E+01   2.881E+01   2.886E+01   2.891E+01
   2.896E+01   2.901E+01   2.906E+01   2.911E+01   2.916E+01   2.921E+01   2.926E+01   2.931E+01   2.936E+01   2.941E+01
   2.946E+01   2.951E+01   2.956E+01   2.961E+01   2.966E+01   2.971E+01   2.976E+01   2.981E+01   2.986E+01   2.991E+01
   2.996E+01   3.001E+01   3.006E+01   3.011E+01   3.016E+01   3.021E+01   3.026E+01   3.031E+01   3.036E+01   3.041E+01
   3.046E+01   3.051E+01   3.056E+01   3.061E+01   3.066E+01   3.071E+01   3.076E+01   3.081E+01   3.086E+01   3.091E+01
   3.096E+01   3.101E+01   3.106E+01   3.111E+01   3.116E+01   3.121E+01   3.126E+01   3.131E+01   3.136E+01   3.141E+01
   3.146E+01   3.151E+01   3.156E+01   3.161E+01   3.166E+01   3.171E+01   3.176E+01   3.181E+01   3.186E+01   3.191E+01
   3.196E+01   3.201E+01   3.206E+01   3.211E+01   3.216E+01   3.221E+01   3.226E+01   3.231E+01   3.236E+01   3.241E+01
   3.246E+01   3.251E+01   3.256E+01   3.261E+01   3.266E+01   3.271E+01   3.276E+01   3.281E+01   3.286E+01   3.291E+01
   3.296E+01   3.301E+01   3.306E+01   3.311E+01   3.316E+01   3.321E+01   3.326E+01   3.331E+01   3.336E+01   3.341E+01
   3.346E+01   3.351E+01   3.356E+01   3.361E+01   3.366E+01   3.371E+01   3.376E+01   3.381E+01   3.386E+01   3.391E+01
   3.396E+01   3.401E+01   3.406E+01   3.411E+01   3.416E+01   3.421E+01   3.426E+01   3.431E+01   3.436E+01   3.441E+01
   3.446E+01   3.451E+01   3.456E+01   3.461E+01   3.466E+01   3.471E+01   3.476E+01   3.481E+01   3.486E+01   3.491E+01
   3.496E+01   3.501E+01   3.506E+01   3.511E+01   3.516E+01   3.521E+01   3.526E+01   3.531E+01   3.536E+01   3.541E+01
   3.546E+01   3.551E+01   3.556E+01   3.561E+01   3.566E+01   3.571E+01   3.576E+01   3.581E+01   3.586E+01   3.591E+01
   3.596E+01   3.601E+01   3.606E+01   3.611E+01   3.616E+01   3.621E+01   3.626E+01   3.631E+01   3.636E+01   3.641E+01
   3.646E+01   3.651E+01   3.656E+01   3.661E+01   3.666E+01   3.671E+01   3.676E+01   3.681E+01   3.686E+01   3.691E+01
   3.696E+01   3.701E+01   3.706E+01   3.711E+01   3.716E+01   3.721E+01   3.726E+01   3.731E+01   3.736E+01   3.741E+01
   3.746E+01   3.751E+01   3.756E+01   3.761E+01   3.766E+01   3.771E+01   3.776E+01   3.781E+01   3.786E+01   3.791E+01
   3.796E+01   3.801E+01   3.806E+01   3.811E+01   3.816E+01   3.821E+01   3.826E+01   3.831E+01   3.836E+01   3.841E+01
   3.846E+01   3.851E+01   3.856E+01   3.861E+01   3.866E+01   3.871E+01   3.876E+01   3.881E+01   3.886E+01   3.891E+01
   3.896E+01   3.901E+01   3.906E+01   3.911E+01   3.916E+01   3.921E+01   3.926E+01   3.931E+01   3.936E+01   3.941E+01
   3.946E+01   3.951E+01   3.956E+01   3.961E+01   3.966E+01   3.971E+01   3.976E+01   3.981E+01   3.986E+01   3.991E+01
   3.996E+01   4.001E+01   4.006E+01   4.011E+01   4.016E+01   4.021E+01   4.026E+01   4.031E+01   4.036E+01   4.041E+01
   4.046E+01   4.051E+01   4.056E+01   4.061E+01   4.066E+01   4.071E+01   4.076E+01   4.081E+01   4.086E+01   4.091E+01
   4.096E+01   4.101E+01   4.106E+01   4.111E+01   4.116E+01   4.121E+01   4.126E+01   4.131E+01   4.136E+01   4.141E+01
   4.146E+01   4.151E+01   4.156E+01   4.161E+01   4.166E+01   4.171E+01   4.176E+01   4.181E+01   4.186E+01   4.191E+01
   4.196E+01   4.201E+01   4.206E+01   4.211E+01   4.216E+01   4.221E+01   4.226E+01   4.231E+01   4.236E+01   4.241E+01
   4.246E+01   4.251E+01   4.256E+01   4.261E+01   4.266E+01   4.271E+01   4.276E+01   4.281E+01   4.286E+01   4.291E+01
   4.296E+01   4.301E+01   4.306E+01   4.311E+01   4.316E+01   4.321E+01   4.326E+01   4.331E+01   4.336E+01   4.341E+01
   4.346E+01   4.351E+01   4.356E+01   4.361E+01   4.366E+01   4.371E+01   4.376E+01   4.381E+01   4.386E+01   4.391E+01
   4.396E+01   4.401E+01   4.406E+01   4.411E+01   4.416E+01   4.421E+01   4.426E+01   4.431E+01   4.436E+01   4.441E+01
   4.446E+01   4.451E+01   4.456E+01   4.461E+01   4.466E+01   4.471E+01   4.476E+01   4.481E+01   4.486E+01   4.491E+01
   4.496E+01   4.501E+01   4.506E+01   4.511E+01   4.516E+01   4.521E+01   4.526E+01   4.531E+01   4.536E+01   4.541E+01
   4.546E+01   4.551E+01   4.556E+01   4.561E+01   4.566E+01   4.571E+01   4.576E+01   4.581E+01   4.586E+01   4.591E+01
   4.596E+01   4.601E+01   4.606E+01   4.611E+01   4.616E+01   4.621E+01   4.626E+01   4.631E+01   4.636E+01   4.641E+01
   4.646E+01   4.651E+01   4.656E+01   4.661E+01   4.666E+01   4.671E+01   4.676E+01   4.681E+01   4.686E+01   4.691E+01
   4.696E+01   4.701E+01   4.706E+01   4.711E+01   4.716E+01   4.721E+01   4.726E+01   4.731E+01   4.736E+01   4.741E+01
   4.746E+01   4.751E+01   4.756E+01   4.761E+01   4.766E+01   4.771E+01   4.776E+01   4.781E+01   4.786E+01   4.791E+01
   4.796E+01   4.801E+01   4.806E+01   4.811E+01   4.816E+01   4.821E+01   4.826E+01   4.831E+01   4.836E+01   4.841E+01
   4.846E+01   4.851E+01   4.856E+01   4.861E+01   4.866E+01   4.871E+01   4.876E+01   4.881E+01   4.886E+01   4.891E+01
   4.896E+01   4.901E+01   4.906E+01   4.911E+01   4.916E+01   4.921E+01   4.926E+01   4.931E+01   4.936E+01   4.941E+01
   4.946E+01   4.951E+01   4.956E+01   4.961E+01   4.966E+01   4.971E+01   4.976E+01   4.981E+01   4.986E+01   4.991E+01
   4.996E+01   5.001E+01   5.006E+01   5.011E+01   5.016E+01   5.021E+01   5.026E+01   5.031E+01   5.036E+01   5.041E+01
   5.046E+01   5.051E+01   5.056E+01   5.061E+01   5.066E+01   5.071E+01   5.076E+01   5.081E+01   5.086E+01   5.091E+01
   5.096E+01   5.101E+01   5.106E+01   5.111E+01   5.116E+01   5.121E+01   5.126E+01   5.131E+01   5.136E+01   5.141E+01
   5.146E+01   5.151E+01   5.156E+01   5.161E+01   5.166E+01   5.171E+01   5.176E+01   5.181E+01   5.186E+01   5.191E+01
   5.196E+01   5.201E+01   5.206E+01   5.211E+01   5.216E+01   5.221E+01   5.226E+01   5.231E+01   5.236E+01   5.241E+01
   5.246E+01   5.251E+01   5.256E+01   5.261E+01   5.266E+01   5.271E+01   5.276E+01   5.281E+01   5.286E+01   5.291E+01
   5.296E+01   5.301E+01   5.306E+01   5.311E+01   5.316E+01   5.321E+01   5.326E+01   5.331E+01   5.336E+01   5.341E+01
   5.346E+01   5.351E+01   5.356E+01   5.361E+01   5.366E+01   5.371E+01   5.376E+01   5.381E+01   5.386E+01   5.391E+01
   5.396E+01   5.401E+01   5.406E+01   5.411E+01   5.416E+01   5.421E+01   5.426E+01   5.431E+01   5.436E+01   5.441E+01
   5.446E+01   5.451E+01   5.456E+01   5.461E+01   5.466E+01   5.471E+01   5.476E+01   5.481E+01   5.486E+01   5.491E+01
   5.496E+01   5.501E+01   5.506E+01   5.511E+01   5.516E+01   5.521E+01   5.526E+01   5.531E+01   5.536E+01   5.541E+01
   5.546E+01   5.551E+01   5.556E+01   5.561E+01   5.566E+01   5.571E+01   5.576E+01   5.581E+01   5.586E+01   5.591E+01
   5.596E+01   5.601E+01   5.606E+01   5.611E+01   5.616E+01   5.621E+01   5.626E+01   5.631E+01   5.636E+01   5.641E+01
   5.646E+01   5.651E+01   5.656E+01   5.661E+01   5.666E+01   5.671E+01   5.676E+01   5.681E+01   5.686E+01   5.691E+01
   5.696E+01   5.701E+01   5.706E+01   5.711E+01   5.716E+01   5.721E+01   5.726E+01   5.731E+01   5.736E+01   5.741E+01
   5.746E+01   5.751E+01   5.756E+01   5.761E+01   5.766E+01   5.771E+01   5.776E+01   5.781E+01   5.786E+01   5.791E+01
   5.796E+01   5.801E+01   5.806E+01   5.811E+01   5.816E+01   5.821E+01   5.826E+01   5.831E+01   5.836E+01   5.841E+01
   5.846E+01   5.851E+01   5.856E+01   5.861E+01   5.866E+01   5.871E+01   5.876E+01   5.881E+01   5.886E+01   5.891E+01
   5.896E+01   5.901E+01   5.906E+01   5.911E+01   5.916E+01   5.921E+01   5.926E+01   5.931E+01   5.936E+01   5.941E+01
   5.946E+01   5.951E+01   5.956E+01   5.961E+01   5.966E+01   5.971E+01   5.976E+01   5.981E+01   5.986E+01   5.991E+01
   5.996E+01   6.001E+01   6.006E+01   6.011E+01   6.016E+01   6.021E+01   6.026E+01   6.031E+01   6.036E+01   6.041E+01
   6.046E+01   6.051E+01   6.056E+01   6.061E+01   6.066E+01   6.071E+01   6.076E+01   6.081E+01   6.086E+01   6.091E+01
   6.096E+01   6.101E+01   6.106E+01   6.111E+01   6.116E+01   6.121E+01   6.126E+01   6.131E+01   6.136E+01   6.141E+01
   6.146E+01   6.151E+01   6.156E+01   6.161E+01   6.166E+01   6.171E+01   6.176E+01   6.181E+01   6.186E+01   6.191E+01
   6.196E+01   6.201E+01   6.206E+01   6.211E+01   6.216E+01   6.221E+01   6.226E+01   6.231E+01   6.236E+01   6.241E+01
   6.246E+01   6.251E+01   6.256E+01   6.261E+01   6.266E+01   6.271E+01   6.276E+01   6.281E+01   6.286E+01   6.291E+01
   6.296E+01   6.301E+01   6.306E+01   6.311E+01   6.316E+01   6.321E+01   6.326E+01   6.331E+01   6.336E+01   6.341E+01
   6.346E+01   6.351E+01   6.356E+01   6.361E+01   6.366E+01   6.371E+01   6.376E+01   6.381E+01   6.386E+01   6.391E+01
   6.396E+01   6.401E+01   6.406E+01   6.411E+01   6.416E+01   6.421E+01   6.426E+01   6.431E+01   6.436E+01   6.441E+01
   6.446E+01   6.451E+01   6.456E+01   6.461E+01   6.466E+01   6.471E+01   6.476E+01   6.481E+01   6.486E+01   6.491E+01
   6.496E+01   6.501E+01   6.506E+01   6.511E+01   6.516E+01   6.521E+01   6.526E+01   6.531E+01   6.536E+01   6.541E+01
   6.546E+01   6.551E+01   6.556E+01   6.561E+01   6.566E+01   6.571E+01   6.576E+01   6.581E+01   6.586E+01   6.591E+01
   6.596E+01   6.601E+01   6.606E+01   6.611E+01   6.616E+01   6.621E+01   6.626E+01   6.631E+01   6.636E+01   6.641E+01
   6.646E+01   6.651E+01   6.656E+01   6.661E+01   6.666E+01   6.671E+01   6.676E+01   6.681E+01   6.686E+01   6.691E+01
   6.696E+01   6.701E+01   6.706E+01   6.711E+01   6.716E+01   6.721E+01   6.726E+01   6.731E+01   6.736E+01   6.741E+01
   6.746E+01   6.751E+01   6.756E+01   6.761E+01   6.766E+01   6.771E+01   6.776E+01   6.781E+01   6.786E+01   6.791E+01
   6.796E+01   6.801E+01   6.806E+01   6.811E+01   6.816E+01   6.821E+01   6.826E+01   6.831E+01   6.836E+01   6.841E+01
   6.846E+01   6.851E+01   6.856E+01   6.861E+01   6.866E+01   6.871E+01   6.876E+01   6.881E+01   6.886E+01   6.891E+01
   6.896E+01   6.901E+01   6.906E+01   6.911E+01   6.916E+01   6.921E+01   6.926E+01   6.931E+01   6.936E+01   6.941E+01
   6.946E+01   6.951E+01   6.956E+01   6.961E+01   6.966E+01   6.971E+01   6.976E+01   6.981E+01   6.986E+01   6.991E+01
   6.996E+01   7.001E+01   7.006E+01   7.011E+01   7.016E+01   7.021E+01   7.026E+01   7.031E+01   7.036E+01   7.041E+01
   7.046E+01   7.051E+01   7.056E+01   7.061E+01   7.066E+01   7.071E+01   7.076E+01   7.081E+01   7.086E+01   7.091E+01
   7.096E+01   7.101E+01   7.106E+01   7.111E+01   7.116E+01   7.121E+01   7.126E+01   7.131E+01   7.136E+01   7.141E+01
   7.146E+01   7.151E+01   7.156E+01   7.161E+01   7.166E+01   7.171E+01   7.176E+01   7.181E+01   7.186E+01   7.191E+01
   7.196E+01   7.201E+01   7.206E+01   7.211E+01   7.216E+01   7.221E+01   7.226E+01   7.231E+01   7.236E+01   7.241E+01
   7.246E+01   7.251E+01   7.256E+01   7.261E+01   7.266E+01   7.271E+01   7.276E+01   7.281E+01   7.286E+01   7.291E+01
   7.296E+01   7.301E+01   7.306E+01   7.311E+01   7.316E+01   7.321E+01   7.326E+01   7.331E+01   7.336E+01   7.341E+01
   7.346E+01   7.351E+01   7.356E+01   7.361E+01   7.366E+01   7.371E+01   7.376E+01   7.381E+01   7.386E+01   7.391E+01
   7.396E+01   7.401E+01   7.406E+01   7.411E+01   7.416E+01   7.421E+01   7.426E+01   7.431E+01   7.436E+01   7.441E+01
   7.446E+01   7.451E+01   7.456E+01   7.461E+01   7.466E+01   7.471E+01   7.476E+01   7.481E+01   7.486E+01   7.491E+01
   7.496E+01   7.501E+01   7.506E+01   7.511E+01   7.516E+01   7.521E+01   7.526E+01   7.531E+01   7.536E+01   7.541E+01
   7.546E+01   7.551E+01   7.556E+01   7.561E+01   7.566E+01   7.571E+01   7.576E+01   7.581E+01   7.586E+01   7.591E+01
   7.596E+01   7.601E+01   7.606E+01   7.611E+01   7.616E+01   7.621E+01   7.626E+01   7.631E+01   7.636E+01   7.641E+01
   7.646E+01   7.651E+01   7.656E+01   7.661E+01   7.666E+01   7.671E+01   7.676E+01   7.681E+01   7.686E+01   7.691E+01
   7.696E+01   7.701E+01   7.706E+01   7.711E+01   7.716E+01   7.721E+01   7.726E+01   7.731E+01   7.736E+01   7.741E+01
   7.746E+01   7.751E+01   7.756E+01   7.761E+01   7.766E+01   7.771E+01   7.776E+01   7.781E+01   7.786E+01   7.791E+01
   7.796E+01   7.801E+01   7.806E+01   7.811E+01   7.816E+01   7.821E+01   7.826E+01   7.831E+01   7.836E+01   7.841E+01
   7.846E+01   7.851E+01   7.856E+01   7.861E+01   7.866E+01   7.871E+01   7.876E+01   7.881E+01   7.886E+01   7.891E+01
   7.896E+01   7.901E+01   7.906E+01   7.911E+01   7.916E+01   7.921E+01   7.926E+01   7.931E+01   7.936E+01   7.941E+01
   7.946E+01   7.951E+01   7.956E+01   7.961E+01   7.966E+01   7.971E+01   7.976E+01   7.981E+01   7.986E+01   7.991E+01
   7.996E+01   8.001E+01   8.006E+01   8.011E+01   8.016E+01   8.021E+01   8.026E+01   8.031E+01   8.036E+01   8.041E+01
   8.046E+01   8.051E+01   8.056E+01   8.061E+01   8.066E+01   8.071E+01   8.076E+01   8.081E+01   8.086E+01   8.091E+01
   8.096E+01   8.101E+01   8.106E+01   8.111E+01   8.116E+01   8.121E+01   8.126E+01   8.131E+01   8.136E+01   8.141E+01
   8.146E+01   8.151E+01   8.156E+01   8.161E+01   8.166E+01   8.171E+01   8.176E+01   8.181E+01   8.186E+01   8.191E+01
   8.196E+01   8.201E+01   8.206E+01   8.211E+01   8.216E+01   8.221E+01   8.226E+01   8.231E+01   8.236E+01   8.241E+01
   8.246E+01   8.251E+01   8.256E+01   8.261E+01   8.266E+01   8.271E+01   8.276E+01   8.281E+01   8.286E+01   8.291E+01
   8.296E+01   8.301E+01   8.306E+01   8.311E+01   8.316E+01   8.321E+01   8.326E+01   8.331E+01   8.336E+01   8.341E+01
   8.346E+01   8.351E+01   8.356E+01   8.361E+01   8.366E+01   8.371E+01   8.376E+01   8.381E+01   8.386E+01   8.391E+01
   8.396E+01   8.401E+01   8.406E+01   8.411E+01   8.416E+01   8.421E+01   8.426E+01   8.431E+01   8.436E+01   8.441E+01
   8.446E+01   8.451E+01   8.456E+01   8.461E+01   8.466E+01   8.471E+01   8.476E+01   8.481E+01   8.486E+01   8.491E+01
   8.496E+01   8.501E+01   8.506E+01   8.511E+01   8.516E+01   8.521E+01   8.526E+01   8.531E+01   8.536E+01   8.541E+01
   8.546E+01   8.551E+01   8.556E+01   8.561E+01   8.566E+01   8.571E+01   8.576E+01   8.581E+01   8.586E+01   8.591E+01
   8.596E+01   8.601E+01   8.606E+01   8.611E+01   8.616E+01   8.621E+01   8.626E+01   8.631E+01   8.636E+01   8.641E+01
   8.646E+01   8.651E+01   8.656E+01   8.661E+01   8.666E+01   8.671E+01   8.676E+01   8.681E+01   8.686E+01   8.691E+01
   8.696E+01   8.701E+01   8.706E+01   8.711E+01   8.716E+01   8.721E+01   8.726E+01   8.731E+01   8.736E+01   8.741E+01
   8.746E+01   8.751E+01   8.756E+01   8.761E+01   8.766E+01   8.771E+01   8.776E+01   8.781E+01   8.786E+01   8.791E+01
   8.796E+01   8.801E+01   8.806E+01   8.811E+01   8.816E+01   8.821E+01   8.826E+01   8.831E+01   8.836E+01   8.841E+01
   8.846E+01   8.851E+01   8.856E+01   8.861E+01   8.866E+01   8.871E+01   8.876E+01   8.881E+01   8.886E+01   8.891E+01
   8.896E+01   8.901E+01   8.906E+01   8.911E+01   8.916E+01   8.921E+01   8.926E+01   8.931E+01   8.936E+01   8.941E+01
   8.946E+01   8.951E+01   8.956E+01   8.961E+01   8.966E+01   8.971E+01   8.976E+01   8.981E+01   8.986E+01   8.991E+01
   8.996E+01   9.001E+01   9.006E+01   9.011E+01   9.016E+01   9.021E+01   9.026E+01   9.031E+01   9.036E+01   9.041E+01
   9.046E+01   9.051E+01   9.056E+01   9.061E+01   9.066E+01   9.071E+01   9.076E+01   9.081E+01   9.086E+01   9.091E+01
   9.096E+01   9.101E+01   9.106E+01   9.111E+01   9.116E+01   9.121E+01   9.126E+01   9.131E+01   9.136E+01   9.141E+01
   9.146E+01   9.151E+01   9.156E+01   9.161E+01   9.166E+01   9.171E+01   9.176E+01   9.181E+01   9.186E+01   9.191E+01
   9.196E+01   9.201E+01   9.206E+01   9.211E+01   9.216E+01   9.221E+01   9.226E+01   9.231E+01   9.236E+01   9.241E+01
   9.246E+01   9.251E+01   9.256E+01   9.261E+01   9.266E+01   9.271E+01   9.276E+01   9.281E+01   9.286E+01   9.291E+01
   9.296E+01   9.301E+01   9.306E+01   9.311E+01   9.316E+01   9.321E+01   9.326E+01   9.331E+01   9.336E+01   9.341E+01
   9.346E+01   9.351E+01   9.356E+01   9.361E+01   9.366E+01   9.371E+01   9.376E+01   9.381E+01   9.386E+01   9.391E+01
   9.396E+01   9.401E+01   9.406E+01   9.411E+01   9.416E+01   9.421E+01   9.426E+01   9.431E+01   9.436E+01   9.441E+01
   9.446E+01   9.451E+01   9.456E+01   9.461E+01   9.466E+01   9.471E+01   9.476E+01   9.481E+01   9.486E+01   9.491E+01
   9.496E+01   9.501E+01   9.506E+01   9.511E+01   9.516E+01   9.521E+01   9.526E+01   9.531E+01   9.536E+01   9.541E+01
   9.546E+01   9.551E+01   9.556E+01   9.561E+01   9.566E+01   9.571E+01   9.576E+01   9.581E+01   9.586E+01   9.591E+01
   9.596E+01   9.601E+01   9.606E+01   9.611E+01   9.616E+01   9.621E+01   9.626E+01   9.631E+01   9.636E+01   9.641E+01
   9.646E+01   9.651E+01   9.656E+01   9.661E+01   9.666E+01   9.671E+01   9.676E+01   9.681E+01   9.686E+01   9.691E+01
   9.696E+01   9.701E+01   9.706E+01   9.711E+01   9.716E+01   9.721E+01   9.726E+01   9.731E+01   9.736E+01   9.741E+01
   9.746E+01   9.751E+01   9.756E+01   9.761E+01   9.766E+01   9.771E+01   9.776E+01   9.781E+01   9.786E+01   9.791E+01
   9.796E+01   9.801E+01   9.806E+01   9.811E+01   9.816E+01   9.821E+01   9.826E+01   9.831E+01   9.836E+01   9.841E+01
   9.846E+01   9.851E+01   9.856E+01   9.861E+01   9.866E+01   9.871E+01   9.876E+01   9.881E+01   9.886E+01   9.891E+01
   9.896E+01   9.901E+01   9.906E+01   9.911E+01   9.916E+01   9.921E+01   9.926E+01   9.931E+01   9.936E+01   9.941E+01
   9.946E+01   9.951E+01   9.956E+01   9.961E+01   9.966E+01   9.971E+01   9.976E+01   9.981E+01   9.986E+01   9.991E+01
   9.996E+01   1.000E+02
```

Figure 6. Initial printout for problem 1.0.

