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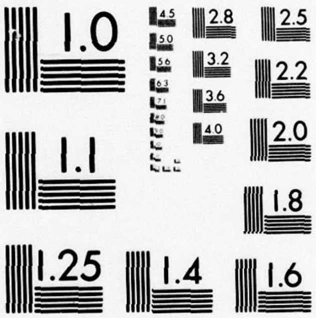
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NUMERICAL SOLUTION OF STIFF ORDINARY DIFFERENTIAL EQUATIONS

FINAL REPORT

Leon Lapidus

January 31, 1977

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

An analysis is presented for alternate numerical techniques for solving stiff ordinary differential equations. These techniques include a singular perturbation or pseudo-steady-state method and an imbedded, error-monitoring semi-implicit Runge-Kutta method. Extensive numerical experience on equations which are linear/nonlinear, small/large dimensional, and moderately/strongly stiff reveals that the singular perturbation method is most efficient for very stiff problems while the imbedded Runge-Kutta method is superb over a wide range of stiffness.

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INTRODUCTION

Many commonly occurring physical and chemical dynamic systems have widely separated time constants. These systems are often represented by sets of initial-value ODE which possess variables that rapidly change during time intervals much smaller than the duration of the phenomenon of interest. This presents the numerical integration difficulties associated with such "stiff" systems. Thus even integration routines stable for any step size (so-called A-stable methods) have accuracy problems in following the eigenvalues large in absolute value which damp out early in the solution. These errors can easily propagate to destroy the remainder of the transient.

The stability limitations involved with most standard numerical techniques for an n-dimensional system is that they require $\max|h\lambda_i|$, $i = 1,2,\ldots,n$, where the λ_i's are the local eigenvalues, to be bounded by a single small number, typically in the 1 to 10 range. Thus if a single eigenvalue is large in absolute value, severe restrictions are placed on the integration step size. Depending upon the length of the solution interval of interest, this can demand a great deal of computation time. Further, there are limits on how small h can be before roundoff errors accumulate and render the calculation meaningless [Lapidus and Seinfeld, 1971].

The practitioner is usually unaware of the nature of stiff systems and the associated numerical integration difficulties. Even arbitrary application of stiff methods is deemed significant enough in many areas of application to be suitable for publication. On the other hand, typical solution characteristics and the requirement on their elucidation may not be fully appreciated by the numerical analyst.

In order to make the nature of the problem clearer, consider a specific linear time invariant system

$$\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = \begin{bmatrix} \lambda_1 & 0 \\ K & \lambda_2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} , \qquad \begin{bmatrix} x(0) \\ y(0) \end{bmatrix}$$

with the analytic solution

$$x(t) = x(0)\exp[\lambda_1 t]$$

$$y(t) = C_1\exp[\lambda_1 t] + C_2\exp[\lambda_2 t]$$

where

$$C_1 = \frac{Kx(0)}{\lambda_1 - \lambda_2} , \qquad C_2 = y(0) - C_1$$

Now pick $\lambda_1 << \lambda_2 < 0$ and $C_1 = C_2 = 1$. In this case the contribution to the solution of λ_1 is negligible after a very short time period; yet its presence will fix the maximum allowable step size through the domain of interest by the bound on $\max_i |h\lambda_i|$. This domain would ordinarily be determined by $\min_i |\lambda_i|$ until a steady-state has essentially been reached; for nonlinear problems this domain may not be obvious.

In the present work we have used two completely different approaches for developing feasible algorithms for solving stiff differential equations. Denoting the stiffness ratio (S.R.) by

$$\text{Stiffness Radio} = \text{S.R.} = \frac{\left|\max_i(\lambda_i)\right|}{\left|\min_i(\lambda_i)\right|}$$

as the ratio of the maximum to minimum eigenvalues, we can define, in an approximate way,

$\text{S.R.} < 10^2$	Non-Stiff Systems
$10^2 < \text{S.R.} < 10^{10}$	Moderate-Stiff Systems
$\text{S.R.} > 10^{10}$	Strongly-Stiff Systems

In the case $\text{S.R.} < 10^2$ there are many feasible and optimal numerical algorithms in the literature [see, Byrne and Hindmarsh, 1975; Shampine, Watts and Davenport, 1976; and Enright and Hull, 1976]; therefore, we shall not consider these further. When $\text{S.R.} > 10^{10}$ the present work has developed a singular perturbation technique which seems quite feasible. When $10^2 < \text{S.R.} < 10^{10}$ the present work has developed, in a preliminary way, new semi-implicit Runge-Kutta methods which are extremely useful and competitive with any other algorithm we have encountered.

I. A Singular Perturbation Approach

Consider a two-variable set of first-order ordinary differential equations with a small parameter ε multiplying the derivative of one of the variables, the type of system for which singular perturbation methods have been developed.

$$\begin{aligned} \frac{dx}{dt} &= f(x,y,\varepsilon) \quad , \quad x(0) = \zeta \\ \varepsilon\frac{dy}{dt} &= g(x,y,\varepsilon) \quad , \quad y(0) = \eta \end{aligned} \qquad (1)$$

where

$$f(0,0,\varepsilon) = g(0,0,\varepsilon) = 0$$

If (1) is linearized along its trajectory, it may be expressed as

$$\begin{bmatrix} \frac{dx}{dt} \\ \frac{dy}{dt} \end{bmatrix} = \begin{bmatrix} f_x & f_y \\ g_x/\varepsilon & g_y/\varepsilon \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} , \quad \begin{bmatrix} x(0) \\ y(0) \end{bmatrix} = \begin{bmatrix} \zeta \\ \eta \end{bmatrix} \tag{2}$$

Examination of the Jacobian eigenvalues indicates that their spread increases the smaller ε becomes, one approaches zero while the other grows larger in absolute value. The occurrence of an eigenvalue large in absolute value defines the stiff problem; thus (2) can be regarded as the linearized representation of a stiff system with widely separated eigenvalues. It then follows that such a stiff system and the singular perturbation form of (1) are at least locally equivalent.

This equivalence allows recent developments in singular perturbation theory to be used in obtaining an effective procedure for the numerical integration of either equation type. It can be shown that the resulting algorithm does not require identification of the perturbing parameter ε, hence is quite applicable to the general stiff system.

Consider initial value problems of the form of (1) with the perturbing parameter ε very small. First assume the solution may be approximated by the simple first-order expansion in the (outer) variables

$$\begin{aligned} x^* &= x_0 + \varepsilon y_1 \\ y^* &= y_0 + \varepsilon y_1 \end{aligned} \tag{3}$$

Substitute (x^*,y^*) into (1) for (x,y) and expand about $\{x_0(t),\ y_0(t)\}$. Matching terms with like powers of ε results in

$$\frac{dx_0}{dt} = f(x_0,y_0,\varepsilon) \quad , \qquad x_0(0) = \zeta \tag{4a}$$

$$0 = g(x_0,y_0,\varepsilon) \quad , \tag{4b}$$

and

$$\frac{dx_1}{dt} = f_x(x_0,y_0)x_1 + f_y(x_0,y_0)y_1 \quad , \qquad x_1(0) = 0 \tag{5a}$$

$$\frac{dy_0}{dt} = g_x(x_0,y_0)x_1 + g_y(x_0,y_0)y_1 \quad , \qquad y_0(0) = \eta \tag{5b}$$

$$\frac{dy_1}{dt} = 0 \quad , \qquad y_1(0) = 0$$

An inconsistency can arise when (4b) is not satisfied by (ζ,η). To alleviate this, additional (inner) variables are introduced which are particularly important to the very early stages of the transient. Expanding these variables to first-order in ε and adding them to (3) gives the new solution approximation (x^*,y^*):

$$\begin{aligned} x^*(t) &= x_0(t) + \varepsilon x_1(t) + X_0(t/\varepsilon) + \varepsilon X_1(t/\varepsilon) \\ y^*(t) &= y_0(t) + \varepsilon y_1(t) + Y_0(t/\varepsilon) + \varepsilon Y_1(t/\varepsilon) \end{aligned} \tag{6}$$

A boundary-layer type characteristic is imposed on the inner variables:

$$\lim_{t/\varepsilon \to \infty} X_0 = X_1 = Y_0 = Y_1 = 0 \tag{7}$$

Let $\tau = t/\varepsilon$ and make this variable change in (1)

$$\begin{aligned} \frac{dx}{d\tau} &= \varepsilon f(x,y,\varepsilon) \quad , \qquad x(0) = \zeta \\ \frac{dy}{d\tau} &= g(x,y,\varepsilon) \quad , \qquad y(0) = \eta \end{aligned} \tag{8}$$

Now substitute (x^*,y^*) in (8) and expand about $\big(x_0(\varepsilon\tau) + X_0(\tau),\ y_0(\varepsilon\tau) + Y_0(\tau)\big)$. Matching terms with like powers in ε results in

$$\begin{aligned} \frac{dX_0}{d\tau} &= 0 \\ \frac{dY_0}{d\tau} &= g\big(x_0(\varepsilon\tau) + X_0(\tau),\ y_0(\varepsilon\tau) + Y_0(\tau)\big) \end{aligned} \tag{9}$$

and

$$\begin{aligned} \frac{dX_1}{dt} &= f\big(x_0(\varepsilon\tau) + X_0(\tau),\ y_0(\varepsilon\tau) + Y_0(\tau)\big) - f\big(x_0(\varepsilon\tau),\ y_0(\varepsilon\tau)\big) \\ \frac{dY_1}{dt} &= g_x X_1(\tau) + g_y y_1(\varepsilon\tau) + g_y Y_1(\tau) - g_x(x_0,y_0)x_1(\varepsilon\tau) \\ &\quad - g_y(x_0,y_0)y_1(\varepsilon\tau) \end{aligned} \tag{10}$$

Equations (4) and (9) share the initial conditions

$$\begin{aligned} x_0(0) + X_0(0) &= \zeta \\ y_0(0) + Y_0(0) &= \eta \end{aligned} \tag{11}$$

while (5) and (10) share

$$\begin{aligned} x_1(0) + X_1(0) &= 0 \\ y_1(0) + Y_1(0) &= 0 \end{aligned} \tag{12}$$

Note that as a result of (7) and (9)

$$X_0(\tau) = 0$$

The conditions under which (6) may be expected to be a valid solution representation over the domain of interest may be found in Hoppensteadt [1971].

Based upon these concepts a numerical procedure has been developed [Aiken and Lapidus, 1974, and Miranker, 1973], which solves the stiff set of equations. Since the details are in the literature, we present here only a summary of the most important results.

The solution is given in terms of the zeroth-order inner (X_0, Y_0) and outer (x_0, y_0) and first-order inner and outer (X_1, Y_1, x_1, y_1) terms (see (w)).

$$x \simeq X_1 + \varepsilon X_1 + x_0 + \varepsilon x_1$$
$$y \simeq Y_0 + \varepsilon Y_1 + y_0 + \varepsilon y_1 \qquad (13)$$

where ε is an artificial bookkeeping indication of the degree of stiffness defined by

$$\varepsilon \dot{y} = g(x,y,\varepsilon) \qquad (14)$$

where $g \equiv \varepsilon w$. This parameter need not actually exist or be identified. The outer terms are of more interest than the inner terms, which are important only within a relatively small boundary layer region of the transient. For systems stiff enough to require special integration techniques, the zeroth-order outer approximation often is sufficiently accurate

$$\dot{x}_0 = f(x_0, y_0) \quad , \quad x_0(0) = x(0) \qquad (15a)$$

$$0 = g(x_0, y_0) = w(x_0, y_0) \qquad (15b)$$

The last equality in (15b) is made since ε is not zero. This is properly what has been referred to as the pseudo steady state approximation (pssa). The conditions for the validity of (15), or for regular degeneracy to the low-order solution, briefly, require that the initial conditions $x(0) = \zeta, y(0) = \eta$ be within the region of asymptotic stability of

$$\frac{dy}{d\tau} = g(\alpha, y) \qquad (16)$$

where $\tau \equiv t/\varepsilon$, and x is replaced by some constant vector α at each instant.

Consideration of the pssa as the zeroth-order approximation (5) reveals that the region of applicability corresponds to the region where the outer variables are much more dominant than the inner ones. The inner variables are then important only within a narrow initial boundary layer and thus can be used to define this region. The zeroth-order inner term for the stiff variable is by far the most dominant [Aiken and Lapidus, 1974].

$$Y_0(t) = Y_0(0)\exp[\partial w/\partial y(x_0,y_0)t] \tag{17}$$

where $Y_0(0) = y(0) - y_0(0)$. Experience by the authors has indicated that (17) is capable of providing an a priori estimate of the boundary layer for linear and nonlinear applications. In this way the boundary layer is defined as a fractional decay of the zeroth-order stiff inner variable, the effective boundary layer length given by t_I

$$t_I = \frac{\left|\ln[Y_0(t)/Y_0(0)]\right|}{\left\|\frac{\partial w}{\partial y}\left(x_0(0),y_0(0)\right)\right\|} \tag{18}$$

where $||\cdot||$ is a suitable matrix norm. Since for any matrix A

$$||A|| > \rho(A)$$

where $\rho(A)$ is the spectral radius of A

$$\rho(A) \equiv \max_{\forall i}|\lambda_i|$$

a conservative estimate of the boundary layer is thus provided by the use of the spectral radius for the matrix norm, that is, if the first step can be taken greater than this boundary layer estimate, the pssa is applicable.

The accuracy of using only the zeroth-order approximation is indicated by the magnitude of the first-order outer terms [Aiken and Lapidus, 1974]

$$\begin{aligned} \varepsilon x_1(t) &= \left(\varepsilon x_1(0) + \frac{b}{a}\right)\exp(at) - \frac{b}{a} \\ \varepsilon y_1(t) &= \frac{b}{f_y} - \frac{w_x \varepsilon x_1(t)}{w_y} \quad , \quad f_y = \frac{\partial f}{\partial y} \quad , \quad \text{etc.} \end{aligned} \tag{19}$$

where

$$a = f_x - \frac{w_x f_y}{w_y}$$

$$b = -\frac{w_x f f_y}{w_y^2}$$

$$\varepsilon x_1(0) = \frac{Y_0(0)}{2w\left[(x(0),y(0)\right)} f\left(x(0),y(0)\right) - f\left(x(0),y_0(0)\right) \tag{20}$$

all derivatives are evaluated at (x_0,y_0), and dimensional notation has been suspended. Note that w_y may not be singular. Since (19) may easily be evaluated periodically at any time during the solution, a convenient upper bound on the error of using the pssa for many common systems is $\varepsilon x_1(t)/x_0(t)$ or $\varepsilon y_1(t)/y_0(t)$. If these ratios are less than say 0.001, the accuracy of the pssa is indicated to be better than 0.1%.

The preceding analysis is useful only for systems which have $w_y < 0$, an initial monotonically decreasing boundary layer [see Aiken and Lapidus, 1975a]. Fortunately, this seems to be true for the great majority of applications in stiff chemical kinetics. It also appears that within this practical context, the dependent variables divide into the stiff and nonstiff groups, and these are often identifiable from a priori considerations. If not, a few small integration steps within the boundary layer may reveal those variables with comparatively rapid transients.

A special characteristic of kinetic systems is that rarely does the model represent the chemical phenomena closely enough to require better than moderate accuracy in the numerical integration. This suggests the permissibility of a model approximation like the pssa. Thus for systems too stiff to be integrated by conventional means, the pssa is likely to yield quite adequate solution accuracy.

The pssa may prove invaluable for the integration of large systems, as explicit routines may be used to eliminate the need to invert a large Jacobian, necessary in all implicit methods. When w is linear in y, often the case in kinetics, a decomposition may be effected to decrease the dimensionality.

Aiken and Lapidus [1975b] have also shown how the initial conditions of the specific system may be chosen to eliminate the stiff variables or those with large eigenvalues. When numerically examined on a set of nonlinear problems, the strength of the present algorithm was confirmed.

It must be pointed out however that the crucial point in the use of this singular perturbation approach lies in the ability to decompose an initial set of ODE into the stiff and nonstiff form of (1). When the original system has a large dimension ($n > 10$), such a discrimination may not be obvious. Further, the eigenvalues of the original system must cluster in groups rather than be spread out over roughly equal intervals. When this happens and the S.R. $> 10^6 - 10^{10}$, the algorithm is an extremely efficient procedure for solving stiff ODE (see comments in later discussions).

II. Semi-Implicit Runge-Kutta Methods

At the same time it must be recognized that the above singular perturbation approach has certain system restrictions; thus there is a question as to whether it can serve as the format for a general purpose algorithm for solving stiff ODE. As a consequence, our work has proceeded along what might be called more conventional directions but with a special emphasis. Here we present some preliminary results on the development and use of imbedded semi-implicit Runge-Kutta methods with special error monitoring characteristics. For problems with $10^2 <$ S.R. $< 10^{10}$ this approach seems to be the most efficient that we have encountered.

As pointed out by Lapidus and Seinfeld [1971], Runge-Kutta integration techniques may be classified as explicit or semi-implicit or implicit; the explicit and implicit forms may be discarded as viable techniques for solving stiff equations either because of extreme stability (and thus step size) bounds or the high level of iteration required. By contrast, semi-implicit methods are A-stable and require no iteration. Thus this class of methods remains as possible candidates for a general purpose algorithm.

Perhaps the best semi-implicit Runge-Kutta algorithm developed to date is due to Michelsen [1976] which we show below

$$\underset{\sim}{y}_{n+1} = \underset{\sim}{y}_n + R_1\underset{\sim}{k}_1 + R_2\underset{\sim}{k}_2 + R_3\underset{\sim}{k}_3 \qquad (21)$$

with

$$\begin{array}{ll} \underset{\sim}{k}_1 = h[\underset{\sim}{I} - ha_1\underset{\sim}{J}(\underset{\sim}{y}_n)]^{-1}\underset{\sim}{f}(\underset{\sim}{y}_n) & \underset{\sim}{J}(\underset{\sim}{y}_n) = \text{Jacobian matrix at } \underset{\sim}{y}_n \\ \underset{\sim}{k}_2 = h[\underset{\sim}{I} - ha_1\underset{\sim}{J}(\underset{\sim}{y}_n)]^{-1}\underset{\sim}{f}(\underset{\sim}{y}_n + b_2\underset{\sim}{k}_1) & \qquad (22) \\ \underset{\sim}{k}_3 = h[\underset{\sim}{I} - ha_1\underset{\sim}{J}(\underset{\sim}{y}_n)]^{-1}(b_{31}\underset{\sim}{k}_1 + b_{32}\underset{\sim}{k}_2) & \end{array}$$

Given the solution $\underset{\sim}{y}_n$ at x_n the solution is advanced over the increment h to x_{n+1} to yield $\underset{\sim}{y}_{n+1}$ via (21). Equation (21) can be used once $\underset{\sim}{k}_1$, $\underset{\sim}{k}_2$, and $\underset{\sim}{k}_3$ are calculated serially assuming all the parameters R_1, R_2, R_3, a_1, b_2, b_{31} and b_{32} are determined. This latter feature can be handled by matching to Taylor Series expansions and using exponential fitting. Thus Michelsen determined

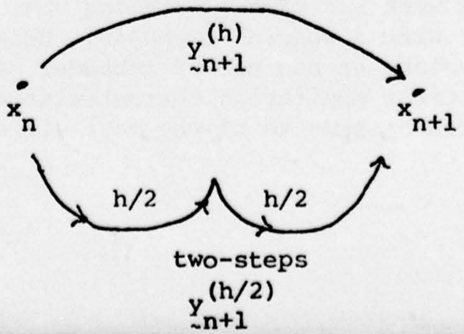
$$a_1 = 0.4358\ldots \; ; \quad R_1 = \frac{11}{27} - b_{31} \; ; \quad R_2 = \frac{16}{27} - b_{32} \; ;$$

$$R_3 = 1 \; ; \quad b_2 = \frac{3}{4} \; ; \quad b_{32} = \frac{2}{9a_1}(6a_1^2 - 6a_1 + 1) \; ;$$

$$b_{31} = -\frac{1}{6a_1}(8a_1^2 - 2a_1 + 1) \qquad (23)$$

These parameters make (21) and (22) A-stable and even further, strongly A-stable.

However, it is necessary to add a step-size adjustment feature so that when $\underset{\sim}{y}$ is changing rapidly h can be decreased and vice versa. Only with this adjustment can the algorithm become truly efficient. This is usually done by the one-step/two-step extrapolation in the form



such that

$$\underset{\sim}{y}_{n+1} = \underset{\sim}{y}^{(h/2)}_{n+1} + \frac{1}{2^p - 1} \underset{\sim}{y}^{(h/2)}_{n+1} - \underset{\sim}{y}^{(h)}_{n+1} \tag{24}$$

where p is the order of the basic method. In the present case p = 3 and

$$\underset{\sim}{y}_{n+1} = \underset{\sim}{y}^{(h/2)}_{n+1} + \frac{1}{7} \underset{\sim}{T}_{n+1} \tag{25}$$

where

$$\underset{\sim}{T}_{n+1} = \underset{\sim}{y}^{(h/2)}_{n+1} - \underset{\sim}{y}^{(h)}_{n+1} = \text{truncation error} \tag{26}$$

Using (26) as an example, the step-size can be adjusted such that $||\underset{\sim}{T}_{n+1}|| \leq$ some error bound. However, the amount of computation required to go from x_n to x_{n+1} has been increased by 200% over the non-error monitoring case.

In the present work we have developed a completely different approach to the error-monitoring procedure. Thus we define a new algorithm

$$\underset{\sim}{y}_{n+1} = \underset{\sim}{y}_n + R_1\underset{\sim}{k}_1 + R_2\underset{\sim}{k}_2 \tag{27}$$

where $\underset{\sim}{k}_1$ and $\underset{\sim}{k}_2$ are identical to those in (22). However, we relax the order of the method by 1 (p = 2) by specifying $b_2 = 1 - 2a_1$ and then applying the Taylor Series expansions and exponential fitting. The end result is a second-order method, (27), imbedded in a third-order method (21), for which (27) can be calculated at essentially no computer cost once (21)-(22) have been evaluated over the step h. This second-order method is also A-stable. Thus we calculate (21)-(22) to generate $\underset{\sim}{y}_{n+1}$, use (27) at almost no cost to generate another $\underset{\sim}{y}_{n+1}$ and compare the two. The number of digit agreement can be used to estimate the truncation error and thus provide a complete error monitoring procedure.

To illustrate the results obtained, we select the fluidized bed system detailed by Luss and Amundson [1968]

$$\begin{aligned}
\frac{dy_1}{dt} &= 1.3(y_3 - y_1) + 1.04 \times 10^4 ky_2 \qquad ; \quad y_1(0) = 759.167 \\
\frac{dy_2}{dt} &= 1.88 \times 10^3\big(y_4 - y_2(1 + k)\big) \qquad ; \quad y_2(0) = 0 \\
\frac{dy_3}{dt} &= 1752 - 269y_3 + 267y_1 \qquad ; \quad y_3(0) = 600 \\
\frac{dy_4}{dt} &= 0.1 + 320y_2 - 321y_4 \qquad ; \quad y_4(0) = 0.1
\end{aligned} \tag{28}$$

where $k = 0.0006 \exp[20.7 - 15000/y_1]$. This system has a S.R. ≃ 10^6, and we wish to integrate from $t = 0$ to $t_f = 500$. The computing time required by the one-step/two-step procedure is 1.76 CPU units, while that for the present imbedded algorithm is 0.42 CPU units. Obviously the present method is considerably more efficient than the one-step/two-step approach. We have also tested the current imbedded algorithm vs. essentially every other algorithm in the literature; this for small/large dimensional systems (n = 2 to 50), linear/nonlinear systems, stiffness ratios of $10^2 \leq$ S.R. $\leq 10^{16}$ and in single/double precision arithmetic. The preliminary results indicate that the current algorithm is more efficient than any competitive procedure.

As problems are considered where the S.R. approaches 10^{10}-10^{12}, the current semi-implicit method may have difficulties unless sufficient computer precision is allowed. However, it is in just this region that the singular perturbation approach of Part I of the report becomes quite efficient. Thus one could suggest that the two algorithms developed in the present work will handle any set of stiff ODE.

REFERENCES

Aiken, R. C., and Lapidus, L., "An Effective Numerical Integrating Method for Typical Stiff Systems", AIChE J. 20, 368 (1974).

Aiken, R. C., and Lapidus, L., "Pseudo Steady State Approximation for the Numerical Integration of Stiff Kinetic Systems, AIChE J. 21, 817 (1975a).

Aiken, R. C., and Lapidus, L., "Problem Approximation for Stiff Ordinary Differential Equations", AIChE J. 21, 1227 (1975b).

Byrne, G. D., and Hindmarsh, A. C., "A Polyalgorithm for the Numerical Solution of Ordinary Differential Equations", ACM Trans. on Math. Software 1, 71 (1975).

Enright, W. H., and Hull, T. E., "Test Results on Initial Value Methods for Nonstiff ODE", SIAM J. Numer. Anal. 13, 944 (1976).

Hoppensteadt, F., "Properties of Solutions of ODE's with Small Parameters", Comm. Pure Appl. Math. 24, 807 (1971).

Lapidus, L., and Seinfeld, J. H., Numerical Solution of Ordinary Differential Equations, Academic Press, 1971.

Luss, D., and Amundson, N. R., "Stability of Batch Catalytic Fluidized Beds", AIChE J. 14, 211 (1968).

Michelsen, M. L., "An Efficient General Purpose Method for the Integration of Stiff ODE", AIChE J. 22, 594 (1976).

Miranker, W. L., "Numerical Methods of Boundary Layer Type for Stiff Systems of Differential Equations", Computing 11, 221 (1973).

Shampine, L. F., Watts, H. A., and Davenport, S. M., "Solving Nonstiff Ordinary Differential Equations -- The State of the Art", SIAM Review 18, 376 (1976).

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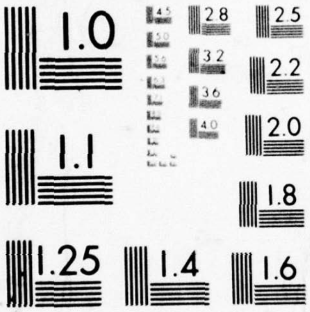

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PLATE: A 2-D TRANSMISSION LINE CURRENT SYMMETRY CODE

Air Force Weapons Laboratory
Kirtland Air Force Base, NM 87117

January 1977

Final Report

Approved for public release; distribution unlimited.

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base, NM 87117

AFWL-TR-76-205

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This technical report has been reviewed and is approved for publication.

Norman F. Roderick

NORMAN F. RODERICK
Maj, USAF
Project Officer

FOR THE COMMANDER

Thomas C. May

THOMAS C. MAY
Maj, USAF
Chief, Advanced Concepts Research
Branch

John S DeWitt

JOHN S. DeWITT
Lt Colonel, USAF
Chief, Technology and Analysis
Division

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This report is primarily intended as a users manual for the two-dimensional current flow code PLATE. The current symmetry to a thin cylindrical foil that is being imploded by the $\bar{J} \times \bar{B}$ force in a short z-pinch device is considered. The code PLATE calculated azimuthal current asymmetries to the experimental load for various capacitor bank and parallel plate transmission line configurations. A discussion of numerical techniques is included. Two sample problems are discussed. A complete listing and sample output are included.

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ILLUSTRATIONS

SECTION I

INTRODUCTION

The Air Force Weapons Laboratory (AFWL) is investigating the $\bar{J} \times \bar{B}$ implosion of thin cylindrical foils in short z-pinch devices. These devices are driven by low inductance capacitor banks which are electrically connected to the z-pinch by flat plate transmission lines.

A computational code (PLATE) was written to evaluate two areas of concern in the design of these capacitor banks. First, uniform current flow into the azimuthally symmetric load is desired because asymmetries may cause irregular foil implosions. Second, a measure of the capacitor bank's effective inductance is useful since this inductance must be kept to a minimum so that the system can discharge quickly. PLATE calculates azimuthal current symmetry in the transmission lines, and it estimates the effective transmission line inductance. To do this, current is constrained to flow from simulated capacitors through a square mesh of inductors, capacitors, and resistors that simulate the electrical characteristics of an actual transmission line. Important results are displayed in calcomp plots. The major approximation in these calculations is that the transmission plate separation is considered to be small compared to the mesh size; otherwise, mutual inductance effects, which are ignored, can become important.

The two objectives of this report are to document the code PLATE and to provide a users manual. To accomplish these objectives, both theory and application are discussed. Sample input is provided in all instances where an example is being discussed. A listing and sample output are provided in the Appendixes.

SECTION II

EXPERIMENTAL SETUP

The transmission lines used at the AFWL consist of two parallel aluminum plates which are separated by mylar. Generally, the top transmission plate is used to carry current to the load, and the bottom plate is at "ground" and acts as a return current carrier.

A typical experimental apparatus consists of a rectangular transmission line with two capacitor bank modules attached to opposing sides. A circular hole of approximately 10 cm radius (R1 in figure 1) is located in the center of the plate. The load is bolted to the periphery of this hole. Figure 1 is a schematic of this apparatus.

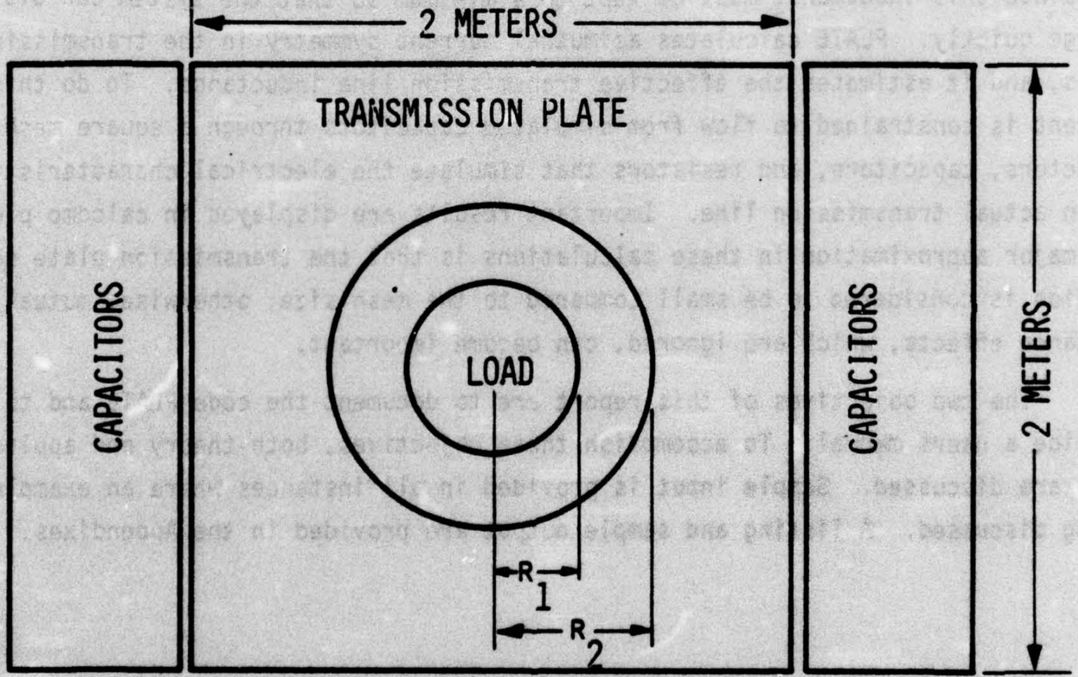

Figure 1. Typical Square Transmission Plate Problem.

