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FFEARS

A DIGITAL COMPUTER PROGRAM FOR THE SIMULATION OF LAPLACE'S EQUATION INCLUDING DIELECTRIC INTERFACES AND SMALL UNGROUNDED ELECTRODES

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Abstract

A digital computer program has been written for the general solution of Laplace's Equation and the plotting of equipotential and equifield lines. The program will simulate any rectangular or axisymmetric configuration of dielectrics and small floating electrodes. The potentials are simulated on a large matrix of up to 201 x 201 points. Solutions with errors of less than five percent are easily obtained in less than ten minutes on the CDC 6600, and solutions can generally be obtained to any resolution desired through the blowup subroutine. It is written in the CDC 6600 Fortran IV programming language, but should easily be translated into any other Fortran dielect. A description of the different techniques employed on the discrete matrix and some typical problems which have been solved during the design of high voltage devices are presented.

Key Words: Potentials, Equipotentials, Equifield

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Introduction

This report describes an expanded and improved version of the program for the solution of Laplace's equation in axisymmetric or rectangular coordinates which was described in an earlier report "Digital Computer Simulation of Laplace's Equation Including Dielectric Surfaces" (SC-RR-69-446). Mathematics Note 72 The improved program will handle virtually any configuration of dielectrics and floating electrodes, producing both equipotential and equifield plots if desired. A blowup routine has been added, permitting the expansion and recomputation of sections of the plot to permit greater resolution and the inclusion of more details. A more powerful interface technique has been added to the basic relaxation techniques to produce greater flexibility in electrode configurations. The program currently employs a matrix 201 x 201 on which the potentials are computed.

The program, FFEARS (Fast Floating Electrode Axisymmetric and Rectangular Simulation), is written in the Fortran IV programming language for the CDC 6600 digital computer, and the Stromberg-Carlson 4020 computer recorder. Execution time is generally less than ten minutes and will vary depending on the size and complexity of the problem, i.e., a large simulation with many floating electrodes will generally require more time than a simulation using only a small portion of the available matrix.

The Simulation Method

The method employed is basic, iterative relaxation of a rectangular array of points, laid out in squares. The simulation is carried out on a matrix of up to 201 x 201 points, all or any portion of which may be employed for a particular problem. All electrode and dielectric surfaces must lie on matrix points; i.e., no partial matrix increments may be employed. Laplace's equation, for isotropic dielectrics, expressed in difference form, is solved iteratively at all points within the electrode configuration, except on the interfaces between materials of different dielectric constant. The difference equations employed will be derived below.

A flow chart for the program is shown in Fig. 1. Initializing the matrix consists of putting linear voltage distributions between electrodes. The relaxation procedure between the coarse matrix (all the odd-numbered matrix points) and the fine matrix (consisting of all matrix points) was improved from that described earlier by Richard Kouzes[1] of the Naval Research Laboratories. Beta is the over-relaxation constant which is initially set in the input data, generally at 1.8, and is reduced as the program approaches convergence. Initially the program alternately relaxes the coarse and fine matrices, and then as it approaches convergence, only the fine matrix relaxation is carried out.

Equifield and equipotential plots are then available as output from the program. Overall and expanded plots of any areas of interest may be obtained from the program. In addition, it is possible to save sufficient data to produce blowups, with greater resolution, by re-solving a section of the plot on a finer mesh. Print out of the above data furnishes immediate, quantitative values of potentials or fields.

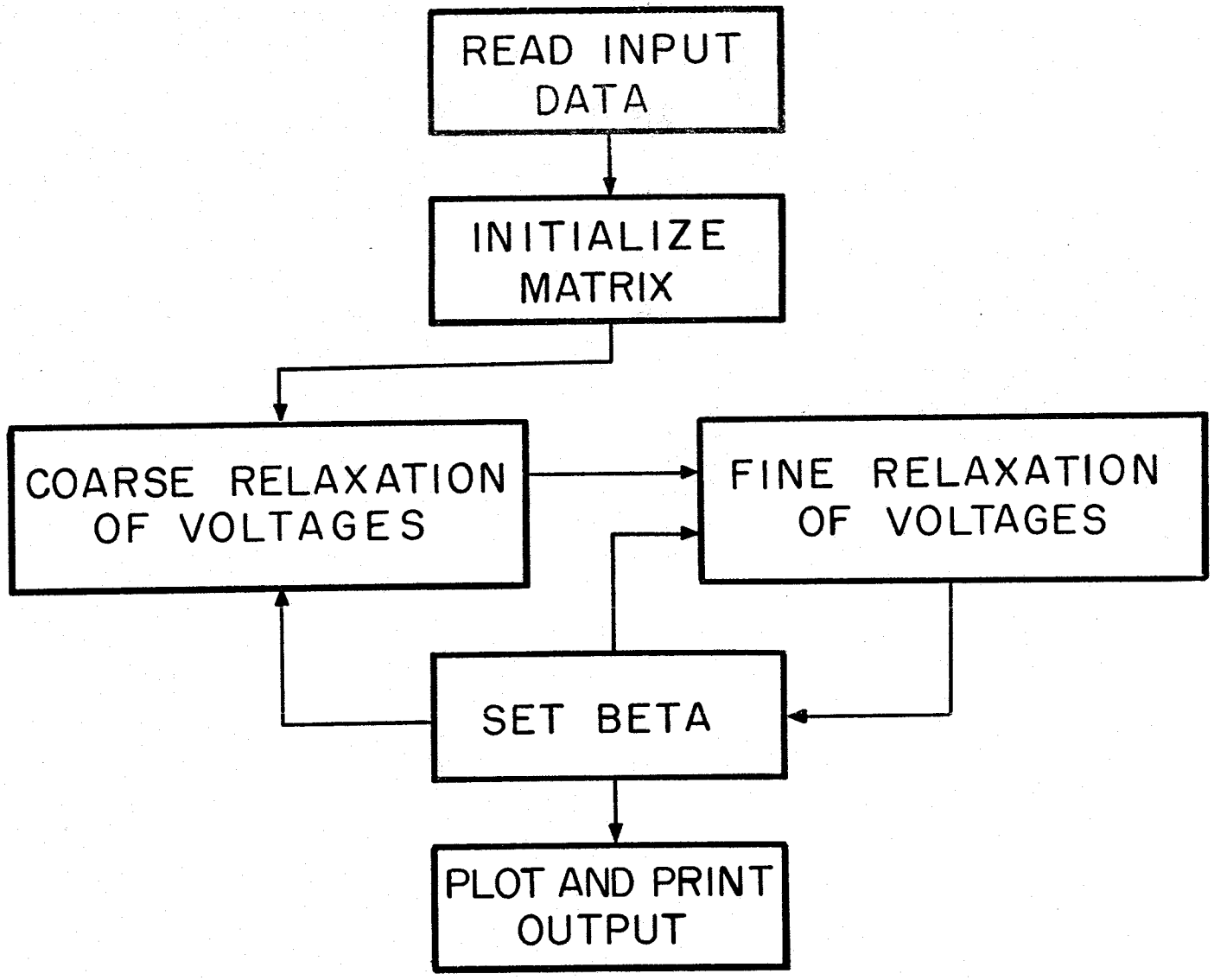

Figure 1. General Flow Chart for Laplace Solution Program

The program listing and input and output data are described in the appendices.

The difference equations employed are derived from Laplace's equation expressed in axisymmetric coordinates

$$\frac{\partial^2 V}{\partial z^2} + \frac{\partial^2 V}{\partial r^2} + \frac{1}{r}\frac{\partial V}{\partial r} = 0 \ . \tag{2}$$

Rectangular coordinates are obtained by letting r become large. The difference equations for a uniform dielectric region are well known:

$$V_{i,j} = \frac{V_{i+1,j} + V_{i,j+1} + V_{i-1,j} + V_{i,j-1}}{4} + \frac{(V_{i,j+1} - V_{i,j-1})\Delta r}{8 r_j} \tag{3}$$

for the general point, and

$$V_{i,j} = \frac{1}{6}\left(4\, V_{i,j+1} + V_{i-1,j} + V_{i+1,j}\right) , \tag{4}$$

for points on the axis, where an array of squares ($\Delta z = \Delta r$) is employed and i, j, r_j, and Δr are described in Fig. 2.