```
SL(I) =
  2.891E+01  2.849E+01  2.867E+01  2.885E+01  2.903E+01  2.922E+01  2.942E+01  2.958E+01  2.977E+01  2.995E+01
  3.014E+01  3.032E+01  3.051E+01  3.070E+01  3.089E+01  3.108E+01  3.127E+01  3.146E+01  3.165E+01  3.184E+01
  3.203E+01  3.223E+01  3.242E+01  3.262E+01  3.281E+01  3.301E+01  3.321E+01  3.341E+01  3.361E+01  3.381E+01
  3.401E+01  3.421E+01  3.441E+01  3.461E+01  3.482E+01  3.502E+01  3.523E+01  3.544E+01  3.564E+01  3.585E+01
  3.606E+01  3.627E+01  3.648E+01  3.669E+01  3.691E+01  3.712E+01  3.733E+01  3.755E+01  3.776E+01  3.798E+01
  3.820E+01  3.842E+01  3.864E+01  3.886E+01  3.908E+01  3.930E+01  3.952E+01  3.974E+01  3.997E+01  4.020E+01
  4.042E+01  4.065E+01  4.088E+01  4.111E+01  4.134E+01  4.157E+01  4.180E+01  4.203E+01  4.227E+01  4.250E+01
  4.274E+01  4.298E+01  4.321E+01  4.345E+01  4.369E+01  4.393E+01  4.417E+01  4.441E+01  4.466E+01  4.490E+01
  4.515E+01  4.539E+01  4.564E+01  4.589E+01  4.614E+01  4.639E+01  4.664E+01  4.689E+01  4.714E+01  4.740E+01
  4.766E+01  4.791E+01  4.817E+01  4.843E+01  4.869E+01  4.895E+01  4.921E+01  4.947E+01  4.974E+01  5.000E+01