Outside a Radius R2, the two plates are separated by 0.15 cm of mylar (figure 2). The circular electrodes have a radius R1 and separation of 1 cm. Between the R1 and R2 radii, the plate separation varies with radius depending on the actual chamber design. In PLATE calculations this region is assumed to have a

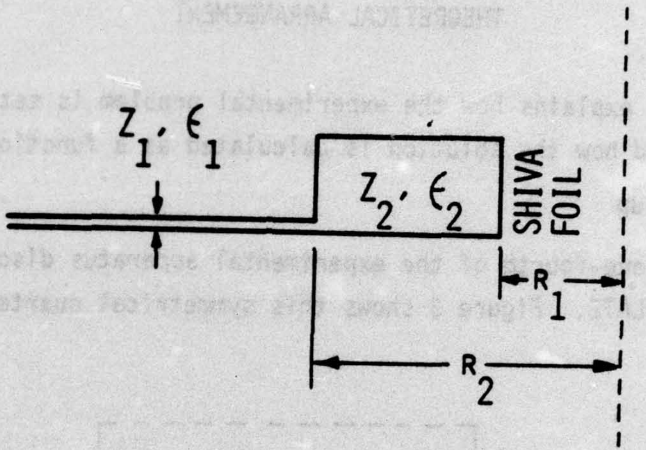

Figure 2. Cross Section of Transmission Plate.

constant plate separation. This value of separation is determined by inductively matching the actual chamber.

"Typical" values for the variables annotated in figures 1 and 2 are:

Δz_1 = normal plate separation = 0.15 cm

Δz_2 = increased plate separation = 1.5 cm

$\varepsilon_1 = \varepsilon_2 = 2.8\varepsilon_0$ (for mylar)

R_1 = radius of the load = 0.10 m

R_2 = outside radius of increased plate separation = 0.14 m

NOTE: For computational purposes, R_1 = 0.25 m and R_2 = 0.40 m. The increased radii allow the respective arcs to approximate circles when they are superimposed on a square mesh.

SECTION III

THEORETICAL ARRANGEMENT

This section explains how the experimental problem is set up as a calculational problem and how the solution is calculated as a function of time.

1. Problem Set-up

A symmetric one-fourth of the experimental apparatus discussed in section II is computed by PLATE. Figure 3 shows this symmetrical quarter of the system.

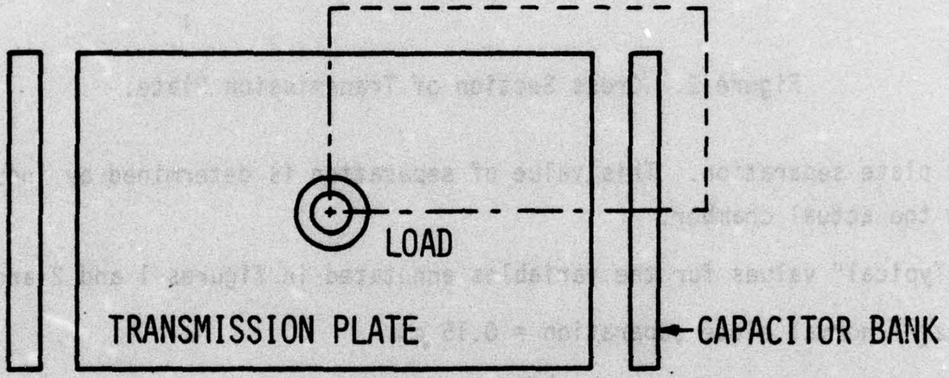

Figure 3. Transmission Plate Symmetry.

The quarter plate is divided into a mesh of square elements. A schematic of a single element is shown in figure 4.

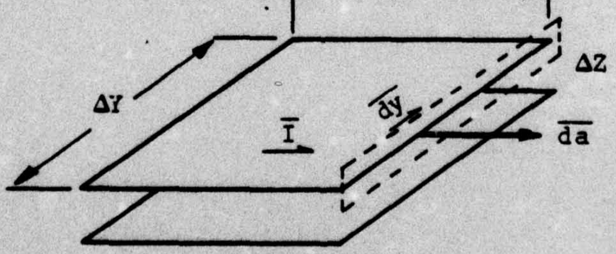

Figure 4. One Square Element.

The capacitance of a parallel plate capacitor is given in Lorrain and Corson (reference 1) as:

$$C = \varepsilon_r \varepsilon_o \frac{S}{s} \tag{1}$$

where S is the plate area, s is the plate separation, ε_r is the relative permittivity of mylar, and ε_o is the permittivity of free space. Since $\varepsilon = \varepsilon_r \varepsilon_o$ and the plate area is $\Delta X \Delta Y$,

$$C = \varepsilon \frac{\Delta X \Delta Y}{\Delta Z} \tag{2}$$

This is the form of capacitance used in PLATE.

The inductance in an infinite parallel plate system (no fringing) can be computed by comparing two mathematical expressions for the enclosed magnetic field energy:

$$1/2\ LI^2 = \text{magnetic field energy} = \int_V \frac{B^2}{2\mu_o} dV \tag{3}$$

With the assumption that displacement currents are zero, the integral form of Amperes law is:

$$\int \overline{B} \cdot \overline{dl} = \mu_o \int_S \overline{J} \cdot \overline{da} \tag{4}$$

Figure 4 shows the parallel plate situation. The first integration is accomplished along the dotted line. The second is done over the area enclosed by the dotted line. The integrations yield:

$$B = \frac{\mu_o I}{\Delta Y} \tag{5}$$

---

1. Lorrain, P. and Corson, D. R., Electromagnetic Fields and Waves, San Francisco: W. H. Freeman and Company, 1970.

Substituting for B in equation (3) gives

$$\frac{1}{2} LI^2 = \frac{1}{2\mu_o} \int_V \left(\frac{\mu_o I}{\Delta Y}\right)^2 dV$$

$$= \frac{\mu_o I^2}{2\Delta Y^2} \int_V dV$$

$$= \frac{\mu_o I^2}{2\Delta Y^2} \Delta X \Delta Y \Delta Z \tag{6}$$

so that

$$L = \frac{\mu_o \Delta X \Delta Z}{\Delta Y} \tag{7}$$

This is the form of self inductance used in PLATE.

In PLATE, square cells are used. Thus, the inductance is the same in the X and the Y directions, and only one inductance array is needed. Because the cells are constrained to be square, the cell capacitance and inductance are:

$$C2 = \epsilon(\Delta X)^2/\Delta Z \tag{8}$$

$$AL2 = \mu_o \Delta Z \tag{9}$$

where C2 and AL2 are the PLATE variables for capacitance and inductance.

Furthermore, since mutual inductances are smaller than self inductances, they are ignored (see Appendix C), and the self inductance becomes the total inductance in each cell.

The resistance for one cell is calculated next. Resistance depends upon skin depth, resistivity, and material geometry.

Skin depth is given by Slater and Frank (reference 2) as

$$\delta = \sqrt{\frac{2}{\sigma\mu\omega}} \qquad (10)$$

where σ = conductivity and ω = frequency. The resistance of a cell is given by

$$R = \rho \frac{L}{A} \qquad (11)$$

where $\rho = 1/\sigma$ is the resistivity, L is the length of the resistor, and A is the cross-sectional area of the resistor. For a cell of width W, length L, and skin depth δ (the skin depth is much less than the plate thickness), the resistance is

$$R = \rho \frac{L}{\delta W} \qquad (12)$$

In PLATE, the cells are constrained to be square; hence

$$R = \frac{\rho}{\delta} \qquad (13)$$

Substituting for δ and using $\rho = 1/\sigma$

$$R = \frac{\rho\mu\omega}{2} \qquad (14)$$

Thus, the resistance, R, is independent of all geometry factors when square cells are used.

The Handbook of Chemistry and Physics (reference 3) gives the resistivity of commercial aluminum as 2.828×10^{-8} ohm-m at 20°C. The frequency of the current wave is on the order of 0.25×10^{6} Hz. Thus, $\omega = 2\pi F = 1.57 \times 10^{6}$ Hz and the resistance of one cell is 1.67 E-04 ohms. This value is used in PLATE.

---

2. Slater, J. C. and Frank, N. H., Electromagnetism, New York; McGraw-Hill Book Company, Inc., 1947.
3. Hodgman, C. D., Weast, R. C., and Selby, S. M., Handbook of Chemistry and Physics, Cleveland: Chemical Rubber Publishing Company, 1960.

2. The Mesh

A circuit schematic for a single cell is shown in figure 5. Current is allowed to flow in both the X and Y directions.

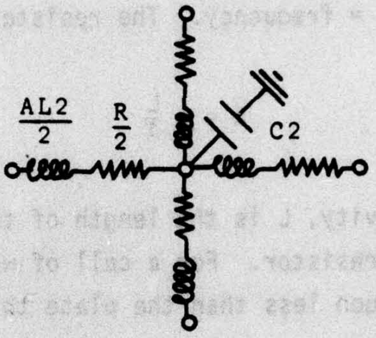

Figure 5. Circuit for One Mesh Element.

Many of these circuits elements can be fitted together to form a representation of an entire transmission plate. Figure 6 shows a portion of such an array.

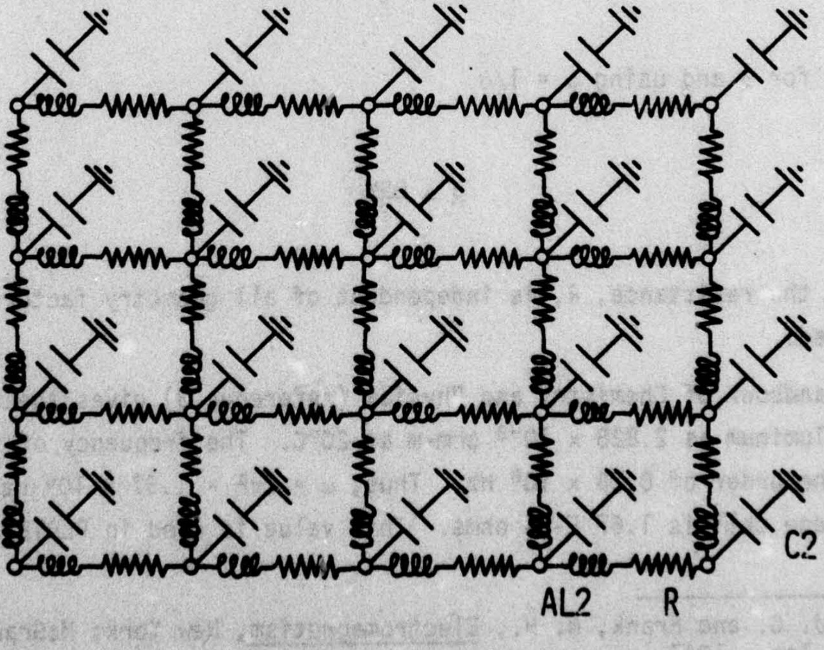

Figure 6. Transmission Plate Circuit Mesh.

In figure 6, each node is connected to a capacitor which is connected to ground and to four inductor and resistor pairs.

The theoretical transmission plate has a load connected at a 25 cm radius circle and an annular ring at 40 cm radius in which the plate separation has been increased to 1.5 cm from 0.15 cm. Capacitance is inversely proportional and inductance is directly proportional to plate separation, ΔZ. Consequently, the elements of capacitance and inductance that are in the annular ring where ΔZ_2 = 1.5 cm have a decreased capacitance and increased inductance by the multiplicative factor $\Delta Z_2/\Delta Z_1$.

Other changes in the plate separation may be simulated by changing the capacitance and inductance in suitable regions of the transmission plate mesh. Modeling of this kind can be used to make the simulated current flow more symmetric as will be seen in section IV.

Inside the radius R_1 = 0.25 cm, the load is simulated as a short circuit. This is done by making the capacitance arbitrarily large inside the radius R_1.

The capacitor bank portion of figure 1 is simulated by an array of capacitors and associated inductors connected to the side of the transmission plate mesh. A schematic of the capacitor bank connection is shown in figure 7.

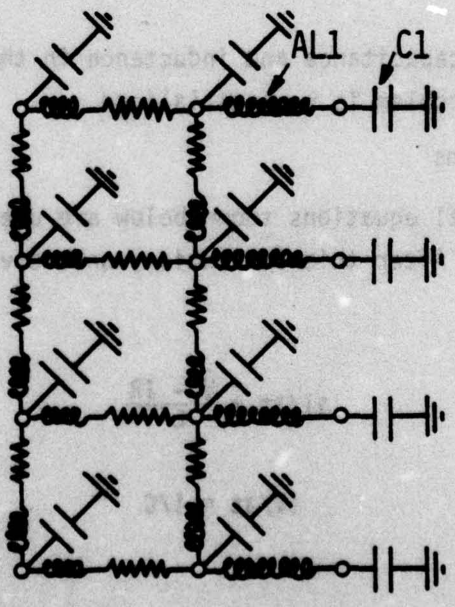

Figure 7. Capacitor Bank Circuitry.

The number of simulated capacitors, NBK, in one-half of one module is equal to the number of mesh points inside the length of that half module. If CT and ALT are the capacitance and inductance of one-half of a module, then the capacitance and inductance of each simulated capacitor is determined by

$$C1 = CT/NBK \tag{15}$$

and

$$AL1 = ALT * NBK \tag{16}$$

where, again NBK is the number of <u>simulated</u> capacitors.

The problem is set up by initializing all of the capacitances and inductances as discussed above. The voltage everywhere is set to zero except in the capacitor banks where it is set to VO, an input variable. The currents are everywhere set to zero.

The timestep, DELT, is determined by the formula

$$DELT = \frac{\pi}{20} \cdot \sqrt{AL2*C2} \tag{17}$$

where C2 and AL2 are the capacitance and inductance in the main portion of the transmission line. The problem is now initialized.

3. Difference Equations

The two differential equations shown below are used to derive the difference equations used in PLATE. After this derivation, an overview of problem solution is presented.

$$\partial I/\partial t = \frac{V - IR}{L} \tag{18}$$

$$\partial V/\partial t = I/C \tag{19}$$

where V = voltage = $f(x,y,t)$

I = current = $f(x,y,t)$

L = inductance = $f(x,y)$

R = resistance = $f(x,y)$

C = capacitance = $f(x,y)$

t = time

Letting I_{n+1} and I_n be the new and old currents, respectively, the difference form of equaiton (18) is:

$$L\,\frac{I_{n+1} - I_n}{\Delta t} = V - \left(\frac{I_{n+1} + I_n}{2}\right) * R \tag{20}$$

The new current is solved for explicitly:

$$I_{n+1} = \frac{\Delta V + I_n\left(\frac{L}{\Delta t} - \frac{R}{2}\right)}{\left(\frac{L}{\Delta t} + \frac{R}{2}\right)} \tag{21}$$

This equation is used in both the vertical and horizontal directions of the mesh. The spatial relationships of the variables are shown in figure 8. In this figure, J_V and J_H are the vertical and horizontal currents.

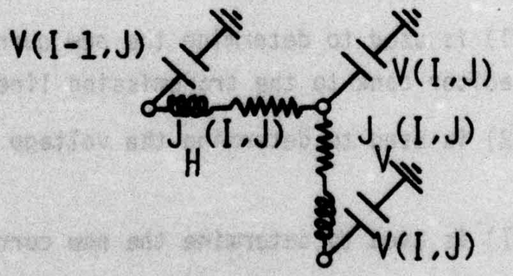

Figure 8. Spatial Relationships of Currents and Voltages.

Equation (19) is used for the derivation of the second difference equation. Letting V_{n+1} and V_n be the new and old voltages, respectively, the difference form of this equation is

$$V_{n+1} = V_n + \Delta t \sum_{i=1}^{4} I_i/C \tag{22}$$

The spatial relationships of the four currents to a node and the voltage at that node is shown in figure 9.

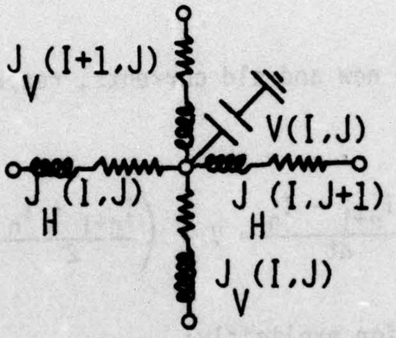

Figure 9. Spatial Relationships of Currents and Voltage.

The variables used in the FORTRAN coding are somewhat different from those used here. Appendix B should be consulted for a definition of all important variables. Appendix E contains a listing of PLATE.

Initially, at t = 0, the charge is present in the capacitor bank; as time progresses, it is moved throughout the mesh and eventually absorbed in the short circuit load. The problem solution proceeds in four parts during each step:

1. Equation (21) is used to determine the new currents through the inductors connecting the capacitor bank to the transmission line.

2. Equation (22) is used to determine the voltage left on the capacitor bank after part 1.

3. Equation (21) is used to determine the new currents between all nodes in the mesh.

4. Equation (22) is used to determine the new voltages on all capacitors after part 3.

The above solution scheme appears to be unstable, but it is not. The two differential equations are coupled and are solved alternately in time. They, thus,

provide feedback to each other, and the solution is a variation of the leap frog scheme.

At various intervals the solution is interrupted to allow printing and/or microfilm plotting of the data.

Appendix D contains the results of two sample problems which validate equations (21) and (22) and the solution scheme in which they are used.

SECTION IV

TRANSMISSION PLATE DESIGN

PLATE determines the current asymmetry at a cylindrical load which is attached in the center of a parallel plate transmission line. PLATE can be used to compare different transmission plate designs. The obvious comparison is current symmetry. Another important comparison that can be made is system inductance.

Greater transmission plate inductance smooths the current and produces better current symmetry. If a very low inductance, high energy system is desired, transmission plate design may involve a trade-off between raising the inductance and improving the current symmetry. The example explained in this section involves exactly this situation.

The objective is to compute the current symmetry of a 1.2 meter square transmission plate with a load radius of 0.14 meter as shown in figure 10. There are two capacitor modules of half-width 0.16 meter, half capacitance 5.55 μF, and half inductance of 24.0 nH (12.0 nH each module because the halves are in parallel) centered on opposing sides of the plate.

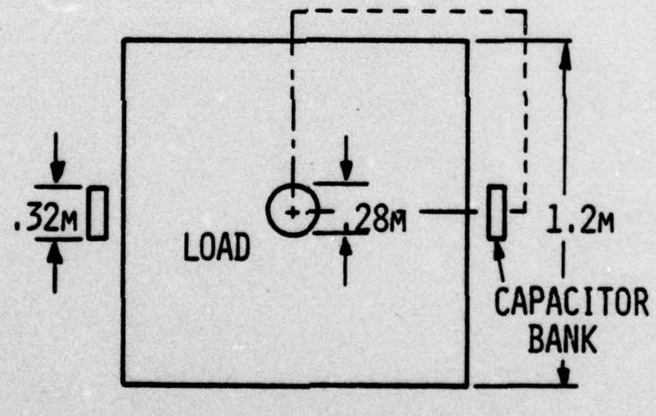

Figure 10. Plate Schematic I.

A symmetric one-fourth of this system was computed using the following input (see Appendix A for an explanation of the input).

```
        DYDIM INPUT
$       N30 = 61, M30 = 61, NP = 1     $
        NORMAL INPUT  (8F10.2)
0.14       0.14       0.18       0.0        2.8       3.0
0.6        0.6        100000.    5.55E-06   24.0E-09  0.16
0.6E-06               0.55
BLANK
BLANK
```

The azimuthal current symmetry around the cylindrical load, after the current flow stabilizes, is computed to be 29.3%. The current flow pattern and azimuthal current symmetry plots for this run are shown in figure 11. The current symmetry plot indicates a current asymmetry of about 30% which agrees closely with the computed value. Unfortunately, 30% asymmetry may not produce a viable experiment so an attempt must be made to improve the current symmetry.

By increasing the inductance in specific regions of the transmission plate, the current symmetry may be improved. One such example is shown in figure 12. This transmission plate is exactly the same as the first one except a wedge on each side of the plate has higher inductance by a factor of 10.

This higher inductance may be obtained by milling the transmission plates and inserting additional dielectric material. Thus, the capacitance is also decreased by a factor of 10.

The input data for this case and

```
        DYDIM  INPUT
$       N30 = 61, M30 = 61, NP = 1     $
        NORMAL INPUT  (8F10.2)
0.14       0.14       0.18       0.0        2.8       3.0
0.6        0.6        100000.    5.55E-06   24.0E-09  0.16       .10        .10
0.6E-06               0.55
BLANK CARD
01213636
01203737
01193838
01183939
01174040
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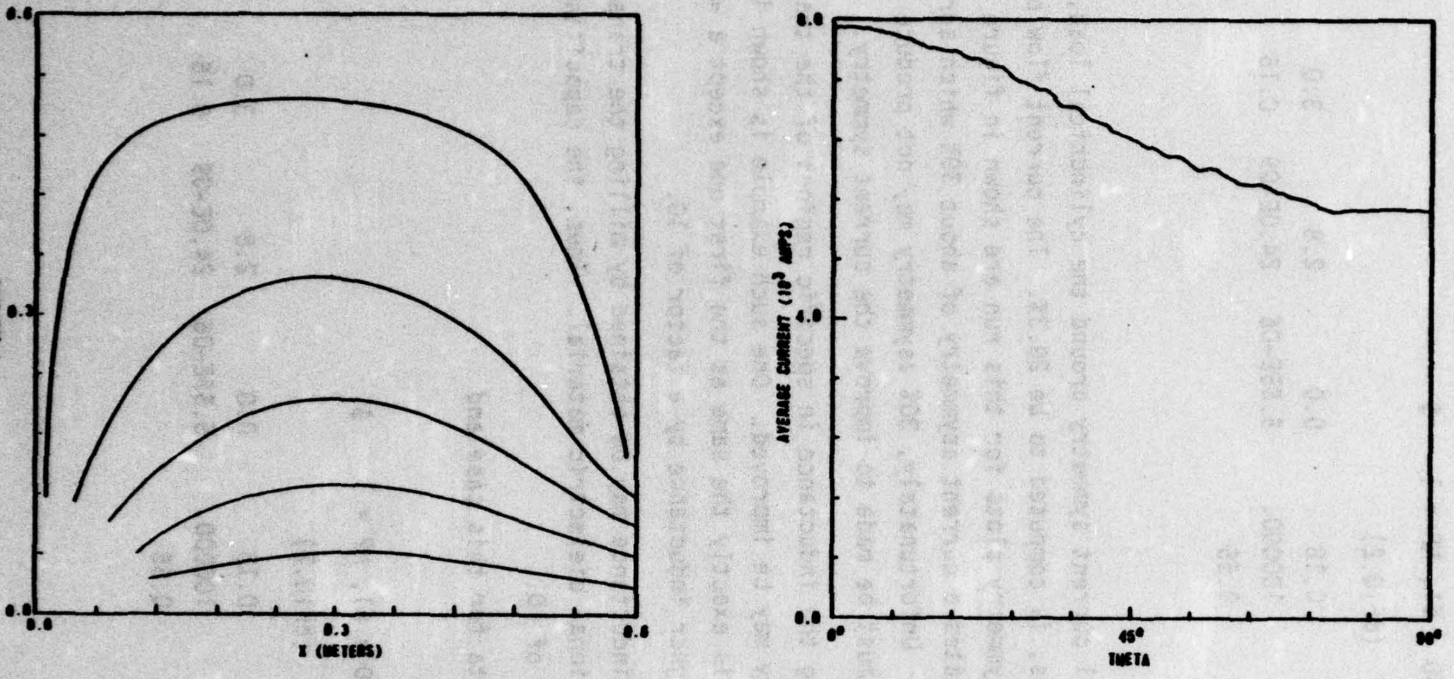

Figure 11. Current Flow and Current Symmetry.

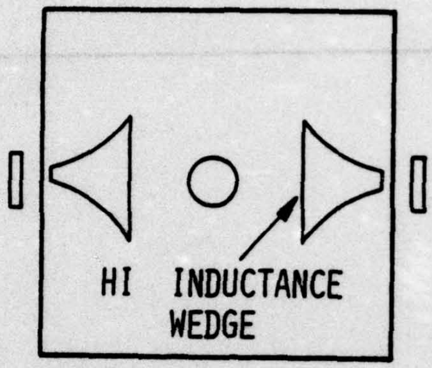

Figure 12. Plate Schematic (With Wedges).

```
01164141
01154242
01144343
01134444
01124545
01114646
01104747
01094848
01084949
01075050
01065151
01055252
01045353
01035454
01025556
01015760
BLANK CARD
BLANK CARD
6/7/8/9
```

The effect of the wedges is to divert the current so that it flows in from the four corners of the transmission plate rather than from two opposing sides. The current flow and current symmetry plots are shown in figure 13. (See Appendix F where this problem was used for sample output.) The current asymmetry was calculated to be 6.4% at 0.18 m radius. This current symmetry should be adequate for a viable experiment.

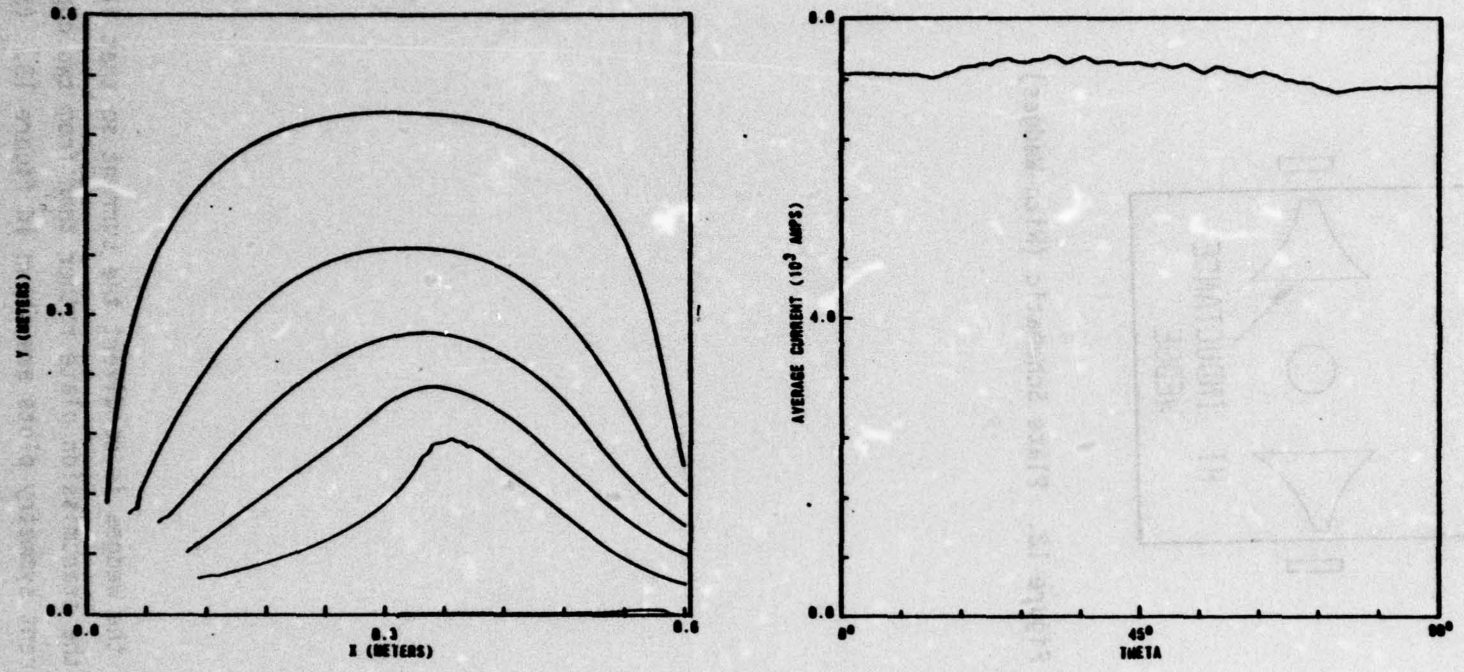

Figure 13. Current Flow and Current Symmetry.

In the preceding discussion, two geometries were compared for current symmetry. The second system was identical to the first except for the inclusion of a high inductance wedge. How much does the wedge cost in terms of an increase in system inductance?

PLATE computes partial system inductance at specified intervals of time. This inductance is reasonably stable as a function of time after about 10 nsec. These calculations indicate an increase in total system inductance of 0.27 nH due to the presence of the wedges. In this particular example, the inductance increase is intolerable and other designs must be tried. One possibility involves changing the inductance of the wedge by a factor of 5 instead of 10. A second possibility involves decreasing the size of the plate but leaving the wedge. One such design will provide the optimum compromise for the experiment considered here.

SECTION V

THE CROSSED-PLATE DESIGN

During the development of a fast one megajoule capacitor bank, the crossed-plate transmission line was proposed. A schematic of this design is shown in figure 14. Twenty capacitor modules are connected to the four "arms" of the transmission plate.

The current symmetry of such a system was in question; consequently, the capability for computing such a design was incorporated into PLATE. This option is called by setting NSETUP = 5 and introducing various input parameters for capacitor module placement. Typical input for the problem discussed in this section is:

```
          DYDIM  INPUT

$         N30 = 780 , M30 = 109 , NP = 1      $

          NORMAL INPUT   Format (8F10.2)