Dielectric interfaces are solved by a powerful technique developed by C. N. Dorny,[2] who employs Gauss' flux theorem

$$-\int_S \epsilon\ V_n dS = Q \tag{5}$$

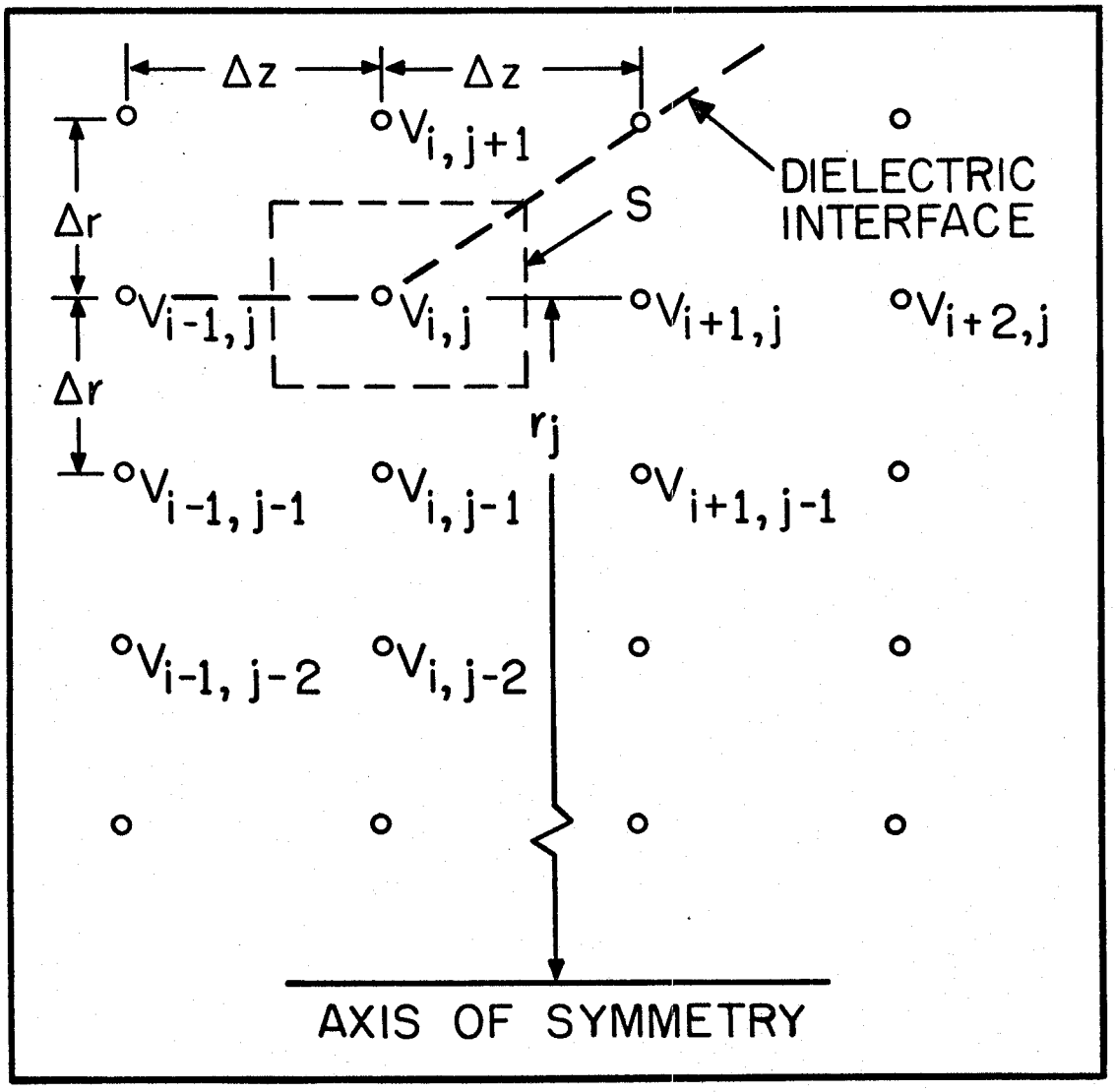

Figure 2. Definition of Terms Used on the Simulation Matrix

for a closed surface S, where V_n is the gradient of V in the direction of the outward normal to S, ϵ is the dielectric constant, and Q the total charge enclosed in S. Integrating this over the surface S in Fig. 2, with ϵ_1, the dielectric below the interface, ϵ_2 the dielectric constant above the interface, $\Delta r = \Delta z$, and Q, the space charge, equal to zero the following can be obtained

$$\left[\frac{\epsilon_1}{2}\left(r_j - \frac{\Delta r}{4}\right) + \frac{\epsilon_2}{2}\left(r_j + \frac{\Delta r}{4}\right)\right]\left(V_{i-1,j} - V_{i,j}\right) + \epsilon_2\left(r_j + \frac{\Delta r}{2}\right)\left(V_{i,j+1} - V_{i,j}\right)$$

$$+ \epsilon_1 r_j\left(V_{i+1,j} - V_{i,j}\right) + \epsilon_1\left(r_j - \frac{\Delta r}{2}\right)\left(V_{i,j-1} - V_{i,j}\right) = 0 \qquad (6)$$

Solving Eq. 13 for $V_{i,j}$ yields

$$V_{i,j} = \frac{\left[\frac{\epsilon_1}{2}\left(1 - \frac{\Delta r}{4r_j}\right) + \frac{\epsilon_2}{2}\left(1 + \frac{\Delta r}{4r_j}\right)\right] V_{i-1,j} + \epsilon_2\left(1 + \frac{\Delta r}{2r_j}\right)V_{i,j+1}}{+ \epsilon_1 V_{i+1,j} + \epsilon_1\left(1 - \frac{\Delta r}{2r_j}\right)V_{i,j-1}}$$

$$\epsilon_1\left(\frac{3}{2} - \frac{5\Delta r}{8r_j}\right) + \epsilon_2\left(\frac{5}{2} + \frac{5\Delta r}{8r_j}\right) \qquad (7)$$

and similar solutions for other dielectric shapes can be easily derived by inspection, as Dorny[2] asserts.

Accuracy of the Program

The difference equations required for the discrete simulation of a second order differential equation on the digital computer are derived from Taylor's series expansion about zero.

$$f(x) = f(o) + xf'(o) + \frac{x^2}{2!} f''(o) + \ldots + \frac{x^n}{n!} f^{(n)}(\alpha x)$$

$$0 < \alpha < 1 . \qquad (8)$$

Assuming a matrix increment h, Eq. 8 can be solved for the first and second derivatives as follows;

$$f'(o) = \frac{f_1 - f_{-1}}{2h} - \frac{h^2}{6} f'''(o) + O(h^4) \qquad (9)$$

and

$$f''(o) = \frac{f_1 - 2f_o + f_{-1}}{h^2} - \frac{h^2}{12} f^{(iv)}(o) + O(h^4) , \qquad (10)$$

where $f_1 = f(h)$, $f_o = f(o)$, and $f_{-1} = f(-h)$. If only the first term on the righthand side of either equation is employed, the error is seen to be the order of h^2.

Results from the computer have indicated that the error in one-dimensional cases is indeed the order of h^2. In two dimensions (as we have here), the error seems to be proportional to h, generally one-half to one-third of h. This gives an error of less than one percent for most interesting cases. Results for cases where the exact solutions are known have generally been within 1/2 percent when a 50 x 50 matrix is employed.

The Computer Program

The iterative procedure consists of applying the difference equations at appropriate points within the area to be analyzed. The matrix consists of a two-dimensional array as shown in Fig. 2. The first subscript (usually I) begins at the left edge of the matrix and increases axially in the +Z direction. The second subscript (usually J) begins at the axis and increases radially. The relaxation operations are generally carried out starting at the left side of the matrix and passing up each column in sequence across the matrix, and then in the reverse direction across the matrix.

This method of computing the potentials requires a knowledge of the locations of electrodes and dielectric interfaces relative to the radial columns. This is accomplished by supplying as input data integer matrices which specify the J coordinates of electrodes and dielectric interfaces. Computations are carried out in each column I from the first matrix J(I,1) to J(I,2), then from J(I,3) to J(I,4), up to seven pairs of matrices. The axis may be included in the computations by specifying appropriate values of J(I,1) as zero. Any finite or infinite offset from the axis may also be specified.

Dielectric surfaces at 45 degrees or less to the axis are specified by setting the upper limit of one of these matrix pairs equal to the lower limit of the next pair; e.g., J(I,2) = J(I,3). Surfaces perpendicular or at steep angles to the axis are treated separately and will be described in detail below.