K10(I) =
    2    4    5    7    8    9   11   12   14   15   17   18   20   21   22   24   25   27   28   29
   31   32   33   35   36   37   39   40   41   43   44   45   46   48   49   50   51   53   54   55
   56   58   59   60   61   62   64   65   66   67   68   69   71   72   73   74   75   76   77   78
   80   81   82   83   84   85   86   87   88   89   90   92   93   94   95   96   97   98   99  100
  101  102  103  104  105  106  107  108  109  110  111  112  113  114  115  116  117  118  119  120
  121  121  122  123  124  125  126  127  128  129  130  131  132  133  133  134  135  136  137  138
  139  140  141  141  142  143  144  145  146  147  147  148  149  150  151  152  152  153  154  155
  156  157  157  158  159  160  161  161  162  163  164  165  165  166  167  168  169  169  170  171
  172  172  173  174  175  175  176  177  178  178  179  180  181  181  182  183  184  184  185  186
  187  187  188  189  189  190  191  192  192  193  194  194  195  196  197  197  198  199  199  200
  201  201  202  203  203  204  205  205  206  207  207  208  209  209  210  211  211  212  213  213
  214  215  215  216  217  217  218  219  219  220  220  221  222  222  223  224  224  225  225  226
  227  227  228  229  229  230  230  231  232  232  233  233  234  235  235  236  236  237  238  238
  239  239  240  241  241  242  242  243  243  244  245  245  246  246  247  247  248  249  249  250
  250  251  251  252  252  253  254  254  255  255  256  256  257  258  258  259  259  260  260  261
  261  262  262  263  263  264  264  265  265  266  266  267  267  268  268  269  269  270  270  271
  272  272  273  273  274  274  275  275  276  276  277  277  278  278  279  279  280  280  281  281
  282  282  283  283  284  284  285  285  286  286  287  287  288  288  289  289  290  290  291  291
  292  292  293  293  294  294  295  295  296  296  297  297  298  298  299  299  300  300  301  301
  301  302  302  302  303  303  304  304  305  305  306  306  307  307  307  308  308  309  309  310
  310  311  311  311  312  312  313  313  314  314  314  315  315  316  316  317  317  317  318  318
  319  319  320  320  320  321  321  322  322  323  323  324  324  325  325  326  326  326  327  327
  327  328  328  328  329  329  330  330  330  331  331  332  332  333  333  333  334  334  335  335
  335  336  336  337  337  337  338  338  339  339  339  340  340  340  341  341  342  342  342  343
  343  344  344  344  345  345  345  346  346  347  347  347  348  348  349  349  349  350  350  350