0.10      0.14      0.20      0.0       2.8       5.0       1.0
7.78      1.07      100000.   5.55E-06  24.0E-09  1.0       13.33
0.1E-06   10000.    1.75      2.542     4.542     5.152     7.152
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BLANK
```

This calculation yielded the current path plots shown in figure 15.

The second plot is a magnified view of the first, looking only in the vicinity of the load. (There is no relative current density associated with the current flow lines.)

The current asymmetry was computed to be 1.5%. Figure 16 shows the current as a function of azimuthal angle around the load. The first plot is unsmoothed and shows the effect of graniness dur to the cell size (in this case the cells are 1 cm square). The second plot is smoothed over a 10 degree azimuthal angle, and it agrees well with the calculated asymmetry. This current symmetry is definitely sufficient for a successful experiment.

The load is approximated inductively; however, instead of resistive losses, the current is deposited in large capacitors after passing through the simulated load. One drawback is that the load is considered to have a static rather than

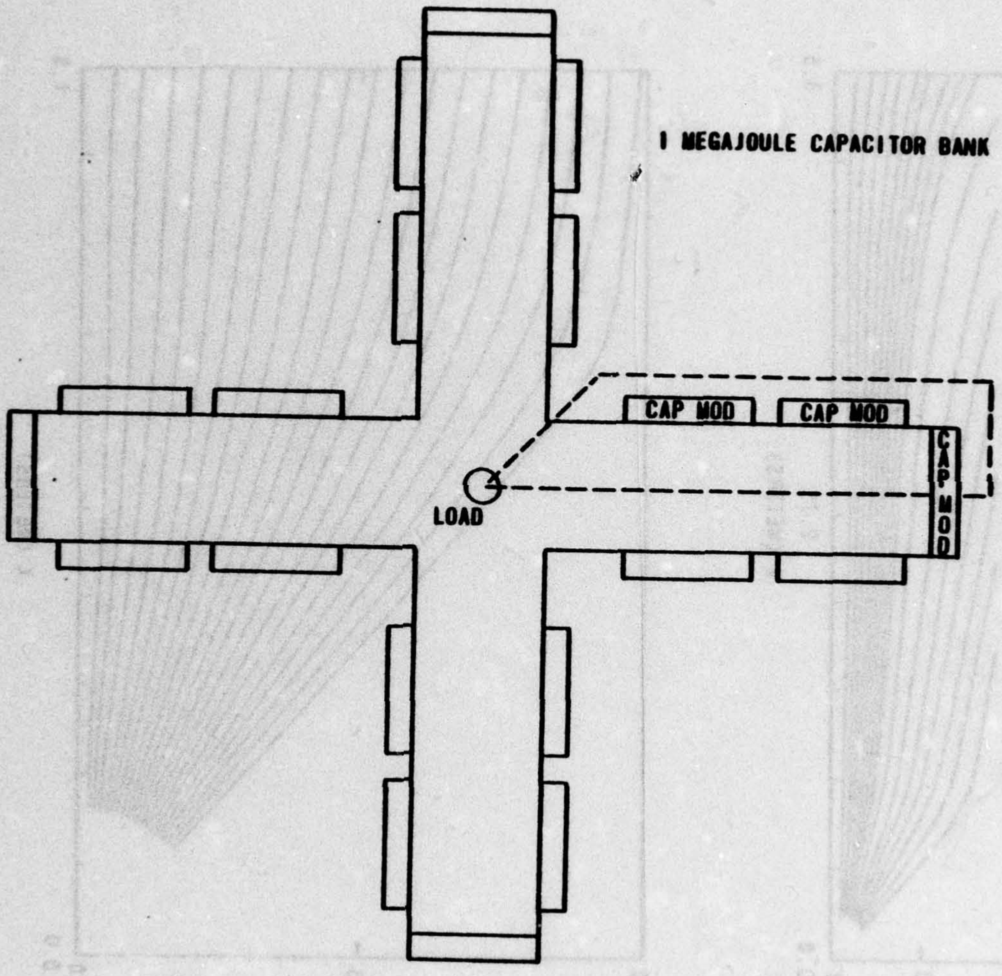


Figure 14. One Megajoule Capacitor Bank.

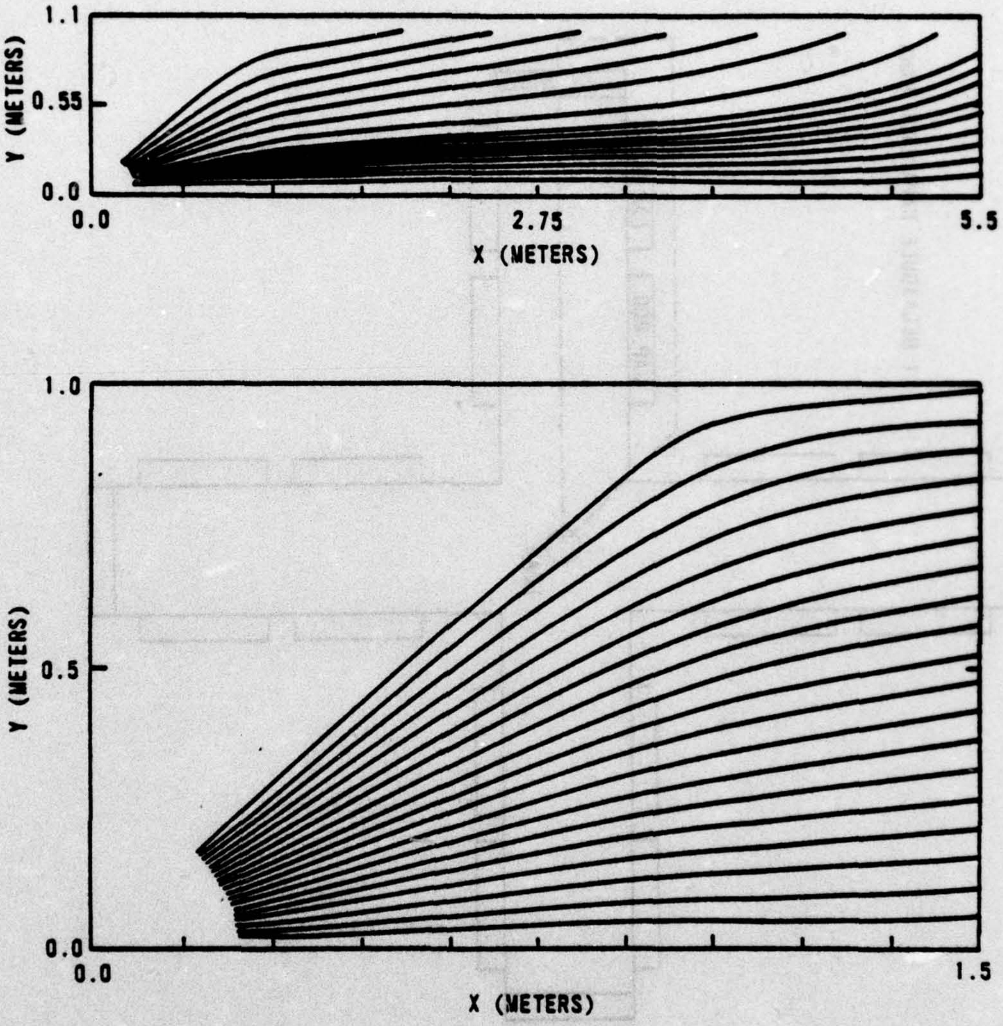


Figure 15. Current Flow.

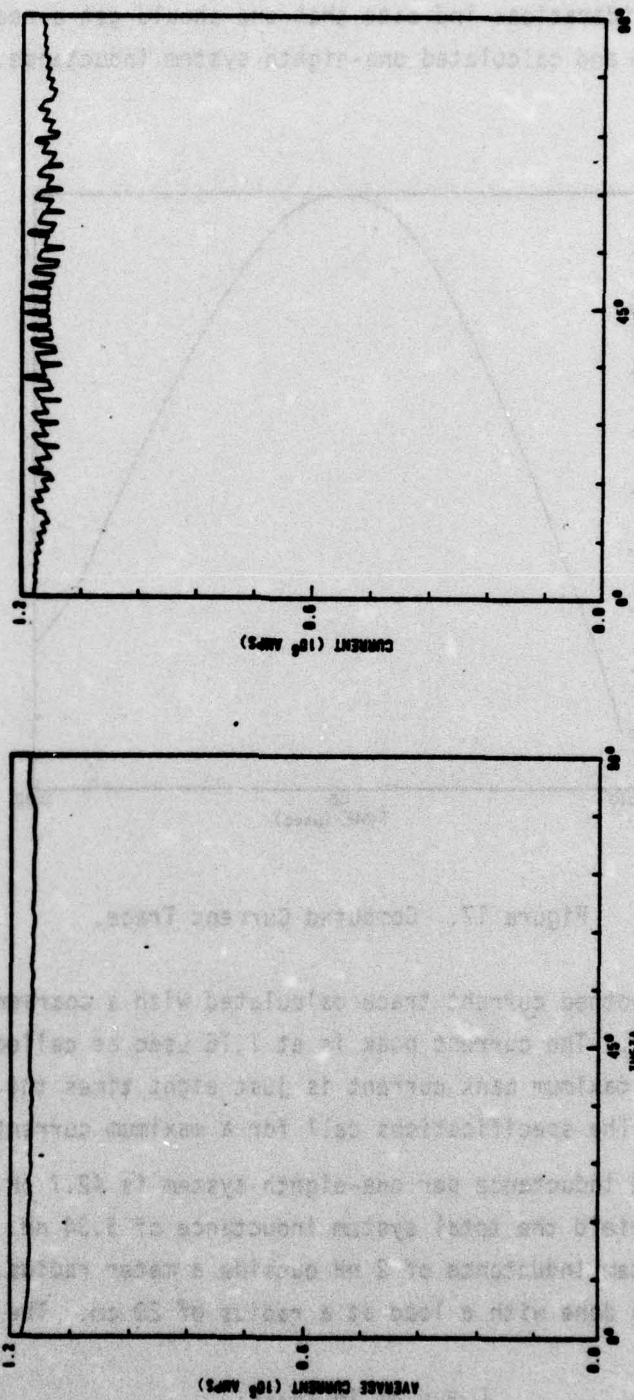


Figure 16. Current Symmetry.

variable inductance. The capacitor banks and transmission plate are all given realistic values of inductance and capacitance.

The above considerations indicate that one should get a realistic time dependent current trace and calculated one-eighth system inductance. Figure 17 shows a 2.32 μsec smoothed current trace calculated with a coarser mesh than was previously considered. The current peak is at 1.16 μsec as called for in the specifications. The maximum bank current is just eight times the current in the graph, or 17.12 MA. The specifications call for a maximum current of about 20 MA.

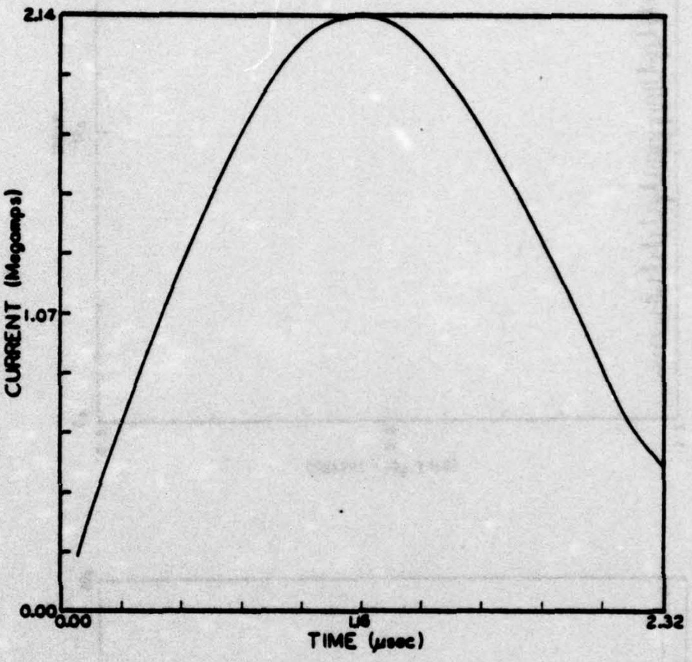


Figure 17. Computed Current Trace.

The calculated inductance per one-eighth system is 42.7 nH. This value is divided by eight to yield the total system inductance of 5.34 nH. The specifications call for a system inductance of 2 nH outside a meter radius. The above PLATE calculation was done with a load at a radius of 20 cm. The formula

$$L = \mu_0 \Delta z \ln (R_2/R_1) \tag{23}$$

may be used to compute the difference in inductance between 20 cm and 100 cm radii. (R_2 + 100 cm, R_1 = 20 cm, and Δz = 0.0015 m.) The difference inductance is 3.03 nH. The proposed system inductance for this load is thus 5.03 nH. The calculated inductance, again, is 5.34 nH.

The two inductances agree very well, considering the approximations made. (The inherent inaccuracy in the inductance calculation is disucssed in Appendix D.) Further error arises from the coarse mesh needed to run the crossed transmission plate problem for 2 μsec of real time. The coarse mesh grossly approximates the load.

The system inductance, current profile, and maximum current are close to the system specifications. The design of this 1 megajoule system is thus validated by PLATE.

SECTION VI

CONCLUSIONS

1. PLATE uses a simple numerical scheme in two dimensions to simulate the current flow in parallel plate transmission lines.

2. PLATE is limited to five transmission plate designs. One of these involves a one-dimensional transmission line. The other four are two-dimensional problems with either four or eight fold symmetry.

3. When proper zoning is used (usually as fine as 1 centimeter square zones), the measured asymmetry around the circumference of a cylindrical load is about 1% accurate at a radius of 30 centimeters.

4. PLATE is a useful tool for designing transmission plates where current symmetry to a cylindrical load is a valid consideration.

5. Current symmetry around a cylindrical load may be improved by current "shaping" techniques. One such technique is the inclusion of high inductance areas in the transmission plates.

6. The one megajoule crossed plate transmission line will yield current asymmetries less than 2%. The system inductance characteristics are verified by PLATE within the errors imposed on this calculation.

APPENDIX A

DEFINITIONS OF INPUT VARIABLES

CARD 1: FORMAT (8F10.2)

R1:	Radius of load
R2:	Radius of increased plate separation (milling)
RAD:	Radius or position of current assymmetry calculation for plotting and first of 15 radii for calculating current assymmetry
R3:	Radius of capacitor bank for symmetry test problem
ER:	Relative permittivity of insulator between transmission plates
SETUP:	(1-5) Determine which type of problem will be run.
	1 Symmetry test problem
	2 Transmission Line Problem with matching side boundary
	3 Rectangular Transmission Plate with two capacitor modules
	4 Square Transmission Plate with four capacitor modules
	5 Crossed plate transmission line
SETUP2:	If SETUP2 $\neq 0$, the program is set to run for a long time and to pick off $\dot{I}$ vs time plots at positions halfway between DIST1 and DIST2 and halfway between DIST3 and DIST4. This also makes a current trace. Use only when SETUP = 5.
SETUP3:	$= 0$, nothing, $\neq 0$, the value of cell inductance in the simulated load.

CARD 2: FORMAT (8F10.2)

X:	X dimension of transmission plate
Y:	Y dimension of transmission plate
Vo:	Voltage on capacitor
CT:	Capacitance of 1/2 module
ALT:	Inductance of 1/2 module
CLENGTH:	Physical length of 1/2 capacitor bank module
FACTOR:	Ratio of annular plate separation to normal plate separation
FACTOR2:	Not used until read in on Card 5

CARD 3: FORMAT (8F10.2)

TSTOP:	Time in sec when program terminates
DELZZ:	Plate separation (Default = .0015m)
DISTO:	X position in plate where current is summed (X < DIST0 < DELX, or error mode 1. results)
DIST1:	First of four variables used to position capacitor banks
DIST2:	All four are the boundaries of the modules on the side
DIST3:	Of the crossed plate geometry. In the case of the transmission
DIST4:	Line DIST 1 and DIST 2 position the capacitor bank

CARD 4: FORMAT (8F10.2)

TEDIT or A:	Initial edit time in sec, if zero default is TEDIT = 40 nsec
DELED or B:	Increment for additional edits, if zero default is DELED = 20 nsec
TEDIT2 or D:	Secondary edit time and increment in sec, if zero default is TEDIT2 = 10 nsec

INPUT TO PLATE

All real input is in the format 8F10.2

All integer input is in the form 5I2

R1	R2	RAD	R3	ER	SETUP	SETUP 2	SETUP 3
X	Y	V	CT	ALT	CLENGTH	FACTOR	FACTOR 2
TSTOP	DELZZ	DISTO	DIST1	DIST2	DIST3	DIST4	
TEDIT	DELED	TEDIT2					

M N K L NQ

FACTOR 2 (Only if NQ ≠ 0)

M N K L NQ

:

M N K L NQ

FACTOR 2 (Only if NQ ≠ 0)

BLANK (To terminate input)

BLANK

Input terminates when K = 0

NOTE: FACTOR 2 is read in after M N K L NQ only when NQ ≠ 0. Otherwise, the previous value of FACTOR 2 is used for inductance/capacitance changes.

NOTE 2: M, N, K, and L are limits on the I and J subscripts which define the X and Y boundaries within which the inductance and capacitance are changed by the factor = FACTOR2. K and L are the lower and upper limits on I, respectively, and they thus define X boundaries. M and N are the lower and upper limits on J, respectively, and they thus define Y boundaries.

The only additional input involves the variable dimensioning feature included by DYDIM. This input is of the form:

```
$     N30 = 145, M30 = 22, NP = 1     $
```

This card is usually included or changed using update. N30 and M30 are the X and Y dimensioning of the arrays. NP is the array size for time dependent current plots selected when SETUP2 $\neq$ 0. If SETUP2 = 0 select NP = 1.

CAUTION: N30 and M30 should be selected so that DELX and DELY are equal; otherwise, current will not flow properly in the simulated transmission plate. DELX and DELY are determined from:

$$DELX = X/(N30-2) \text{ and } DELY = Y/(M30-2)$$

where X and Y are the plate dimensions.

APPENDIX B

LIST OF VARIABLES

A list of important variables is found below. In some cases the variables have a real and integer representation because they are read in as real variables and used as integers.

A
Initial edit time = TEDIT

AINCX
Number of increments in the X direction

AINCY
Number of increments in the Y direction

AJH
Horizontal current array

AJHQ
ECS array of AJH

AJV
Vertical current.array

AJVQ
ECS array of AJV

AK
No longer used

AL
Inductance array

ALN
No longer used

ALQ
No longer used

ALQQ
ECS array of AL

ALT
Total inductance of 1/2 module

AL1
Inductance of each simulated capacitor in the bank

AL2
Inductance of a normal cell

AMUO
Permeability of free space

ANU
No longer used

AT
Time array for plotting

B
    Time increment for addition edits = DELED

C
    Capacitance array

CLENGTH
    Length of 1/2 module of capacitor bank

CQ
    ECS array of C

CT
    Total capacitance for 1/2 module

CTRAC
    Array for plotting time dependent current trace

CTR1
    Array for plotting $\dot{I}$ trace of one side module (one megajoule bank)

CTR2
    Array for plotting $\dot{I}$ trace for other side module (one megajoule bank)

C1
    Capacitance of one simulated capacitor in bank

C2
    Capacitance of a normal cell

C3
    No longer used

C4
    Capacitance of a load cell

D
    Secondary edit time = TEDIT2

DELED
    Edit interval

DELT
    Time increment

DELX
    X dimension of cells

DELY
    Y dimension of cells

DELZ
    Normal plate separation

DELZZ
    Input variable for DELZ

DISTO
    X position in plate where current is summed

DIST1 - DIST4
    The four boundaries of the two capacitor modules on the sides of the one megajoule transmission line arms.

EPSI
    ϵ, permittivity of the dielectric

EPSIO	ε_0, permittivity of free space
ER	Relative permittivity of the dielectric
FACTOR	Ratio of annular plate separation to normal plate separation
FACTOR2	Ratio of special regions to normal plate separation
I	Do loop index in X direction
III	No longer used
INCX	Same as AINCX
INCXO	INCX - 1
INCX1	INCX + 1
INCY	Same as AINCY
INCY1	INCY + 1
K	Index for the major loop over time also passed from WEDGE to SETUPX as a plotting array size
KSEN	No longer used
KSENSW	No longer used
NCAP	Number of capacitors in one-half module
NDIST1 - NDIST4	Corresponds to *DIST1 - DIST4 except these are cell designations of the* boundaries of the two capacitor modules
NN	NDIST1 or NDIST3
NNN	NDIST2 or NDIST4
NECS	Decimal ECS needed
NPOSX1	Position of one I trace
NPOSX2	Position of second I trace

NSETUP
Type of problem being run

NSETUP2
Cross plate only - picks off I traces as well as I vs t and plots them

NSETUP3
If ≠ 0 read in as the value of cell inductance in the simulated load

NT
Number of time increments

NZAP
An integer variable used for filling plotting arrays

N100
Subscript of plotting arrays while they are being filled.

RAD
Radius where current assymmetry information is tabulated

RESIS
Resistance of one cell

R1
Radius of load

R2
Outside radius of annular region of increased plate separation

R3
Radius of inner edge of capacitor bank when symmetry test problem is run

R4
No longer used

T
Problem time

TEDIT
Initial edit time

TEDIT2
Secondary edit time and increment

TSTOP
Stop time of problem

V
Voltage array

VO
Initial capacitor bank voltage

VQ
ECS array of V

V1
Scratch array

WA
Scratch array

WB
Scratch array

X

X dimension of plate

Y

Y dimension of plate

APPENDIX C

MUTUAL INDUCTANCE EFFECTS

The program PLATE ignores mutual inductance. This appendix justifies that assumption and gives a feeling for the magnitude of error introduced. The mutual inductance between adjacent cells is calculated, assuming the cells are like small inductors in parallel, with the accompanying fringing which leads to this mutual inductance. It is concluded that mutual inductance has only a small effect on total plate inductance as long as the cell size is large compared to the plate separation.

Figure C-1 shows two adjacent cells where a discontinuity in plate separation exists at the interface. Such discontinuities can be used for selectively controlling cell inductance.

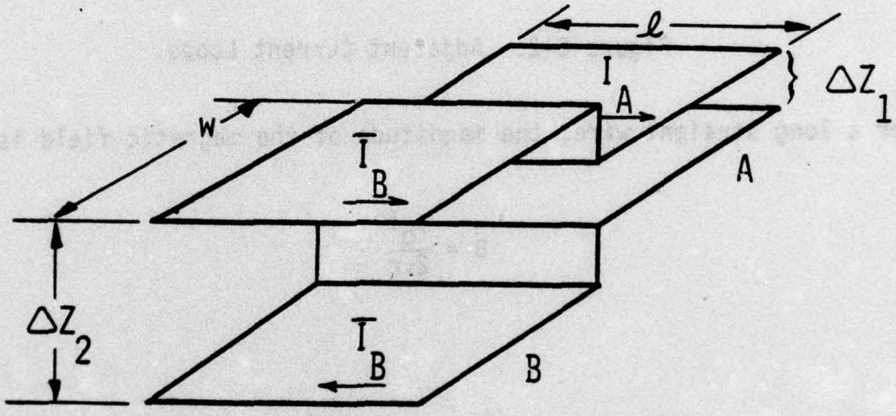
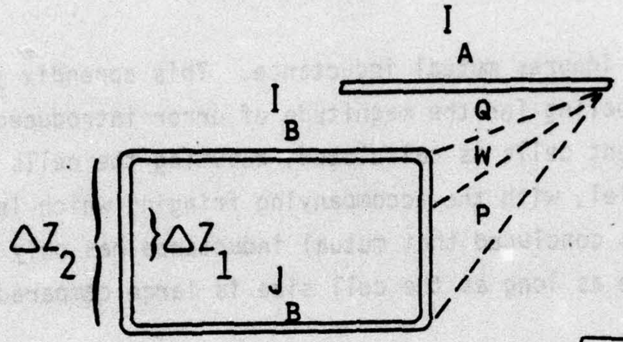


Figure C-1. Adjacent Cells.

If each cell is considered to be a current loop, the mutual inductance of a half-loop acting on a whole current loop as shown in figure C-2 can be determined.

The currents in the Z direction are cancelled by adjacent current loops and can thus be ignored. The flux created by wire A which passes through current loop B is given by

$$\phi = \int_S \overline{B} \cdot \hat{n} \, da \qquad (C-1)$$



where $q = W\sqrt{1 + \left(\frac{\Delta Z_2 - \Delta Z_1}{2w}\right)^2}$

and $p = W\sqrt{1 + \left(\frac{\Delta Z_2 + \Delta Z_1}{2w}\right)^2}$

Figure C-2. Adjacent Current Loops.

For a long straight wire, the magnitude of the magnetic field is given by

$$B = \frac{\mu_o I}{2\pi r} \qquad \text{(C-2)}$$

So that

$$\Phi_{ab} = \frac{\mu_o Ia}{2\pi} \int_s \frac{\overline{B} \cdot \hat{n}}{r}\, da$$

$$= \frac{\mu_o Ia}{2\pi} \int_o^l dl \int_q^p \frac{dr}{r} \qquad \text{(C-3)}$$

The limits p and q are given in figure C-2 and are substituted for explicitly so the integration yields:

$$\Phi_{ab} = \frac{\mu_o I a \ell}{2\pi} \ln \left[1+\left(\frac{\Delta Z_2+\Delta Z_1}{2W}\right)^2\right]^{1/2} \left[1+\left(\frac{\Delta Z_2-\Delta Z_1}{2W}\right)^2\right]^{-1/2} \tag{C-4}$$

For the bottom half of current loop A, Ia is negative and the limits on r are reversed; hence, there are two equal contributions to the flux. Since $M_{ab} = \Phi_{ab}/I_{a}$,

$$M_{ab} = \frac{\mu_o \ell}{\pi} \ln \left[1+\left(\frac{\Delta Z_2+\Delta Z_1}{2W}\right)^2\right]^{1/2} \left[1+\left(\frac{\Delta Z_2-\Delta Z_1}{2W}\right)^2\right]^{-1/2} \tag{C-5}$$

In general the self-inductance is given by

$$L = \mu_o \frac{\Delta Z \ell}{W} \tag{C-6}$$

and the coefficient of coupling is given by

$$k = \frac{M}{L} \tag{C-7}$$

Substituting for M and L the coefficient of coupling becomes

$$k = \frac{W}{\pi \Delta Z} \ln \left[1+\left(\frac{\Delta Z_2+\Delta Z_1}{2W}\right)^2\right]^{1/2} \left[1+\left(\frac{\Delta Z_2-\Delta Z_1}{2W}\right)^2\right]^{-1/2}. \tag{C-8}$$

For the specific case where $\Delta Z_2 = 11\Delta Z_1$, and $W = 10\Delta Z_1$,

$$k = \frac{10}{\pi} \ln \sqrt{\frac{1+(3/5)^2}{1+(1/2)^2}} = \frac{10}{\pi}(0.04217) = 0.134 \tag{C-9}$$

Thus the mutual inductance is 13.4% of the smaller inductor and about 1.2% of the larger inductor.

For cases where $\Delta Z_1 = \Delta Z_2$, the coefficient of coupling reduces to

$$k = \frac{W}{\pi \Delta Z} \ln \sqrt{1+\left(\frac{\Delta Z}{W}\right)^2} \tag{C-10}$$

when $\Delta Z < W$, the ℓn term may be expanded so that

$$k = \frac{W}{\pi \Delta Z} (1/2) \left[\left(\frac{\Delta Z}{W}\right)^2 - (1/2) \left(\frac{\Delta Z}{W}\right)^4 + (1/3) \left(\frac{\Delta Z}{W}\right)^6 - \cdot \cdot \cdot \right]$$

or

$$k = \frac{\Delta Z}{2\pi W} \left[1 - (1/2) \left(\frac{\Delta Z}{W}\right)^2 + (1/3) \left(\frac{\Delta Z}{W}\right)^4 + \cdot \cdot \cdot \right] \qquad \text{(C-11)}$$

when $\Delta Z \ll W$ only the first term is needed so that

$$k = \frac{\Delta Z}{2\pi W} \qquad \text{(C-12)}$$

This coefficient of coupling between cells with plate separation $\Delta Z = 0.1 \Delta X$ is 0.016. Clearly, all mutual inductance effects can be kept insignificant by keeping the ratio of ΔZ to ΔX smaller than 0.1. This limit is approximately maintained in PLATE calculations except in the simulated load and the high inductance wedges, where the plate separation and cell size are approximately equal.

A violation of the above limit, where high inductance wedges are included, is discussed in section IV. For that calculation, the plate separation is 1.5 times the cell size in a wedge shaped area. The total increase in system inductance is only 0.27 nH. The mutual inductance effect on the system inductance is maximized near this discontinuity. The coefficient of coupling of a cell at the discontinuity is calculated [using equation (C-10)] to be 0.587 when compared to a normal cell and 0.0587 when compared to a wedge cell. Fortunately, the wedge interface into the plate is over a limited region. The effective mutual inductance of the wedge is expected to add less than 1.0 nH to the system.

Thus the typical transmission plate inductance is accurate to within 5% if the criterion $\Delta Z \leq 0.1 \Delta X$ is met everywhere except in the load and the high inductance wedges. If this criterion is met everywhere, the transmission plate inductance is accurate to within 1.6%.

APPENDIX D

VALIDATION OF PLATE

Two test problems are solved in this Appendix. The first is a transmission plate with imposed azimuthal symmetry. The calculations show that current is propagated with azimuthal symmetry through the square mesh and that current symmetry at the simulated load is excellent. The second problem is a parallel plate transmission line with a capacitor bank on one side and a load on the other. The system inductance is calculated two ways: in PLATE and analytically using equation (7) in section IV. The two results agree nicely. The PLATE calculation was accomplished with two different cell sizes. Cell size is shown to have only a small effect on system inductance.

1. Symmetry Test Problem

This problem is a specific option in PLATE. It is called with SETUP = 1. The input cards for this problem with 25 x 25 zones are

DYDIM Input