Floating electrodes are treated as special dielectrics and are specified by separate pairs of matrices in the input data. These are given an initial relative dielectric constant of 101.0 in the input data. This value is automatically increased by the program up to a final value of 100,000 in three steps. The initial relatively low dielectric constant permits the electrode to "float" to the local potential value, then as the dielectric constant is increased the equipotentials inside the electrode are pushed out until the dielectric becomes a unipotential body.

The relaxation procedure is a combination of two over-relaxation methods. The original method alternately relaxed the potentials on a coarse matrix (all the odd-numbered matrix points) and then on a fine matrix consisting of all the points within the configuration. R. Kouzes at NRL combined this with an over-relaxation technique, and substantially improved the speed of convergence of the program.

The method Kouzes developed consists of three cycles each consisting of several hundred iterations. In the first cycle, the potentials are alternately relaxed on the coarse and fine matrices with an over-relaxation factor (β - typically 1.8), e.g.,

$$V_{n+1} = (V_{new} - V_n) \cdot \beta + V_n$$

where V_n is the value on the n^{th} iteration. In the second cycle, β is reduced halfway to 1.0, e.g., $\beta_{new} = (\beta_{old} + 1)/2$, and the relaxation is carried out only over the fine matrix. In the third cycle, β is reduced to 1.0. If floating electrodes are present, three additional cycles are carried out with the relative dielectric constant of the metal increased to 1000, 10,000, and finally 100,000.

If equipotential plots are desired, up to 24 equipotentials to be plotted are specified in the input data. In addition to an overall plot, expanded plots of sections of the matrix can be obtained by specifying the desired sections in the input data.

The equifield plots are obtained in a similar manner, but the field values plotted are determined automatically by the program since it is generally impossible to know the values desired ahead of time. The values and plots must be interpreted fairly carefully, since there will be discontinuities in the field at dielectric and electrode boundaries.

Data may be saved by the blowup subroutine to permit analysis of small sections of a larger plot. This routine saves the boundary data for the section to be expanded and interpolates for the intermediate values. The data so saved can be used by the main program to resolve the problem and obtain greater resolution.

Input Data

Input data to the program consists of five groups of data. These control the flow of the program, set dielectric constants, define the configuration, set voltages, and determine the plotting by the program.

Flow is controlled by integers on the first card. These integers are:

MM	The number of passes through the matrix in the relaxation process, generally 200 or more.
NVEM	The number of points which may still be in error at convergence, generally 2.
NZ	The axial length of the matrix to be employed in the analysis, 201 or less (as the program is listed in Appendix C).
NR	The radial extent of the matrix to be employed, 201 or less (as listed in Appendix C). It is desirable (but not necessary) that NR end in 1 for plotting purposes.
NRO	The radial offset of the matrix in matrix square lengths (Δr), zero if the axis corresponds to the bottom edge of the matrix, 9999 for rectangular configurations.
MU	Controls the saving and restoring of data on magnetic tape: 1. Neither saves nor restores data. 2. Saves data. 3. Restores and saves data. 4. Restores data but does not save. If electric fields and/or expanded accuracy computations are desired, this must be 2 or 3.

JJV(1),...,JJV(7), IVER,IHOR,LOG	Control potential setting (see below).
IRN	The number of the data set on tape to be restored.
IPD	If equal to zero, normal printout is obtained; if one, the voltage matrix is not printed.

On the next two cards convergence criterion and dielectric constants are set. EPSV is the maximum fractional change that may occur at a converged matrix point. If the change in potential from one pass to the next is greater than EPSV, the point is considered to be in error. A typical value for EPSV is 0.0001 or less.

The second number on this card is BETA, the over-relaxation constant. 1.8 seems to be an acceptable value for this number, but is not necessarily an optimum. Optimized values for Beta can be determined using methods developed by Sheldon.[3]

The last six numbers plus the first number on the next card are the relative dielectric constants between the seven possible pairs of matrices available. All seven values must be read, but constants corresponding to unused pairs of matrices may be left zero (or blank). If there are no dielectric interfaces, all these values may be left zero or blank.

The number of radial interfaces is specified on the next card by IDI. The maximum number of interfaces is 47 as the program is listed in Appendix C.

The second number on this card is METAL. This is the number of pairs of matrices for describing floating electrodes to be read (see below).

The relative dielectric constants (EPV) across the vertical interfaces are then listed. The first two values are to the left and right of the first interface. The second and third values are to the left and right of the second interface. The third and fourth values are to the left and right of the third interface, etc. Note that there will be one more constant listed than

there are actual interfaces. It may also be necessary to have "dummy" interfaces (see below) to make the dielectric constants come out right.

The interfaces are specified in detail on the ID matrix, each interface being described by a sequence of four numbers. The first number in the sequence specifies the type of boundary at the lower and upper ends of the column. The possible boundary conditions are shown in Fig. 3. The six numbered lines at the bottom and top of the interface are the only possible directions a dielectric boundary can take. Numbers (from 0 to 6) are used to tell the program the type of boundary to compute. The boundary conditions are given by a 4-digit number, the first two digits specify conditions at the lower limit and the last two digits specify conditions at the upper limit. A metallic boundary is given by the value zero, and the six possible dielectric configurations are shown in Fig. 3. Examples will be given in the sample plot discussion.

The next three numbers give the location of the interface. The first of these numbers is the column I, and the last two are the lower and upper J coordinates, respectively.

This sequence of 4 numbers is repeated for all such interfaces.

The electrode (and dielectric) configuration is specified by the integer matrices described above. Some restrictions and requirements will be listed here. As described above, dielectric interfaces sloping at 45 degrees or less to the axis or lower edge of the matrix are specified by making the upper limit matrix values, e.g., J(I,2), the same as the next lower limit matrix, e.g., J(I,3). Steeper interfaces must employ the radial interface technique described above. Also any electrode sloping at 45 degrees or less to the axis must be at least one matrix square thick.

The normal procedure in relaxing the potentials is to compute the matrix starting at J(I,1), proceeding up the column to J(I,2), then from J(I,3) to

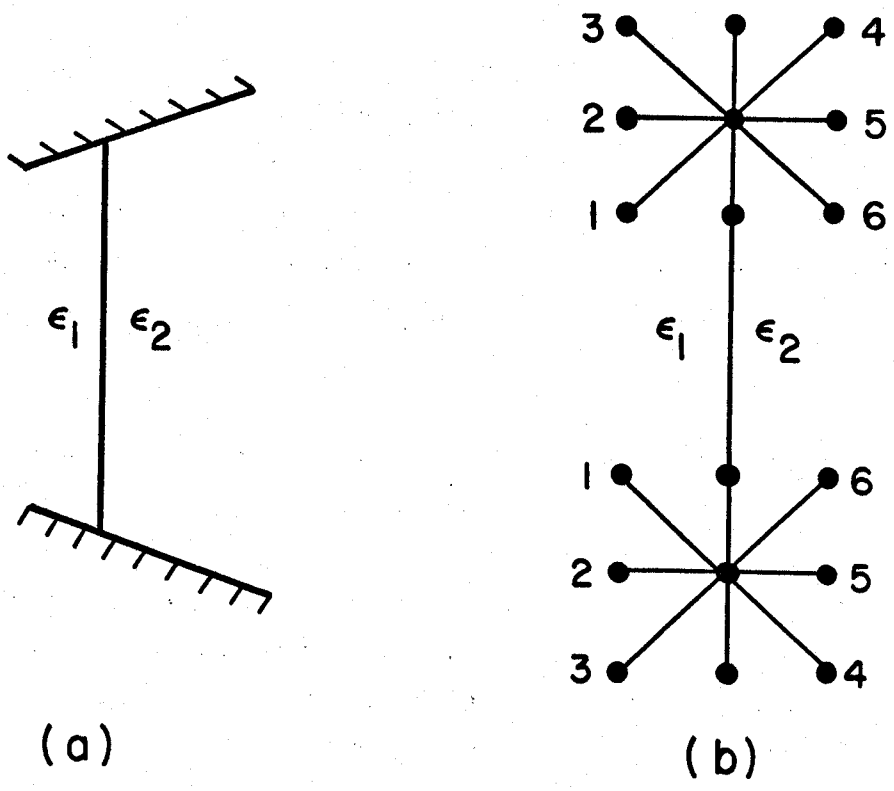

Figure. 3. Types of Possible Boundary Conditions at the Top and Bottom of a Vertical Dielectric Interface; a, metallic boundaries; b, dielectric boundaries

J(I,4), etc. If any of these pairs is zero, it will be skipped. The reason for skipping a pair would be to obtain the proper dielectric constants at a dielectric interface.