INPUT ENERGIES AND SPECTRUM
ENERGIES (KEV)...
  1.000E+01  4.000E+01  1.000E+02  1.500E+02  2.000E+02  2.500E+02  3.000E+02  4.000E+02  5.000E+02  6.000E+02
  7.000E+02  8.000E+02  1.000E+03  1.200E+03  1.400E+03  1.600E+03  1.800E+03  2.000E+03  2.200E+03  2.400E+03
  2.600E+03  2.800E+03  3.000E+03  3.300E+03  3.600E+03  3.900E+03  4.200E+03  4.600E+03  5.000E+03  5.500E+03
  6.000E+03  7.000E+03

SPECTRUM
  5.447E-06  1.634E-05  3.431E-05  9.768E-06  1.178E-05  8.724E-06  9.712E-06  8.015E-06  6.542E-06  5.352E-06
  4.348E-06  3.535E-06  2.818E-06  1.628E-06  1.044E-06  6.768E-07  4.382E-07  2.850E-07  1.571E-07  6.67+E-08
  8.288E-08  4.252E-08  2.355E-08  1.295E-08  6.527E-09  3.219E-09  2.728E-09  1.132E-09  4.714E-10  9.353E-11
  3.592E-11  5.813E-12
```

Figure 6 (Continued). Initial printout for problem 1.0.

```
NORMAL ENERGY SPECTRUM...
   5.514E-25   4.425E-25   2.428E-25   1.506E-25   1.198E-25   9.794E-26   8.229E-26   5.494E-26   3.877E-26   2.794E-26
   2.344E-26   1.572E-26   8.407E-27   4.731E-27   2.675E-27   1.525E-27   8.687E-28   4.577E-28   2.771E-28   1.711E-28
   1.033E-28   5.682E-29   3.403E-29   1.694E-29   8.730E-10   4.912E-10   2.783E-10   1.229E-10   3.696E-11   9.101E-12
   3.571E-12   4.324E-13

VELOCITIES AND NORMAL VELOCITY SPECTRUM ARE
VELOCITIES (CM/SEC)...
   7.243E+08   1.287E+09   1.873E+09   2.292E+09   2.645E+09   2.945E+09   3.236E+09   3.729E+09   4.143E+09   4.554E+09
   4.912E+09   5.243E+09   5.845E+09   6.385E+09   6.877E+09   7.331E+09   7.754E+09   8.152E+09   8.524E+09   8.874E+09
   9.215E+09   9.537E+09   9.844E+09   1.298E+10   1.078E+10   1.109E+10   1.146E+10   1.193E+10   1.237E+10   1.289E+10
   1.338E+10   1.427E+10

NORMAL VELOCITY SPECTRUM
   2.279E-14   3.174E-14   2.804E-14   1.944E-14   1.826E-14   1.660E-14   1.509E-14   1.200E-14   9.518E-15   7.558E-15
   5.818E-15   4.811E-15   3.237E-15   1.874E-15   1.157E-15   7.136E-16   4.348E-16   2.812E-16   1.573E-16   1.026E-16
   6.516E-17   3.742E-17   2.359E-17   1.252E-17   6.851E-18   4.979E-18   2.438E-18   9.636E-19   3.598E-19   9.845E-20
   4.116E-20   5.644E-21
INTEGRAL OF THIS SPECTRUM (FROM VE(1) TO VE(NV)) IS  8.281E-25
AVERAGE NORMAL VELOCITY IS  2.638E+09 (CM/SEC)
AVERAGE NORMAL ENERGY   IS  2.661E+00 (KEV)

NORMALIZED VELOCITIES AND SPECTRUM...
VELOCITIES
   2.753E-01   4.787E-01   7.122E-01   8.692E-01   1.023E+00   1.120E+00   1.226E+00   1.414E+00   1.578E+00   1.727E+00
   1.862E+00   1.985E+00   2.210E+00   2.421E+00   2.607E+00   2.781E+00   2.940E+00   3.090E+00   3.232E+00   3.366E+00
   3.494E+00   3.616E+00   3.732E+00   3.899E+00   4.056E+00   4.204E+00   4.345E+00   4.523E+00   4.691E+00   4.849E+00
   5.272E+00   5.449E+00

SPECTRUM
   7.249E-01   1.211E+00   8.294E-01   6.321E-01   5.824E-01   5.289E-01   4.827E-01   3.822E-01   3.032E-01   2.407E-01
   1.917E-01   1.532E-01   9.673E-02   5.968E-02   3.687E-02   2.273E-02   1.389E-02   8.312E-03   5.219E-03   3.267E-03
   2.075E-03   1.198E-03   7.513E-04   3.987E-04   2.182E-04   1.295E-04   7.765E-05   3.369E-05   1.146E-05   3.136E-06
   1.311E-06   1.796E-07

EMISSION VELOCITIES AFTER EQUALIZING WEIGHTS...
   8.271E-02   1.549E-01   2.540E-01   3.022E-01   3.455E-01   3.858E-01   4.237E-01   4.595E-01   4.941E-01   5.291E-01
   5.650E-01   6.021E-01   6.403E-01   6.799E-01   7.212E-01   7.648E-01   8.119E-01   8.630E-01   9.178E-01   9.748E-01
   1.034E+00   1.096E+00   1.162E+00   1.231E+00   1.306E+00   1.385E+00   1.482E+00   1.586E+00   1.716E+00   1.877E+00
   2.127E+00   3.027E+00

EMISSION WEIGHTS...
   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02
   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02
   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02   3.125E-02
   3.125E-02   3.125E-02


PLASMA PERIOD = TP =  4.215E+09 (SEC)
ALPHA = PHHM/TP   =  2.492E+00
AL = (UT/TP)**2   =  1.000E+00
DL                =  8.000E-02
```

Figure 6 (Continued). Initial printout for problem 1.0.

```
   UNIT OF
   ---- --

TIME                =  4.015E-09 SEC
LENGTH              =  1.059E+01 CM
                    =  1.059E-01 M
VELOCITY            =  2.638E+09 CM/SEC
                    =  2.638E+07 M/SEC
CHARGE/UNIT AREA    =  9.913E-02 ESU/CM**2
                    =  3.307E-07 COUL/M**2
ELECTRIC FIELD      =  1.246E+02 ESU
                    =  3.735E+04 VOLTS/M
POTENTIAL           =  1.319E+01 ESU
                    =  3.955E+03 VOLTS
NUMBER DENSITY      =  1.949E+07 /CM**3
                    =  1.949E+13 /M**3
CHARGE DENSITY      =  9.360E-03 ESU/CM**3
                    =  3.122E-06 COUL/M**3
CURRENT DENSITY     =  8.235E-04 ABAMPS/CM**2
                    =  8.235E+01 AMPS/M**2
CURRENT INTEGRAL    =  8.722E-03 ABAMPS/CM
                    =  8.722E+00 AMPS/M
DIPOLE MOMENT       =  1.650E+00 ESU/CM
                    =  3.532E-08 COUL/M
```

Figure 6 (Continued). Initial printout for problem 1.0.

```
CYCLE NO.   130   TIME = 3.250E+00   NP = 3364   NKILL = 796   NPxMAx =     0   QTOT = 1.507E+00  QR = 0.
FIELD AT SURFACE =  1.507E+00
POTENTIAL AT SURFACE =  0.
FIELD EVERY 0.1 LENGTH UNITS...
  1.271E+00   1.192E+00   9.757E-01   8.783E-01   7.899E-01   7.168E-01   6.536E-01   5.972E-01   5.468E-01   5.221E-01
  4.612E-01   4.240E-01   3.998E-01   3.616E-01   3.342E-01   3.096E-01   2.886E-01   2.680E-01   2.486E-01   2.287E-01
  2.132E-01   1.978E-01   1.834E-01   1.710E-01   1.590E-01   1.473E-01   1.368E-01   1.286E-01   1.195E-01   1.106E-01
  1.031E-01   9.598E-02   9.006E-02   8.378E-02   7.776E-02   7.249E-02   6.796E-02   6.348E-02   5.955E-02   5.550E-02
  5.191E-02   4.845E-02   4.533E-02   4.284E-02   4.041E-02   3.745E-02   3.566E-02   3.355E-02   3.144E-02   2.966E-02
  2.837E-02   2.694E-02   2.553E-02   2.408E-02   2.293E-02   2.174E-02   2.065E-02   1.967E-02   1.919E-02   1.831E-02
  1.757E-02   1.678E-02   1.596E-02   1.541E-02   1.475E-02   1.416E-02   1.382E-02   1.327E-02   1.258E-02   1.211E-02
  1.165E-02   1.141E-02   1.118E-02   1.074E-02   1.032E-02   9.809E-03   9.494E-03   9.098E-03   8.715E-03   8.317E-03
  7.971E-03   7.614E-03   7.268E-03   6.934E-03   6.602E-03   6.293E-03   5.974E-03   5.673E-03   5.381E-03   5.098E-03
  4.824E-03   4.596E-03   4.331E-03   4.082E-03   3.812E-03   3.582E-03   3.372E-03   2.922E-03   2.721E-03