```
$      N30 = 27, M30 = 27, NP = 1     $
```

Normal Input

```
0.259        0.408        0.3        0.8        2.8        1.0
1.0          1.0          100000.    5.55E-06   24.0E-09   1.0        10.0
0.6E-07                   1.0
BLANK
BLANK
```

The current flow pattern and current symmetry plots are shown in figure D-1. The minimum calculated current asymmetry was 5.6% (the current asymmetry is calculated at many radii outside the load). The cells had a size of 4 cm square. This coarse mesh contributes to the current asymmetry.

A second problem was run with 100 x 100 zones. The cell size was 1 cm square. The minimum calculated current asymmetry was 1%. This 1% current asymmetry is excellent, considering it was calculated around a quarter circle that was superimposed on square cells. The current flow equations are shown to be spatially valid, since current does not flow preferentially in the horizontal, vertical, or diagonal direction relative to the square grid.

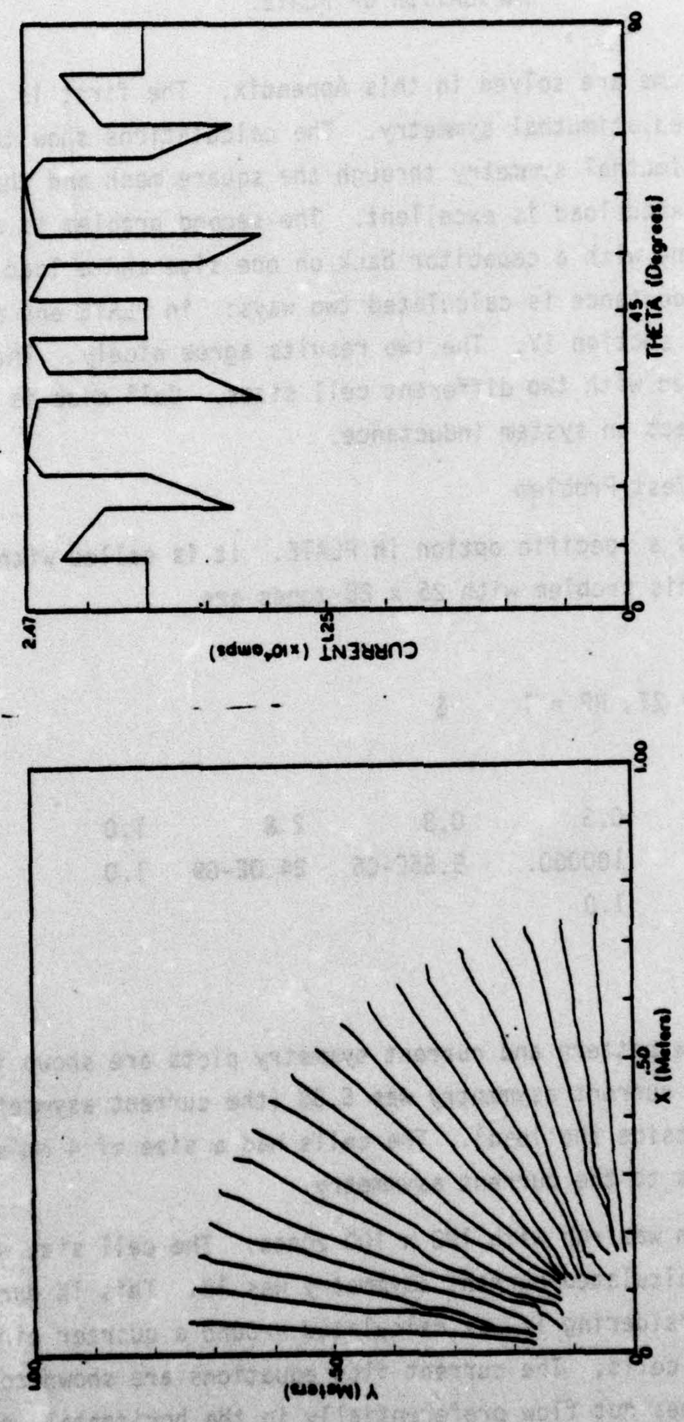


Figure D-1. Current Flow and Current Symmetry Plot.

The current flow pattern and current symmetry plots for this run are shown in figure D-2.

These two plots agree in substance, but the first shows the effect (graininess) of the relatively large 4 cm square cells. Current flow varies drastically with angle at the plotted radius. The second plot shows an almost constant current flow for different angles.

2. Parallel Plate Transmission Line

The second test problem involves a parallel plate transmission line with matching side boundaries. This approximates a cylindrical co-axial transmission line.

A transmission line of this sort may be represented as an inductor connected between two capacitors. One of the capacitors is the capacitor bank, and it is charged to a predetermined voltage. The second capacitor is a short circuit load.

The current in the inductor is given by

$$\frac{dI}{dt} = \frac{V}{L} \tag{D-1}$$

or

$$L \cong \frac{\Delta t \, \Delta V}{I_{n+1} - I_n} \tag{D-2}$$

where V is the average voltage across the inductor, t is the time interval, $(I_{n+1} - I_n)$ is the increase in the current during this time interval, and L is the effective inductance of the system. This equation is used to determine the inductance of the system.

The accuracy of this method is limited. There is a wave superimposed on the plotted current trace. This wavy nature is caused by waves sloshing around the simulated plate because the capacitor bank and load are not exactly matched. Because of these waves, relatively long intervals of time must be considered to make the inductance calculations meaningful.

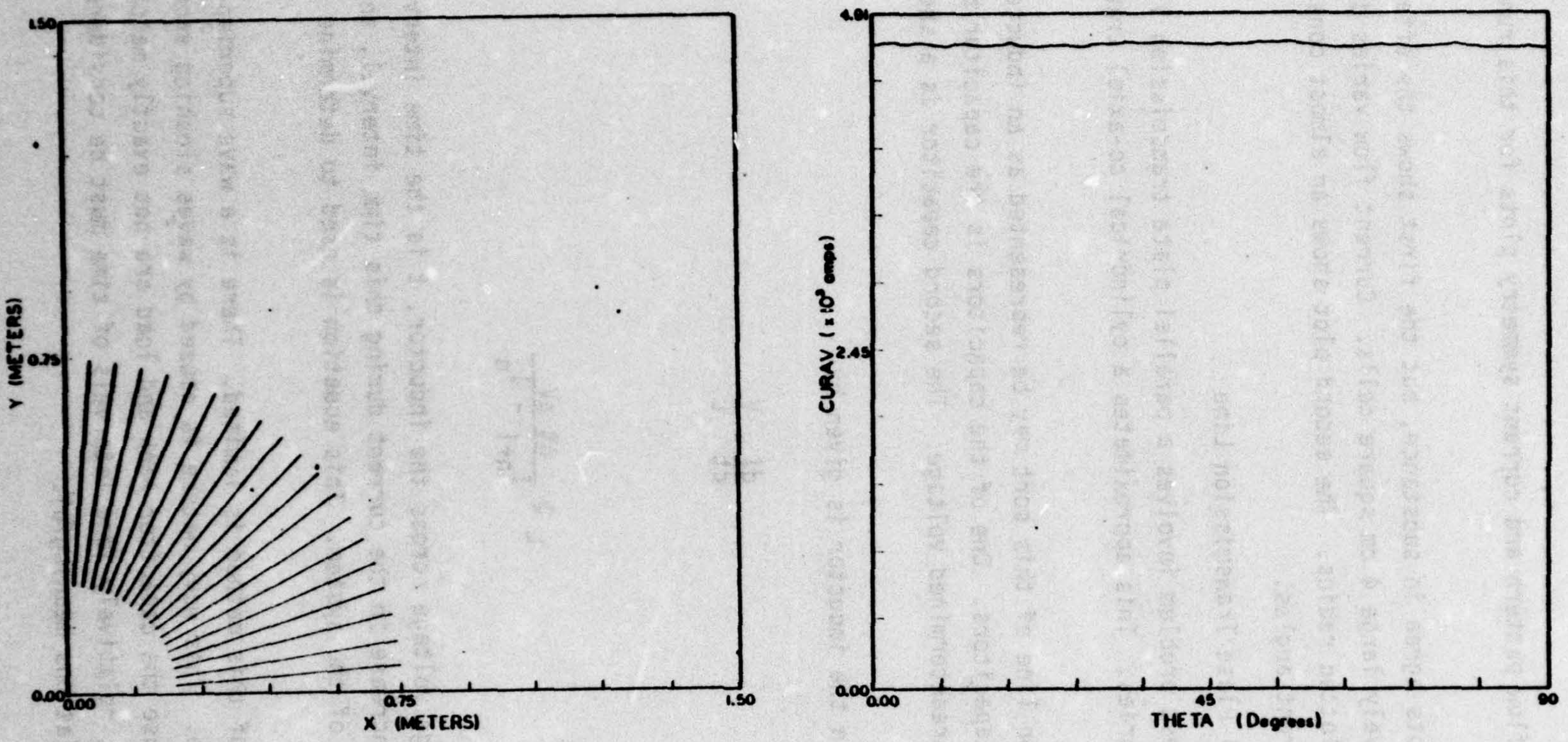


Figure D-2. Current Flow and Current Symmetry Plot.

The transmission line problem is specified with the following input:

```
0.0        0.0        0.0        0.0        2.8        2.0
1.0        1.0        100000.    5.55E-06   4.0E-09    1.0
1.5E-07    0.0015     0.05
BLANK
BLANK
```

DYDIM input is also used to specify 25 x 25 zones or 50 x 50 zones. The important part of the above input is the capacitor bank inductance $L = 4$ nH.

The 25 x 25 zones and 50 x 50 zones problems yielded system inductances 6.15 nH and 6.05 nH, respectively, between 50 nsec and 100 nsec problem time after initiation.

The bank has an inductance of 4 nH. There is, thus, approximately 2.1 nH in the transmission line.

Using equation (9) from section III, the inductance of a parallel plate transmission line with dielectric thickness 0.0015 m, length $x = 1.0$ m, and width $y = 1.0$ m is given by

$$L = \mu_0 \frac{\Delta X}{\Delta Z} \Delta Z = 4\pi \times 10^{-7}\ 0.0015 = 1.88 \text{ nH}$$

This value is about 10% less than the value of inductance calculated by PLATE, even so this comparison helps to validate the numerical method used.

The plotted current trace is an approximation, since the inductance calculations are tied directly to the current values. In Z-pinch type problems, the inductance of the load increases as the foil implodes. No attempt has been made to simulate the rising inductance in these calculations. Thus, the inductance calculations and current trace do not approximate the real experiments after 0.3 μsec (that is after the foil begins to implode).

APPENDIX E

LISTING OF PLATE

```
      PROGRAM PLATE(INPUT,OUTPUT,MF35PL)
C
C     ********************************************************************
C
C           PLATE IS A CODE WHICH DETERMINES THE PATHS ALONG WHICH
C     CURRENTS FLOW THROUGH TRANSMISSION PLATES.  A PLATE IS DIVIDED
C     INTO A SQUARE MESH.  EACH CORNER
C     IN THE MESH HAS A CAPACITOR CONNECTED TO GROUND.  THE VOLTAGE FOR
C     THE NEXT TIME STEP ON THIS CAPACITOR IS DETERMINED BY THE
C     CURRENTS IN THE FOUR LINES COMING TO THAT CAPACITOR BY
C
C                   V2 = V1 - DELT*(J1+J2+J3+J4)/C
C
C     WHERE  V2 IS THE NEW VOLTAGE
C            V1 IS THE OLD VOLTAGE
C            DELT IS THE TIME STEP
C            J1, J2, J3, J4 ARE THE FOUR CURRENTS WHICH CONTAIN
C            INTERNAL SIGNS AND WHERE THE SIGN CONVENTION IS IMPORTANT
C            C IS THE CAPACITANCE
C
C           THE LINKS IN THE MESH WHICH CONNECT THE CAPACITORS CONTAIN
C     INDUCTORS AND RESISTORS IN SERIES.  THE CURRENTS WHICH PROPAGATE
C     THROUGH THESE LINKS ARE CHANGED IN TIME BY
C
C           J2 = (VA - VB + J1*(L/DELT-R/2))/(L/DELT+R/2)
C
C      WHERE J2 IS THE NEW CURRENT
C            J1 IS THE OLD CURRENT
C            VA,VB ARE THE VOLTAGES ON THE CAPACITORS AT EITHER END
C            OF THE INDUCTOR AND RESISTOR PAIRS.  AGAIN THE SIGN
C            CONVENTION IS IMPORTANT, WITH SIGNS CONTAINED INTERNALLY
C            IN VA AND VB.
C            L IS THE INDUCTANCE IN A CONNECTING LINK
C            R IS THE RESISTANCE IN A CONNECTING LINK
C
C           THE MAIN ROUTINE PLATE IS THE CONTROLLING ROUTINE WHICH
C     CALLS THE VARIOUS SUBROUTINES.  SUBROUTINES CBANK AND CFLOW
C     CONTROL CURRENT FLOW OUT OF THE CAPACITOR BANKS AND THROUGH THE
C     PLATE, RESPECTIVELY.  DURING EACH TIME STEP THE CURRENT IS MOVED
C     THROUGH THE ENTIRE MESH USING OLD VOLTAGES.  THEN THE VOLTAGES
C     ARE CHANGED USING THE NEW CURRENTS.
C           THE PROGRAM BEGINS AT T=0 WITH THE CAPACITOR BANK BEING
C     SWITCHED ON.  ONE MUST NOTE HERE THAT USUALLY A SYMMETRIC ONE-
C     QUARTER OR ONE-EIGHTH OF THE PROBLEM IS CONSIDERED DURING A RUN.
C     THIS ALLOWS A FINER MESH AND A MORE ACCURATE SOLUTION.
C           THE PROGRAM PLATE CALLS THE FOLLOWING SUBROUTINES
C     THESE ROUTINES ARE LISTED IN THE ORDER THEY APPEAR IN THE
C     LISTING.
C
C           CBANK - PROPAGATES CURRENT OUT OF THE CAPACITOR BANKS AND
C     INTO THE PLATE.
C
C           CFLOW - PROPAGATES CURRENT THROUGH THE MESH OF THE PLATE.
C
```

```
C         MISCELL - THIS SUBROUTINE READS THE INPUT AND PRINTS IT OUT.  PLATE 55
C     IT USES THIS INPUT TO SET UP THE PROBLEM.  IT DETERMINES THE TIME PLATE 56
C     STEP AND OTHER VARIABLES NEEDED TO RUN THE PROBLEM.  THEN IT      PLATE 57
C     CALLS THE FOLLOWING THREE SUBROUTINES WHICH ACTUALLY              PLATE 58
C     INITIATE THE ARRAYS NEEDED TO RUN THE PROBLEMS.                   PLATE 59
C                                                                       PLATE 60
C         MESH - THIS SUBROUTINE INITIALLIZES THE INDUCTANCE,           PLATE 61
C     CAPACITANCE, VOLTAGE, AND CURRENT ARRAYS TO GENERAL PLATE VALUES. PLATE 62
C                                                                       PLATE 63
C         LOAD - THIS SUBROUTINE RESETS ARRAY VALUES TO SET UP A        PLATE 64
C     SIMULATED LOAD.                                                   PLATE 65
C                                                                       PLATE 66
C         WEDGE - THIS SUBROUTINE RESETS ARRAY VALUES IN INPUTED        PLATE 67
C     REGIONS OF THE PLATE TO HELP IN OBTAINING BETTER CURRENT          PLATE 68
C     SYMMETRY.                                                         PLATE 69
C                                                                       PLATE 70
C         SETUPX - PLOTS ON MICROFILM THE PROBLEM SETUP BY DRAWING      PLATE 71
C     LINES WHICH SEPARATE DIFFERENT REGIONS IN THE PLATE.              PLATE 72
C                                                                       PLATE 73
C         PRINT1(NEDIT) - PRINTS EDITED VERSIONS OF THE VOLTAGE,        PLATE 74
C     CAPACITANCE, INDUCTANCE, VERTICAL CURRENT OR HORIZONTAL CURRENT   PLATE 75
C     ARRAYS.  WHICH ARRAY IS PRINTED DEPENDS ON THE CALLING VARIABLE   PLATE 76
C     NEDIT.                                                            PLATE 77
C                                                                       PLATE 78
C         PRINT2 - PRINTS SMALLER EDITED ARRAYS OF VOLTAGE,             PLATE 79
C     HORIZONTAL, AND VERTICAL CURRENT.                                 PLATE 80
C                                                                       PLATE 81
C         INDUCT - THIS SUBROUTINE COMPUTES AND PRINTS THE CURRENT      PLATE 82
C     FLOWING IN THE PLATE EACH NANO-SECOND.  IT PRINTS CHARGE          PLATE 83
C     CONSERVATION.  IT ALSO SAVES THE CURRENT AT EQUAL TIME INTERVALS  PLATE 84
C     SO THAT A TIME DEPENDENT CURRENT TRACE CAN BE MADE BY SUBROUTINE  PLATE 85
C     CTRAC.                                                            PLATE 86
C                                                                       PLATE 87
C         INDUCT2 - THIS SUBROUTINE COMPUTES AND PRINTS SMOOTHED        PLATE 88
C     SYSTEM INDUCTANCE FOR SPECIFIC TIME INTERVALS.                    PLATE 89
C                                                                       PLATE 90
C         CTRACE - THIS SUBROUTINE PLOTS A TIME DEPENDENT CURRENT       PLATE 91
C     TRACE.  THIS SUBROUTINE AND THE NEXT ARE NOT CALLED EXCEPT WHEN   PLATE 92
C     SETUP2 IS NOT EQUAL TO 0 IN WHICH CASE THE PROBLEM IS SET UP TO   PLATE 93
C     RUN WITH A GROSS MESH AND FOR A LONG TIME.                        PLATE 94
C                                                                       PLATE 95
C         CTRAC2 - THIS SUBROUTINE COMPUTES AND PLOTS DI/DT TERMS FOR   PLATE 96
C     THE CAPACITOR MODULES.                                            PLATE 97
C                                                                       PLATE 98
C         CURRENT - COMPUTES AND PLOTS SEVERAL CURRENT PATHS FROM THE   PLATE 99
C     CAPACITOR BANK TO THE LOAD.                                       PLATE100
C                                                                       PLATE101
C         UNWIND - COMPUTES AND PLOTS THE THETA CURRENT SYMMETRY OF     PLATE102
C     THE CURRENT GOING TO THE LOAD.                                    PLATE103
C                                                                       PLATE104
C         LINPLOT - PLOTS THE DATA ON MICROFILM.                        PLATE105
C                                                                       PLATE106
C     LIST OF VARIABLES IN DIFFERENCE EQUATIONS                         PLATE107
C                                                                       PLATE108
```

```
C     V - VOLTAGE
C     AJV - VERTICAL CURRENT
C     AJH - HORIZONTAL CURRENT
C     C - CAPACITANCE
C     AL - INDUCTANCE
C     AL1 - BANK INDUCTANCE
C     RESIS - RESISTANCE
C     DELT - TIME STEP
C     V1 - SCRATCH ARRAY USED FOR VOLTAGE OR CURRENT
C
C     SIMILAR VARIABLES ENDING IN Q ARE TWO DIMENSIONAL ECS ARRAYS AND
C     THEY REPRESENT THE SAME QUANTITIES.
C
C     *****************************************************************
C

      COMMON X,    R1,    VO,  INCX, NDIST1,   DIST0,    RESIS,    AJV(26),
     1        Y,    R2,    CT,  INCY, NDIST2,   INCX0,   KSENSW,    AJH(26),
     2        K,    R3,   ALT, AINCX, NDIST3,   TSTOP,   NSETUP,      V(26),
     3        T,    R4,    NT, AINCY, NDIST4,   TEDIT,  NSETUP2,      C(26),
     4       AK,   RAD,   ALN, INCX1,  DIST1,   DELED,  NSETUP3,     V1(26),
     5     DELT,   AL1,   ALQ, INCY1,  DIST2,  TEDIT2,  NSETUP4,     AL(26),
     6     KSEN,   AL2,   ANU,  DELX,  DIST3,  NPOSX1,  NSETUP5, WA(26,26),
     7     NCAP,  N100,  NZAP,  DELY,  DIST4,  NPOSX2,  III(10), WB(26,26),
     8    X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)

      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),
     1 ALQQ(26,26)

      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ

      COMMON /ECS1/ AJVQ
      COMMON /ECS2/ AJHQ
      COMMON /ECS3/ VQ
      COMMON /ECS4/ CQ
      COMMON /ECS5/ ALQQ

C
C     FIX ECS FIELD LENGTH
C
      CALL INITPLT
      CALL MISCELL
      T=0.0
      N100=0
      KSENSW=0
C
C     IF DELX DOES NOT EQUAL DELY THE CALCULATION TERMINATES.
C
      IF ((DELX-DELY)/DELX.LT.1.0/AMAX1(AINCX,AINCY)) GO TO 1
      PRINT 7
      PRINT 8
      STOP
1     CONTINUE
C
```

```
C     THESE LOOPS PERFORM THE ITERATIONS OVER A TIME STEP DELT.
C
      DO 6 K=1,NT
      T=T+DELT
      CALL CBANK
      CALL CFLOW
C
C     THE REST OF THIS PROGRAM CALLS VARIOUS CHECKING, PRINTING,
C     AND PLOTTING SUBROUTINES.
C
      IF (NSETUP2.EQ.0) GO TO 2
      IF (NZAP.EQ.0) GO TO 3
      GO TO 4
2     CONTINUE
      IF (T.LT.TEDIT2) GO TO 4
      TEDIT2=TEDIT2+1.0E-09
3     CONTINUE
4     CONTINUE
      IF (T.LT.TEDIT) GO TO 5
      TEDIT=TEDIT+DELED
      KSENSW=0
      CALL PRINT2
      CALL CURRENT
      CALL UNWIND
5     CONTINUE
      CALL XTIME (CP,PP,IO,TIMTGO)
      IF (TIMTGO.GT.30.0.AND.T.LE.TSTOP) GO TO 6
      CALL CTRACE
      IF (NSETUP2.GT.0) CALL CTRAC2
      STOP
6     CONTINUE
C
7     FORMAT (5X,72HTHIS PROGRAM TERMINATED BECAUSE DELX DID NOT EQUAL D
     1ELY (APPROXIMATELY).)
8     FORMAT (5X,54HCORRECT DYDIM INPUT N30 OR M30 TO ADJUST DELX OR DEL
     1Y.)
      END
```

```
      SUBROUTINE CBANK

      COMMON X,    R1,    VO,  INCX, NDIST1,  DISTO,   RESIS,     AJV(26),
     1       Y,    R2,    CT,  INCY, NDIST2,  INCXO,  KSENSW,     AJH(26),
     2       K,    R3,   ALT, AINCX, NDIST3,  TSTOP,  NSETUP,       V(26),
     3       T,    R4,    NT, AINCY, NDIST4,  TEDIT, NSETUP2,       C(26),
     4      AK,   RAD,   ALN, INCX1,  DIST1,  DELED, NSETUP3,      V1(26),
     5    DELT,   AL1,   ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,      AL(26),
     6    KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),
     7    NCAP,  N10C,  NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)

      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),
     1  ALQQ(26,26)

      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ

      COMMON /ECS1/ AJVQ
      COMMON /ECS2/ AJHQ
      COMMON /ECS3/ VQ
      COMMON /ECS4/ CQ
      COMMON /ECS5/ ALQQ

C
C     IF NSETUP DOES NOT EQUAL 1 THE LOOPS TO STATEMENT 6 SEND CURRENT
C     INTO THE PLATE FROM THE CAPACITOR BANKS.
C
      IF (NSETUP.EQ.1) GO TO 5
      I=INCX1
      DO 1 J=1,NCAP
      CALL READEC (AJV(I),AJVQ(I,J),1)
      CALL READEC (V(1),VQ(I-1,J),2)
      CALL READEC (C(I),CQ(I,J),1)
      AJV(I)=AJV(I)+DELT*(V(2)-V(1))/AL1
      V(2)=V(2)-AJV(I)*DELT/C(I)
      CALL WRITEC (V(2),VQ(I,J),1)
      CALL WRITEC (AJV(I),AJVQ(I,J),1)
1     CONTINUE
C
C     IF NSETUP=5 CURRENT IS FED FROM THE CAPACITOR BANKS ON THE SIDE
C     OF THE CROSSED TRANSMISSION PLATE.  THE TWO SIDE CAPACITOR
C     MODULES HAVE LIMITS OF NDIST1, NDIST2, NDIST3, AND NDIST4.
C
      IF (NSETUP.NE.5) GO TO 5
      NN=NDIST1
      NNN=NDIST2
      J=INCY1
      CALL READEC (AJH(1),AJHQ(1,J),INCX)
      CALL READEC (V(1),VQ(1,J),INCX)
      CALL READEC (V1(1),VQ(1,J-1),INCX)
      CALL READEC (C(1),CQ(1,J),INCX)
      NZAP=MOD(K,100)
      IF (NZAP.NE.0.OR.NSETUP2.EQ.0) GO TO 2
      N100=N100+1
```

```
      CTR1(N100)=(V(NPOSX1)-V1(NPOSX1))*DELT/AL1                        PLATE254
      CTR2(N100)=(V(NPOSX2)-V1(NPOSX2))*DELT/AL1                        PLATE255
    2 CONTINUE                                                          PLATE256
      DO 3 I=NN,NNN                                                     PLATE257
      AJH(I)=AJH(I)+(V(I)-V1(I))*DELT/AL1                               PLATE258
      V(I)=V(I)-DELT*AJH(I)/C(I)                                        PLATE259
    3 CONTINUE                                                          PLATE260
      NN=NDIST3                                                         PLATE261
      NNN=NDIST4                                                        PLATE262
      DO 4 I=NN,NNN                                                     PLATE263
      AJH(I)=AJH(I)+(V(I)-V1(I))*DELT/AL1                               PLATE264
      V(I)=V(I)-DELT*AJH(I)/C(I)                                        PLATE265
    4 CONTINUE                                                          PLATE266
      CALL WRITEC (V(1),VQ(1,J),INCX)                                   PLATE267
      CALL WRITEC (AJH(1),AJHQ(1,J),INCX)                               PLATE268
    5 CONTINUE                                                          PLATE269
      RETURN                                                            PLATE270
      END                                                               PLATE271
```

```
      SUBROUTINE CFLOW                                                  PLATE272
                                                                        PLATE273
      COMMON X,    R1,    VO,  INCX, NDIST1,  DISTO,   RESIS,   AJV(26), PLATE274
     1      Y,    R2,    CT,  INCY, NDIST2,  INCX0,  KSENS*,   AJH(26), PLATE275
     2      K,    R3,   ALT, AINCX, NDIST3,  TSTOP,  NSETUP,     V(26), PLATE276
     3      T,    R4,    NT, AINCY, NDIST4,  TEDIT, NSETUP2,     C(26), PLATE277
     4     AK,   RAD,   ALN, INCX1,  DIST1,  DELED, NSETUP3,    V1(26), PLATE278
     5   DELT,   AL1,   ALO, INCY1,  DIST2, TEDIT2, NSETUP4,    AL(26), PLATE279
     6   KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),  PLATE280
     7   NCAP, N100, NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),  PLATE281
     8  X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)             PLATE282
                                                                        PLATE283
      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),        PLATE284
     1  ALQQ(26,26)                                                     PLATE285
                                                                        PLATE286
      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ                                 PLATE287
                                                                        PLATE288
      COMMON /ECS1/ AJVQ                                                PLATE289
      COMMON /ECS2/ AJHQ                                                PLATE290
      COMMON /ECS3/ VQ                                                  PLATE291
      COMMON /ECS4/ CQ                                                  PLATE292
      COMMON /ECS5/ ALQQ                                                PLATE293
                                                                        PLATE294
C                                                                       PLATE295
C     THE LOOPS OVER STATEMENT  8 CHANGE THE VERTICAL CURRENT AJV FOR   PLATE296
C     ALL THE MESH POINTS IN THE TRANSMISSION PLATE.                    PLATE297
C                                                                       PLATE298
      RESI2 =RESIS/2.                                                   PLATE299
      DELTI=1./DELT                                                     PLATE300
      DO 2 J=1,INCY                                                     PLATE301
      CALL READEC (AJV(1),AJVQ(1,J),INCX)                               PLATE302
      CALL READEC (V(1),VQ(1,J),INCX)                                   PLATE303
      CALL READEC (AL(1),ALQQ(1,J),INCX)                                PLATE304
      DO 1 I=2,INCX                                                     PLATE305
      AJV(I)=(V(I)-V(I-1)+AJV(I)*(AL(I)*DELTI-RESI2))/(AL(I)*DELTI+RESI2PLATE306
     1)                                                                 PLATE307
    1 CONTINUE                                                          PLATE308
      AJV(1)=-AJV(2)                                                    PLATE309
      CALL WRITEC (AJV(1),AJVQ(I,J),INCX)                               PLATE310
    2 CONTINUE                                                          PLATE311
C                                                                       PLATE312
C     THE LOOPS OVER STATEMENT 10 CHANGE THE HORIZONTAL CURRENT AJH FOR PLATE313
C     ALL THE MESH POINTS IN THE TRANSMISSION PLATE.                    PLATE314
C                                                                       PLATE315
      DO 4 J=2,INCY                                                     PLATE316
      CALL READEC (AJH(1),AJHQ(1,J),INCX)                               PLATE317
      CALL READEC (V(1),VQ(1,J),INCX)                                   PLATE318
      CALL READEC (V1(1),VQ(1,J-1),INCX)                                PLATE319
      CALL READEC (AL(1),ALQQ(1,J),INCX)                                PLATE320
      DO 3 I=1,INCX                                                     PLATE321
      AJH(I)=(V(I)-V1(I)+AJH(I)*(AL(I)*DELTI-RESI2))/(AL(I)*DELTI+RESI2)PLATE322
    3 CONTINUE                                                          PLATE323
      CALL WRITEC (AJH(1),AJHQ(1,J),INCX)                               PLATE324
    4 CONTINUE                                                          PLATE325
```

```
      CALL READEC (AJH(1),AJHQ(1,2),INCX)                               PLATE326
C                                                                       PLATE327
C     THE LOOP OVER STATEMENT 11 IS A REFLECTED BOUNDARY CONDITION      PLATE328
C     CAUSED BY SYMMETRY.                                               PLATE329
C                                                                       PLATE330
      DO 5 I=1,INCX                                                     PLATE331
5     AJH(I)=-AJH(I)                                                    PLATE332
      CALL WRITEC (AJH(1),AJHQ(1,1),INCX)                               PLATE333
C                                                                       PLATE334
C     THE LOOPS OVER STATEMENT 13 CHANGE THE VOLTAGE V FOR ALL THE MESH PLATE335
C     POINTS IN THE TRANSMISSION PLATE.                                 PLATE336
C                                                                       PLATE337
      DO 7 J=1,INCY                                                     PLATE338
      CALL READEC (V(1),VQ(1,J),INCX)                                   PLATE339
      CALL READEC (AJH(1),AJHQ(1,J),INCX1)                              PLATE340
      CALL READEC (AJV(1),AJVQ(1,J),INCX1)                              PLATE341
      CALL READEC (C(1),CQ(1,J),INCX)                                   PLATE342
      CALL READEC (V1(1),AJHQ(1,J+1),INCX1)                             PLATE343
      DO 6 I=1,INCX                                                     PLATE344
      V(I)=V(I)+DELT*(AJV(I+1)-AJV(I)+V1(I)-AJH(I))/C(I)                PLATE345
6     CONTINUE                                                          PLATE346
      CALL WRITEC (V(1),VQ(1,J),INCX)                                   PLATE347
7     CONTINUE                                                          PLATE348
C                                                                       PLATE349
C     WHEN NSETUP EQUALS 4 OR WHEN NSETUP EQUALS 5                      PLATE350
C     THE LOOPS OVER STATEMENTS 14 AND 16, 17 AND 19 DO A REFLECTION    PLATE351
C     ACROSS A 45 DEGREE ANGLE IN THE CENTER OF THE CROSSED             PLATE352
C     TRANSMISSION PLATE TO IMPOSE 8 FOLD SYMMETRY.                     PLATE353
C                                                                       PLATE354
      IF (NSETUP.NE.5.AND.NSETUP.NE.4) GO TO 14                         PLATE355
      IF (NSETUP.NE.5.AND.NSETUP.NE.4) GO TO 14                         PLATE356
      DO 8 J=1,INCY1                                                    PLATE357
8     CALL READEC (WB(1,J),VQ(1,J),INCY1)                               PLATE358
      DO 10 LM=1,INCY                                                   PLATE359
      J=INCY1-LM+1                                                      PLATE360
      DO 9 I=1,J                                                        PLATE361
9     WB(I,J)=WB(J,I)                                                   PLATE362
      CALL WRITEC (WB(1,J),VQ(1,J),J)                                   PLATE363
10    CONTINUE                                                          PLATE364
      DO 11 J=1,INCY1                                                   PLATE365
      CALL READEC (WB(1,J),AJHQ(1,J),INCY1)                             PLATE366
11    CALL READEC (WA(1,J),AJVQ(1,J),INCY1)                             PLATE367
      DO 13 LM=1,INCY                                                   PLATE368
      J=INCY1-LM+1                                                      PLATE369
      DO 12 I=1,J                                                       PLATE370
      WB(I,J)=WA(J,I)                                                   PLATE371
12    WA(I,J)=WB(J,I)                                                   PLATE372
      CALL WRITEC (WB(1,J),AJHQ(1,J),J)                                 PLATE373
      CALL WRITEC (WA(1,J),AJVQ(1,J),J)                                 PLATE374
13    CONTINUE                                                          PLATE375
14    CONTINUE                                                          PLATE376
      IF (NSETUP.NE.2) GO TO 16                                         PLATE377
      CALL READEC (V(1),VQ(1,1),INCX)                                   PLATE378
      CALL READEC (V1(1),VQ(1,INCY1),INCX)                              PLATE379
```

```
                                                                  PLATE380
      DO 15 I=1,INCX                                              PLATE381
      V(I)=V1(I)=(V(I)+V1(I))/2.0                                 PLATE382
   15 CONTINUE                                                    PLATE383
      CALL WRITEC (V(1),VQ(1,1),INCX)                             PLATE384
      CALL WRITEC (V1(1),VQ(1,INCY1),INCX)                        PLATE385
   16 CONTINUE                                                    PLATE386
      RETURN                                                      PLATE387
      END
```

```
      SUBROUTINE MISCELL

      COMMON X,    R1,    VO,  INCX, NDIST1,  DIST0,   RESIS,    AJV(26),
     1       Y,    R2,    CT,  INCY, NDIST2,  INCX0,  KSENS*,    AJH(26),
     2       K,    R3,   ALT, AINCX, NDIST3,  TSTOP,  NSETUP,      V(26),
     3       T,    R4,    NT, AINCY, NDIST4,  TEDIT, NSETUP2,      C(26),
     4      AK,   RAD,   ALN, INCX1,  DIST1,  DELED, NSETUP3,     V1(26),
     5    DELT,   AL1,   ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,     AL(26),
     6    KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1, NSETUP5, *A(26,26),
     7    NCAP,  N100,  NZAP,  DELY,  DIST4, NPOSX2, III(10), *B(26,26),
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)

      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),
     1  ALQQ(26,26)

      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ

      COMMON /ECS1/ AJVQ
      COMMON /ECS2/ AJHQ
      COMMON /ECS3/ VQ
      COMMON /ECS4/ CQ
      COMMON /ECS5/ ALQQ

C
C     THIS SUBROUTINE SETS UP THE PLATE PROBLEM.
C
C
C     READ STATEMENTS AND SHUFFLING OF REAL TO INTEGER VARIABLES.
C
      PRINT 5
      DELZ=0.0015
      ANT=10000.
      INCX =26 - 1
      INCY =26 - 1
      READ 7, R1,R2,RAD,R3,ER,SETUP,SETUP2,SETUP3
      READ 7, X,Y,VO,CT,ALT,CLENGTH,FACTOR,FACTOR2
      READ 7, TSTOP,DELZZ,DIST0,DIST1,DIST2,DIST3,DIST4
      IF (DELZZ.NE.0.0) DELZ=DELZZ
      AINCX=INCX
      AINCY=INCY
      AZ=AINCY/Y
      NSETUP=SETUP
      NSETUP2=SETUP2
      NSETUP3=SETUP3
      IF (NSETUP.EQ.1) PRINT 22
      IF (NSETUP.EQ.2) PRINT 23
      IF (NSETUP.EQ.3) PRINT 24
      IF (NSETUP.EQ.4) PRINT 25
      IF (NSETUP.EQ.5) PRINT 26
      PRINT 21, R1,R2,RAD,R3,ER,SETUP,SETUP2,SETUP3
      PRINT 21, X,Y,VO,CT,ALT,CLENGTH,FACTOR,FACTOR2
      PRINT 21, TSTOP,DELZZ,DIST0,DIST1,DIST2,DIST3,DIST4
      RESIS=1.67E-04
      TEDIT=0.04E-06
```