Floating electrodes are described by the JM matrices. The matrix JM(I,1) describes the lower edge of a floating electrode and JM(I,2) the upper edge. These numbers are selected from inside the electrode, i.e., JM(I,1) is selected by looking down the column I at the first metallic edge seen. Points on fixed potential electrodes are selected by the same procedure looking from outside the metal. This will be further discussed in the sample plot. More than one floating electrode may be simulated on a pair of matrices but they must not overlap radially, overlapping electrodes must be put on separate pairs of JM matrices. The number of pairs of JM matrices read is given by METAL (see above).

The potentials on the electrodes and boundary points are set by the next section of the data. Nonzero potentials are set along the lower and upper surfaces of fixed potential electrodes within the configuration. For each potential along each section of the electrode, the potential can be set by specifying the integer matrix to be used to store the potentials, the lower and upper I limits, and the potential to be stored. The number of potentials to be set are specified by the JJV matrix on the first card. Two numbers are again combined into each 4-digit JJV value, the first two digits refer to J(I,1), and the last two J(I,2), similarly JJV(2) refers to J(I,3) and J(I,4), etc. If no potentials need to be set on a particular matrix, the number should be zero. If n pairs of the J matrices are employed, the n+1'th value of JJV must be -1.

Potentials within electrodes and on vertical (radial) surfaces will be set automatically, provided the potentials on the top and bottom surfaces are set correctly.

Linearly and logarithmically varying voltages may be set along vertical (radial) lines and linearly varying voltages may be set along horizontal (axial) lines. The number of vertical linear potentials is given by IVER, the number of logarithmical voltages by LOG, and the number of axial linear potentials by IHOR all on the first data card (see above).

The first group of these data cards set the vertical linear distribution. On each card are given I, the column number; JL, the lower J limit; JH, the upper J limit, VSL, the voltage at (I,JL); and VSH, the voltage at (I,JH). The second group is identical in form to the first but sets logarithmic potentials. The last group read sets horizontal linear distributions and has IL, the left "I" coordinate; IH, the right "I" coordinate; J, the row number; VSL, the voltage at (IL,J); and VSH, the voltage at (IH,J). Note that the potentials of all boundary points (with the possible exception of the axis) must be set by the input data. Under some circumstances potentials at the bottom edge of the matrix on an electrode must be set.

If MU (see above) is 2 or 3, the numbers IBU and IEF which control the blowup routine for improved resolution and the electric field plotting routine will be read. IBU is the number of areas to be recomputed for greater resolution. In the context of this report, blowup will always refer to this re-solving of the configuration on a finer mesh. If IBU is zero, no blowups will be made. If IEF is one, the electric field will be plotted and, if it is 2, the square of the field will be plotted.

If IBU is one (or larger) the next card (or cards) must contain the blowup factor (IEX), and the limits of the area to be blown up (IL, IH, JL, JH; the left and right, bottom and top coordinate respectively). There must be as many cards as IBU calls for. The actual blowup recomputation is carried out later.

If IEF is one or two, the next cards must specify the sections of the electric field matrix to be plotted on an expanded scale. These sections must be square and are specified by giving IL, IH, JL, JH the left and right, bottom and top coordinates, respective. Up to ten expanded plots may be made, the last of these cards should be blank.

The next group of cards gives the information needed for plotting equipotentials and are read regardless of the value of MU. If an equipotential plot is desired, the potentials desired are listed on the next three cards. Up to 24 values may be plotted, if fewer are desired they must be listed consecutively. If the zero equipotential is desired, a value such as 0.0001 can be used.

If it is desired to expand any square areas of the plot, it is necessary to specify these areas on up to 10 cards giving the left and right, bottom and top coordinates on consecutive cards.

The data set is terminated with one blank card. The program may be terminated by 3 additional blank cards, or any number of additional data sets may be added. The last data set must be terminated with a total of 4 blank cards.

Sample Plots

Figure 4 shows a proposed design of the insulators for a high voltage diode. To the upper left is a coaxial transmission line with transformer oil insulation having a relative dielectric constant of 2.14. The vacuum interface insulators are lucite with a relative dielectric constant of 3.0. Between insulators are metallic rings to help in grading the structure. The area to the right of the insulators is vacuum with a relative dielectric constant of 1.0. The axis of symmetry corresponds to the lower edge of the figure.

Figure 5 is the complete equipotential plot for this design. Equipotentials are plotted at 5 percent intervals. Note that the 25, 50 and 75 percent

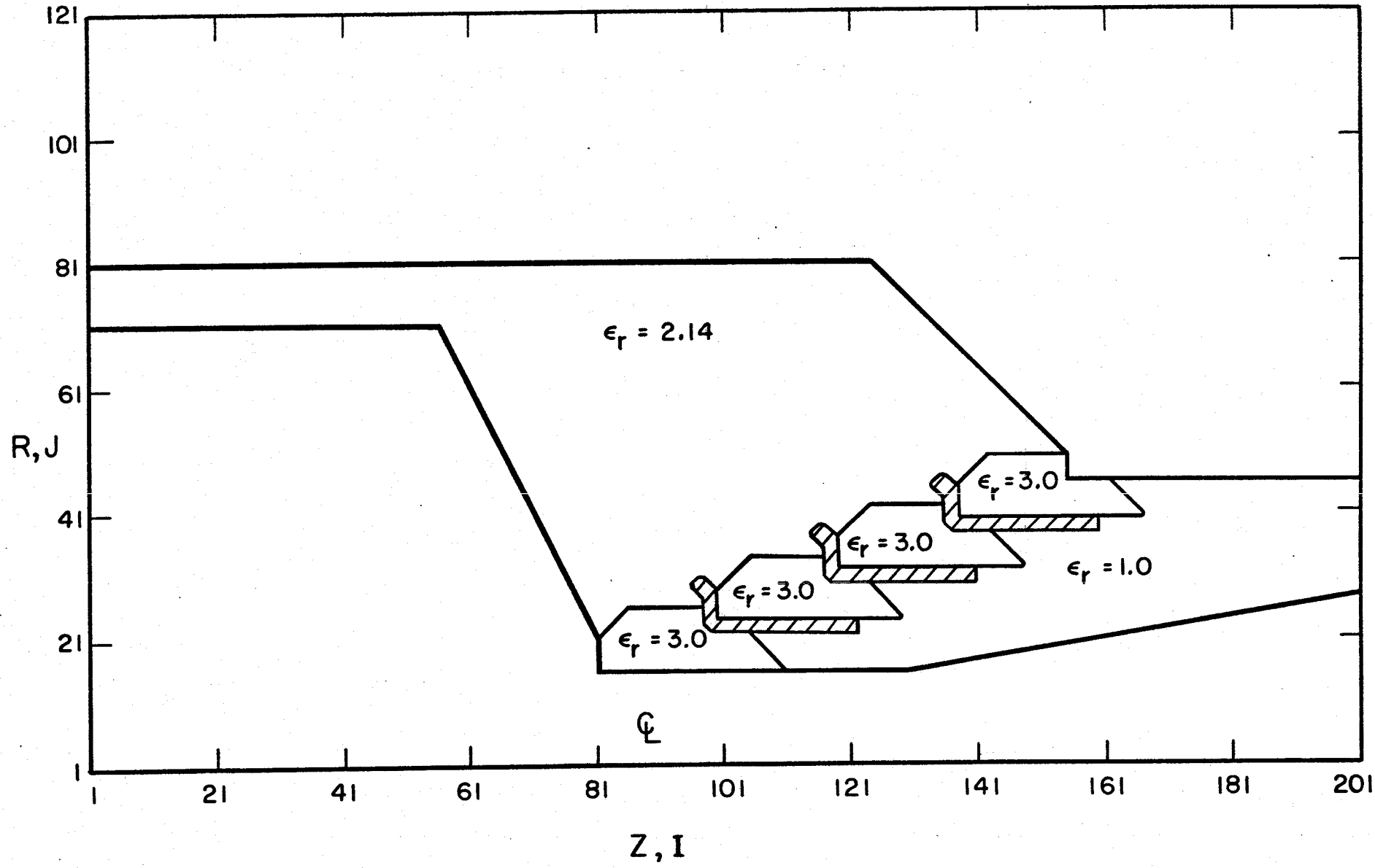

Figure 4. Initial Proposed Insulator Design for Low-inductance, High-voltage Diode