POTENTIAL EVERY 0.1 LENGTH UNITS...
  1.389E-01   2.574E-01   3.615E-01   4.542E-01   5.373E-01   6.126E-01   6.811E-01   7.437E-01   8.009E-01   8.533E-01
  9.015E-01   9.457E-01   9.864E-01   1.024E+00   1.059E+00   1.091E+00   1.121E+00   1.148E+00   1.174E+00   1.198E+00
  1.220E+00   1.241E+00   1.260E+00   1.277E+00   1.294E+00   1.309E+00   1.323E+00   1.337E+00   1.349E+00   1.360E+00
  1.371E+00   1.381E+00   1.390E+00   1.399E+00   1.407E+00   1.415E+00   1.422E+00   1.428E+00   1.434E+00   1.440E+00
  1.444E+00   1.451E+00   1.455E+00   1.462E+00   1.464E+00   1.468E+00   1.471E+00   1.475E+00   1.478E+00   1.481E+00
  1.484E+00   1.487E+00   1.489E+00   1.492E+00   1.494E+00   1.497E+00   1.499E+00   1.501E+00   1.503E+00   1.504E+00
  1.506E+00   1.508E+00   1.510E+00   1.511E+00   1.513E+00   1.514E+00   1.516E+00   1.517E+00   1.518E+00   1.519E+00
  1.521E+00   1.522E+00   1.523E+00   1.524E+00   1.525E+00   1.526E+00   1.527E+00   1.528E+00   1.529E+00   1.530E+00
  1.531E+00   1.531E+00   1.532E+00   1.533E+00   1.533E+00   1.534E+00   1.535E+00   1.535E+00   1.536E+00   1.536E+00
  1.537E+00   1.537E+00   1.538E+00   1.538E+00   1.539E+00   1.539E+00   1.539E+00   1.540E+00   1.540E+00

NUMBER OF PARTICLES IN FIRST  100 BINS...
 289  221  171  154  130  110  106   99   86   85   79   73   73   66   66   63   61   55   56   51
  51   39   45   47   41   42   42   38   41   34   34   35   34   29   31   29   29   29   21   26
  25   25   23   21   23   18   20   20   19   16   17   16   15   15   14   13   14   12   12   12
  10   12    8    9    9    8    8    7    6    6    7    5    7    4    5    4    3    5    4    3
   3    2    3    3    2    3    3    1    1    1    0    1    1    1    1    1    1    1    1    1
CHARGE Q(I) IN FIRST   60 BINS
  1.678E-01   1.339E-01   1.215E-01   8.926E-02   7.600E-02   6.334E-02   5.891E-02   5.488E-02   4.683E-02   4.456E-02
  3.993E-02   3.792E-02   3.573E-02   3.135E-02   3.067E-02   2.884E-02   2.789E-02   2.349E-02   2.348E-02   2.111E-02
  2.227E-02   1.953E-02   1.737E-02   1.813E-02   1.493E-02   1.498E-02   1.507E-02   1.198E-02   1.397E-02   1.111E-02
  1.196E-02   1.137E-02   1.027E-02   9.162E-03   9.264E-03   8.754E-03   8.919E-03   8.123E-03   8.620E-03   7.017E-03
  6.533E-03   7.227E-03   6.824E-03   5.780E-03   5.459E-03   4.164E-03   5.274E-03   4.894E-03   4.525E-03   3.894E-03
  3.529E-03   3.670E-03   3.168E-03   3.223E-03   3.357E-03   2.799E-03   2.863E-03   2.728E-03   2.863E-03   2.886E-03

CHARGE DENSITY EVERY 0.1 LENGTH UNITS...
  2.215E+00   1.431E+00   1.133E+00   9.087E-01   7.995E-01   6.799E-01   5.942E-01   5.377E-01   4.694E-01   4.309E-01
  3.975E-01   3.432E-01   3.131E-01   2.897E-01   2.579E-01   2.444E-01   2.116E-01   2.060E-01   1.784E-01   1.741E-01
  1.515E-01   1.498E-01   1.333E-01   1.224E-01   1.177E-01   1.133E-01   8.891E-02   9.264E-02   8.894E-02   8.254E-02
  7.382E-02   6.626E-02   5.821E-02   6.264E-02   5.699E-02   4.865E-02   4.480E-02   4.184E-02   3.976E-02   3.899E-02
  3.434E-02   3.373E-02   2.784E-02   2.482E-02   2.539E-02   2.468E-02   1.959E-02   2.190E-02   1.884E-02   1.634E-02
  1.217E-02   1.481E-02   1.461E-02   1.258E-02   1.214E-02   1.106E-02   1.061E-02   7.354E-03   6.251E-03   8.373E-03
  7.712E-03   7.632E-03   6.732E-03   6.585E-03   6.263E-03   5.682E-03   5.487E-03   5.249E-03   4.781E-03   4.644E-03
  2.337E-03   2.389E-03   4.422E-03   4.317E-03   4.213E-03   4.110E-03   4.008E-03   3.907E-03   3.808E-03   3.709E-03
  3.612E-03   3.516E-03   3.421E-03   3.327E-03   3.234E-03   3.143E-03   3.052E-03   2.962E-03   2.874E-03   2.786E-03
  2.700E-03   2.614E-03   2.530E-03   2.446E-03   2.364E-03   2.282E-03   2.410E-03   2.853E-03   1.987E-03
```

Figure 7. Time cycle print for problem 1.0.

```
CURRENT DENSITY EVERY 0.1 LENGTH UNITS...
 1.969E-01  1.916E-01  2.286E-01  2.598E-01  2.671E-01  2.713E-01  2.713E-01  2.709E-01  2.677E-01  2.610E-01
 2.543E-01  2.496E-01  2.397E-01  2.325E-01  2.251E-01  2.151E-01  2.073E-01  2.021E-01  1.949E-01  1.843E-01
 1.777E-01  1.712E-01  1.653E-01  1.583E-01  1.516E-01  1.451E-01  1.421E-01  1.357E-01  1.286E-01  1.222E-01
 1.140E-01  1.132E-01  1.073E-01  1.002E-01  9.549E-02  9.088E-02  8.706E-02  8.386E-02  7.794E-02  7.311E-02
 4.925E-02  6.566E-02  6.331E-02  6.069E-02  5.823E-02  5.251E-02  4.945E-02  4.674E-02  4.458E-02  4.330E-02
 4.105E-02  3.812E-02  3.526E-02  3.365E-02  3.161E-02  2.981E-02  2.886E-02  2.825E-02  2.690E-02  2.553E-02
 2.381E-02  2.214E-02  2.131E-02  2.053E-02  1.969E-02  1.886E-02  1.803E-02  1.749E-02  1.731E-02  1.694E-02
 1.661E-02  1.629E-02  1.597E-02  1.564E-02  1.532E-02  1.473E-02  1.442E-02  1.414E-02  1.388E-02  1.361E-02
 1.333E-02  1.306E-02  1.279E-02  1.252E-02  1.225E-02  1.198E-02  1.172E-02  1.142E-02  1.114E-02  1.086E-02
 1.057E-02  1.028E-02  9.915E-03  9.499E-03  9.152E-03  8.851E-03  8.551E-03  8.254E-03  7.982E-03

DIPOLE MOMENT OUT TO X, EVERY 0.1 LENGTH UNIT...
 0.         1.105E-02  3.544E-02  6.674E-02  1.019E-01  1.401E-01  1.822E-01  2.212E-01  2.535E-01  3.262E-01
 3.488E-01  3.921E-01  4.144E-01  4.755E-01  5.157E-01  5.548E-01  5.937E-01  6.312E-01  6.675E-01  7.332E-01
 7.376E-01  7.709E-01  8.033E-01  8.352E-01  8.649E-01  8.943E-01  9.238E-01  9.504E-01  9.749E-01  1.020E+00
 1.036E+00  1.049E+00  1.071E+00  1.092E+00  1.112E+00  1.132E+00  1.151E+00  1.168E+00  1.184E+00  1.214E+00
 1.216E+00  1.231E+00  1.245E+00  1.258E+00  1.269E+00  1.282E+00  1.292E+00  1.302E+00  1.312E+00  1.329E+00
 1.330E+00  1.338E+00  1.344E+00  1.352E+00  1.359E+00  1.366E+00  1.373E+00  1.379E+00  1.384E+00  1.388E+00
 1.390E+00  1.397E+00  1.402E+00  1.406E+00  1.411E+00  1.415E+00  1.419E+00  1.422E+00  1.426E+00  1.429E+00
 1.431E+00  1.435E+00  1.437E+00  1.439E+00  1.442E+00  1.444E+00  1.449E+00  1.452E+00  1.455E+00  1.458E+00
 1.481E+00  1.484E+00  1.487E+00  1.479E+00  1.472E+00  1.475E+00  1.478E+00  1.481E+00  1.483E+00  1.486E+00
 1.488E+00  1.491E+00  1.493E+00  1.496E+00  1.498E+00  1.500E+00  1.503E+00  1.505E+00  1.508E+00  1.511E+00
CURRENT INTEGRAL = 8.825E-01
```

Figure 7 (Continued). Time cycle print for problem 1.0.

```
                    SCALID PROBLEM NUMBER      2.0D
                    SAMPLE PROBLEM TWO,  LINEAR RISE.

   NT    NC    IR   ICN    NV    IT    IP    LP
  400   350     1     2    32     1    10     0

     DT          XMAX          XI          PO          PROBNO
  2.500E-02   5.000E+01   1.224E+00   1.000E+00   2.000E+00

     YIE         FLU         FWHM
  2.572E+12   2.000E+12   0.