```
      DELED=0.02E-06                                                    PLATE442
      TEDIT2=0.01E-06                                                   PLATE443
      READ 1, A,B,D                                                     PLATE444
      IF (A.NE.0.0) TEDIT=A                                             PLATE445
      IF (B.NE.0.0) DELED=B                                             PLATE446
      IF (D.NE.0.0) TEDIT2=D                                            PLATE447
      PRINT 2, A,B,D                                                    PLATE448
      PRINT 3, TEDIT,DELED,TEDIT2                                       PLATE449
      PRINT 14, R1,R2,RAD,R3                                            PLATE450
      PRINT 15, NSETUP,NSETUP2,NSETUP3                                  PLATE451
      PRINT 16, X,Y,FACTOR,FACTOR2,ER                                   PLATE452
      PRINT 17, VO,CT,ALT,CLENGTH                                       PLATE453
      PRINT 18, TSTOP,ANT,AINCX,AINCY                                   PLATE454
      PRINT 19, DIST1,DIST2,DIST3,DIST4,DISTO                           PLATE455
C                                                                       PLATE456
C     NSETUP = 1 PRODUCES A SQUARE TEST PROBLEM.                        PLATE457
C     NSETUP = 2 PRODUCES A PARALLEL PLATE TRANSMISSION LINE PROBLEM.   PLATE458
C     NSETUP = 3 PRODUCES A RECTANGULAR PROBLEM WITH CAPACITOR BANKS    PLATE459
C     ON TWO SIDES.                                                     PLATE460
C     NSETUP = 4, PRODUCES A RECTANGULAR PROBLEM WITH CAPACITOR BANKS   PLATE461
C     ON ALL FOUR SIDES.                                                PLATE462
C     NSETUP = 5 PRODUCES THE CROSSED PLATE GEOMETRY.                   PLATE463
C                                                                       PLATE464
C                                                                       PLATE465
C     INCX AND INCY ARE THE NUMBER OF X AND Y INCREMENTS RESPECTIVELY.  PLATE466
C                                                                       PLATE467
      INCX1=INCX+1                                                      PLATE468
      INCY1=INCY+1                                                      PLATE469
      INCX0=INCX-1                                                      PLATE470
C                                                                       PLATE471
C     NT IS THE NUMBER OF TIME INCREMENTS.                              PLATE472
C                                                                       PLATE473
      NT=ANT                                                            PLATE474
      PI=3.1415926535                                                   PLATE475
C                                                                       PLATE476
C     AMUO IS THE PERMEABILITY OF FREE SPACE.                           PLATE477
C     EPSI IS THE PERMITTIVITY OF MYLAR.                                PLATE478
C                                                                       PLATE479
      AMUO=4.0*PI*1.0E-07                                               PLATE480
      EPSIO=1.0/(AMUO*(2.9979E+08)**2)                                  PLATE481
      EPSI=ER*EPSIO                                                     PLATE482
      PRINT 20, AMUO,EPSIO,EPSI                                         PLATE483
C                                                                       PLATE484
C     DELX AND DELY ARE THE DIMENSIONS OF ONE CELL.  DELX AND DELY      PLATE485
C     SHOULD BE APPROXIMATELY EQUAL.  DELZ IS THE PLATE SEPARATION.     PLATE486
C                                                                       PLATE487
      DELX=X/(AINCX-1.0)                                                PLATE488
      DELY=Y/(AINCY-1.0)                                                PLATE489
      NPOSX1=((DIST1+DIST2)/2.0)/DELX                                   PLATE490
      NPOSX2=((DIST3+DIST4)/2.0)/DELX                                   PLATE491
      PRINT 4, NPOSX1,NPOSX2                                            PLATE492
C                                                                       PLATE493
C     NDIST1 AND NDIST2 ARE THE X COORDINATE BOUNDARIES OF ONE          PLATE494
C     CAPACITOR BANK MODULE ON THE SIDE OF THE CROSSED TRANSMISSION     PLATE495
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C     PLATE.                                                            PLATE496
C     NDIST3 AND NDIST4 ARE THE X COORDINATE BOUNDARIES OF THE SECOND   PLATE497
C     MODULE ON THE SIDE OF THE TRANSMISSION PLATE.                     PLATE498
C                                                                       PLATE499
      NDIST1=(DIST1/DELX)+1                                             PLATE500
      NDIST2=(DIST2/DELX)+1                                             PLATE501
      NDIST3=(DIST3/DELX)+1                                             PLATE502
      NDIST4=(DIST4/DELX)+1                                             PLATE503
C                                                                       PLATE504
C     AL2 AND C2 ARE THE INDUCTANCE AND CAPACITANCE IN THE NORMAL PART  PLATE505
C     OF A TRANSMISSION PLATE.                                          PLATE506
C                                                                       PLATE507
      AL2=AMUO*DELY*DELZ/DELX                                           PLATE508
      C2=EPSI*DELX*DELY/DELZ                                            PLATE509
C                                                                       PLATE510
C     AL1 AND C1 ARE THE INDUCTANCE AND CAPACITANCE OF EACH CAPACITOR   PLATE511
C     AND SWITCH ASSEMBLY ASSUMING THE NUMBER OF CAPACITORS EQUALS THE  PLATE512
C     NUMBER OF X MESH POINTS WITHIN THE BOUNDARIES OF A CAPACITOR BANK PLATE513
C     MODULE.                                                           PLATE514
C                                                                       PLATE515
      NCAP=CLENGTH/DELY                                                 PLATE516
      IF (NCAP.EQ.0) NCAP=INCY                                          PLATE517
      IF (NCAP.GT.INCY) NCAP=INCY                                       PLATE518
      C1=CT/(NCAP-1.)                                                   PLATE519
      AL1=ALT*(NCAP-1.0)                                                PLATE520
C                                                                       PLATE521
C     AL4 AND C4 ARE THE INDUCTANCE AND CAPACITANCE IN THE LOAD WHERE   PLATE522
C     C4 IS SET ARBITRARILY LARGE.                                      PLATE523
C                                                                       PLATE524
      C4=C2*1000000.                                                    PLATE525
      C4=C2*100000000.                                                  PLATE526
      AL4=AL2                                                           PLATE527
C                                                                       PLATE528
C     DELT IS THE TIME STEP                                             PLATE529
C                                                                       PLATE530
      DELT=PI/20.*SQRT(C2*AL2)                                          PLATE531
      DELT=DELT*2.0                                                     PLATE532
      PRINT 6                                                           PLATE533
      PRINT 8, AINCX,AINCY,ANT,X,Y                                      PLATE534
      PRINT 9, VO,CT,ALT                                                PLATE535
C                                                                       PLATE536
C     X AND Y ARE THE DIMENSIONS OF THE TRANSMISSION PLATE (METERS).    PLATE537
C     DELZ IS THE THICKNESS OF THE MYLAR.                               PLATE538
C                                                                       PLATE539
      PRINT 11, C2,AL2                                                  PLATE540
      PRINT 12, C1,AL1                                                  PLATE541
      PRINT 13, C4,AL4                                                  PLATE542
      PRINT 10, DELT,DELX,DELY,DELZ,R1                                  PLATE543
      PRINT 6                                                           PLATE544
      CALL MESH (C1,C2,C3,C4,AL3,AL4,FACTOR,FACTOR1,FACTOR2)            PLATE545
      CALL LOAD(SETUP3)                                                 PLATE546
      CALL WEDGE (C1,C2,C3,C4,AL3,AL4,FACTOR,FACTOR1,FACTOR2)           PLATE547
      CALL FRAME                                                        PLATE548
      CALL PRINT1 (1)                                                   PLATE549
```

```
      CALL PRINT1 (2)                                                   PLATE550
      CALL PRINT1 (3)                                                   PLATE551
      PRINT 6                                                           PLATE552
   30 FORMAT(10X,*DIAGONAL CAPACITIVE ELEMENTS ARE*,/)                  PLATE553
      PRINT 30                                                          PLATE554
   31 FORMAT(10E10.2)                                                   PLATE555
      INCY0=INCY-1                                                      PLATE556
      DO 50 I=1,INCY0                                                   PLATE557
      CALL READEC(X1(I),CQ(I,I),1)                                      PLATE558
      CALL READEC(Y1(I),ALQQ(I,I),1)                                    PLATE559
   50 CONTINUE                                                          PLATE560
      PRINT  31, (X1(I),I=1,INCY0)                                      PLATE561
   32 FORMAT(10X,*DIAGONAL INDUCTIVE ELEMENTS ARE*,/)                   PLATE562
      PRINT 32                                                          PLATE563
      PRINT 31,(Y1(I),I=1,INCY0)                                        PLATE564
      RETURN                                                            PLATE565
C                                                                       PLATE566
C                                                                       PLATE567
1     FORMAT (8F10.2)                                                   PLATE568
2     FORMAT (10X,2P8E12.1,/,/)                                         PLATE569
3     FORMAT (10X,8HTEDIT = ,2PE12.1,10H  DELED = ,2PE12.1,11H  TEDIT2 =PLATE570
     1 ,2PE12.1,/,/)                                                    PLATE571
4     FORMAT (10X,9HNPOSX1 = ,I5,10H NPOSX2 = ,I5,/)                    PLATE572
5     FORMAT (1H1)                                                      PLATE573
6     FORMAT (1H0)                                                      PLATE574
7     FORMAT (8F10.2)                                                   PLATE575
8     FORMAT (1X,7HINCX = ,1PE14.6,8H INCY = ,E14.6,10H 6 INCR = ,E14.6,PLATE576
     125H  X,Y PLATE DIMENSIONS = ,E14.6,3H X ,E14.6,/)                 PLATE577
9     FORMAT (2X,45HCHARACTERISTICS OF ONE-HALF OF A MODULE ARE  ,1PE14.PLATE578
     16,9H VOLTS  ,E14.6,13H FARADS AND  ,E14.6,8H HENRIES,/)           PLATE579
10    FORMAT (3X,7HDELT = ,1PE14.6,8H DELX = ,E14.6,8H DELY = ,E14.6,8H PLATE580
     1DELZ = ,E14.6,24H FRACTIONAL HOLE SIZE = ,E14.6,/)                PLATE581
11    FORMAT (3X,55HCHARACTERISTICS OF THE TRANSMISSION PLATE ELEMENTS APLATE582
     1RE ,1PE14.6,9H FARADS  ,E14.6,9H HENRIES.,/)                      PLATE583
12    FORMAT (4X,72HCHARACTERISTICS OF EACH MESH POINT THAT SERVES AS A PLATE584
     1BREAKDOWN POINT ARE ,1PE14.6,9H FARADS  ,E14.6,9H HENRIES.,/)     PLATE585
13    FORMAT (5X,61HCHARACTERISTICS OF EACH MESH POINT THAT SERVES AS A PLATE586
     1SINK ARE ,1PE14.6,9H FARADS  ,E14.6,9H HENRIES.,/)                PLATE587
14    FORMAT (10X,5HR1 = ,1PE14.6,6H R2 = ,1PE14.6,7H RAD = ,1PE14.6,6H PLATE588
     1R3 = ,1PE14.6,/)                                                  PLATE589
15    FORMAT (10X,9HNSETUP = ,I3,11H NSETUP2 = ,I3,11H NSETUP3 = ,I3,/) PLATE590
16    FORMAT (10X,4HX = ,1PE14.6,5H Y = ,1PE14.6,10H FACTOR = ,1PE14.6,1PLATE591
     11H FACTOR2 = ,1PE14.6,6H ER = ,1PE14.6,/)                         PLATE592
17    FORMAT (5X,5HV0 = ,1PE14.6,6H CT = ,1PE14.6,7H ALT = ,1PE14.6,10HCPLATE593
     1LENGTH = ,1PE14.6,/)                                              PLATE594
18    FORMAT (5X,8HTSTOP = ,1PE14.6,7H ANT = ,1PE14.6,9H AINCX = ,1PE14.PLATE595
     16,9H AINCY = ,1PE14.6,/)                                          PLATE596
19    FORMAT (5X,8HDIST1 = ,1PE14.6,9H DIST2 = ,1PE14.6,9H DIST3 = ,1PE1PLATE597
     14.6,9H DIST4 = ,1PE14.6,9H DIST0 = ,1PE14.6,/)                    PLATE598
20    FORMAT (5X,7HAMU0 = ,1PE14.6,9H EPSI0 = ,1PE14.6,8H EPSI = ,1PE14.PLATE599
     16,/)                                                              PLATE600
21    FORMAT (10X,1P8E12.2,/)                                           PLATE601
22    FORMAT (10X,37H$$$$$   SYMMETRY TEST PROBLEM   $$$$$,/)           PLATE602
23    FORMAT (10X,38H$$$$$   P.P. TRANSMISSION LINE   $$$$$,/)          PLATE603
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```
24    FORMAT (10X,44HSSSSS   TWO SIDED TRANSMISSION PLATE   SSSSS,/)     PLATE604
25    FORMAT (10X,45HSSSSS   FOUR SIDED TRANSMISSION PLATE   SSSSS,/)    PLATE605
26    FORMAT (10X,35HSSSSS   CROSSED PLATE, 1 MJ   SSSSS,/)              PLATE606
      END                                                                PLATE607
```

```
      SUBROUTINE MESH(C1,C2,C3,C4,AL3,AL4,FACTOR,FACTOR1,FACTOR2)       PLATE608
                                                                        PLATE609
      COMMON X,    R1,   VO,  INCX, NDIST1,  DIST0,   RESIS,   AJV(26), PLATE610
     1       Y,    R2,   CT,  INCY, NDIST2,  INCX0,  KSENSW,   AJH(26), PLATE611
     2       K,    R3,  ALT, AINCX, NDIST3,  TSTOP,  NSETUP,     V(26), PLATE612
     3       T,    R4,   NT, AINCY, NDIST4,  TEDIT, NSETUP2,     C(26), PLATE613
     4      AK,   RAD,  ALN, INCX1,  DIST1,  DELED, NSETUP3,    V1(26), PLATE614
     5    DELT,   AL1,  ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,    AL(26), PLATE615
     6    KSEN,   AL2,  ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),  PLATE616
     7    NCAP, N100, NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),  PLATE617
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)            PLATE618
                                                                        PLATE619
      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),        PLATE620
     1  ALQQ(26,26)                                                     PLATE621
                                                                        PLATE622
      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ                                 PLATE623
                                                                        PLATE624
      COMMON /ECS1/ AJVQ                                                PLATE625
      COMMON /ECS2/ AJHQ                                                PLATE626
      COMMON /ECS3/ VQ                                                  PLATE627
      COMMON /ECS4/ CQ                                                  PLATE628
      COMMON /ECS5/ ALQQ                                                PLATE629
                                                                        PLATE630
C                                                                       PLATE631
C     THIS LOOP INITIALLIZES CAPACITANCE AND VOLTAGE THROUGHOUT THE     PLATE632
C     MESH.                                                             PLATE633
C                                                                       PLATE634
      ZERO=0.0                                                          PLATE635
      DO 1 J=1,INCY1                                                    PLATE636
      DO 1 I=1,INCX1                                                    PLATE637
      CALL WRITEC (C2,CQ(I,J),1)                                        PLATE638
      CALL WRITEC (ZERO,VQ(I,J),1)                                      PLATE639
      CALL WRITEC (ZERO,AJVQ(I,J),1)                                    PLATE640
      CALL WRITEC (ZERO,AJHQ(I,J),1)                                    PLATE641
      CALL WRITEC (AL2,ALQQ(I,J),1)                                     PLATE642
    1 CONTINUE                                                          PLATE643
      IF (NSETUP.EQ.2) GO TO 7                                          PLATE644
C                                                                       PLATE645
C     THIS SECTION SETS UP A TEST PROBLEM TO DETERMINE AZIMUTHAL        PLATE646
C     ASSYMMETRY WHEN NSETUP = 1.  THIS IS THE ASSYMMETRY WHICH IS      PLATE647
C     CAUSED BY THE SQUARE MESH.                                        PLATE648
C                                                                       PLATE649
      C2FAC=C2/FACTOR                                                   PLATE650
      ALFAC=AL2*FACTOR                                                  PLATE651
      IF (NSETUP.NE.1) GO TO 3                                          PLATE652
      DO 2 J=1,INCY1                                                    PLATE653
      DO 2 I=1,INCX1                                                    PLATE654
      AX=I*DELX                                                         PLATE655
      AY=J*DELY                                                         PLATE656
      RAD=SQRT(AX*AX+AY*AY)                                             PLATE657
      IF (RAD.GT.R3) CALL WRITEC (C1,CQ(I,J),1)                         PLATE658
      IF (RAD.GT.R3) CALL WRITEC (VO,VQ(I,J),1)                         PLATE659
      ALMMM=AL1/5.                                                      PLATE660
      CT10=CT*10.                                                       PLATE661
```

```
      IF(RAD.GT.R3-3.*DELY) CALL WRITEC(ALMMM,ALQQ(I,J),1)
      IF (RAD.LT.R2) CALL WRITEC (ALFAC,ALQQ(I,J),1)
      IF (RAD.LT.R2) CALL WRITEC (C2FAC,CQ(I,J),1)
      IF (RAD.LT.R1) CALL WRITEC (CT10,CQ(I,J),1)
      IF (RAD.LT.R1) CALL WRITEC (AL2,ALQQ(I,J),1)
    2 CONTINUE
      GO TO 10
    3 CONTINUE
      LN=INCY/2+1
C
C     THE LOOPS OVER INDEX 4 SET UP A REGION OF GREATER PLATE SEPARATION
C     JUST OUTSIDE THE HOLE IN THE CENTER WHICH REPRESENTS THE LOAD.
C     THE VARIABLE FACTOR IS THE RATIO OF THE NEW SEPARATION TO THE
C     OLD SEPARATION.
C
      DO 4 I=1,LN
      DO 4 J=1,LN
      AX=I*DELX
      AY=J*DELY
      RA=SQRT(AX*AX+AY*AY)
      CT10=CT*10.
      IF (RA.LT.R2) CALL WRITEC (C2FAC,CQ(I,J),1)
      IF (RA.LT.R2) CALL WRITEC (ALFAC,ALQQ(I,J),1)
      IF (RA.LT.R1) CALL WRITEC (C4,CQ(I,J),1)
      IF (RA.LT.R1) CALL WRITEC (ALFAC,ALQQ(I,J),1)
    4 CONTINUE
      I=INCX1
C
C     THE LOOP OVER 5 CHARGES THE CAPACITORS AT THE END OF THE
C     TRANSMISSION PLATE.
C
      DO 5 J=1,NCAP
      CALL WRITEC (C1,CQ(I,J),1)
      CALL WRITEC (VO,VQ(I,J),1)
      CALL WRITEC (AL1,ALQQ(I,J),1)
    5 CONTINUE
      IF (NSETUP.NE.5) GO TO 10
C
C     THE LOOP OVER 7 CHARGES THE TWO CAPACITOR BANK MODULES ON THE
C     SIDE OF THE TRANSMISSION PLATE.
C
      J=INCY1
      DO 6 I=1,INCX
      QDIST=I*DELX
      IF (QDIST.GE.DIST1.AND.QDIST.LE.DIST2) CALL WRITEC (C1,CQ(I,J),1)
      IF (QDIST.GE.DIST1.AND.QDIST.LE.DIST2) CALL WRITEC (VO,VQ(I,J),1)
      IF (QDIST.GE.DIST1.AND.QDIST.LE.DIST2) CALL WRITEC (AL1,ALQQ(I,J),
     11)
      IF (QDIST.GE.DIST3.AND.QDIST.LE.DIST4) CALL WRITEC (C1,CQ(I,J),1)
      IF (QDIST.GE.DIST3.AND.QDIST.LE.DIST4) CALL WRITEC (VO,VQ(I,J),1)
      IF (QDIST.GE.DIST3.AND.QDIST.LE.DIST4) CALL WRITEC (AL1,ALQQ(I,J),
     11)
    6 CONTINUE
      GO TO 10
```

```
C
C     WHEN NSETUP=2 THIS SETS UP A PARALLEL PLATE TRANSMISSION LINE
C     PROBLEM FOR COMPARISON TO AN ANALYTICAL SOLUTION.
C
 7    CONTINUE
      I=1
      DO 8 J=1,INCY1
      CALL WRITEC (C4,CQ(I,J),1)
 8    CONTINUE
      I=INCX1
      INQ=DIST1/DELY+1
      INQQ=DIST2/DELY+1
      NUM=INQQ-INQ+1
      C1=CT/NUM
      AL1=ALT*NUM
      DO 9 J=INQ,INQQ
      CALL WRITEC (C1,CQ(I,J),1)
      CALL WRITEC (VO,VQ(I,J),2)
 9    CONTINUE
 10   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE LOAD (SETUP3)                                          PLATE738
                                                                        PLATE739
      COMMON X,   R1,   VO,  INCX, NDIST1,  DISTO,   RESIS,   AJV(26),  PLATE740
     1       Y,   R2,   CT,  INCY, NDIST2,  INCX0,  KSENSW,   AJH(26),  PLATE741
     2       K,   R3,  ALT, AINCX, NDIST3,  TSTOP,  NSETUP,     V(26),  PLATE742
     3       T,   R4,   NT, AINCY, NDIST4,  TEDIT, NSETUP2,     C(26),  PLATE743
     4      AK,  RAD,  ALN, INCX1,  DIST1,  DELED, NSETUP3,    V1(26),  PLATE744
     5    DELT,  AL1,  ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,    AL(26),  PLATE745
     6    KSEN,  AL2,  ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),  PLATE746
     7    NCAP, N100, NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),  PLATE747
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)            PLATE748
                                                                        PLATE749
      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),        PLATE750
     1  ALQQ(26,26)                                                     PLATE751
                                                                        PLATE752
      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ                                 PLATE753
                                                                        PLATE754
      COMMON /ECS1/ AJVQ                                                PLATE755
      COMMON /ECS2/ AJHQ                                                PLATE756
      COMMON /ECS3/ VQ                                                  PLATE757
      COMMON /ECS4/ CQ                                                  PLATE758
      COMMON /ECS5/ ALQQ                                                PLATE759
                                                                        PLATE760
C                                                                       PLATE761
C     THIS SECTION INCREASES THE INDUCTANCE IN THE LOAD TO SIMULATE A   PLATE762
C     SHIVA LOAD INSTEAD OF A SHORT CIRCUIT.  (WHEN SETUP3.NE.0.0,      PLATE763
C     AL(I,J)=SETUP3.)                                                  PLATE764
C                                                                       PLATE765
      IF(SETUP3.EQ.0.0) GO TO 2                                         PLATE766
      NNN=AMIN1(AINCX,AINCY,55.)                                        PLATE767
      DO 1 I=1,NNN                                                      PLATE768
      DO 1 J=1,NNN                                                      PLATE769
      AX=I*DELX                                                         PLATE770
      AY=J*DELY                                                         PLATE771
      RA=SQRT(AX*AX+AY*AY)                                              PLATE772
      IF (RA.LT.R1+3.0*DELX) CALL WRITEC (SETUP3,ALQQ(I,J),1)           PLATE773
1     CONTINUE                                                          PLATE774
2     CONTINUE                                                          PLATE775
      RETURN                                                            PLATE776
      END                                                               PLATE777
```

```
      SUBROUTINE WEDGE (C1,C2,C3,C4,AL3,AL4,FACTOR,FACTOR1,FACTOR2)

      COMMON X,    R1,    VO,  INCX, NDIST1,  DISTO,   RESIS,    AJV(26),
     1       Y,    R2,    CT,  INCY, NDIST2,  INCXO,  KSENS4,    AJH(26),
     2       K,    R3,   ALT, AINCX, NDIST3,  TSTOP,  NSETUP,      V(26),
     3       T,    R4,    NT, AINCY, NDIST4,  TEDIT, NSETUP2,      C(26),
     4      AK,   RAD,   ALN, INCX1,  DIST1,  DELED, NSETUP3,     V1(26),
     5    DELT,   AL1,   ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,     AL(26),
     6    KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),
     7    NCAP,  N100,  NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)

      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),
     1  ALQQ(26,26)

      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ

      COMMON /ECS1/ AJVQ
      COMMON /ECS2/ AJHQ
      COMMON /ECS3/ VQ
      COMMON /ECS4/ CQ
      COMMON /ECS5/ ALQQ

      KK=1
      CALL SETUPX (1)
1     CONTINUE
      READ 6, M,N,K,L,NQ
      IF (K.EQ.0) GO TO 3
      IF(NQ.GT.0) FACTOR2=NQ
C
C     WHEN THIS SECTION IS USED CARE IS NECESSARY TO INSURE THAT KK
C     NEVER EXCEEDS THE DIMENSIONED SIZE OF X1 AND Y1 ARRAYS,
C     IF THAT DOES HAPPEN, SOME OF THE COMMON BLOCK WILL BE WIPED OUT.
C
      PRINT 5, M,N,K,L,NQ
      IF (L.EQ.0) L=INCX
      C2F2=C2/FACTOR2
      AL2F2=AL2*FACTOR2
      DO 2 I=K,L
      DO 2 J=M,N
      CALL WRITEC (C2F2,CQ(I,J),1)
      CALL WRITEC (AL2F2,ALQQ(I,J),1)
2     CONTINUE
      X1(KK)=K*DELX
      Y1(KK)=M*DELY
      X1(KK+1)=K*DELX
      Y1(KK+1)=N*DELY
      X1(KK+2)=L*DELX
      Y1(KK+2)=N*DELY
      X1(KK+3)=L*DELX
      Y1(KK+3)=M*DELX
      X1(KK+4)=X1(KK)
      Y1(KK+4)=Y1(KK)
      K=5
```

```
      CALL SETUPX(2)                                                    PLATE832
      GO TO 1                                                           PLATE833
    3 CONTINUE                                                          PLATE834
      RETURN                                                            PLATE835
C                                                                       PLATE836
C                                                                       PLATE837
    4 FORMAT (8F10.2)                                                   PLATE838
    5 FORMAT (2X,5I5)                                                   PLATE839
    6 FORMAT (6I2)                                                      PLATE840
      END                                                               PLATE841
```

```
      SUBROUTINE SETUPX (KLM)

      COMMON X,    R1,    VO,  INCX, NDIST1,  DISTO,   RESIS,    AJV(26),
     1       Y,    R2,    CT,  INCY, NDIST2,  INCXO,  KSENSW,    AJH(26),
     2       K,    R3,   ALT, AINCX, NDIST3,  TSTOP,  NSETUP,      V(26),
     3       T,    R4,    NT, AINCY, NDIST4,  TEDIT, NSETUP2,      C(26),
     4      AK,   RAD,   ALN, INCX1,  DIST1,  DELED, NSETUP3,     V1(26),
     5    DELT,   AL1,   ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,     AL(26),
     6    KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),
     7    NCAP, N100, NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)

      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),
     1  ALQQ(26,26)

      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ

      COMMON /ECS1/ AJVQ
      COMMON /ECS2/ AJHQ
      COMMON /ECS3/ VQ
      COMMON /ECS4/ CQ
      COMMON /ECS5/ ALQQ

      COMMON RADIUS(4)
      PI=3.14159265
      XMN=YMN=0.0
      XMX=YMX=AMAX1(X,Y)
      IF(KLM.EQ.1) GO TO 3
      CALL LINPLOT(X1,Y1,K,XMX,XMN,YMX,YMN)
      RETURN
    3 CONTINUE
      CALL GRIDQ (XMX,XMN,YMX,YMN,XMX,XMN,YMX,YMN,10,10,1,0,1HX,1,1HY,1)
      RADIUS(1)=R1
      RADIUS(2)=R2
      RADIUS(3)=R3
      RADIUS(4)=RAD
      N=50
      DO 2 I=1,4
      THETA=0.0
      IF (RADIUS(I).EQ.0.) GO TO 2
      DO 1 J=1,N
      X1(J)=X-RADIUS(I)*SIN(THETA)
      Y1(J)=Y-RADIUS(I)*COS(THETA)
      THETA=THETA+PI/(2.*N)
    1 CONTINUE
      CALL LINPLOT (X1,Y1,N,XMX,XMN,YMX,YMN)
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRINT1 (NEDIT)                                         PLATE891
                                                                        PLATE892
      COMMON X,    R1,    VO,  INCX, NDIST1,  DISTO,    RESIS,   AJV(26), PLATE893
     1       Y,    R2,    CT,  INCY, NDIST2,  INCX0,   KSENSW,   AJH(26), PLATE894
     2       K,    R3,   ALT, AINCX, NDIST3,  TSTOP,   NSETUP,     V(26), PLATE895
     3       T,    R4,    NT, AINCY, NDIST4,  TEDIT, NSETUP2,     C(26), PLATE896
     4      AK,   RAD,   ALN, INCX1,  DIST1,  DELED, NSETUP3,    V1(26), PLATE897
     5    DELT,   AL1,   ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,    AL(26), PLATE898
     6    KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),  PLATE899
     7    NCAP,  N100,  NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),  PLATE900
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)            PLATE901
                                                                        PLATE902
      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),        PLATE903
     1  ALQQ(26,26)                                                     PLATE904
                                                                        PLATE905
      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ                                 PLATE906
                                                                        PLATE907
      COMMON /ECS1/ AJVQ                                                PLATE908
      COMMON /ECS2/ AJHQ                                                PLATE909
      COMMON /ECS3/ VQ                                                  PLATE910
      COMMON /ECS4/ CQ                                                  PLATE911
      COMMON /ECS5/ ALQQ                                                PLATE912
                                                                        PLATE913
C                                                                       PLATE914
C     THIS SUBROUTINE PRINTS VARIOUS EDITED ARRAYS DEPENDING ON THE     PLATE915
C     CALLED VARIABLE NEDIT.                                            PLATE916
C     THIS SUBROUTINE MUST BE CALLED WITH NEDIT SET TO AN INTEGER 1     PLATE917
C     THROUGH 5.                                                        PLATE918
C     WHEN NEDIT =1 THE VOLTAGE ARRAY IS PRINTED.                       PLATE919
C     WHEN NEDIT =2 THE CAPACITANCE ARRAY IS PRINTED.                   PLATE920
C     WHEN NEDIT =3 THE INDUCTANCE ARRAY IS PRINTED.                    PLATE921
C     WHEN NEDIT =4 THE VERTICAL CURRENT ARRAY IS PRINTED.              PLATE922
C     WHEN NEDIT =5 THE HORIZONTAL CURRENT ARRAY IS PRINTED.            PLATE923
C                                                                       PLATE924
      PRINT 6                                                           PLATE925
      NY=(INCY+14)/15                                                   PLATE926
      IF (NEDIT.EQ.1) PRINT 13, INCX,INCY,INCX1,INCY1                   PLATE927
      IF (NEDIT.EQ.1) PRINT 8                                           PLATE928
      IF (NEDIT.EQ.2) PRINT 9                                           PLATE929
      IF (NEDIT.EQ.3) PRINT 10                                          PLATE930
      IF (NEDIT.EQ.4) PRINT 11                                          PLATE931
      IF (NEDIT.EQ.5) PRINT 12                                          PLATE932
      DO 2 I=1,INCX1,5                                                  PLATE933
      DO 1 J=1,INCY1                                                    PLATE934
      IF (NEDIT.EQ.1) CALL READEC (V1(J),VQ(I,J),1)                     PLATE935
      IF (NEDIT.EQ.2) CALL READEC (V1(J),CQ(I,J),1)                     PLATE936
      IF (NEDIT.EQ.3) CALL READEC (V1(J),ALQQ(I,J),1)                   PLATE937
      IF (NEDIT.EQ.4) CALL READEC (V1(J),AJVQ(I,J),1)                   PLATE938
      IF (NEDIT.EQ.5) CALL READEC (V1(J),AJHQ(I,J),1)                   PLATE939
1     CONTINUE                                                          PLATE940
      PRINT 7, (V1(J),J=1,INCY,NY),V1(INCY1)                            PLATE941
2     CONTINUE                                                          PLATE942
      I=INCX1                                                           PLATE943
      DO 3 J=1,INCY1                                                    PLATE944
```