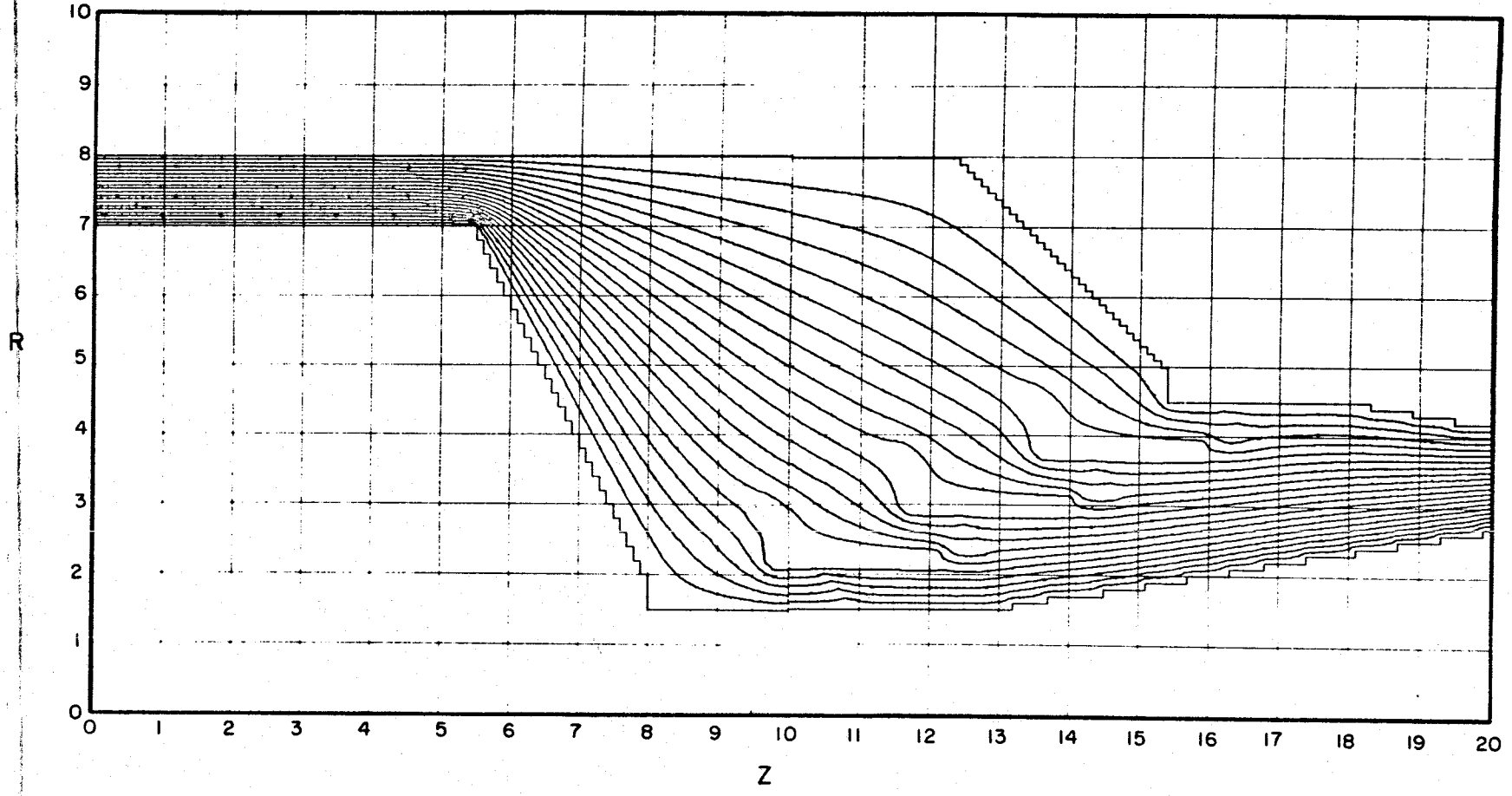

Figure 5. Equipotentials for Each Five Percent of the Voltage Across the Insulators

lines lie on or very near the metallic rings indicating nearly perfect grading across the insulators. It should also be noted that the equipotentials drop out of the bottom of the insulators near the pointed edge so that the holdoff capability would most likely be poor.

Figures 6 and 7 are slightly expanded plots of the insulator section.

Figure 8 and 9 are plots of the equifield lines. Figure 8 is the raw plot from the computer and Fig. 9 is the interpretation of the lines accounting for discontinuities at dielectric and metallic surfaces. Note the high field region in the oil where the inner cylinder bends sharply.

A detailed description of the input data for the above plots is given in Appendix A. A sample plot including the use of the blowup routine is also presented there.

An improved version of the insulator section is shown in Fig. 10 where a fifth insulator has been added and the grading rings extended past the tip of the insulators. Note that the peak field in the oil has also been reduced by smoothing the bend in the cylinder.