FIRST  100 BINS...
XB(I) =
  6.571E-02   6.597E-02   6.623E-02   6.650E-02   6.676E-02   6.703E-02   6.730E-02   6.757E-02   6.784E-02   6.811E-02
  6.838E-02   6.865E-02   6.893E-02   6.921E-02   6.948E-02   6.976E-02   7.004E-02   7.032E-02   7.060E-02   7.088E-02
  7.117E-02   7.145E-02   7.174E-02   7.202E-02   7.231E-02   7.260E-02   7.289E-02   7.318E-02   7.347E-02   7.377E-02
  7.406E-02   7.436E-02   7.466E-02   7.496E-02   7.526E-02   7.556E-02   7.586E-02   7.616E-02   7.647E-02   7.677E-02
  7.708E-02   7.739E-02   7.770E-02   7.801E-02   7.832E-02   7.863E-02   7.895E-02   7.927E-02   7.958E-02   7.990E-02
  8.022E-02   8.054E-02   8.086E-02   8.119E-02   8.151E-02   8.184E-02   8.217E-02   8.249E-02   8.282E-02   8.315E-02
  8.349E-02   8.382E-02   8.416E-02   8.449E-02   8.483E-02   8.517E-02   8.551E-02   8.585E-02   8.620E-02   8.654E-02
  8.689E-02   8.724E-02   8.758E-02   8.793E-02   8.828E-02   8.863E-02   8.898E-02   8.933E-02   8.971E-02   9.007E-02
  9.043E-02   9.079E-02   9.115E-02   9.152E-02   9.189E-02   9.226E-02   9.262E-02   9.299E-02   9.336E-02   9.373E-02
  9.411E-02   9.449E-02   9.486E-02   9.524E-02   9.562E-02   9.601E-02   9.639E-02   9.678E-02   9.716E-02   9.755E-02

SL(I) =
  0.          6.571E-02   1.317E-01   1.979E-01   2.644E-01   3.310E-01   3.980E-01   4.655E-01   5.331E-01   6.009E-01
  6.689E-01   7.374E-01   8.060E-01   8.750E-01   9.440E-01   1.014E+00   1.084E+00   1.155E+00   1.226E+00   1.298E+00
  1.369E+00   1.442E+00   1.514E+00   1.588E+00   1.662E+00   1.736E+00   1.811E+00   1.887E+00   1.963E+00   2.040E+00
  2.117E+00   2.194E+00   2.272E+00   2.351E+00   2.430E+00   2.510E+00   2.590E+00   2.671E+00   2.753E+00   2.835E+00
  2.918E+00   3.001E+00   3.085E+00   3.170E+00   3.255E+00   3.341E+00   3.427E+00   3.514E+00   3.602E+00   3.690E+00
  3.779E+00   3.869E+00   3.959E+00   4.050E+00   4.142E+00   4.234E+00   4.327E+00   4.421E+00   4.515E+00   4.610E+00
  4.706E+00   4.802E+00   4.899E+00   4.997E+00   5.095E+00   5.194E+00   5.294E+00   5.395E+00   5.496E+00   5.598E+00
  5.701E+00   5.805E+00   5.909E+00   6.014E+00   6.120E+00   6.227E+00   6.334E+00   6.442E+00   6.551E+00   6.661E+00
  6.771E+00   6.882E+00   6.994E+00   7.107E+00   7.220E+00   7.334E+00   7.449E+00   7.565E+00   7.681E+00   7.798E+00

LAST  100 BINS...
XB(I) =
  1.799E+01   1.799E+01   1.797E+01   1.794E+01   1.791E+01   1.787E+01   1.783E+01   1.779E+01   1.774E+01   1.769E+01
  1.763E+01   1.757E+01   1.751E+01   1.744E+01   1.737E+01   1.730E+01   1.722E+01   1.714E+01   1.706E+01   1.697E+01
  1.688E+01   1.679E+01   1.669E+01   1.659E+01   1.649E+01   1.638E+01   1.627E+01   1.616E+01   1.604E+01   1.592E+01
  1.580E+01   1.567E+01   1.554E+01   1.541E+01   1.527E+01   1.513E+01   1.499E+01   1.484E+01   1.469E+01   1.454E+01
  1.438E+01   1.422E+01   1.406E+01   1.389E+01   1.372E+01   1.355E+01   1.337E+01   1.319E+01   1.301E+01   1.282E+01
  1.263E+01   1.244E+01   1.224E+01   1.204E+01   1.184E+01   1.163E+01   1.142E+01   1.121E+01   1.099E+01   1.077E+01
  1.055E+01   1.032E+01   1.009E+01   9.859E+00   9.623E+00   9.384E+00   9.142E+00   8.897E+00   8.649E+00   8.398E+00
  8.144E+00   7.887E+00   7.627E+00   7.364E+00   7.098E+00   6.829E+00   6.557E+00   6.282E+00   6.004E+00   5.723E+00
  5.439E+00   5.152E+00   4.862E+00   4.569E+00   4.273E+00   3.974E+00   3.672E+00   3.367E+00   3.059E+00   2.748E+00
  2.434E+00   2.117E+00   1.797E+00   1.474E+00   1.148E+00   8.191E-01   4.875E-01   1.532E-01  -1.837E-01  -5.234E-01
```

Figure 8. Initial printout for problem 2.0.

```
SL(I) =
   2.831E+01   2.863E+01   2.867E+01   2.895E+01   2.903E+01   2.935E+01   2.943E+01   2.95BE+01   2.977E+01   2.995E+01
   3.014E+01   3.033E+01   3.051E+01   3.073E+01   3.089E+01   3.113E+01   3.127E+01   3.145E+01   3.165E+01   3.185E+01
   3.203E+01   3.223E+01   3.243E+01   3.253E+01   3.281E+01   3.301E+01   3.321E+01   3.341E+01   3.361E+01   3.381E+01
   3.401E+01   3.421E+01   3.441E+01   3.461E+01   3.481E+01   3.502E+01   3.523E+01   3.546E+01   3.564E+01   3.585E+01
   3.606E+01   3.627E+01   3.648E+01   3.669E+01   3.691E+01   3.712E+01   3.733E+01   3.756E+01   3.776E+01   3.798E+01
   3.820E+01   3.842E+01   3.864E+01   3.886E+01   3.908E+01   3.930E+01   3.952E+01   3.975E+01   3.997E+01   4.020E+01
   4.042E+01   4.065E+01   4.088E+01   4.111E+01   4.134E+01   4.157E+01   4.180E+01   4.203E+01   4.227E+01   4.250E+01
   4.274E+01   4.298E+01   4.321E+01   4.345E+01   4.369E+01   4.393E+01   4.417E+01   4.441E+01   4.466E+01   4.490E+01
   4.515E+01   4.539E+01   4.564E+01   4.589E+01   4.614E+01   4.639E+01   4.664E+01   4.689E+01   4.715E+01   4.740E+01
   4.766E+01   4.791E+01   4.817E+01   4.843E+01   4.869E+01   4.895E+01   4.921E+01   4.947E+01   4.974E+01   5.000E+01

K10(I)
    2    4    5    7    8    9   11   12   14   15   17   18   20   21   22   24   25   27   28   29
   31   32   33   35   36   37   39   40   41   43   44   45   46   48   49   50   51   53   54   55
   56   58   59   60   61   62   64   65   66   67   68   69   71   72   73   74   75   76   77   78
   80   81   82   83   84   85   86   87   88   89   90   92   93   94   95   96   97   98   99  100
  101  102  103  104  105  106  107  108  109  110  111  112  113  114  115  116  117  118  119  120
  121  121  122  123  124  125  126  127  128  129  130  131  132  133  134  134  135  136  137  138
  139  140  141  141  142  143  144  145  146  147  147  148  149  150  151  152  152  153  154  155
  156  157  157  158  159  160  161  161  162  163  164  165  165  166  167  168  169  169  170  171
  172  172  173  174  175  175  176  177  178  178  179  180  181  181  182  183  184  184  185  186
  187  187  188  189  189  190  191  192  192  193  194  194  195  196  197  197  198  199  199  200
  201  201  202  203  203  204  205  205  206  207  207  208  209  209  210  211  211  212  213  213
  214  215  215  216  217  217  216  219  219  220  220  221  222  222  223  224  224  225  225  226
  227  227  228  229  229  230  230  231  232  232  233  233  234  235  235  235  236  237  238  238
  239  239  240  241  241  242  242  243  243  244  245  245  246  247  247  248  249  249  250  250
  252  251  251  252  253  253  254  254  255  255  256  256  257  258  258  259  259  260  260  261
  261  262  262  263  263  264  265  265  266  266  267  267  268  268  269  269  270  270  271  271
  272  272  273  273  274  274  275  275  276  276  277  277  278  278  279  279  280  280  281  281
  282  282  283  283  284  284  285  285  286  286  287  287  288  288  289  289  290  290  291  291
  292  292  293  293  294  294  295  295  295  296  296  297  297  298  298  299  299  300  300  301
  301  302  302  302  303  303  304  304  305  305  306  306  307  307  307  308  308  309  309  310
  310  311  311  311  312  312  313  313  314  314  314  315  315  316  316  317  317  317  318  318
  319  319  320  320  320  321  321  322  322  323  323  324  324  324  325  325  326  326  326  327
  327  328  328  328  329  329  330  330  331  331  332  332  333  333  333  334  334  335  335  335
  335  336  336  337  337  337  338  338  339  339  339  340  340  340  341  341  342  342  342  343
  343  344  344  344  345  345  346  346  346  347  347  347  348  348  349  349  349  350  350  350

SPECTRUM AND VELOCITIES ARE SAME AS PREVIOUS PROBLEM

PLASMA PERIOD = TP =  5.443E-09 (SEC)
ALPHA = FWHM/TP   =  1.200E+00
AL = (UT/TP)**2   =  1.000E+00
DL                =  8.000E-02
```

Figure 8 (Continued). Initial printout for problem 2.0.