```
      IF (NEDIT.EQ.1) CALL READEC (V1(J),VQ(I,J),1)                 PLATE945
      IF (NEDIT.EQ.2) CALL READEC (V1(J),CQ(I,J),1)                 PLATE946
      IF (NEDIT.EQ.3) CALL READEC (V1(J),ALQQ(I,J),1)               PLATE947
      IF (NEDIT.EQ.4) CALL READEC (V1(J),AJVQ(I,J),1)               PLATE948
      IF (NEDIT.EQ.5) CALL READEC (V1(J),AJHQ(I,J),1)               PLATE949
3     CONTINUE                                                      PLATE950
      PRINT 7, (V1(J),J=1,INCY,NY),V1(INCY1)                        PLATE951
      PRINT 5                                                       PLATE952
      NMINX=MIN0(16,INCY1,INCX1)                                    PLATE953
      DO 4 J=1,NMINX                                                PLATE954
      IF (NEDIT.EQ.1) CALL READEC (V1(1),VQ(1,J),NMINX)             PLATE955
      IF (NEDIT.EQ.2) CALL READEC (V1(1),CQ(1,J),NMINX)             PLATE956
      IF (NEDIT.EQ.3) CALL READEC (V1(1),ALQQ(1,J),NMINX)           PLATE957
      IF (NEDIT.EQ.4) CALL READEC (V1(1),AJVQ(1,J),NMINX)           PLATE958
      IF (NEDIT.EQ.5) CALL READEC (V1(1),AJHQ(1,J),NMINX)           PLATE959
      PRINT 7, (V1(I),I=1,NMINX)                                    PLATE960
4     CONTINUE                                                      PLATE961
      RETURN                                                        PLATE962
C                                                                   PLATE963
C                                                                   PLATE964
5     FORMAT (1X,/,10X,15HLOAD AREA ARRAY,/)                        PLATE965
6     FORMAT (1H1)                                                  PLATE966
7     FORMAT (1X,16E8.1)                                            PLATE967
8     FORMAT (10X,13HVOLTAGE ARRAY,/)                               PLATE968
9     FORMAT (10X,17HCAPACITANCE ARRAY,/)                           PLATE969
10    FORMAT (10X,16HINDUCTANCE ARRAY,/)                            PLATE970
11    FORMAT (10X,22HVERTICAL CURRENT ARRAY,/)                      PLATE971
12    FORMAT (10X,24HHORIZONTAL CURRENT ARRAY,/)                    PLATE972
13    FORMAT (2X,4I5)                                               PLATE973
      END                                                           PLATE974
```

```
      SUBROUTINE PRINT2                                                 PLATE975
                                                                        PLATE976
      COMMON X,    R1,   VO,  INCX, NDIST1,  DIST0,    RESIS,   AJV(26), PLATE977
     1       Y,    R2,   CT,  INCY, NDIST2,  INCX0,  KSENSW,    AJH(26), PLATE978
     2       K,    R3,  ALT, AINCX, NDIST3,  TSTOP,  NSETUP,      V(26), PLATE979
     3       T,    R4,   NT, AINCY, NDIST4,  TEDIT, NSETUP2,      C(26), PLATE980
     4      AK,   RAD,  ALN, INCX1,  DIST1,  DELED, NSETUP3,     V1(26), PLATE981
     5    DELT,   AL1,  ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,     AL(26), PLATE982
     6    KSEN,   AL2,  ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),  PLATE983
     7    NCAP, N100, NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),  PLATE984
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)             PLATE985
                                                                        PLATE986
      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),        PLATE987
     1  ALQQ(26,26)                                                     PLATE988
                                                                        PLATE989
      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ                                 PLATE990
                                                                        PLATE991
      COMMON /ECS1/ AJVQ                                                PLATE992
      COMMON /ECS2/ AJHQ                                                PLATE993
      COMMON /ECS3/ VQ                                                  PLATE994
      COMMON /ECS4/ CQ                                                  PLATE995
      COMMON /ECS5/ ALQQ                                                PLATE996
                                                                        PLATE997
C                                                                       PLATE998
C     THIS SUBROUTINE PRINTS SEVERLY EDITED VOLTAGE, HORIZONTAL CURRENT,PLATE999
C     AND VERTICAL CURRENT ARRAYS.                                      PLAT1000
C                                                                       PLAT1001
C     FORMAT STATEMENTS                                                 PLAT1002
C                                                                       PLAT1003
      NZ=(INCY+3)/9                                                     PLAT1004
      INNZ=INCY1-NZ-2                                                   PLAT1005
      NZ=MAX0(NZ,2)                                                     PLAT1006
      PRINT 7                                                           PLAT1007
      PRINT 8, T                                                        PLAT1008
      PRINT 9                                                           PLAT1009
      NN=0                                                              PLAT1010
      DO 1 I=1,INNZ,NZ                                                  PLAT1011
      NN=NN+1                                                           PLAT1012
      X1(NN)=I                                                          PLAT1013
1     CONTINUE                                                          PLAT1014
      NN=NN+1                                                           PLAT1015
      X1(NN)=INCX1                                                      PLAT1016
      PRINT 5, (X1(I),I=1,NN)                                           PLAT1017
      PRINT 6                                                           PLAT1018
      DO 2 J=1,10                                                       PLAT1019
      JJ=(J-1)*NZ+1                                                     PLAT1020
      IF (J.EQ.10) JJ=INCY1                                             PLAT1021
      CALL READEC (AJV(1),AJVQ(1,JJ),INCX1)                             PLAT1022
      PRINT 5, (AJV(I),I=1,INNZ,NZ),AJV(INCX1)                          PLAT1023
2     CONTINUE                                                          PLAT1024
      PRINT 6                                                           PLAT1025
      PRINT 10                                                          PLAT1026
      DO 3 J=1,10                                                       PLAT1027
      JJ=(J-1)*NZ+1                                                     PLAT1028
```

```
      IF (J.EQ.10) JJ=INCY1
      CALL READEC (AJH(1),AJHQ(1,JJ),INCX1)
      PRINT 5, (AJH(I),I=1,INNZ,NZ),AJH(INCX1)
    3 CONTINUE
      PRINT 6
      PRINT 11
      DO 4 J=1,10
      JJ=(J-1)*NZ+1
      IF (J.EQ.10) JJ=INCY1
      CALL READEC (V(1),VQ(1,JJ),INCX1)
      PRINT 5, (V(I),I=1,INNZ,NZ),V(INCX1)
    4 CONTINUE
      PRINT 6
      RETURN
C
C
    5 FORMAT (1X,1P11E12.2)
    6 FORMAT (1H0)
    7 FORMAT (1H1)
    8 FORMAT (10X,24HTIME AFTER INITIATION = ,1PE20.8,/)
    9 FORMAT (10X,30HPARTIAL VERTICAL CURRENT ARRAY,/)
   10 FORMAT (10X,32HPARTIAL HORIZONTAL CURRENT ARRAY,/)
   11 FORMAT (10X,21HPARTIAL VOLTAGE ARRAY,/)
      END
```

```
      SUBROUTINE INDUCT

      COMMON X,    R1,    VO,  INCX, NDIST1,  DIST0,    RESIS,    AJV(26),
     1      Y,    R2,    CT,  INCY, NDIST2,  INCX0,   KSENSW,    AJH(26),
     2      K,    R3,   ALT, AINCX, NDIST3,  TSTOP,   NSETUP,      V(26),
     3      T,    R4,    NT, AINCY, NDIST4,  TEDIT,  NSETUP2,      C(26),
     4     AK,   RAD,   ALN, INCX1,  DIST1,  DELED,  NSETUP3,     V1(26),
     5   DELT,   AL1,   ALQ, INCY1,  DIST2, TEDIT2,  NSETUP4,     AL(26),
     6   KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1,  NSETUP5, WA(26,26),
     7   NCAP,  N100,  NZAP,  DELY,  DIST4, NPOSX2,  III(10), WB(26,26),
     8  X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)

      DIMENSION  AJVG(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),
     1  ALQQ(26,26)

      LEVEL 3, AJVG, AJHQ, VQ, CQ, ALQQ

      COMMON /ECS1/ AJVQ
      COMMON /ECS2/ AJHQ
      COMMON /ECS3/ VQ
      COMMON /ECS4/ CQ
      COMMON /ECS5/ ALQQ

C
C     THIS SUBROUTINE SUMS THE VERTICAL CURRENT IN THE PLATE AT A
C     POSITION X=DIST0.
C
      IF(T.LE.0.5E-09) KSEN=0
      KSEN=KSEN+1
      KSENSW=KSENSW+1
      IF (KSENSW.EQ.1) PRINT 8
      IF (KSENSW.EQ.1) PRINT 9
      I=DIST0/DELX
      CUR1=0.0
      DO 1 J=1,INCY1
      CALL READEC (AJV(I),AJVQ(I,J),1)
      IF (J.EQ.1) AJV(I)=AJV(I)/2.0
      CUR1=CUR1+AJV(I)
1     CONTINUE
      IF (CUR1.LE.1.0E-99) GO TO 2
      ALL=VO*T/CUR1
2     CONTINUE
C
C     THIS SUBROUTINE SUMS AND PRINTS THE CURRENT COMING OUT OF THE
C     CAPACITOR BANKS.
C
      CUR=CURA=CURB=CURC=0.0
      IF (NSETUP.NE.5) GO TO 6
      I=INCX1
      DO 3 J=1,INCY
      CALL READEC (AJV(I),AJVQ(I,J),1)
      IF (J.EQ.1) AJV(I)=AJV(I)/2.0
      CURA=CURA+AJV(I)
3     CONTINUE
```

```
      NN=NDIST1                                                         PLAT1107
      NNN=NDIST2                                                        PLAT1108
      J=INCY1                                                           PLAT1109
      CALL READEC (AJH(1),AJHQ(1,J),INCX)                               PLAT1110
      DO 4 I=NN,NNN                                                     PLAT1111
      CURB=CURB+AJH(I)                                                  PLAT1112
4     CONTINUE                                                          PLAT1113
      NN=NDIST3                                                         PLAT1114
      NNN=NDIST4                                                        PLAT1115
      DO 5 I=NN,NNN                                                     PLAT1116
      CURC=CURC+AJH(I)                                                  PLAT1117
5     CONTINUE                                                          PLAT1118
6     CONTINUE                                                          PLAT1119
      CUR=CURA+CURB+CURC                                                PLAT1120
C                                                                       PLAT1121
C     THIS SUBROUTINE SUMS THE CHARGE ACROSS EACH CAPACITOR AND PRINTS  PLAT1122
C     OUT THE RESULT AS TOTAL CHARGE.  THIS ALLOWS CONSERVATION OF      PLAT1123
C     CHARGE TO BE CHECKED.                                             PLAT1124
C                                                                       PLAT1125
      CH=0.0                                                            PLAT1126
      DO 7 J=1,INCY1                                                    PLAT1127
      CALL READEC (V(1),VQ(1,J),INCX1)                                  PLAT1128
      CALL READEC (C(1),CQ(1,J),INCX1)                                  PLAT1129
      DO 7 I=1,INCX1                                                    PLAT1130
      IF (J.GT.I) GO TO 7                                               PLAT1131
      IF (J.EQ.1) V(I)=V(I)/2.0                                         PLAT1132
      CH=CH+V(I)*C(I)                                                   PLAT1133
7     CONTINUE                                                          PLAT1134
      PRINT 10, T,CUR1,CUR,CH,ALL,CURA,CURB,CURC                        PLAT1135
C                                                                       PLAT1136
C     THIS SECTION SAVES CURRENTS AND TIMES FOR A TIME DEPENDENT        PLAT1137
C     CURRENT TRACE TO BE PLOTTED BY SUBROUTINE CTRACE.                 PLAT1138
C                                                                       PLAT1139
      AT(KSEN)=T                                                        PLAT1140
      CTRAC(KSEN)=CUR1                                                  PLAT1141
      CALL INDUCT2 (CUR1)                                               PLAT1142
      RETURN                                                            PLAT1143
C                                                                       PLAT1144
C                                                                       PLAT1145
8     FORMAT (1H1)                                                      PLAT1146
9     FORMAT (10X,4HTIME,8X,4HCUR1,8X,4HCUR2,7X,6HCHARGE,6X,6HINDUCT,7X,PLAT1147
     14HCURA,8X,4HCURB,8X,4HCURC,/)                                     PLAT1148
10    FORMAT (5X,1P8E12.4)                                              PLAT1149
      END                                                               PLAT1150
```

```
      SUBROUTINE INDUCT2 (CUR1)

      COMMON X,    R1,    VO,  INCX, NDIST1,  DIST0,   RESIS,     AJV(26),
     1       Y,    R2,    CT,  INCY, NDIST2,  INCX0,  KSENSW,     AJH(26),
     2       K,    R3,   ALT, AINCX, NDIST3,  TSTOP,  NSETUP,       V(26),
     3       T,    R4,    NT, AINCY, NDIST4,  TEDIT, NSETUP2,       C(26),
     4      AK,   RAD,   ALN, INCX1,  DIST1,  DELED, NSETUP3,      V1(26),
     5    DELT,   AL1,   ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,      AL(26),
     6    KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),
     7    NCAP,  N100,  NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)

      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),
     1  ALQG(26,26)

      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ

      COMMON /ECS1/ AJVQ
      COMMON /ECS2/ AJHQ
      COMMON /ECS3/ VQ
      COMMON /ECS4/ CQ
      COMMON /ECS5/ ALQQ

      M10=M10+1
      M10=MOD(M10,10)
      IF (M10.NE.0) RETURN
      VOLT1=VOLT2
      TIM1=TIM2
      CU1=CU2
      CALL READEC (VOLT2,VQ(INCX1,4),1)
      TIM2=T
      CU2=CUR1
      IF (CU2.EQ.CU1) RETURN
      ALNEW=((VOLT1+VOLT2)/2)*(TIM2-TIM1)/(CU2-CU1)
      PRINT 1, ALNEW
      RETURN
C
1     FORMAT (10X,62HTHE AVERAGE INDUCTANCE SINCE THE LAST STATEMENT LIK
     1E THIS IS  ,E12.4,10H  HENRIES.,/)
      END
```

```
      SUBROUTINE CTRACE                                                 PLAT1191
                                                                        PLAT1192
      COMMON X,   R1,   VO,  INCX, NDIST1,  DIST0,   RESIS,    AJV(26), PLAT1193
     1       Y,   R2,   CT,  INCY, NDIST2,  INCX0,  KSENSW,    AJH(26), PLAT1194
     2       K,   R3,  ALT, AINCX, NDIST3,  TSTOP,  NSETUP,      V(26), PLAT1195
     3       T,   R4,   NT, AINCY, NDIST4,  TEDIT, NSETUP2,      C(26), PLAT1196
     4      AK,  RAD,  ALN, INCX1,  DIST1,  DELED, NSETUP3,     V1(26), PLAT1197
     5    DELT,  AL1,  ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,     AL(26), PLAT1198
     6    KSEN,  AL2,  ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),  PLAT1199
     7    NCAP, N100, NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),  PLAT1200
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)            PLAT1201
                                                                        PLAT1202
      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),        PLAT1203
     1  ALQQ(26,26)                                                     PLAT1204
                                                                        PLAT1205
      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ                                 PLAT1206
                                                                        PLAT1207
      COMMON /ECS1/ AJVQ                                                PLAT1208
      COMMON /ECS2/ AJHQ                                                PLAT1209
      COMMON /ECS3/ VQ                                                  PLAT1210
      COMMON /ECS4/ CQ                                                  PLAT1211
      COMMON /ECS5/ ALQQ                                                PLAT1212
                                                                        PLAT1213
      XMN=XMX=YMN=YMX=0.0                                               PLAT1214
      IF(KSEN.LT.3) RETURN                                              PLAT1215
      DO 1 K=1,KSEN                                                     PLAT1216
      XMN=AMIN1(XMN,AT(K))                                              PLAT1217
      YMN=AMIN1(YMN,CTRAC(K))                                           PLAT1218
      XMX=AMAX1(XMX,AT(K))                                              PLAT1219
      YMX=AMAX1(YMX,CTRAC(K))                                           PLAT1220
    1 CONTINUE                                                          PLAT1221
      CALL GRIDQ (XMX,XMN,YMX,YMN,XMX,XMN,YMX,YMN,10,10,1,0,4HTIME,4,7HCPLAT1222
     1URRENT,7)                                                         PLAT1223
      CALL LINPLOT (AT,CTRAC,KSEN,XMX,XMN,YMX,YMN)                      PLAT1224
      CALL LINPLOT(AT,CTRAC,KSEN,XMX,XMN,YMX,YMN)                       PLAT1225
      CALL FRAME                                                        PLAT1226
      RETURN                                                            PLAT1227
      END                                                               PLAT1228
```

```
      SUBROUTINE CTRAC2

      COMMON X,    R1,   VO,  INCX, NDIST1,  DIST0,   RESIS,    AJV(26),
     1       Y,    R2,   CT,  INCY, NDIST2,  INCX0,  KSENSW,    AJH(26),
     2       K,    R3,  ALT, AINCX, NDIST3,  TSTOP,  NSETUP,      V(26),
     3       T,    R4,   NT, AINCY, NDIST4,  TEDIT, NSETUP2,      C(26),
     4      AK,   RAD,  ALN, INCX1,  DIST1,  DELED, NSETUP3,     V1(26),
     5    DELT,   AL1,  ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,     AL(26),
     6    KSEN,   AL2,  ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),
     7    NCAP, N100, NZAP,   DELY,  DIST4, NPOSX2, III(10), WB(26,26),
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)

      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),
     1  ALQQ(26,26)

      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ

      COMMON /ECS1/ AJVQ
      COMMON /ECS2/ AJHQ
      COMMON /ECS3/ VQ
      COMMON /ECS4/ CQ
      COMMON /ECS5/ ALQQ

      XMX=XMN=YMN=YMX=0.0
      IF(N100.LT.3) RETURN
      DO 1 K=1,N100
      XMN=AMIN1(XMN,AT(K))
      YMN=AMIN1(YMN,CTR1(K))
      XMX=AMAX1(XMX,AT(K))
      YMX=AMAX1(YMX,CTR1(K))
    1 CONTINUE
      YMX=1.5*YMX
      CALL GRIDQ (XMX,XMN,YMX,YMN,XMX,XMN,YMX,YMN,10,10,1,0,4HTIME,4,7HC
     1URMOD1,7)
      CALL LINPLOT (AT,CTR1,N100,XMX,XMN,YMX,YMN)
      CALL LINPLOT(AT,CTR1,N100 ,XMX,XMN,YMX,YMN)
      CALL FRAME
      CALL GRIDQ (XMX,XMN,YMX,YMN,XMX,XMN,YMX,YMN,10,10,1,0,4HTIME,4,7HC
     1URMOD2,7)
      CALL LINPLOT (AT,CTR2,N100,XMX,XMN,YMX,YMN)
      CALL LINPLOT(AT,CTR2,N100 ,XMX,XMN,YMX,YMN)
      CALL FRAME
      RETURN
      END
```

```
      SUBROUTINE CURRENT                                                PLAT1273
      DIMENSION LABEL(2), XTRALB(2)                                     PLAT1274
                                                                        PLAT1275
      COMMON X,    R1,    VO,  INCX, NDIST1,  DISTO,   RESIS,   AJV(26), PLAT1276
     1       Y,    R2,    CT,  INCY, NDIST2,  INCX0,  KSENS*,   AJH(26), PLAT1277
     2       K,    R3,   ALT, AINCX, NDIST3,  TSTOP,  NSETUP,     V(26), PLAT1278
     3       T,    R4,    NT, AINCY, NDIST4,  TEDIT, NSETUP2,     C(26), PLAT1279
     4      AK,   RAD,   ALN, INCX1,  DIST1,  DELED, NSETUP3,    V1(26), PLAT1280
     5    DELT,   AL1,   ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,    AL(26), PLAT1281
     6    KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),  PLAT1282
     7    NCAP,  N100,  NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),  PLAT1283
     8   X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)            PLAT1284
                                                                        PLAT1285
      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),        PLAT1286
     1  ALQQ(26,26)                                                     PLAT1287
                                                                        PLAT1288
      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ                                 PLAT1289
                                                                        PLAT1290
      COMMON /ECS1/ AJVQ                                                PLAT1291
      COMMON /ECS2/ AJHQ                                                PLAT1292
      COMMON /ECS3/ VQ                                                  PLAT1293
      COMMON /ECS4/ CQ                                                  PLAT1294
      COMMON /ECS5/ ALQQ                                                PLAT1295
                                                                        PLAT1296
      COMMON AX(1000),AY(1000)                                          PLAT1297
C                                                                       PLAT1298
C     THIS SUBROUTINE FOLLOWS SEVERAL CURRENT PATHS IN THE TRANSMISSION PLAT1299
C     FOR A SPECIFIC TIME THEN PLOTS THESE PATHS ON MICROFILM.          PLAT1300
C                                                                       PLAT1301
      XMN=YMN=0.0                                                       PLAT1302
      YMX=XMX=AMAX1(X,Y)                                                PLAT1303
      IF (NSETUP.EQ.5) YMX=XMX=1.5*Y                                    PLAT1304
      LABEL(1)=5HTIME=                                                  PLAT1305
      LABEL(2)=4H SEC                                                   PLAT1306
      ENCODE (20,7,XTRALB) LABEL(1),T,LABEL(2)                          PLAT1307
      NKT=2                                                             PLAT1308
      PI2=3.1415926535/2.0                                              PLAT1309
      IF (NSETUP.NE.5) NKT=1                                            PLAT1310
      DO 6 MMM=1,NKT                                                    PLAT1311
      IF (MMM.EQ.2) XMX=YMX=X                                           PLAT1312
      AINCR=(XMX+YMX)/1000.                                             PLAT1313
      CALL GRIDQ (XMX,XMN,YMX,YMN,XMX,XMN,YMX,YMN,10,10,1,1,1HX,1,1HY,1,PLAT1314
     1XTRALB,20)                                                        PLAT1315
      MNK=21                                                            PLAT1316
      IF(NSETUP.EQ.1) MNK=INCY1                                         PLAT1317
      DO 5 L=1,MNK                                                      PLAT1318
      FIX=MNK-1.                                                        PLAT1319
      AX(1)=XMX                                                         PLAT1320
      AY(1)=(L-1)*Y/FIX                                                 PLAT1321
      IF (NSETUP.NE.5) GO TO 1                                          PLAT1322
      LL=(L+1)/2                                                        PLAT1323
      LQ=L/2                                                            PLAT1324
      IF (MMM.EQ.1.OR.LQ.LT.LL) GO TO 1                                 PLAT1325
      AY(1)=Y                                                           PLAT1326
```

```
      AX(1)=((L-1)/FIX)*X
1     CONTINUE
      IF (NSETUP.NE.1) GO TO 2
      THET=(L-1)*PI2/FIX
      AX(1)=0.85*X*COS(THET)
      AY(1)=0.85*Y*SIN(THET)
2     CONTINUE
      DO 3 K=1,999
      I=(AX(K)/X)*(AINCX-1.)+2.
      J=(AY(K)/Y)*(AINCY-1.)+2.
      X3=(I-2)*DELX
      X2=(I-1)*DELX
      Y3=(J-2)*DELY
      Y2=(J-1)*DELY
      CALL READEC (AJH(I-1),AJHQ(I-1,J),2)
      CALL READEC (AJV(2),AJVQ(I,J),1)
      CALL READEC (AJV(1),AJVQ(I,J-1),1)
      CURH=AJH(I)*(X2-AX(K))/DELX+AJH(I-1)*(AX(K)-X3)/DELX
      CURV=AJV(2)*(Y2-AY(K))/DELY+AJV(1)*(AY(K)-Y3)/DELY
      CUR=SQRT(CURH*CURH+CURV*CURV)
      IF (CUR.LE.1.0) GO TO 4
      AX(K+1)=AX(K)-AINCR*CURV/CUR
      AY(K+1)=AY(K)-AINCR*CURH/CUR
      N=K
      IF (AX(K+1).LT.0.0.OR.AX(K+1).GT.XMX.OR.AY(K+1).LT.0.0.OR.AY(K+1).
     1GT.YMX) GO TO 4
3     CONTINUE
4     CONTINUE
      CALL LINPLOT (AX,AY,N,XMX,XMN,YMX,YMN)
      CALL LINPLOT(AX,AY,N,XMX,XMN,YMX,YMN)
5     CONTINUE
      CALL FRAME
6     CONTINUE
      RETURN
C
C
7     FORMAT (A5,1PE11.2,A4)
      END
```

```
      SUBROUTINE UNWIND

      COMMON X,    R1,    VO,  INCX, NDIST1,  DISTO,    RESIS,    AJV(26),
     1      Y,    R2,    CT,  INCY, NDIST2,  INCX0,  KSENS*,    AJH(26),
     2      K,    R3,   ALT, AINCX, NDIST3,  TSTOP,  NSETUP,      V(26),
     3      T,    R4,    NT, AINCY, NDIST4,  TEDIT, NSETUP2,      C(26),
     4     AK,   RAD,   ALN, INCX1,  DIST1,  DELED, NSETUP3,     V1(26),
     5   DELT,   AL1,   ALQ, INCY1,  DIST2, TEDIT2, NSETUP4,     AL(26),
     6   KSEN,   AL2,   ANU,  DELX,  DIST3, NPOSX1, NSETUP5, WA(26,26),
     7   NCAP,  N100,  NZAP,  DELY,  DIST4, NPOSX2, III(10), WB(26,26),
     8  X1(100), Y1(100), AT(1), CTRAC(1), CTR1(1), CTR2(1)

      DIMENSION  AJVQ(26,26), AJHQ(26,26), VQ(26,26), CQ(26,26),
     1  ALQQ(26,26)

      LEVEL 3, AJVQ, AJHQ, VQ, CQ, ALQQ

      COMMON /ECS1/ AJVQ
      COMMON /ECS2/ AJHQ
      COMMON /ECS3/ VQ
      COMMON /ECS4/ CQ
      COMMON /ECS5/ ALQQ

      COMMON DELPHI(500), CUR(500), THETA(501), CURAV(500)
      DIMENSION DELPHIA(500)
C
C     THIS SUBROUTINE COMPUTES THE RELATIVE CURRENT DENSITY CROSSING
C     AN ARC OUTSIDE THE LOAD AND IT PLOTS CURRENT VERSUS THETA
C     (IN RADIANS).  IT THEN PLOTS PHI VERSUS THETA, WHERE PHI IS THE
C     ANGLE BETWEEN THE CURRENT VECTOR AND THE NEGATIVE RADIUS VECTOR.
C
      EQUIVALENCE (CURAV(1),DELPHIA(1))
      PI2=3.1415926535/2.0
      THETA(1)=0.0
      N=500
      AN=N
      XMX=PI2
      XMN=0.
      ZMX=.50
      ZMN=-ZMX
      DO 10 LM=1,20
      RAZ=R1+0.02*LM*Y
      DO 3 K=1,N
      AY=RAZ*SIN(THETA(K))
      AX=RAZ*COS(THETA(K))
      IF (NSETUP.NE.2) GO TO 1
      AY=THETA(K)
      AX=RAZ
    1 CONTINUE
      I=(AX/X)*(AINCX-1.)+2.
      J=(AY/Y)*(AINCY-1.)+2.
      X0=(I-2)*DELX
      X2=(I-1)*DELX
      Y0=(J-2)*DELY
```

```
      Y2=(J-1)*DELY
      CALL READEC (AJH(I-1),AJHQ(I-1,J),2)
      CALL READEC (AJV(2),AJVQ(I,J),1)
      CALL READEC (AJV(1),AJVQ(I,J-1),1)
      CURH=AJH(I)*(X2-AX)/DELX+AJH(I-1)*(AX-X0)/DELX
      CURV=AJV(2)*(Y2-AY)/DELY+AJV(1)*(AY-Y0)/DELY
      CUR(K)=SQRT(CURH*CURH+CURV*CURV)
      IF (CUR(K).LE.0.) PHI=0.
      IF (CUR(K).LE.0.) GO TO 2
      PHI=ACOS(CURV/CUR(K))
2     CONTINUE
      DELPHI(K)=PHI-THETA(K)
      IF (K.EQ.1) YMN=YMX=CUR(K)
      YMN=AMIN1(YMN,CUR(K))
      YMN=0.0
      YMX=AMAX1(YMX,CUR(K))
      THETA(K+1)=THETA(K)+PI2/AN
      IF (NSETUP.EQ.2) THETA(K+1)=K*Y/AN
3     CONTINUE
      IF (LM.NE.2) GO TO 4
      CALL GRIDQ (XMX,XMN,YMX,YMN,XMX,XMN,YMX,YMN,10,10,1,0,5HTHETA,5,7H
     1CURRENT,7)
      CALL LINPLOT (THETA,CUR,N,XMX,XMN,YMX,YMN)
      CALL LINPLOT(THETA,CUR,N,XMX,XMN,YMX,YMN)
      CALL FRAME
4     CONTINUE
      CUR(1)=CUR(2)
      NN=51
      DO 6 K=1,N
      LL=K-1-NN/2
      IF (LL.LT.0) CURAV(K)=CUR(-LL)
      IF (LL.EQ.0) CURAV(K)=CUR(1)
      IF (LL.GT.0) CURAV(K)=CUR(LL)
      DO 5 I=2,NN
      KK=I+K-2-NN/2
      KKK=-KK
      IF (KK.LT.0) CURSE=CUR(KKK)
      IF (KK.EQ.0) CURSE=CUR(1)
      IF (KK.GT.500) CURSE=CUR(2*N-KK)
      IF (KK.GE.1.AND.KK.LE.500) CURSE=CUR(KK)
5     CURAV(K)=CURAV(K)+CURSE
6     CURAV(K)=CURAV(K)/NN
      CURMX=CURMN=CURAV(1)
      CURX=CURN=CUR(10)
      DO 7 K=2,N
      CURMX=AMAX1(CURAV(K),CURMX)
      CURMN=AMIN1(CURAV(K),CURMN)
      CURX=AMAX1(CUR(K),CURX)
      CUPN=AMIN1(CUR(K),CURN)
7     CONTINUE
      DEVIATE=(CURMX-CURMN)*200./(CURMX+CURMN)
      DEV2=(CURX-CURN)*200./(CURX+CURN)
      PRINT 11, R1,R2,RAZ
      PRINT 12, DEVIATE,DEV2
```

```
      IF (LM.NE.2) GO TO 10                                             PLAT1473
      CALL GRIDQ (XMX,XMN,YMX,YMN,XMX,XMN,YMX,YMN,10,10,1,0,5HTHETA,5,5HPLAT1474
     1CURAV,5)                                                          PLAT1475
      CALL LINPLOT (THETA,CURAV,N,XMX,XMN,YMX,YMN)                      PLAT1476
      CALL LINPLOT(THETA,CURAV,N,XMX,XMN,YMX,YMN)                       PLAT1477
      CALL FRAME                                                        PLAT1478
      NN=50                                                             PLAT1479
      M=N-NN                                                            PLAT1480
      DO 9 K=1,M                                                        PLAT1481
      DELPHIA(K)=DELPHI(K)                                              PLAT1482
      DO 8 I=2,NN                                                       PLAT1483
8     DELPHIA(K)=DELPHIA(K)+DELPHI(K+I-1)                               PLAT1484
9     DELPHIA(K)=DELPHIA(K)/NN                                          PLAT1485
      CALL GRIDQ (XMX,XMN,ZMX,ZMN,XMX,XMN,ZMX,ZMN,10,10,1,0,5HTHETA,5,7HPLAT1486
     1DELPHIA,7)                                                        PLAT1487
      CALL LINPLOT (THETA,DELPHIA,M,XMX,XMN,ZMX,ZMN)                    PLAT1488
      CALL LINPLOT(THETA,DELPHIA,M,XMX,XMN,ZMX,ZMN)                     PLAT1489
      CALL FRAME                                                        PLAT1490
      CALL GRIDQ (XMX,XMN,ZMX,ZMN,XMX,XMN,ZMX,ZMN,10,10,1,0,5HTHETA,5,6HPLAT1491
     1DELPHI,6)                                                         PLAT1492
      CALL LINPLOT (THETA,DELPHI,N,XMX,XMN,ZMX,ZMN)                     PLAT1493
      CALL LINPLOT(THETA,DELPHI ,M,XMX,XMN,ZMX,ZMN)                     PLAT1494
      CALL FRAME                                                        PLAT1495
10    CONTINUE                                                          PLAT1496
      RETURN                                                            PLAT1497
C                                                                       PLAT1498
C                                                                       PLAT1499
11    FORMAT (10X,5HR1 = ,E10.3,7H  R2 = ,E10.3,8H  RAD = ,E10.3)       PLAT1500
12    FORMAT (10X,37HPERCENT THETA VARIATION OF CURRENT = ,F10.2,9H  DEVPLAT1501
     12 = ,F10.2,//)                                                    PLAT1502
      END                                                               PLAT1503
```

```
      SUBROUTINE LINPLOT (A,B,N,AMAX,AMIN,BMAX,BMIN)                    PLAT1504
      DIMENSION A(1), B(1)                                              PLAT1505
C                                                                       PLAT1506
C     THIS SUBROUTINE PLOTS DATA ON MICROFILM.                          PLAT1507
C                                                                       PLAT1508
      CALL SMAPX (AMIN,AMAX,0.079,0.979)                                PLAT1509
      CALL SMAPY (BMIN,BMAX,0.079,0.979)                                PLAT1510
      CALL SVTRS (A,B,N)                                                PLAT1511
      RETURN                                                            PLAT1512
      END                                                               PLAT1513
```

APPENDIX F

SAMPLE OUTPUT

The input for the second example in Section IV produced the printed output that is listed on the following pages. When variable names are used, they correspond to the same variables in the code. The definitions of most of these variables can be found in the list of variables in Appendix A.