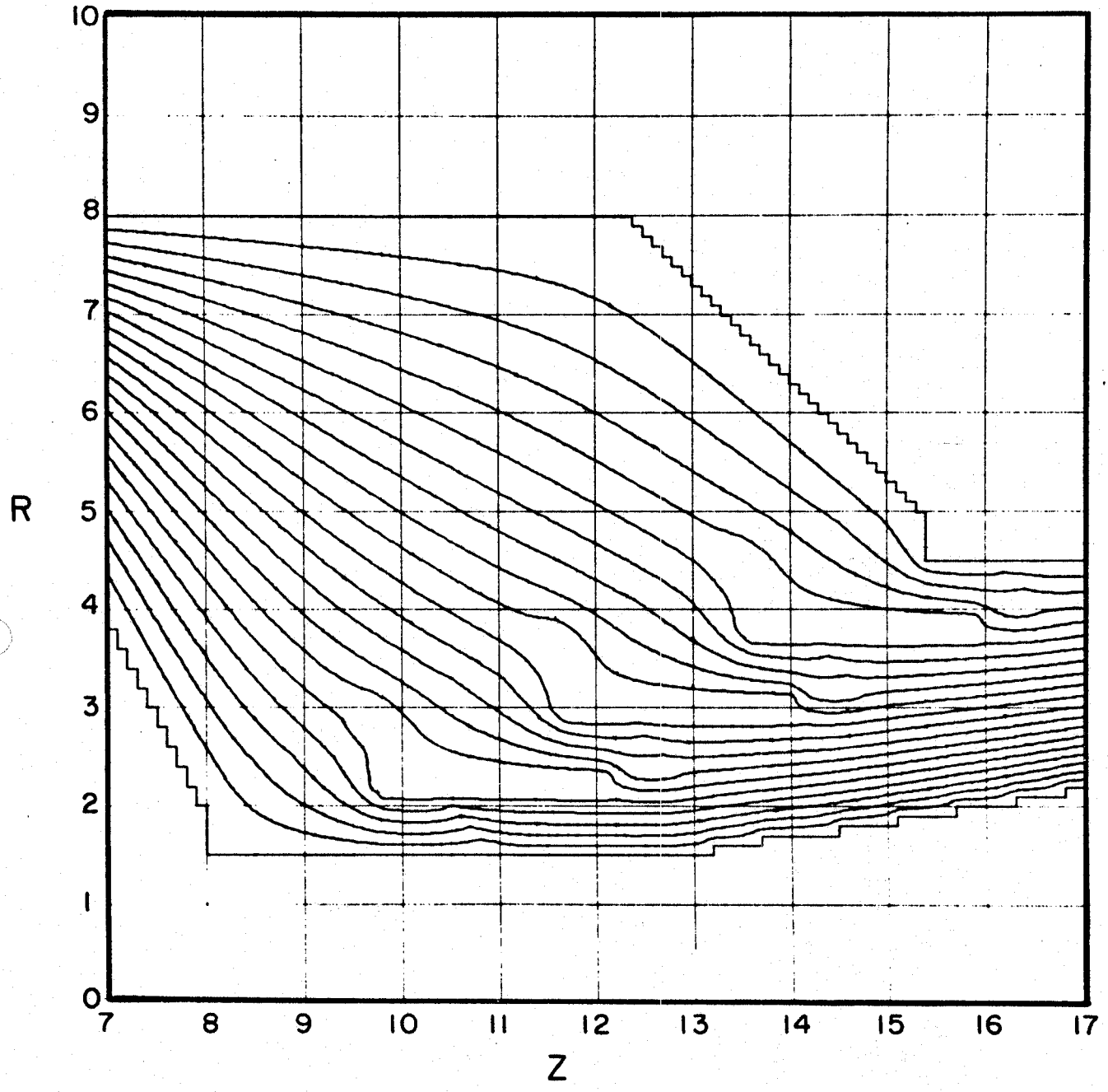

Figure 6. Blowup of the Insulator Section of the Equipotential Plot

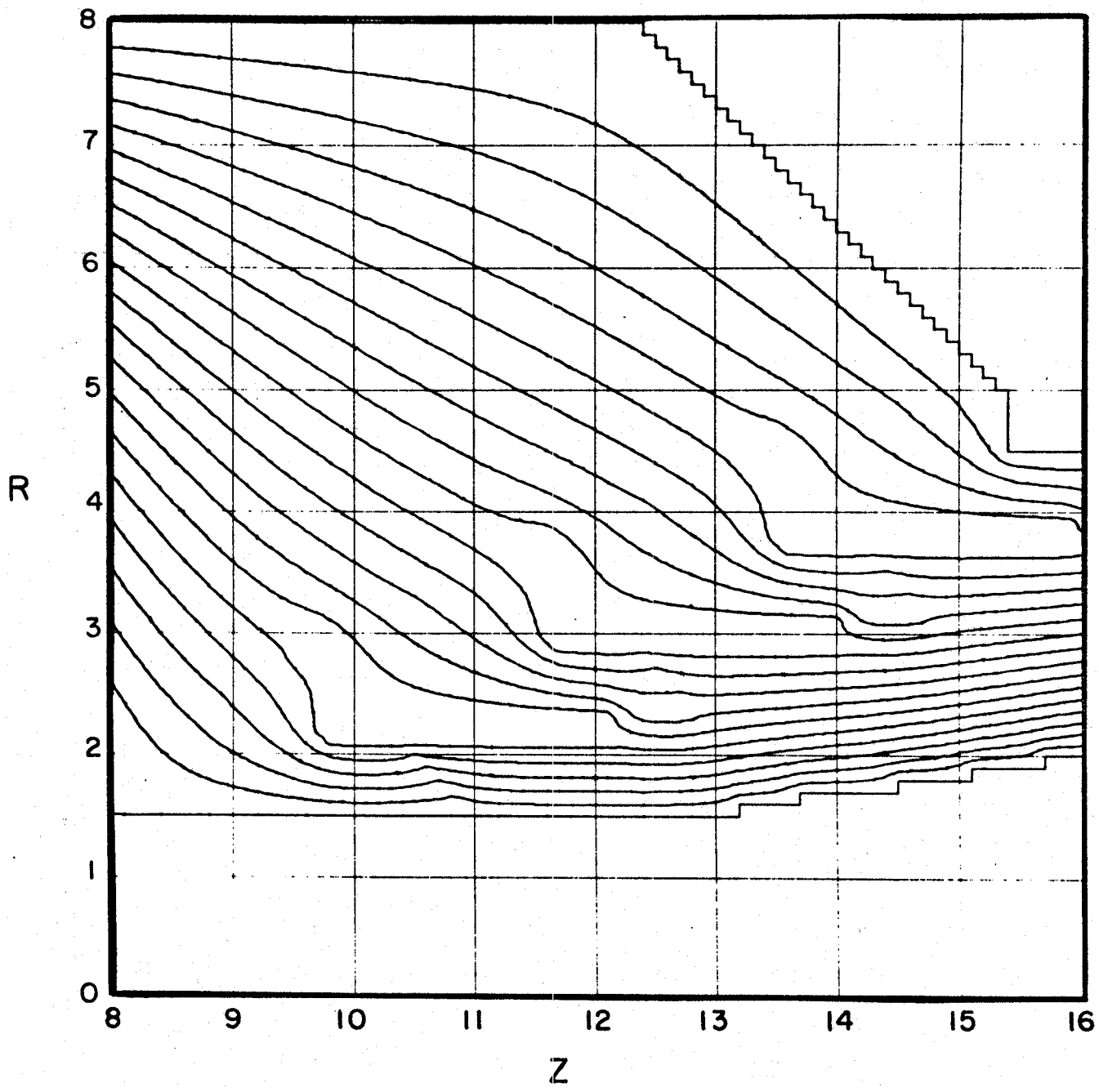

Figure 7. Further Blowup of the Insulator Section

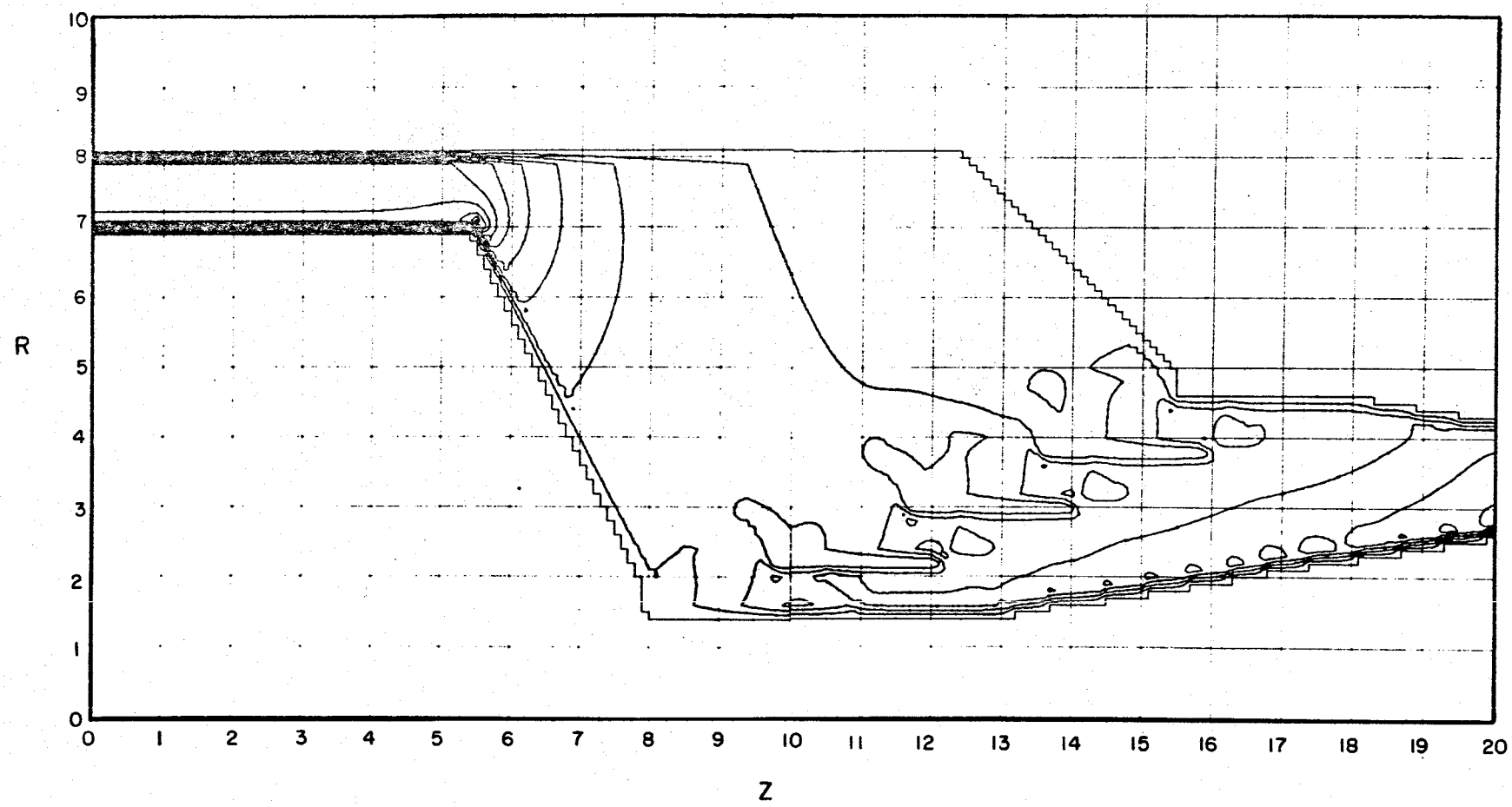

Figure 8. Equifield Plot for the Insulators of Fig. 4

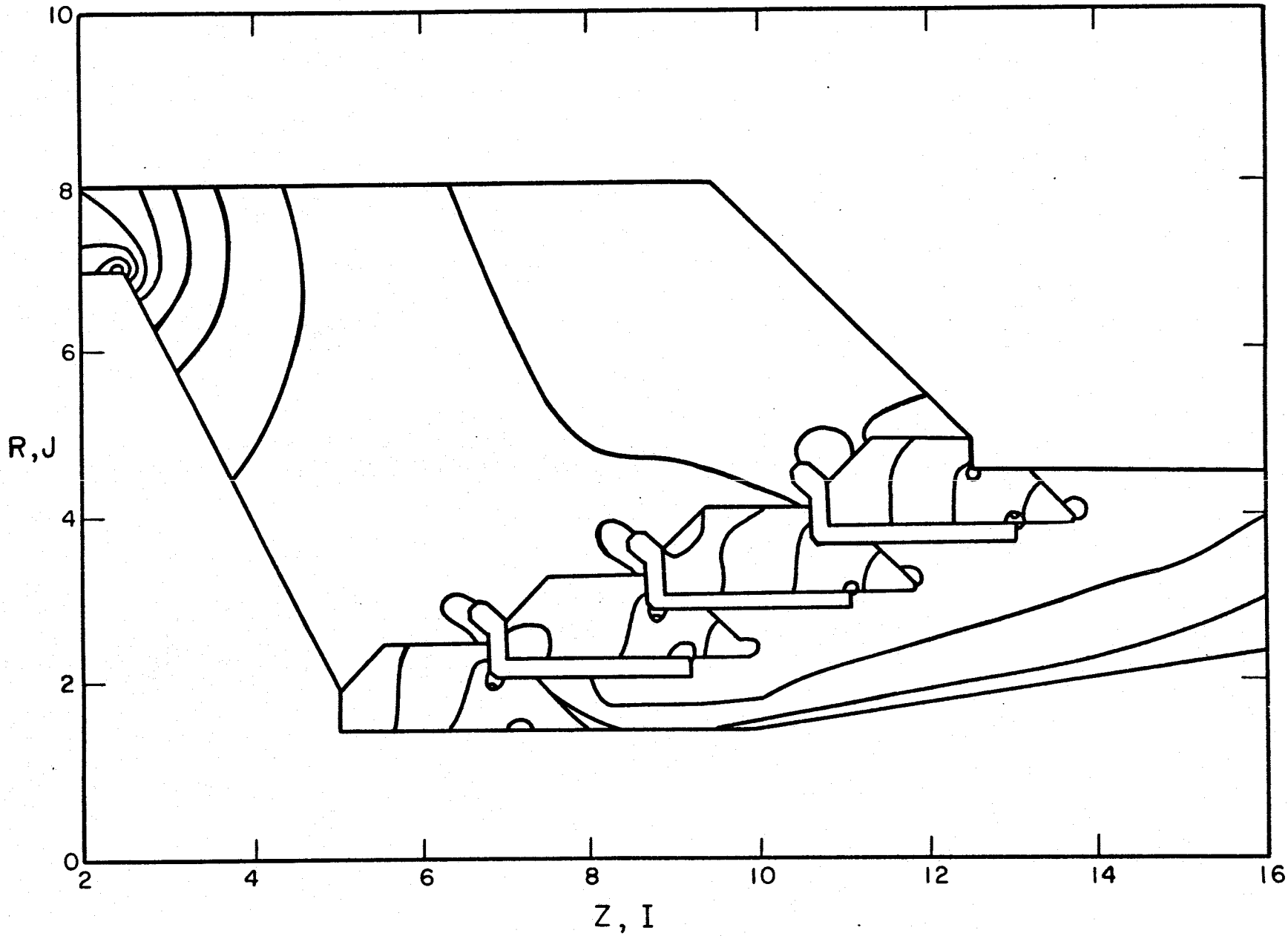

Figure 9. Interpretation of Equifield Lines Shown in Fig. 8, accounting for discontinuities in electric fields at dielectric boundaries and electrodes

References

1. Richard Kouzes; private communication.

2. C. N. Dorny, Proc. IEEE (Letters), Vol. 57, May 1969, pp. 856-858.

3. J. W. Sheldon, Iterative Methods for the Solution of Elliptic Partial Differential Equations, Mathematical Method for Dig. Computer Ed., by A. Ralston and H. S. Wilf Wiley, 1962.

APPENDICES

Appendix A

Sample Data Sets

Two data sets will be presented in this appendix, one will be described in detail. The data set shown in Table I describes the configuration of Fig. 4 to the program. Each card (or group of cards) will be described in some detail.

The data on the first card are:

MM=300	The maximum number of passes through the voltage matrix during each of the six relaxation cycles. (Three cycles if there are no floating electrodes.)
NVEM=2	The maximum number of errors to be left in the potential relaxation at convergence.
NZ=201	The number of axial matrix points employed.
NR=101	The number of radial matrix points employed. The actual maximum could be 81, but 101 produces a more manageable plot.
NRO=0	The structure is axisymmetric about the lower edge of the matrix.
MU=2	Data are to be saved for an equifield plot (see below).
JJV(1)=1	One potential is to be set along J(2), none are set along J(1).
JJV(2)=1	One potential set along J(4), none along J(3).
JJV(3)=0	No potentials are set along J(5) or J(6).
JJV(4)=3	Three sections of potentials are set along J(8), none along J(7).
JJV(5)=1	One potential is set along J(10), none along J(9).
JJV(6)=1	One potential is set along J(12), none along J(11).
JJV(7)=-1	Matrices J(13) and J(14) are not needed.
IVER=14	Fourteen linearly varying potentials are set in radial columns.
IHOR=8	Eight linearly varying potentials are set in axial rows.
LOG=2	Two logarithmically varying potentials are set in radial columns.

TABLE I

Listing of Input Data Required for the Configuration Shown in Fig. 4

```
300    2 201 101    0    2 001 001 000 003 001 001   -1   14    8    2    0    0