```
IT = 1
X-RAY FLUX IS PROPORTIONAL TO T**  1.0000
THERE IS NO FLUENCE OR FWHM


      UNIT OF
      ---- --

TIME                =  5.443E-09 SEC
LENGTH              =  1.436E+01 CM
                    =  1.436E-01 M
VELOCITY            =  2.636E+09 CM/SEC
                    =  2.636E+07 M/SEC
CHARGE/UNIT AREA    =  7.314E+02 ESU/CM**2
                    =  2.444E-07 COUL/M**2
ELECTRIC FIELD      =  9.194E-01 ESU
                    =  2.755E+04 VOLTS/M
POTENTIAL           =  1.319E+01 ESU
                    =  3.955E+03 VOLTS
NUMBER DENSITY      =  1.861E+07 /CM**3
                    =  1.861E+13 /M**3
CHARGE DENSITY      =  5.095E-23 ESU/CM**3
                    =  1.699E-06 COUL/M**3
CURRENT DENSITY     =  4.482E-04 ABAMPS/CM**2
                    =  4.482E+01 AMPS/M**2
CURRENT INTEGRAL    =  6.434E-03 ABAMPS/CM
                    =  6.434E+00 AMPS/M
DIPOLE MOMENT       =  1.054E+00 ESU/CM
                    =  3.502E-08 COUL/M
```

Figure 8 (Continued). Initial printout for problem 2.0.

```
CYCLE NO.    50   TIME =  1.250E+00   NP =  1570   NKILL =   30   NFXMAX =     0   QTOT =  7.831E-01   QR =  0.
FIELD AT SURFACE =  7.831E-01
POTENTIAL AT SURFACE =  0.
FIELD EVERY 0.1 LENGTH UNITS...
  5.764E-01   4.294E-01   3.321E-01   2.596E-01   2.042E-01   1.614E-01   1.323E-01   1.044E-01   8.485E-02   6.823E-02
  5.544E-02   4.529E-02   3.673E-02   3.066E-02   2.521E-02   2.065E-02   1.744E-02   1.478E-02   1.238E-02   1.094E-02
  9.199E-03   7.974E-03   7.316E-03   6.534E-03   5.722E-03   5.442E-03   4.889E-03   4.337E-03   3.816E-03   3.724E-03
  3.232E-03   2.794E-03   2.388E-03   2.327E-03   1.945E-03   1.619E-03   1.316E-03   1.074E-03   1.003E-03   7.746E-04
  5.799E-04   4.281E-04   2.492E-0    1.953E-04   1.444E-04   6.744E-05   1.886E-05   0.          0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.

POTENTIAL EVERY 0.1 LENGTH UNITS...
  6.797E-02   1.183E-01   1.564E-01   1.860E-01   2.092E-01   2.275E-01   2.422E-01   2.540E-01   2.634E-01   2.711E-01
  2.772E-01   2.823E-01   2.863E-01   2.897E-01   2.925E-01   2.948E-01   2.967E-01   2.983E-01   2.997E-01   3.006E-01
  3.018E-01   3.027E-01   3.035E-01   3.042E-01   3.048E-01   3.053E-01   3.058E-01   3.063E-01   3.067E-01   3.071E-01
  3.074E-01   3.077E-01   3.080E-01   3.082E-01   3.084E-01   3.086E-01   3.088E-01   3.089E-01   3.091E-01   3.091E-01
  3.091E-01   3.092E-01   3.092E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01
  3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01
  3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01
  3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01
  3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01   3.093E-01

NUMBER OF PARTICLES IN FIRST  100 BINS...
  174  152  141  119  109   91   88   78   63   64   52   48   42   37   37   30   27   25   21   19
   19   14   15   13   11    8   10    6    6    7    4    5    2    3    3    2    2    1    1    1
    1    0    1    1    1    1    0    1    1    1    1    1    0    1    1    1    1    1    1    0
    1    1    1    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
CHARGE Q(I) IN FIRST   60 BINS
  1.482E-01   1.129E-01   9.218E-02   6.877E-02   5.826E-02   4.432E-02   3.951E-02   3.312E-02   2.498E-02   2.426E-02
  1.849E-02   1.795E-02   1.371E-02   1.182E-02   1.154E-02   8.574E-03   7.432E-03   7.227E-03   5.584E-03   4.223E-03
  4.846E-03   3.340E-03   3.477E-03   2.383E-03   2.385E-03   1.707E-03   2.168E-03   8.594E-04   1.191E-03   1.347E-03
  8.694E-04   9.941E-04   1.748E-04   6.445E-04   6.641E-04   5.273E-04   5.859E-05   4.492E-04   4.297E-04   4.102E-04
  3.906E-04   0.          3.711E-04   3.516E-04   3.320E-04   3.125E-04   0.          2.930E-04   2.734E-04   2.539E-04
  2.344E-04   2.148E-04   0.          1.953E-04   1.758E-04   1.563E-04   1.367E-04   1.172E-04   9.766E-05   0.