```
$$$$$   TWO SIDED TRANSMISSION PLATE   $$$$$
    1.40E-01   1.40E-01   1.80E-01   0.         2.80E+00   3.00E+00   0.         0.
    6.00E-01   6.00E-01   1.00E+05   5.55E-06   2.40E-08   1.60E-01   1.00E-01   1.00E-01
    6.00E-07   0.         5.50E-01   0.         0.         0.         0.
     0.         0.         0.
TEDIT =      40.E-09  DELED =      20.E-09  TEDIT2 =      10.E-09

R1 =   1.400000E-01 R2 =   1.400000E-01 RAD =   1.000000E-01 R3 =   0.
NSETUP =   3 NSETUP2 =   6 NSETUP3 =   0
X =   6.000000E-01 Y =   6.000000E-01 FACTOR =   1.090000E-01 FACTOR2 =   1.000000E-01 ER =   2.800000E+00
VO =   1.000000E+05 CI =   5.550000E-06 ALT =   2.400000E-08CLENGTH =   1.600000E-01
TSTOP =   6.000000E-07 ANT =   1.000000E+04 AINCX =   6.000000E+01 AINCY =   6.000000E+01
DIST1 =   0.            DIST2 =   0.            DIST3 =   0.            DIST4 =   0.            DISTO =   5.500000E-01
AMUO =   1.256637E-06 EPSIO =   8.854333E-12 EPSI =   2.479213E-11
NPOSX1 =      0 NPOSX2 =      6

INCX =   6.000000E+01 INCY =   6.000000E+01 & INCR =   1.000000E+04  X,Y PLATE DIMENSIONS =   6.000000E-01 X   6.000000E-01
 CHARACTERISTICS OF ONE-HALF OF A MODULE ARE     1.000000E+05 VOLTS     5.550000E-06 FARADS AND     2.400000E-08 HENRIES
  CHARACTERISTICS OF THE TRANSMISSION PLATE ELEMENTS ARE   1.709311E-12 FARADS     1.884956E-09 HENRIES.
   CHARACTERISTICS OF EACH MESH POINT THAT SERVES AS A BREAKDOWN POINT ARE   3.964286E-07 FARADS     3.360000E-07 HENRIES.
    CHARACTERISTICS OF EACH MESH POINT THAT SERVES AS A SINK ARE   1.709311E-04 FARADS     1.884956E-09 HENRIES.
  DELT =   1.783245E-11 DELX =   1.016949E-02 DELY =   1.016949E-02 DELZ =   1.500000E-03 FRACTIONAL HOLE SIZE =   1.400000E-01


  1   21   36   36   0
  1   20   37   37   0
  1   19   38   38   0
  1   18   39   39   0
  1   17   40   40   0
  1   16   41   41   0
  1   15   42   42   0
  1   14   43   43   0
  1   13   44   44   0
  1   12   45   45   0
  1   11   46   46   0
  1   10   47   47   0
  1    9   48   48   0
  1    8   49   49   0
  1    7   50   50   0
  1    6   51   51   0
  1    5   52   52   0
  1    4   53   53   0
  1    3   54   54   0
```

1 2 55 56 4
1 1 57 60 7

```
  60   69   61   61
          VOLTAGE ARRAY

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.       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.       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.       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.
 .1E+06   .1E+06   .1E+06   .1E+06  0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
 .1E+06   .1E+06   .1E+06   .1E+06  0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.       0.

          LOAD AREA ARRAY

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.       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.       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.       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.
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.
```

```
CAPACITANCE ARRAY

.2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-10  .2E-10  .2E-10  .2E-10  .2E-10  .2E-10  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-10  .2E-10  .2E-10  .2E-10  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-10  .2E-10  .2E-10  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-10  .2E-10  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-10  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.4E-06  .4E-06  .4E-06  .4E-06  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.4E-06  .4E-06  .4E-06  .4E-06  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11

LOAD AREA ARRAY

.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-03  .2E-03  .2E-03  .2E-03  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
.2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11  .2E-11
```

```
INDUCTANCE ARRAY

.2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-08  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.3E-06  .3E-06  .3E-06  .3E-06  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.3E-06  .3E-06  .3E-06  .3E-06  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08

LOAD AREA ARRAY

.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-09  .2E-09  .2E-09  .2E-09  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08
.2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08  .2E-08

DIAGONAL CAPACITIVE ELEMENTS ARE

.17E-03   .17E-03   .17E-03   .17E-03   .17E-03   .17E-03   .17E-03   .17E-03   .17E-03   .17E-11
.17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11
.17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11
.17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11
.17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11
.17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11   .17E-11
  DIAGONAL INDUCTIVE ELEMENTS ARE

.19E-09   .19E-09   .19E-09   .19E-09   .19E-09   .19E-09   .19E-09   .19E-09   .19E-09   .19E-08
.19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08
.19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08
.19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08
.19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08
.19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08   .19E-08
```

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TIME AFTER INITIATION =        4.00160150E-08

PARTIAL VERTICAL CURRENT ARRAY

 1.00E+00    8.00E+00    1.50E+01    2.20E+01    2.90E+01    3.60E+01    4.30E+01    5.00E+01    6.10E+01


-1.70E-30    8.25E-15    8.91E+03    6.69E+03    5.95E+03    5.96E+03    9.16E+03    1.49E+04    1.08E+04
-9.69E-17    8.24E-07    6.93E+03    6.00E+03    5.60E+03    5.68E+03    8.36E+03    3.79E+03    1.06E+04
-1.82E+02    2.90E+03    4.31E+03    4.66E+03    4.74E+03    5.08E+03    1.35E+03    2.86E+03    1.07E+04
-1.29E+02    1.58E+03    2.72E+03    3.26E+03    3.48E+03    1.82E+03    1.33E+03    1.67E+03    0.
-7.84E+01    9.70E+02    1.77E+03    2.21E+03    2.27E+03    1.81E+03    1.32E+03    1.05E+03    0.
-5.10E+01    6.38E+02    1.18E+03    1.51E+03    1.57E+03    1.39E+03    1.04E+03    7.50E+02    0.
-3.55E+01    4.44E+02    8.33E+02    1.08E+03    1.16E+03    1.07E+03    8.69E+02    5.75E+02    0.
-2.67E+01    3.36E+02    6.41E+02    8.42E+02    9.15E+02    8.65E+02    7.08E+02    4.73E+02    0.
-2.23E+01    2.88E+02    5.55E+02    7.34E+02    8.01E+02    7.65E+02    6.28E+02    4.24E+02    0.
 0.          0.          0.          0.          0.          0.          0.          0.          0.

PARTIAL HORIZONTAL CURRENT ARRAY

-7.30E-39   -1.15E-16   -1.95E+02   -8.82E+01   -1.68E+01    2.08E+02    2.95E+02    7.45E+02    0.
 4.93E-15    8.14E-07    2.80E+03    9.84E+02    1.79E+02   -2.66E+03   -3.51E+03    2.01E+03    0.
 6.44E+03    5.31E+03    3.03E+03    1.30E+03    1.23E+02   -5.44E+03    3.30E+01   -6.40E+02    0.
 4.00E+03    3.49E+03    2.34E+03    1.08E+03   -2.33E+02   -2.95E+03   -1.03E+03   -1.55E+03    0.
 2.53E+03    2.28E+03    1.63E+03    7.85E+02   -1.47E+02   -8.95E+02   -1.07E+03   -1.38E+03    0.
 1.62E+03    1.48E+03    1.09E+03    5.59E+02   -6.11E+00   -4.68E+02   -7.62E+02   -9.98E+02    0.
 9.97E+02    9.15E+02    6.91E+02    3.75E+02    3.75E+01   -2.64E+02   -4.96E+02   -6.61E+02    0.
 5.46E+02    4.99E+02    3.83E+02    2.20E+02    3.56E+01   -1.37E+02   -2.77E+02   -3.75E+02    0.
 1.84E+02    1.71E+02    1.30E+02    7.53E+01    1.40E+01   -4.64E+01   -9.66E+01   -1.33E+02    0.
 0.          0.          0.          0.          0.          0.          0.          0.          0.

PARTIAL VOLTAGE ARRAY

 4.03E-43    5.60E-16    1.90E+02    9.22E+02    2.30E+03    3.72E+03    4.08E+03    4.36E+03    9.95E+04
 3.43E-16    4.08E-08    6.73E+01    8.83E+02    2.38E+03    3.65E+03    3.94E+03    4.38E+03    9.95E+04
 7.85E+02    3.48E+02    3.53E+02    9.23E+02    2.21E+03    3.41E+03    3.65E+03    3.87E+03    9.95E+04
 9.30E+02    8.23E+02    6.99E+02    9.60E+02    1.67E+03    2.76E+03    2.94E+03    3.13E+03    0.
 1.18E+03    9.51E+02    8.49E+02    8.32E+02    1.12E+03    1.66E+03    2.01E+03    2.44E+03    0.
 8.44E+02    7.89E+02    6.98E+02    6.44E+02    7.99E+02    1.20E+03    1.57E+03    1.75E+03    0.
 1.72E+02    2.38E+02    3.46E+02    3.77E+02    5.91E+02    1.16E+03    1.37E+03    1.33E+03    0.
-3.91E+02   -4.07E+02   -1.02E+02    2.07E+02    6.15E+02    7.41E+02    8.43E+02    8.32E+02    0.
-1.10E+03   -8.87E+02   -6.37E+02    2.91E+01    5.57E+02    7.53E+02    7.15E+02    3.36E+02    0.
 0.          0.          0.          0.          0.          0.          0.          0.          0.

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .152E+00
     PERCENT THETA VARIATION OF CURRENT =      33.79  DEV2 =       39.34

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .164E+00
     PERCENT THETA VARIATION OF CURRENT =      39.90  DEV2 =       42.52

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .176E+00
     PERCENT THETA VARIATION OF CURRENT =      40.50  DEV2 =       45.00

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .188E+00
     PERCENT THETA VARIATION OF CURRENT =      43.82  DEV2 =       46.60
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RI =   .140E+00  R2 =   .140E+00  RAD =    .200E+00
PERCENT THETA VARIATION OF CURRENT =      47.41  DEV2 =       50.24

RI =   .140E+00  R2 =   .140E+00  RAD =    .212E+00
PERCENT THETA VARIATION OF CURRENT =      51.09  DEV2 =       53.15

RI =   .140E+00  R2 =   .140E+00  RAD =    .224E+00
PERCENT THETA VARIATION OF CURRENT =      56.40  DEV2 =       60.59

RI =   .140E+00  R2 =   .140E+00  RAD =    .236E+00
PERCENT THETA VARIATION OF CURRENT =      62.40  DEV2 =       64.10

RI =   .140E+00  R2 =   .140E+00  RAD =    .248E+00
PERCENT THETA VARIATION OF CURRENT =      66.93  DEV2 =       68.33

RI =   .140E+00  R2 =   .140E+00  RAD =    .260E+00
PERCENT THETA VARIATION OF CURRENT =      71.54  DEV2 =       73.09

RI =   .140E+00  R2 =   .140E+00  RAD =    .272E+00
PERCENT THETA VARIATION OF CURRENT =      76.14  DEV2 =       77.76

RI =   .140E+00  R2 =   .140E+00  RAD =    .284E+00
PERCENT THETA VARIATION OF CURRENT =      80.78  DEV2 =       82.69

RI =   .140E+00  R2 =   .140E+00  RAD =    .296E+00
PERCENT THETA VARIATION OF CURRENT =      90.05  DEV2 =       90.62

RI =   .140E+00  R2 =   .140E+00  RAD =    .308E+00
PERCENT THETA VARIATION OF CURRENT =      94.86  DEV2 =       95.67

RI =   .140E+00  R2 =   .140E+00  RAD =    .320E+00
PERCENT THETA VARIATION OF CURRENT =      99.70  DEV2 =      100.64

RI =   .140E+00  R2 =   .140E+00  RAD =    .332E+00
PERCENT THETA VARIATION OF CURRENT =     104.54  DEV2 =      105.46

RI =   .140E+00  R2 =   .140E+00  RAD =    .344E+00
PERCENT THETA VARIATION OF CURRENT =     109.42  DEV2 =      110.14

RI =   .140E+00  R2 =   .140E+00  RAD =    .356E+00
PERCENT THETA VARIATION OF CURRENT =     116.53  DEV2 =      124.42

RI =   .140E+00  R2 =   .140E+00  RAD =    .368E+00
PERCENT THETA VARIATION OF CURRENT =     130.78  DEV2 =      134.19

RI =   .140E+00  R2 =   .140E+00  RAD =    .380E+00
PERCENT THETA VARIATION OF CURRENT =     138.37  DEV2 =      143.58
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TIME AFTER INITIATION =       6.00061991E-08

PARTIAL VERTICAL CURRENT ARRAY

 1.60E+00   8.00E+00   1.50E+01   2.70E+01   2.96E+01   3.60E+01   4.30E+01   5.00E+01   6.10E+01

-8.97E-34   2.46E-12   1.32E+04   9.90E+03   8.81E+03   8.85E+03   1.37E+04   2.22E+04   1.61E+04
-3.08E-14   4.18E-05   1.63E+04   8.87E+03   8.29E+03   8.44E+03   1.25E+04   5.66E+03   1.59E+04
-2.68E+02   4.28E+03   6.40E+03   6.82E+03   7.02E+03   7.55E+03   2.02E+03   4.27E+03   1.60E+04
-1.92E+02   2.34E+03   4.03E+03   4.83E+03   5.17E+03   2.72E+03   1.98E+03   2.48E+03   0.
-1.15E+02   1.43E+03   2.62E+03   3.27E+03   3.37E+03   2.70E+03   1.97E+03   1.55E+03   0.
-7.42E+01   9.39E+02   1.70E+03   2.24E+03   2.34E+03   2.07E+03   1.62E+03   1.11E+03   0.
-5.18E+01   6.56E+02   1.24E+03   1.61E+03   1.72E+03   1.59E+03   1.28E+03   8.53E+02   0.
-3.93E+01   5.06E+02   9.52E+02   1.25E+03   1.36E+03   1.28E+03   1.05E+03   7.03E+02   0.
-3.37E+01   4.28E+02   8.25E+02   1.09E+03   1.19E+03   1.14E+03   9.41E+02   6.33E+02   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

PARTIAL HORIZONTAL CURRENT ARRAY

-4.93E-34  -3.55E-14  -2.88E+02  -1.31E+02  -2.42E+01   3.24E+02   4.50E+02   1.11E+03   0.
 1.63E-12   4.14E-05   4.13E+03   1.45E+03   2.54E+02  -4.10E+03  -5.33E+03   2.98E+03   0.
 9.46E+03   7.82E+03   4.45E+03   1.89E+03   1.56E+02  -8.22E+03   1.57E+01  -9.93E+02   0.
 5.88E+03   5.12E+03   3.41E+03   1.54E+03  -3.92E+02  -4.43E+03  -1.57E+03  -2.35E+03   0.
 3.71E+03   3.33E+03   2.36E+03   1.11E+03  -2.65E+02  -1.37E+03  -1.63E+03  -2.10E+03   0.
 2.35E+03   2.14E+03   1.57E+03   7.89E+02  -4.89E+01  -7.46E+02  -1.19E+03  -1.54E+03   0.
 1.44E+03   1.32E+03   9.87E+02   5.26E+02   1.39E+01  -4.34E+02  -7.74E+02  -1.01E+03   0.
 7.80E+02   7.16E+02   5.44E+02   2.94E+02   2.16E+01  -2.29E+02  -4.29E+02  -5.69E+02   0.
 2.68E+02   2.44E+02   1.86E+02   1.06E+02   1.04E+01  -7.71E+01  -1.48E+02  -2.00E+02   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

PARTIAL VOLTAGE ARRAY

 3.53E-38   1.07E-13   6.93E+02   2.79E+03   4.33E+03   5.77E+03   5.97E+03   6.45E+03   9.88E+04
 7.19E-14   1.31E-06   1.17E+03   3.06E+03   4.47E+03   5.70E+03   5.82E+03   6.25E+03   9.88E+04
 3.03E+02   8.05E+02   2.11E+03   3.50E+03   4.70E+03   5.49E+03   5.58E+03   6.13E+03   9.88E+04
 1.19E+03   1.50E+03   2.65E+03   3.74E+03   4.74E+03   5.38E+03   5.69E+03   5.94E+03   0.
 1.67E+03   2.08E+03   3.05E+03   3.86E+03   4.57E+03   5.30E+03   5.79E+03   5.96E+03   0.
 2.26E+03   2.57E+03   3.34E+03   3.78E+03   4.42E+03   5.27E+03   5.58E+03   5.80E+03   0.
 3.44E+03   3.49E+03   3.54E+03   3.67E+03   3.98E+03   4.40E+03   4.75E+03   4.80E+03   0.
 4.25E+03   4.26E+03   3.80E+03   3.61E+03   3.78E+03   3.96E+03   4.33E+03   4.63E+03   0.
 4.10E+03   4.11E+03   3.86E+03   3.91E+03   3.95E+03   4.07E+03   4.57E+03   4.95E+03   0.
 0.         .0.        0.         0.         0.         0.         0.         0.         0.

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .152E+00
     PERCENT THETA VARIATION OF CURRENT =      34.51  DEV2 =      40.00

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .164E+00
     PERCENT THETA VARIATION OF CURRENT =      40.64  DEV2 =      43.27

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .176E+00
     PERCENT THETA VARIATION OF CURRENT =      41.22  DEV2 =      45.72

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .188E+00
     PERCENT THETA VARIATION OF CURRENT =      44.55  DEV2 =      47.31
```

```
R1 =   .140E+00  R2 =   .140E+00  RAD =   .200E+00
PERCENT THETA VARIATION OF CURRENT =     48.16  DEV2 =       50.96

R1 =   .140E+00  R2 =   .140E+00  RAD =   .212E+00
PERCENT THETA VARIATION OF CURRENT =     51.86  DEV2 =       53.91

R1 =   .140E+00  R2 =   .140E+00  RAD =   .224E+00
PERCENT THETA VARIATION OF CURRENT =     57.17  DEV2 =       61.36

R1 =   .140E+00  R2 =   .140E+00  RAD =   .236E+00
PERCENT THETA VARIATION OF CURRENT =     63.16  DEV2 =       64.88

R1 =   .140E+00  R2 =   .140E+00  RAD =   .248E+00
PERCENT THETA VARIATION OF CURRENT =     67.72  DEV2 =       69.16

R1 =   .140E+00  R2 =   .140E+00  RAD =   .260E+00
PERCENT THETA VARIATION OF CURRENT =     72.36  DEV2 =       73.95

R1 =   .140E+00  R2 =   .140E+00  RAD =   .272E+00
PERCENT THETA VARIATION OF CURRENT =     77.02  DEV2 =       78.66

R1 =   .140E+00  R2 =   .140E+00  RAD =   .284E+00
PERCENT THETA VARIATION OF CURRENT =     81.72  DEV2 =       83.62

R1 =   .140E+00  R2 =   .140E+00  RAD =   .296E+00
PERCENT THETA VARIATION OF CURRENT =     91.22  DEV2 =       91.79

R1 =   .140E+00  R2 =   .140E+00  RAD =   .308E+00
PERCENT THETA VARIATION OF CURRENT =     96.15  DEV2 =       96.96

R1 =   .140E+00  R2 =   .140E+00  RAD =   .320E+00
PERCENT THETA VARIATION OF CURRENT =    101.08  DEV2 =      101.99

R1 =   .140E+00  R2 =   .140E+00  RAD =   .332E+00
PERCENT THETA VARIATION OF CURRENT =    105.97  DEV2 =      106.85

R1 =   .140E+00  R2 =   .140E+00  RAD =   .344E+00
PERCENT THETA VARIATION OF CURRENT =    110.88  DEV2 =      111.51

R1 =   .140E+00  R2 =   .140E+00  RAD =   .356E+00
PERCENT THETA VARIATION OF CURRENT =    118.04  DEV2 =      126.38

R1 =   .140E+00  R2 =   .140E+00  RAD =   .368E+00
PERCENT THETA VARIATION OF CURRENT =    132.38  DEV2 =      136.10

R1 =   .140E+00  R2 =   .140E+00  RAD =   .380E+00
PERCENT THETA VARIATION OF CURRENT =    140.27  DEV2 =      145.28
```

AD-A036 161 AIR FORCE WEAPONS LAB KIRTLAND AFB N MEX F/G 9/1
PLATE: A 2-D TRANSMISSION LINE CURRENT SYMMETRY CODE.(U)
JAN 77 J A JUSTICE
UNCLASSIFIED AFWL-TR-76-205 NL

2 OF 2
AD
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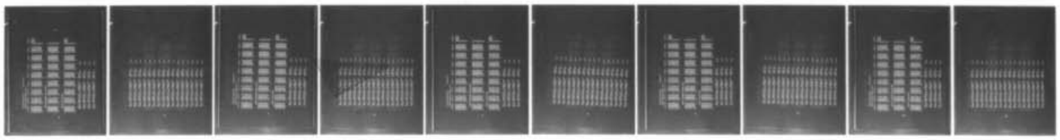

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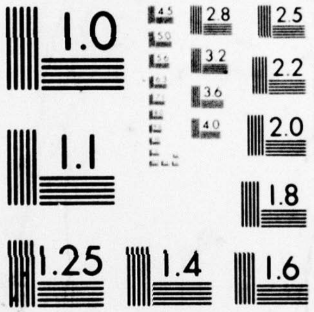

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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        TIME AFTER INITIATION =        8.00141976E-08

        PARTIAL VERTICAL CURRENT ARRAY

 1.00E+00   8.00E+00   1.50E+01   2.20E+01   2.90E+01   3.60E+01   4.30E+01   5.00E+01   6.10E+01

-1.77E-30   1.24E-10   1.73E+04   1.29E+04   1.15E+04   1.16E+04   1.79E+04   2.92E+04   2.15E+04
-1.59E-12   6.10E-04   1.34E+04   1.16E+04   1.08E+04   1.10E+04   1.64E+04   7.50E+03   2.11E+04
-3.51E+02   5.60E+03   8.37E+03   8.91E+03   9.17E+03   9.85E+03   2.68E+03   5.06E+03   2.13E+04
-2.51E+02   3.00E+03   5.27E+03   6.31E+03   6.75E+03   3.55E+03   2.62E+03   3.28E+03   0.
-1.51E+02   1.80E+03   3.43E+03   4.70E+03   4.40E+03   3.53E+03   2.59E+03   2.04E+03   0.
-9.70E+01   1.23E+03   2.30E+03   2.94E+03   3.06E+03   2.71E+03   2.12E+03   1.46E+03   0.
-6.70E+01   8.53E+02   1.62E+03   2.11E+03   2.26E+03   2.08E+03   1.68E+03   1.12E+03   0.
-5.03E+01   6.43E+02   1.24E+03   1.63E+03   1.70E+03   1.69E+03   1.38E+03   9.19E+02   0.
-4.31E+01   5.51E+02   1.07E+03   1.41E+03   1.56E+03   1.50E+03   1.24E+03   8.27E+02   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

        PARTIAL HORIZONTAL CURRENT ARRAY

-1.09E-30  -1.01E-12  -3.78E+02  -1.70E+02  -3.22E+01   4.20E+02   5.84E+02   1.45E+03   0.
 8.51E-11   6.04E-04   5.41E+03   1.89E+03   3.36E+02  -5.29E+03  -6.93E+03   3.95E+03   0.
 1.24E+04   1.02E+04   5.82E+03   2.48E+03   2.11E+02  -1.06E+04   5.13E+01  -1.29E+03   0.
 7.68E+03   6.69E+03   4.46E+03   2.03E+03  -4.97E+02  -5.73E+03  -2.02E+03  -3.07E+03   0.
 4.85E+03   4.36E+03   3.18E+03   1.47E+03  -3.32E+02  -1.78E+03  -2.13E+03  -2.75E+03   0.
 3.10E+03   2.82E+03   2.07E+03   1.04E+03  -4.73E+01  -9.48E+02  -1.53E+03  -2.00E+03   0.
 1.92E+03   1.76E+03   1.32E+03   7.00E+02   3.98E+01  -5.41E+02  -9.87E+02  -1.31E+03   0.
 1.06E+03   9.76E+02   7.39E+02   4.08E+02   4.58E+01  -2.86E+02  -5.47E+02  -7.31E+02   0.
 3.57E+02   3.31E+02   2.54E+02   1.47E+02   2.08E+01  -9.41E+01  -1.88E+02  -2.53E+02   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

        PARTIAL VOLTAGE ARRAY

 9.80E-35   3.96E-12   1.65E+03   4.00E+03   6.36E+03   7.94E+03   8.00E+03   8.29E+03   9.78E+04
 2.74E-12   1.40E-05   1.68E+03   4.13E+03   6.43E+03   8.12E+03   8.16E+03   8.46E+03   9.79E+04
 9.80E+02   1.45E+03   2.96E+03   4.76E+03   6.50E+03   8.34E+03   8.41E+03   9.14E+03   9.78E+04
 3.39E+03   3.55E+03   4.20E+03   5.18E+03   6.49E+03   8.01E+03   8.27E+03   8.92E+03   0.
 4.91E+03   4.99E+03   5.42E+03   5.73E+03   6.69E+03   7.82E+03   8.52E+03   8.97E+03   0.
 5.93E+03   6.16E+03   6.37E+03   6.63E+03   7.22E+03   8.10E+03   8.08E+03   9.18E+03   0.
 7.21E+03   7.24E+03   7.08E+03   7.08E+03   7.53E+03   8.01E+03   8.58E+03   8.77E+03   0.
 7.95E+03   7.73E+03   7.60E+03   7.60E+03   7.79E+03   8.27E+03   8.46E+03   8.66E+03   0.
 8.12E+03   8.06E+03   8.00E+03   7.94E+03   8.13E+03   8.53E+03   8.48E+03   8.58E+03   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

        R1 =   .146E+00  R2 =   .140E+00  RAD =   .152E+00
        PERCENT THETA VARIATION OF CURRENT =      34.51  DEV2 =       40.00

        R1 =   .146E+00  R2 =   .140E+00  RAD =   .164E+00
        PERCENT THETA VARIATION OF CURRENT =      40.64  DEV2 =       43.27

        R1 =   .140E+00  R2 =   .140E+00  RAD =   .176E+00
        PERCENT THETA VARIATION OF CURRENT =      41.22  DEV2 =       45.71

        R1 =   .140E+00  R2 =   .140E+00  RAD =   .188E+00
        PERCENT THETA VARIATION OF CURRENT =      44.53  DEV2 =       47.29
```