 0.00004        1.8         1.0         3.0         1.0         3.0        2.14        2.14
      0.0
 23    2
 2.14 101.0    3.0 101.0    3.0 101.0    3.0  2.14 101.0  2.14 101.0    1.0
101.0    1.0 101.0    1.0    3.0    1.0    3.0    1.0    3.0    1.0    3.0 101.0
404  96  29  30 503 100  24  29 403 117  31  35 503 119  32  37 403 136  39  43
503 138  40  45                404 115  37  38                404 134  45  46
202 122  22  24                202 141  30  32                202 160  38  40
                203 129  24  25                    203 148  32  33
203 167  40  41                403  98  23  27
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81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81
81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81
81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81
81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81
81                                                          0
 0                                                       22 22
22 22 24 24 24 24 24 24 24                           30 30 30
30 32 32 32 32 32 32 32                    38 38 38 38 38 38
40 40 40 40 40 40 40 46 46 46 46 46 46 46 46 46 46 46 46 46
46 46 46 45 45 45 45 45 45 44 44 44 44 44 44 43 43 43 43 43
43
 0  0                                                       0
 0                                                          0
 0                                                          0
 0                                                          0
 0                                                          0
16 16 16 16 16 16 16 16 16 16                           24 24
24 24 24 24 24 24 24 24                              32 32 32
32 32 32 32 32 32 32                       40 40 40 40 40 40
40 40 40 40 40 40                                          0
 0                                                         0
 0
 0  0                                                      0
 0                                                         0
 0                                                         0
 0                                                         0
 0                                                         0
22 22 22 22 22 21 20 19 18 17                           30 30
30 30 30 30 29 28 27 26                              38 38 38
38 38 38 37 36 35 34                       46 46 46 46 46 46
```