CHARGE DENSITY EVERY 0.1 LENGTH UNITS...
  1.741E+00   1.194E+00   8.560E-01   6.223E-01   4.842E-01   3.625E-01   2.881E-01   2.285E-01   1.779E-01   1.502E-01
  1.115E-01   9.594E-02   6.569E-02   5.182E-02   4.826E-02   3.792E-02   2.992E-02   2.710E-02   1.679E-02   1.575E-02
  1.452E-02   1.290E-02   9.326E-03   8.652E-03   6.162E-03   3.986E-03   5.728E-03   5.364E-03   3.431E-03   2.449E-03
  4.552E-04   4.216E-03   2.362E-03   2.199E-03   3.468E-03   3.140E-03   2.893E-03   1.192E-03   1.711E-03   2.132E-03
  1.829E-03   1.535E-03   1.172E-03   4.301E-04   7.523E-04   6.150E-04   3.411E-04   8.365E-05   0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
  0.          0.          0.          0.          0.          0.          0.          0.          0.
```

Figure 9. Time cycle print for problem 2.0.

CURRENT DENSITY EVERY 0.1 LENGTH UNITS...

8.971E-01	7.935E-01	6.687E-01	5.639E-01	4.806E-01	4.092E-01	3.468E-01	2.983E-01	2.529E-01	2.160E-01
1.861E-01	1.548E-01	1.347E-01	1.129E-01	9.390E-02	8.227E-02	6.789E-02	5.613E-02	5.045E-02	4.147E-02
3.457E-02	3.162E-02	2.730E-02	2.246E-02	2.095E-02	2.005E-02	1.686E-02	1.565E-02	1.596E-02	1.553E-02
1.382E-02	1.260E-02	1.256E-02	1.238E-02	1.057E-02	9.543E-03	8.945E-03	8.712E-03	7.954E-03	6.557E-03
5.715E-03	5.013E-03	4.387E-03	3.700E-03	2.768E-03	1.775E-03	1.021E-03	3.694E-04	4.869E-05	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	

DIPOLE MOMENT OUT TO X, EVERY 0.1 LENGTH UNIT...

0.	9.622E-03	3.023E-02	5.497E-02	8.026E-02	1.048E-01	1.278E-01	1.487E-01	1.680E-01	1.851E-01
2.006E-01	2.143E-01	2.262E-01	2.362E-01	2.449E-01	2.528E-01	2.594E-01	2.650E-01	2.700E-01	2.740E-01
2.773E-01	2.805E-01	2.832E-01	2.850E-01	2.867E-01	2.885E-01	2.896E-01	2.908E-01	2.923E-01	2.936E-01
2.945E-01	2.955E-01	2.969E-01	2.982E-01	2.987E-01	2.997E-01	3.009E-01	3.020E-01	3.027E-01	3.033E-01
3.042E-01	3.048E-01	3.055E-01	3.061E-01	3.064E-01	3.067E-01	3.070E-01	3.072E-01	3.073E-01	3.074E-01
3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01
3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01
3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01
3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01
3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01	3.074E-01

CURRENT INTEGRAL = 5.636E-01

Figure 9 (Continued). Time cycle print for problem 2.0.

printed next, showing for example that $x = 2.4$ occurs in cell 35 (between SL(35) and SL(36)). The input spectrum is printed first as read in and then after conversion to a normal energy spectrum. The spectrum is then converted to a normal velocity spectrum and printed again. The average normal velocity is computed and is used as the unit of velocity. The velocities and spectrum are then normalized and printed again. Finally, equal weights are chosen for the emission particles, and their velocities are printed.

The plasma period, computed by Equation (8) or (42), the parameter α of Equation (29), and the quantity A of Equation (31), (called AL in the code) are then printed together with DL. DL is one-half of the particle length. Particles are given a length of 0.16 length units (essentially 0.16 Debye lengths) for the purpose of computing their charge and current densities more smoothly.

Finally the physical units are printed in Gaussian cgs and in MKS units. Quantities printed in the time cycle output must be multiplied by the appropriate dimensional unit to obtain the physical result. For example, the unit of time is 4.015 ns, the unit of electric field is 37.35 kV/m (or 1.246 esu), and the unit of length is 10.59 cm.

As a sample of the time cycle output, we show cycle 130 of problem 1.0 in Figure 7. This is at time 3.25×4.015 ns, or 13.05 ns. There are 3364 live particles. A total of 796 have been killed since the start of the problem, but none has passed XMAX. The total charge is 1.507 charge units, or 4.984×10^{-7} coulomb/m^2, obtained by multiplying by the unit of charge/unit area. The surface field is 1.507×37.35 kV/m = 56.29 kV/m.

The printout for the field every 0.1 length unit shows that at, say, 0.4 length units from the surface (4.24 cm) the field strength has dropped to $0.8753 \times 37.35 = 32.69$ kV/m.

The potential is measured from zero at the surface. At 10.59 cm (1 length unit), for example, it has risen to 0.8533×3.955 kV = 3.375 kV as shown in the printout.

The next group of numbers shows how many particles are in each cell. There are 285 in the first cell, 221 in the second, etc. The charge (per unit area) in the first several bins is printed next.

The charge density and current density every 0.1 length unit are printed next in dimensionless form. The first number printed is at 0.1 length unit (1.059 cm) from the surface, not at the surface. The surface charge and current densities are not computed by the code. Thus at 130 cycles, the charge density at 1.059 cm is $2.015 \times 3.122 \times 10^{-6} = 6.29 \times 10^{-6}$ Coul/m^3, and the current density is $0.1369 \times 82.35 = 11.27$ Amps/m^2.

The electron number density can also be obtained from the dimensionless charge density output by multiplying by the unit of number density (1.949×10^7 elec/cm^3), showing, for example, that at 0.6 length units (6.35 cm) the number density is $0.6729 \times 1.949 \times 10^7 = 1.31 \times 10^7$ cm^{-3}.

The dipole moment (per unit surface area) contributed by all electrons out to x,

$$P = \int_0^x x\rho(x)\, dx$$

is printed next. Here the first number is at the surface, $x = 0$, and so is 0. At, say, 0.7 length units (7.41 cm) the dipole moment is seen to be $0.2212 \times 3.502 \times 10^{-8} = 7.75 \times 10^{-9}$ Coul/m. Out to 9.9 length units it is $1.511 \times 3.502 \times 10^{-8} = 5.29 \times 10^{-8}$ Coul/m.

Finally, the integral of the current density,

$$CI = \int_0^\infty j(x,t)dx$$

is printed, having the value $0.8625 \times 8.722 = 7.52$ Amps/m.

The initial print for problem 2.0 is shown in Figure 8. The XB, SL, and K10 arrays are the same, and the spectrum is the same. The plasma period in this case is computed by Equation (43) with POW = 1.0, and has a slightly different value than in problem 1.0. Similarly, the units of length, number density, etc. are not exactly the same.

We show the output for cycle 50 in Figure 9. It is at time 1.25 units = 6.804 ns. The fastest emitted particle had velocity 3.827 units and so will not have travelled farther than 4.78 length units by this time. Hence, the field beyond 4.7 length units is still 0, and the printout shows no particles beyond the 64-th cell. Otherwise the interpretation of quantities is the same as for the previous problem.

Problem 1.0 ran for 500 cycles and moved a maximum of 3542 particles (at cycle 190). Problem 2.0 ran for 400 cycles and moved a maximum of 2500 particles (at cycle 110). Total CP time for both problems on a CDC 7600 was 41.4 sec.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

Director
Defense Advanced Research Proj. Agency
ATTN: NMR

Director
Defense Communications Agency
ATTN: NMR

Defense Documentation Center
Cameron Station
12 cy ATTN: TC

Director
Defense Intelligence Agency
ATTN: DB-4C

Director
Defense Nuclear Agency
2 cy ATTN: RAEV
ATTN: STSI, Archives
3 cy ATTN: STTL, Tech. Library
ATTN: DDST

Commander
Field Command
Defense Nuclear Agency
ATTN: FCLMC
ATTN: FCPR

Director
Interservice Nuclear Weapons School
ATTN: Document Control

Director
Joint Strat. Target Planning Staff, JCS
ATTN: JLTW-2

Chief
Livermore Division, Field Command, DNA
Lawrence Livermore Laboratory
ATTN: FCPRL

National Communications System
Office of the Manager
ATTN: NCS-TS

Director
National Security Agency
ATTN: R-425

OJCS/J-3
ATTN: J-3, RDTA Br., WWMCCS Plans Div.

OJCS/J-5
ATTN: J-5, Plans & Policy Nuc. Div.

Dir. of Defense Research & Engineering
Department of Defense
ATTN: S&SS (OS)

DEPARTMENT OF THE ARMY

Director
BMD Advanced Tech. Center
Huntsville Office
ATTN: RDMH-O

DEPARTMENT OF THE ARMY (Continued)

Commander
BMD System Command
ATTN: BDMSC-TEN

Dep. Chief of Staff for Research Dev. & Acq.
Department of the Army
ATTN: DAMA-CSM-N

Commander
Harry Diamond Laboratories
ATTN: DRXDO-RCC, John A. Rosado
ATTN: DRXDO-TI, Tech. Lib.
ATTN: DRXDO-RCC, Raine Gilbert

Commander
Picatinny Arsenal
ATTN: SARPA
ATTN: SMUPA

Commander
Redstone Scientific Information Center
US Army Missile Command
ATTN: Chief, Documents

Chief
US Army Communications Sys. Agency
ATTN: SCCM-AD-SV, Library

Commander
US Army Electronics Command
ATTN: DRSEL

Commander
US Army Foreign Science & Tech. Center
ATTN: DRXST-ISI

DEPARTMENT OF THE NAVY

Chief of Naval Operations
Navy Department
ATTN: Code 604C3

Chief of Naval Research
Navy Department
ATTN: Henry Mullaney, Code 427

Director
Naval Research Laboratory
ATTN: Code 7701
ATTN: Code 7756, J. Davis

Commander
Naval Surface Weapons Center
ATTN: Code WA501, Navy Nuc. Prgms. Off.

Director
Strategic Systems Project Office
Navy Department
ATTN: NSP

DEPARTMENT OF THE AIR FORCE

AF Geophysics Laboratory, AFSC
ATTN: Charles Pike

AF Materials Laboratory, AFSC
ATTN: Library

AF Weapons Laboratory, AFSC
2 cy ATTN: DYC
ATTN: NT
ATTN: SUL
2 cy ATTN: NTS

Hq. USAF/RD
ATTN: RDQSM

Commander
Rome Air Development Center, AFSC
ATTN: Edward A. Burke

SAMSO/DY
ATTN: DYS

SAMSO/MN
ATTN: MNNH
ATTN: MNNG

SAMSO/SK
ATTN: SKF

SAMSO/XR
ATTN: XRS

Commander In Chief
Strategic Air Command
ATTN: NRI-STINFO, Library
ATTN: XPFS

ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION

University of California
Lawrence Livermore Laboratory
ATTN: L-531
ATTN: Info. Dept., L-3

Los Alamos Scientific Laboratory
ATTN: Doc. Control for Reports Lib.

Sandia Laboratories
Livermore Laboratory
ATTN: Doc. Con. for Theodore A. Dellin

Sandia Laboratories
ATTN: Doc. Con. for 3141 Sandia Rpt. Coll.

OTHER GOVERNMENT AGENCIES

NASA
Lewis Research Center
ATTN: N. J. Stevens
ATTN: Carolyn Purvis
ATTN: Library

DEPARTMENT OF DEFENSE CONTRACTORS

Aerospace Corporation
ATTN: Library
ATTN: V. Josephson
ATTN: Frank Hai
ATTN: Julian Reinheimer

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Avco Research & Systems Group
ATTN: Research Lib., A830, Rm. 7201

The Boeing Company
ATTN: Preston Geren

University of California at San Diego
ATTN: Sherman De Forest

Computer Sciences Corporation
ATTN: Alvin T. Schiff

Dr. Eugene P. DePlomb
ATTN: Eugene P. DePlomb

Dikewood Industries, Inc.
ATTN: Tech. Lib.
ATTN: K. Lee

EG&G, Inc.
Albuquerque Division
ATTN: Technical Library

Ford Aerospace & Communications Corp.
ATTN: Library
ATTN: Donald R. McMorrow, MS G30

General Electric Company
Space Division
Valley Forge Space Center
ATTN: Joseph C. Peden, VFSC, Rm. 4230M

General Electric Company
TEMPO-Center for Advanced Studies
ATTN: William McNarama
ATTN: DASIAC

Hughes Aircraft Company
Centinela & Teale
ATTN: Tech. Lib.

Hughes Aircraft Company, El Segundo Site
ATTN: Edward C. Smith, MS A620
ATTN: William W. Scott, MS A1080

Institute for Defense Analyses
ATTN: IDA Librarian

IRT Corporation
ATTN: Dennis Swift
ATTN: Library

Jaycor
ATTN: Eric P. Wenaas
ATTN: Library

Jaycor
ATTN: Robert Sullivan

Johns Hopkins University
Applied Physics Laboratory
ATTN: Peter E. Partridge

Kaman Sciences Corporation
ATTN: Jerry I. Lubell
ATTN: W. Foster Rich
ATTN: Library

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Lockheed Missiles & Space Company, Inc.
ATTN: Dept. 85-85

McDonnell Douglas Corporation
ATTN: Stanley Schneider

Mission Research Corporation
ATTN: Roger Stettner
ATTN: Conrad L. Longmire
5 cy ATTN: Library
ATTN: N. J. Carron

Mission Research Corporation-San Diego
ATTN: V. A. J. Van Lint
ATTN: Library

R & D Associates
ATTN: Leonard Schlessinger
ATTN: Library

Rockwell International Corporation
ATTN: N. J. Rudie, FA53
ATTN: Library

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Science Applications, Incorporated
ATTN: William L. Chadsey

Simulation Physics, Inc.
ATTN: Roger G. Little

Stanford Research Institute
ATTN: Library

Systems, Science & Software, Inc.
ATTN: Andrew R. Wilson
ATTN: Library

TRW Systems Group
2 cy ATTN: Robert M. Webb, R1-2410
ATTN: Tech. Info. Center/S-1930