```
R1 =  .140E+00  R2 =  .140E+00  RAD =  .200E+00
PERCENT THETA VARIATION OF CURRENT =   48.12  DEV2 =     50.48

R1 =  .140E+00  R2 =  .140E+00  RAD =  .212E+00
PERCENT THETA VARIATION OF CURRENT =   51.77  DEV2 =     53.79

R1 =  .140E+00  R2 =  .140E+00  RAD =  .224E+00
PERCENT THETA VARIATION OF CURRENT =   57.67  DEV2 =     61.26

R1 =  .140E+00  R2 =  .140E+00  RAD =  .236E+00
PERCENT THETA VARIATION OF CURRENT =   62.99  DEV2 =     64.71

R1 =  .140E+00  R2 =  .140E+00  RAD =  .248E+00
PERCENT THETA VARIATION OF CURRENT =   67.40  DEV2 =     68.88

R1 =  .140E+00  R2 =  .140E+00  RAD =  .260E+00
PERCENT THETA VARIATION OF CURRENT =   72.08  DEV2 =     73.63

R1 =  .140E+00  R2 =  .140E+00  RAD =  .272E+00
PERCENT THETA VARIATION OF CURRENT =   76.71  DEV2 =     78.33

R1 =  .140E+00  R2 =  .140E+00  RAD =  .284E+00
PERCENT THETA VARIATION OF CURRENT =   81.40  DEV2 =     83.29

R1 =  .140E+00  R2 =  .140E+00  RAD =  .296E+00
PERCENT THETA VARIATION OF CURRENT =   90.82  DEV2 =     91.40

R1 =  .140E+00  R2 =  .140E+00  RAD =  .308E+00
PERCENT THETA VARIATION OF CURRENT =   95.70  DEV2 =     96.54

R1 =  .140E+00  R2 =  .140E+00  RAD =  .320E+00
PERCENT THETA VARIATION OF CURRENT =  100.62  DEV2 =    101.57

R1 =  .140E+00  R2 =  .140E+00  RAD =  .332E+00
PERCENT THETA VARIATION OF CURRENT =  105.50  DEV2 =    106.43

R1 =  .140E+00  R2 =  .140E+00  RAD =  .344E+00
PERCENT THETA VARIATION OF CURRENT =  110.38  DEV2 =    111.12

R1 =  .140E+00  R2 =  .140E+00  RAD =  .356E+00
PERCENT THETA VARIATION OF CURRENT =  117.50  DEV2 =    125.52

R1 =  .140E+00  R2 =  .140E+00  RAD =  .368E+00
PERCENT THETA VARIATION OF CURRENT =  131.85  DEV2 =    135.13

R1 =  .140E+00  R2 =  .140E+00  RAD =  .380E+00
PERCENT THETA VARIATION OF CURRENT =  139.39  DEV2 =    144.27
```

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TIME AFTER INITIATION =        1.00004373E-17

 PARTIAL VERTICAL CURRENT ARRAY

 1.00E+00   8.00E+00   1.50E+01   2.29E+01   2.90E+01   3.60E+01   4.30E+01   5.00E+01   6.10E+01

-5.07E-20   2.44E-69   2.11E+04   1.58E+04   1.41E+04   1.47E+04   2.23E+04   3.63E+04   2.60E+04
-3.19E-11   4.67E-03   1.64E+04   1.42E+04   1.32E+04   1.35E+04   2.03E+04   9.37E+03   2.63E+04
-4.30E+02   6.80E+03   1.02E+04   1.09E+04   1.12E+04   1.21E+04   3.35E+03   7.06E+03   2.66E+04
-3.00E+02   3.75E+03   6.44E+03   7.72E+03   8.25E+03   4.36E+03   3.24E+03   4.00E+03   0.
-1.83E+02   2.29E+03   4.19E+03   5.24E+03   5.38E+03   4.32E+03   3.18E+03   2.52E+03   0.
-1.19E+02   1.58E+03   2.82E+03   3.60E+03   3.74E+03   3.31E+03   2.60E+03   1.79E+03   0.
-8.34E+01   1.05E+03   1.99E+03   2.59E+03   2.76E+03   2.54E+03   2.05E+03   1.37E+03   0.
-6.27E+01   7.93E+02   1.52E+03   2.00E+03   2.18E+03   2.06E+03   1.69E+03   1.12E+03   0.
-5.33E+01   6.78E+02   1.30E+03   1.73E+03   1.91E+03   1.83E+03   1.51E+03   9.94E+02   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

 PARTIAL HORIZONTAL CURRENT ARRAY

-3.01E-20  -3.60E-11  -4.63E+02  -2.09E+02  -3.97E+01   5.09E+02   7.17E+02   1.00E+03   0.
 1.71E-69   4.62E-03   6.62E+03   2.31E+03   4.07E+02  -6.46E+03  -8.52E+03   4.92E+03   0.
 1.51E+04   1.25E+04   7.12E+03   3.02E+03   2.49E+02  -1.30E+04   7.57E+01  -1.61E+03   0.
 9.41E+03   8.19E+03   5.45E+03   2.40E+03  -6.11E+02  -7.00E+03  -2.50E+03  -3.02E+03   0.
 5.94E+03   5.33E+03   3.80E+03   1.80E+03  -3.96E+02  -2.18E+03  -2.62E+03  -3.41E+03   0.
 3.77E+03   3.44E+03   2.53E+03   1.20E+03  -5.40E+01  -1.15E+03  -1.08E+03  -2.46E+03   0.
 2.33E+03   2.14E+03   1.60E+03   8.55E+02   4.86E+01  -6.54E+02  -1.20E+03  -1.59E+03   0.
 1.29E+03   1.19E+03   8.98E+02   4.90E+02   4.33E+01  -3.61E+02  -6.79E+02  -4.09E+02   0.
 4.51E+02   4.14E+02   3.14E+02   1.70E+02   1.46E+01  -1.25E+02  -2.36E+02  -3.22E+02   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

 PARTIAL VOLTAGE ARRAY

 4.20E-32   6.17E-11   1.08E+03   4.74E+03   8.31E+03   1.09E+04   1.13E+04   1.22E+04   9.66E+04
 4.33E-11   8.49E-05   2.04E+03   5.07E+03   8.34E+03   1.08E+04   1.13E+04   1.22E+04   9.67E+04
 1.09E+03   2.01E+03   3.89E+03   6.04E+03   8.38E+03   1.05E+04   1.11E+04   1.25E+04   9.66E+04
 4.65E+03   4.64E+03   5.83E+03   7.08E+03   8.73E+03   1.01E+04   1.09E+04   1.21E+04   0.
 5.36E+03   5.93E+03   7.05E+03   8.01E+03   9.04E+03   9.96E+03   1.07E+04   1.14E+04   0.
 6.60E+03   6.89E+03   7.61E+03   8.25E+03   9.01E+03   9.77E+03   1.04E+04   1.08E+04   0.
 7.61E+03   7.75E+03   8.13E+03   8.50E+03   8.99E+03   9.64E+03   1.01E+04   1.04E+04   0.
 8.07E+03   8.24E+03   8.43E+03   8.59E+03   9.00E+03   9.50E+03   9.81E+03   1.00E+04   0.
 8.49E+03   8.19E+03   8.20E+03   8.64E+03   9.15E+03   9.53E+03   9.85E+03   1.02E+04   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .152E+00
     PERCENT THETA VARIATION OF CURRENT =      34.48  DEV2 =      39.97

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .164E+00
     PERCENT THETA VARIATION OF CURRENT =      40.67  DEV2 =      43.25

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .176E+00
     PERCENT THETA VARIATION OF CURRENT =      41.19  DEV2 =      45.68

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .188E+00
     PERCENT THETA VARIATION OF CURRENT =      44.49  DEV2 =      47.26
```

```
R1 =   .140E+00  R2 =   .140E+00  RAD =   .200E+00
PERCENT THETA VARIATION OF CURRENT =      48.06  DEV2 =       50.06

R1 =   .140E+00  R2 =   .140E+00  RAD =   .212E+00
PERCENT THETA VARIATION OF CURRENT =      51.72  DEV2 =       53.77

R1 =   .140E+00  R2 =   .140E+00  RAD =   .224E+00
PERCENT THETA VARIATION OF CURRENT =      56.99  DEV2 =       61.19

R1 =   .140E+00  R2 =   .140E+00  RAD =   .236E+00
PERCENT THETA VARIATION OF CURRENT =      62.92  DEV2 =       64.60

R1 =   .140E+00  R2 =   .140E+00  RAD =   .248E+00
PERCENT THETA VARIATION OF CURRENT =      67.44  DEV2 =       68.89

R1 =   .140E+00  R2 =   .140E+00  RAD =   .260E+00
PERCENT THETA VARIATION OF CURRENT =      72.07  DEV2 =       73.67

R1 =   .140E+00  R2 =   .140E+00  RAD =   .272E+00
PERCENT THETA VARIATION OF CURRENT =      76.74  DEV2 =       78.39

R1 =   .140E+00  R2 =   .140E+00  RAD =   .284E+00
PERCENT THETA VARIATION OF CURRENT =      81.45  DEV2 =       83.37

R1 =   .140E+00  R2 =   .140E+00  RAD =   .296E+00
PERCENT THETA VARIATION OF CURRENT =      90.9[illegible]  DEV2 =       91.48

R1 =   .140E+00  R2 =   .140E+00  RAD =   .308E+00
PERCENT THETA VARIATION OF CURRENT =      95.85  DEV2 =       96.67

R1 =   .140E+00  R2 =   .140E+00  RAD =   .320E+00
PERCENT THETA VARIATION OF CURRENT =     100.83  DEV2 =      101.74

R1 =   .140E+00  R2 =   .140E+00  RAD =   .332E+00
PERCENT THETA VARIATION OF CURRENT =     105.79  DEV2 =      106.63

R1 =   .140E+00  R2 =   .140E+00  RAD =   .344E+00
PERCENT THETA VARIATION OF CURRENT =     110.75  DEV2 =      111.34

R1 =   .140E+00  R2 =   .140E+00  RAD =   .356E+00
PERCENT THETA VARIATION OF CURRENT =     118.00  DEV2 =      125.96

R1 =   .140E+00  R2 =   .140E+00  RAD =   .368E+00
PERCENT THETA VARIATION OF CURRENT =     132.59  DEV2 =      135.54

R1 =   .140E+00  R2 =   .140E+00  RAD =   .380E+00
PERCENT THETA VARIATION OF CURRENT =     139.94  DEV2 =      144.67
```

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TIME AFTER INITIATION =        1.20012300E-07

PARTIAL VERTICAL CURRENT ARRAY

 1.00E+00    8.00E+00    1.56E+01    2.20E+01    2.90E+01    3.60E+01    4.30E+01    5.00E+01    6.10E+01

-6.46E-26    2.77E-08    2.40E+04    1.86E+04    1.66E+04    1.60E+04    2.65E+04    4.33E+04    3.20E+04
-3.59E-10    2.41E-02    1.93E+04    1.67E+04    1.56E+04    1.60E+04    2.42E+04    1.12E+04    3.14E+04
-5.05E+02    8.04E+03    1.20E+04    1.70E+04    1.33E+04    1.43E+04    3.90E+03    8.43E+03    3.18E+04
-3.61E+02    4.39E+03    7.57E+03    9.09E+03    9.76E+03    5.17E+03    3.86E+03    4.86E+03    0.
-2.15E+02    2.69E+03    4.92E+03    6.17E+03    6.37E+03    5.12E+03    3.70E+03    3.00E+03    0.
-1.40E+02    1.76E+03    3.31E+03    4.24E+03    4.43E+03    3.92E+03    3.08E+03    2.12E+03    0.
-9.67E+01    1.23E+03    2.35E+03    3.06E+03    3.27E+03    3.02E+03    2.43E+03    1.62E+03    0.
-7.42E+01    9.44E+02    1.81E+03    2.39E+03    2.59E+03    2.44E+03    1.94E+03    1.32E+03    0.
-6.54E+01    8.21E+02    1.57E+03    2.08E+03    2.28E+03    2.17E+03    1.78E+03    1.17E+03    0.
 0.          0.          0.          0.          0.          0.          0.          0.          0.

PARTIAL HORIZONTAL CURRENT ARRAY

-4.32E-26   -4.05E-10   -5.43E+02   -2.43E+02   -4.41E+01    6.20E+02    8.67E+02    2.15E+03    0.
 1.91E-08    2.39E-02    7.75E+03    2.69E+03    4.55E+02   -7.83E+03   -1.03E+04    5.83E+03    0.
 1.77E+04    1.46E+04    8.32E+03    3.51E+03    2.42E+02   -1.56E+04    3.73E+01   -1.90E+03    0.
 1.10E+04    9.56E+03    6.35E+03    2.85E+03   -7.96E+02   -8.39E+03   -3.04E+03   -4.62E+03    0.
 6.91E+03    6.20E+03    4.39E+03    2.04E+03   -5.56E+02   -2.66E+03   -3.18E+03   -4.13E+03    0.
 4.36E+03    3.97E+03    2.91E+03    1.44E+03   -1.34E+02   -1.44E+03   -2.30E+03   -2.99E+03    0.
 2.66E+03    2.44E+03    1.82E+03    9.56E+02    1.58E+01   -8.26E+02   -1.47E+03   -1.95E+03    0.
 1.45E+03    1.34E+03    1.01E+03    5.44E+02    3.22E+01   -4.39E+02   -8.23E+02   -1.10E+03    0.
 4.92E+02    4.58E+02    3.53E+02    1.91E+02    1.41E+01   -1.51E+02   -2.86E+02   -3.89E+02    0.
 0.          0.          0.          0.          0.          0.          0.          0.          0.

PARTIAL VOLTAGE ARRAY

 5.66E-30    5.60E-16    1.49E+03    6.01E+03    9.90E+03    1.32E+04    1.35E+04    1.37E+04    9.51E+04
 4.91E-10    3.64E-04    2.57E+03    6.50E+03    1.01E+04    1.30E+04    1.33E+04    1.38E+04    9.52E+04
 1.11E+03    1.97E+03    4.46E+03    7.18E+03    1.01E+04    1.26E+04    1.31E+04    1.40E+04    9.51E+04
 3.96E+03    4.56E+03    5.93E+03    7.60E+03    9.79E+03    1.19E+04    1.31E+04    1.40E+04    0.
 6.05E+03    6.30E+03    6.80E+03    7.87E+03    9.37E+03    1.09E+04    1.21E+04    1.29E+04    0.
 7.33E+03    7.37E+03    7.46E+03    8.24E+03    9.20E+03    1.03E+04    1.11E+04    1.17E+04    0.
 7.72E+03    7.98E+03    8.16E+03    8.66E+03    9.30E+03    9.94E+03    1.06E+04    1.08E+04    0.
 8.05E+03    8.33E+03    8.68E+03    9.08E+03    9.53E+03    9.75E+03    1.02E+04    1.06E+04    0.
 8.47E+03    8.44E+03    8.82E+03    9.24E+03    9.74E+03    1.02E+04    1.07E+04    1.09E+04    0.
 0.          0.          0.          0.          0.          0.          0.          0.          0.

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .152E+00
     PERCENT THETA VARIATION OF CURRENT =      34.89  DEV2 =       40.37

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .164E+00
     PERCENT THETA VARIATION OF CURRENT =      41.10  DEV2 =       43.72

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .176E+00
     PERCENT THETA VARIATION OF CURRENT =      41.76  DEV2 =       46.21

     R1 =   .140E+00  R2 =   .140E+00  RAD =   .188E+00
     PERCENT THETA VARIATION OF CURRENT =      45.11  DEV2 =       47.83
```

```
R1 =   .140E+00  R2 =   .140E+00  RAD =   .200E+00
PERCENT THETA VARIATION OF CURRENT =      48.74  DEV2 =      51.53

R1 =   .140E+00  R2 =   .140E+00  RAD =   .212E+00
PERCENT THETA VARIATION OF CURRENT =      52.46  DEV2 =      54.50

R1 =   .140E+00  R2 =   .140E+00  RAD =   .224E+00
PERCENT THETA VARIATION OF CURRENT =      57.87  DEV2 =      62.03

R1 =   .140E+00  R2 =   .140E+00  RAD =   .236E+00
PERCENT THETA VARIATION OF CURRENT =      63.90  DEV2 =      65.60

R1 =   .140E+00  R2 =   .140E+00  RAD =   .248E+00
PERCENT THETA VARIATION OF CURRENT =      68.50  DEV2 =      69.94

R1 =   .140E+00  R2 =   .140E+00  RAD =   .260E+00
PERCENT THETA VARIATION OF CURRENT =      73.21  DEV2 =      74.80

R1 =   .140E+00  R2 =   .140E+00  RAD =   .272E+00
PERCENT THETA VARIATION OF CURRENT =      77.95  DEV2 =      79.50

R1 =   .140E+00  R2 =   .140E+00  RAD =   .284E+00
PERCENT THETA VARIATION OF CURRENT =      82.72  DEV2 =      84.59

R1 =   .140E+00  R2 =   .140E+00  RAD =   .296E+00
PERCENT THETA VARIATION OF CURRENT =      92.30  DEV2 =      92.88

R1 =   .140E+00  R2 =   .140E+00  RAD =   .308E+00
PERCENT THETA VARIATION OF CURRENT =      97.28  DEV2 =      98.09

R1 =   .140E+00  R2 =   .140E+00  RAD =   .320E+00
PERCENT THETA VARIATION OF CURRENT =     102.28  DEV2 =     103.16

R1 =   .140E+00  R2 =   .140E+00  RAD =   .332E+00
PERCENT THETA VARIATION OF CURRENT =     107.27  DEV2 =     108.04

R1 =   .140E+00  R2 =   .140E+00  RAD =   .344E+00
PERCENT THETA VARIATION OF CURRENT =     112.23  DEV2 =     112.72

R1 =   .140E+00  R2 =   .140E+00  RAD =   .356E+00
PERCENT THETA VARIATION OF CURRENT =     119.50  DEV2 =     127.75

R1 =   .140E+00  R2 =   .140E+00  RAD =   .368E+00
PERCENT THETA VARIATION OF CURRENT =     134.12  DEV2 =     137.36

R1 =   .140E+00  R2 =   .140E+00  RAD =   .380E+00
PERCENT THETA VARIATION OF CURRENT =     141.69  DEV2 =     146.39
```

```
TIME AFTER INITIATION =        1.40002555E-07

PARTIAL VERTICAL CURRENT ARRAY

 1.00E+00   8.00E+00   1.50E+01   2.20E+01   2.90E+01   3.60E+01   4.30E+01   5.00E+01   6.10E+01

-3.32E-24   2.05E-67   2.05E+04   2.14E+04   1.91E+04   1.92E+04   3.06E+04   5.01E+04   3.71E+04
-2.73E-09   9.53E-02   2.21E+04   1.92E+04   1.79E+04   1.83E+04   2.79E+04   1.30E+04   3.65E+04
-5.70E+02   9.20E+03   1.30E+04   1.47E+04   1.52E+04   1.64E+04   4.50E+03   9.76E+03   3.60E+04
-4.14E+02   5.05E+03   8.70E+03   1.04E+04   1.12E+04   5.95E+03   4.44E+03   5.61E+03   0.
-2.48E+02   3.10E+03   5.66E+03   7.16E+03   7.31E+03   5.88E+03   4.35E+03   3.45E+03   0.
-1.62E+02   2.04E+03   3.81E+03   4.87E+03   5.09E+03   4.51E+03   3.55E+03   2.45E+03   0.
-1.12E+02   1.42E+03   2.70E+03   3.51E+03   3.75E+03   3.47E+03   2.80E+03   1.87E+03   0.
-8.50E+01   1.00E+03   2.07E+03   2.73E+03   2.97E+03   2.81E+03   2.30E+03   1.52E+03   0.
-7.29E+01   9.20E+02   1.79E+03   2.37E+03   2.61E+03   2.49E+03   2.05E+03   1.36E+03   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

PARTIAL HORIZONTAL CURRENT ARRAY

-2.26E-24  -3.08E-09  -6.23E+02  -2.77E+02  -4.83E+01   7.20E+02   1.00E+03   2.49E+03   0.
 1.45E-07   9.44E-02   8.86E+03   3.07E+03   4.99E+02  -9.07E+03  -1.19E+04   6.71E+03   0.
 2.02E+04   1.67E+04   9.48E+03   3.98E+03   2.39E+02  -1.81E+04   7.93E-01  -2.34E+03   0.
 1.25E+04   1.09E+04   7.20E+03   3.20E+03  -9.76E+02  -9.74E+03  -3.56E+03  -5.40E+03   0.
 7.84E+03   7.03E+03   4.96E+03   2.26E+03  -7.11E+02  -3.12E+03  -3.72E+03  -4.82E+03   0.
 4.96E+03   4.51E+03   3.28E+03   1.59E+03  -2.23E+02  -1.72E+03  -2.70E+03  -3.50E+03   0.
 3.04E+03   2.78E+03   2.06E+03   1.05E+03  -3.85E+01  -1.00E+03  -1.75E+03  -2.24E+03   0.
 1.66E+03   1.53E+03   1.15E+03   6.05E+02   1.37E+01  -5.38E+02  -9.81E+02  -1.30E+03   0.
 5.71E+02   5.25E+02   3.98E+02   2.12E+02   5.97E+00  -1.80E+02  -3.38E+02  -4.51E+02   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

PARTIAL VOLTAGE ARRAY

 3.45E-28   3.65E-09   1.78E+03   6.85E+03   9.98E+03   1.20E+04   1.23E+04   1.29E+04   9.34E+04
 2.59E-09   1.23E-03   2.84E+03   6.94E+03   1.00E+04   1.21E+04   1.24E+04   1.29E+04   9.35E+04
 1.60E+03   2.23E+03   4.64E+03   7.72E+03   1.03E+04   1.22E+04   1.25E+04   1.36E+04   9.34E+04
 4.10E+03   4.83E+03   6.49E+03   8.64E+03   1.05E+04   1.17E+04   1.24E+04   1.32E+04   0.
 6.11E+03   6.46E+03   7.65E+03   9.20E+03   1.04E+04   1.11E+04   1.16E+04   1.22E+04   0.
 7.21E+03   7.57E+03   8.63E+03   9.67E+03   1.05E+04   1.11E+04   1.14E+04   1.18E+04   0.
 8.47E+03   8.61E+03   9.34E+03   1.00E+04   1.05E+04   1.11E+04   1.15E+04   1.20E+04   0.
 9.74E+03   9.72E+03   9.94E+03   1.03E+04   1.06E+04   1.11E+04   1.16E+04   1.23E+04   0.
 1.06E+04   1.08E+04   1.06E+04   1.04E+04   1.04E+04   1.06E+04   1.14E+04   1.19E+04   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

R1 =   .140E+00  R2 =   .140E+00  RAD =   .152E+00
PERCENT THETA VARIATION OF CURRENT =      35.41  DEV2 =       40.82

R1 =   .140E+00  R2 =   .140E+00  RAD =   .164E+00
PERCENT THETA VARIATION OF CURRENT =      41.69  DEV2 =       44.31

R1 =   .140E+00  R2 =   .140E+00  RAD =   .176E+00
PERCENT THETA VARIATION OF CURRENT =      42.39  DEV2 =       46.78

R1 =   .140E+00  R2 =   .140E+00  RAD =   .188E+00
PERCENT THETA VARIATION OF CURRENT =      45.76  DEV2 =       48.41
```

```
RI =   .140E+00  R2 =   .140E+00  RAD =   .200E+00
PERCENT THETA VARIATION OF CURRENT =      49.46  DEV2 =      52.14

RI =   .140E+00  R2 =   .140E+00  RAD =   .212E+00
PERCENT THETA VARIATION OF CURRENT =      53.13  DEV2 =      55.14

RI =   .140E+00  R2 =   .140E+00  RAD =   .224E+00
PERCENT THETA VARIATION OF CURRENT =      58.59  DEV2 =      62.79

RI =   .140E+00  R2 =   .140E+00  RAD =   .236E+00
PERCENT THETA VARIATION OF CURRENT =      64.60  DEV2 =      66.34

RI =   .140E+00  R2 =   .140E+00  RAD =   .248E+00
PERCENT THETA VARIATION OF CURRENT =      69.28  DEV2 =      70.67

RI =   .140E+00  R2 =   .140E+00  RAD =   .260E+00
PERCENT THETA VARIATION OF CURRENT =      73.98  DEV2 =      75.50

RI =   .140E+00  R2 =   .140E+00  RAD =   .272E+00
PERCENT THETA VARIATION OF CURRENT =      78.69  DEV2 =      80.24

RI =   .140E+00  R2 =   .140E+00  RAD =   .284E+00
PERCENT THETA VARIATION OF CURRENT =      83.43  DEV2 =      85.20

RI =   .140E+00  R2 =   .140E+00  RAD =   .296E+00
PERCENT THETA VARIATION OF CURRENT =      93.18  DEV2 =      93.65

RI =   .140E+00  R2 =   .140E+00  RAD =   .308E+00
PERCENT THETA VARIATION OF CURRENT =      98.06  DEV2 =      98.79

RI =   .140E+00  R2 =   .140E+00  RAD =   .320E+00
PERCENT THETA VARIATION OF CURRENT =     103.02  DEV2 =     103.81

RI =   .140E+00  R2 =   .140E+00  RAD =   .332E+00
PERCENT THETA VARIATION OF CURRENT =     107.98  DEV2 =     108.64

RI =   .140E+00  R2 =   .140E+00  RAD =   .344E+00
PERCENT THETA VARIATION OF CURRENT =     112.90  DEV2 =     113.29

RI =   .140E+00  R2 =   .140E+00  RAD =   .356E+00
PERCENT THETA VARIATION OF CURRENT =     120.12  DEV2 =     128.46

RI =   .140E+00  R2 =   .140E+00  RAD =   .368E+00
PERCENT THETA VARIATION OF CURRENT =     134.67  DEV2 =     138.02

RI =   .140E+00  R2 =   .140E+00  RAD =   .380E+00
PERCENT THETA VARIATION OF CURRENT =     142.25  DEV2 =     146.95
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TIME AFTER INITIATION =      1.60010563E-07

PARTIAL VERTICAL CURRENT ARRAY

 1.00E+00   8.00E+00   1.50E+01   2.20E+01   2.90E+01   3.60E+01   4.30E+01   5.00E+01   6.10E+01

-9.91E-23   1.17E-06   3.20E+04   2.40E+04   2.14E+04   2.16E+04   3.45E+04   5.60E+04   4.21E+04
-1.58E-08   3.10E-01   2.49E+04   2.15E+04   2.02E+04   2.06E+04   3.14E+04   1.40E+04   4.14E+04
-6.52E+02   1.03E+04   1.55E+04   1.65E+04   1.71E+04   1.05E+04   5.22E+03   1.11E+04   4.10E+04
-4.66E+02   5.67E+03   9.77E+03   1.17E+04   1.26E+04   6.71E+03   5.04E+03   6.30E+03   0.
-2.79E+02   3.40E+03   6.35E+03   7.97E+03   8.23E+03   6.63E+03   4.92E+03   3.92E+03   0.
-1.81E+02   2.20E+03   4.27E+03   5.40E+03   5.73E+03   5.09E+03   4.07E+03   2.77E+03   0.
-1.26E+02   1.60E+03   3.03E+03   3.95E+03   4.23E+03   3.91E+03   3.16E+03   2.11E+03   0.
-9.57E+01   1.22E+03   2.33E+03   3.06E+03   3.34E+03   3.16E+03   2.59E+03   1.72E+03   0.
-8.31E+01   1.04E+03   2.41E+03   2.67E+03   2.93E+03   2.80E+03   2.30E+03   1.53E+03   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

PARTIAL HORIZONTAL CURRENT ARRAY

-6.03E-23  -1.70E-08  -7.02E+02  -3.11E+02  -5.57E+01   7.96E+02   1.12E+03   2.00E+03   0.
 8.29E-07   3.07E-01   9.97E+03   3.44E+03   5.61E+02  -1.01E+04  -1.32E+04   7.65E+03   0.
 2.20E+04   1.80E+04   1.07E+04   4.47E+03   2.62E+02  -2.01E+04   3.44E+01  -2.63E+03   0.
 1.41E+04   1.22E+04   8.11E+03   3.66E+03  -1.09E+03  -1.09E+04  -3.99E+03  -6.10E+03   0.
 8.04E+03   7.92E+03   5.59E+03   2.56E+03  -7.81E+02  -3.49E+03  -4.17E+03  -5.42E+03   0.
 5.59E+03   5.08E+03   3.73E+03   1.81E+03  -2.24E+02  -1.91E+03  -3.02E+03  -3.93E+03   0.
 3.42E+03   3.13E+03   2.33E+03   1.70E+03  -2.41E+01  -1.11E+03  -1.96E+03  -2.50E+03   0.
 1.88E+03   1.72E+03   1.30E+03   6.92E+02   2.10E+01  -5.99E+02  -1.10E+03  -1.47E+03   0.
 6.40E+02   5.90E+02   4.49E+02   2.44E+02   1.61E+01  -2.04E+02  -3.83E+02  -5.12E+02   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

PARTIAL VOLTAGE ARRAY

 1.19E-26   1.81E-08   1.32E+03   5.06E+03   7.77E+03   1.01E+04   1.05E+04   1.10E+04   9.14E+04
 1.29E-08   3.40E-03   2.30E+03   5.51E+03   7.92E+03   1.01E+04   1.05E+04   1.11E+04   9.15E+04
 1.29E+03   2.19E+03   4.25E+03   6.47E+03   8.35E+03   1.01E+04   1.05E+04   1.17E+04   9.14E+04
 4.53E+03   4.97E+03   6.00E+03   7.19E+03   8.46E+03   9.88E+03   1.06E+04   1.15E+04   0.
 6.95E+03   6.91E+03   7.20E+03   7.95E+03   8.75E+03   9.60E+03   1.04E+04   1.12E+04   0.
 8.07E+03   8.09E+03   8.34E+03   8.86E+03   9.35E+03   9.89E+03   1.01E+04   1.06E+04   0.
 8.52E+03   8.53E+03   8.94E+03   9.55E+03   1.01E+04   1.03E+04   1.04E+04   1.08E+04   0.
 8.62E+03   8.89E+03   9.41E+03   1.02E+04   1.07E+04   1.10E+04   1.12E+04   1.15E+04   0.
 8.72E+03   9.15E+03   9.88E+03   1.05E+04   1.09E+04   1.12E+04   1.16E+04   1.15E+04   0.
 0.         0.         0.         0.         0.         0.         0.         0.         0.

R1 =   .140E+00  R2 =   .140E+00  RAD =   .152E+00
PERCENT THETA VARIATION OF CURRENT =      35.35  DEV2 =      40.78

R1 =   .140E+00  R2 =   .140E+00  RAD =   .164E+00
PERCENT THETA VARIATION OF CURRENT =      41.61  DEV2 =      44.23

R1 =   .140E+00  R2 =   .140E+00  RAD =   .176E+00
PERCENT THETA VARIATION OF CURRENT =      42.31  DEV2 =      46.71

R1 =   .140E+00  R2 =   .140E+00  RAD =   .188E+00
PERCENT THETA VARIATION OF CURRENT =      45.68  DEV2 =      48.34
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R1 =   .140E+00  R2 =   .140E+00  RAD =    .200E+00
PERCENT THETA VARIATION OF CURRENT =      49.32  DEV2 =       52.08

R1 =   .140E+00  R2 =   .140E+00  RAD =    .212E+00
PERCENT THETA VARIATION OF CURRENT =      53.04  DEV2 =       55.06

R1 =   .140E+00  R2 =   .140E+00  RAD =    .224E+00
PERCENT THETA VARIATION OF CURRENT =      58.47  DEV2 =       62.67

R1 =   .140E+00  R2 =   .140E+00  RAD =    .236E+00
PERCENT THETA VARIATION OF CURRENT =      64.55  DEV2 =       66.21

R1 =   .140E+00  R2 =   .140E+00  RAD =    .248E+00
PERCENT THETA VARIATION OF CURRENT =      69.14  DEV2 =       70.53

R1 =   .140E+00  R2 =   .140E+00  RAD =    .260E+00
PERCENT THETA VARIATION OF CURRENT =      73.82  DEV2 =       75.35

R1 =   .140E+00  R2 =   .140E+00  RAD =    .272E+00
PERCENT THETA VARIATION OF CURRENT =      78.52  DEV2 =       80.10

R1 =   .140E+00  R2 =   .140E+00  RAD =    .284E+00
PERCENT THETA VARIATION OF CURRENT =      83.26  DEV2 =       85.09

R1 =   .140E+00  R2 =   .140E+00  RAD =    .296E+00
PERCENT THETA VARIATION OF CURRENT =      92.89  DEV2 =       93.46

R1 =   .140E+00  R2 =   .140E+00  RAD =    .308E+00
PERCENT THETA VARIATION OF CURRENT =      97.86  DEV2 =       98.63

R1 =   .140E+00  R2 =   .140E+00  RAD =    .320E+00
PERCENT THETA VARIATION OF CURRENT =     102.82  DEV2 =      103.67

R1 =   .140E+00  R2 =   .140E+00  RAD =    .332E+00
PERCENT THETA VARIATION OF CURRENT =     107.80  DEV2 =      108.54

R1 =   .140E+00  R2 =   .140E+00  RAD =    .344E+00
PERCENT THETA VARIATION OF CURRENT =     112.74  DEV2 =      113.20

R1 =   .140E+00  R2 =   .140E+00  RAD =    .356E+00
PERCENT THETA VARIATION OF CURRENT =     119.99  DEV2 =      128.15

R1 =   .140E+00  R2 =   .140E+00  RAD =    .368E+00
PERCENT THETA VARIATION OF CURRENT =     134.60  DEV2 =      137.72

R1 =   .140E+00  R2 =   .140E+00  RAD =    .380E+00
PERCENT THETA VARIATION OF CURRENT =     142.04  DEV2 =      146.71
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