Table I continued

46	46	45	44	43	42															0
0																				0
0																				
0	0																			
0																				0
0																				0
0																				0
0																				0
0					21	20	19	18	17	16	16	16	16	16	16	16	16			0
0				29	28	27	26	25	16	16	16	17	17	17	17	17				0
0			37	36	35	34	33	19	19	19	20	20	20							0
0		45	44	43	42	41														0
0																				0
0																				
0	0																			0
0																				0
0																				0
0																				0
0																				0
0					22	22	22	22	22	22	22	22	22	22	22	22	22			0
0				30	30	30	30	30	30	30	30	30	30	30	30	30				0
0			38	38	38	38	38	38	38	38	38	38	38							0
0		46	46	46	46	46														0
0																				0
0																				
0	0																			0
0																				0
0																				0
0																				0
0	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24			32
32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32			40	40
40	40	40	40	40	40	40	40	40	40	40	40	40	40							0
0																				0
0																				0
0																				
0	0																			0
0																				0
0																				0
0																				0
0	22	23	24	25	26	26	26	26	26	26	26	26	26	26	26	26	23	22	22	
30	31	32	33	34	34	34	34	34	34	34	34	34	34	34	34	31	30			38
39	40	41	42	42	42	42	42	42	42	42	42	42	42	42	39	38			46	47
48	49	50	50	50	50	50	50	50	50	50	50	50	50							0
0																				0
0																				0
0																				
0	0																			0
0																				0
0																				0
0																				0
0	22	23	24	25	26	26	26	26	26	26	26	26	26	26	26	26	31	30	29	
30	31	32	33	34	34	34	34	34	34	34	34	34	34	34	34	39	38	37	38	
39	40	41	42	42	42	42	42	42	42	42	42	42	42	42	47	46	45	46	47	

Table I continued

48	49	50	50	50	50	50	50	50	50	50	50	50	50					0
0																		0
0																		0
0																		
0	0																	0
0																		0
0																		0
0																		0
0	81	81	81	81	81	81	81	81	81	81	81	81	81	81	29	28	81	81	81
81	81	81	81	81	81	81	81	81	81	81	81	81	81	37	36	81	81	81	81
81	81	81	81	80	79	78	77	76	75	74	73	72	45	44	69	68	67	66	65
64	63	62	61	60	59	58	57	56	55	54	53	52	51						0
0																			0
0																			0
0																			
0	0																		0
0																			0
0																			0
0																			0
0															30	31			0
0														38	39				0
0													46	47					0
0																			0
0																			0
0																			0
0																			
0	0																		0
0																			0
0																			0
0																			0
0															81	81			0
0														81	81				0
0													71	70					0
0																			0
0																			0
0																			0
0																			
0	0	0	0																0
0																			0
0																			0
0																			0
0																			0
0															29	28	27	22	22
22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
22	22												45	44	43	38	38	38	38
38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
0																			0
0																			0
0																			
0	0	0	0																0
0																			0
0																			0
0																			0
0															30	31	31	30	24
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

Table I continued

```
24 24                                                    46 47 47 46 40 40 40
40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40
 0                                                                        0
 0                                                                        0
 0
 0  0                                                                     0
 0                                                                        0
 0                                                                        0
 0                                                                        0
 0                                                                        0
 0                                                       37 36 35 30 30 30
30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30
30                                                                        0
 0                                                                        0
 0                                                                        0
 0
 0  0                                                                     0
 0                                                                        0
 0                                                                        0
 0                                                                        0
 0                                                                        0
 0                                                       38 39 39 38 32 32
32 32 32 32 32 32 32 32 32 32 32 32 32 32 32 32 32 32 32 32
32                                                                        0
 0                                                                        0
 0                                                                        0
 0
168 201       1.0
155 166       1.0
 82 118      0.25
120 137       0.5
139 154      0.75
121 154       1.0
134 135       1.0
 96  16  81        0.0        1.0
 98  16  81        0.0        1.0
100  16  81        0.0        1.0
115  16  81        0.0        1.0
117  16  81        0.0        1.0
119  16  81        0.0        1.0
122  16  81        0.0        1.0
129  16  76        0.0        1.0
134  17  71        0.0        1.0
136  17  69        0.0        1.0
138  18  67        0.0        1.0
141  19  63        0.0        1.0
148  19  57        0.0        1.0
160  22  45        0.0        1.0
  1  71  81        0.0        1.0
201  28  43        0.0        1.0
  1 201  81        1.0        1.0
163 167  46        1.0        1.0
 91 130  22        0.2        0.2
 91 131  24       0.25       0.25
```

Table I continued

```
111  141   30        0.5        0.5
111  151   32         .55       0.55
131  165   38       0.75        0.75
131  171   40       0.75        0.75
  0    1
 71  171    1  101

  0.0001       0.05        0.1        0.15        0.2        0.25        0.3        0.35
     0.4       0.45        0.5        0.55        0.6        0.65        0.7        0.75
     0.8       0.85        0.9        0.95     0.9999
 71  171    1  101
 81  161    1   81


     END
```

IRN=0	The data to be saved will be under the restore number zero.
IPD=0	The voltage matrix is to be printed.

The second data card gives the error limit on the voltage computation as 0.004 percent, the limit is smaller than usual because of the floating electrodes. The over-relaxation factor BETA is given as 1.8. The dielectric constants between consecutive pairs of matrices are 1.0, 3.0, 1.0, 3.0, 2.14, and 2.14; the constant for the seventh pair of matrices is not needed since only six pairs of matrices are employed.

The fourth card specifies 23 vertical dielectric interfaces. The makeup of these interfaces will be discussed below. The constant METAL is also on this card and is 2, calling for two pairs of matrices for the description of floating electrodes.

The next two groups of data to be read describe the vertical dielectric interfaces. The first group gives the relative dielectric constants to the left and right of each interface and second group describes the type and location of each interface.

The EPV matrix is used to store the relative dielectric constants; EPV(1) and EPV(2) will be to the left and right, respectively, of the first interface, EPV(2) and EPV(3) will be to the left and right, respectively, of the second interface, etc. Floating electrodes in the simulation are treated as dielectrics with (initial) relative dielectric constants of 101.0. Some of these will be discussed here.

The first interface is described by the dielectric constants 2.14 and 101.0 and the four numbers 404, 96, 29, 30. This interface is in column 96 and extends from J=29 to J=30, which is seen to be the left-most edge of the metal grading ring. The first part of 404 is 4 so that the lower end of this interface slopes down to the right at 45 degrees and the second part (also 4 in this case) means the interface slopes upward to the right at the top end. These numbers correspond to those given in Fig. 3. The relative dielectric

constant of 2.14 corresponds to that of the oil on the left of the interface, and the constant 101.0 is the initial value which is always given to floating electrodes.

The second interface is specified by the constants 101.0 and 3.0 and the integers 503, 100, 24, 29. This is in column 100 between J=24 and J=29. This is seen to be the inner surface of the metallic grading ring. At the bottom of this column, the interface goes to the right giving the value 5 (from Fig. 3) in the 503. At the top of the column there are three dielectrics (the grading ring is being considered as a dielectric in this case) but the program can handle only two dielectrics. In this case the 2.14 of the oil and 3.0 of the lucite are fairly close in value while the grading ring is being treated as having the value 101.0, so the best approximation that can be made is to follow the metallic interface which gives the number 3 (from Fig. 3) for the top end of this interface.

The third interface is in column 117 from J=31 to J=35. Here again there is a point, this time on the interface, where three surfaces come together. Again the two constants, 2.14 and 3.0, are close in value, while the metal with the initial value of 101.0 is quite different. The value of 3.0 is employed since most of the dielectric to the left has that value. The bottom and top values are 4 and 3, respectively, representing a slope down to the right from the bottom and up to the left from the top.

The fourth, fifth, and sixth columns are similar to one of the above, but the seventh interface calls for the relative dielectric constant 3.0 to be on the left. In this case it was desired to complete the left most tips of the grading rings where the oil dielectric is present. To obtain the proper relative dielectric constant, one interface is left blank, and the next constant is set to 2.14. The eighth interface can now be the oil-to-metal values. Note that a total of eight "dummy" interfaces are left blank.

The remaining interfaces are determined in a similar manner using Fig. 4.

The next data to be read are the integer matrices which describe the configuration to be simulated. The procedure to be used depends on the type of simulation to be carried out. If there is only one dielectric in the region to be analyzed, considerable less care need be taken in selection of matrices than is required for an analysis with several dielectrics.

For an anlysis with several dielectrics (and floating electrodes) as we have here, great care must be taken in the selection of matrices to be sure the correct dielectric boundaries are formed. First, the number of pairs of matrices needed to describe the dielectric regions (without considering any floating electrodes) must be determined. In this case consider the column at I=126; starting at the inner metallic surface the dielectrics are seen to be vacuum, lucite, vacuum, lucite (ignore metals), and oil. If we look at column 135 two oil regions, inside and outside, the tip of the grading rings are needed. A total requirement of 6 pairs of matrices can be seen (vacuum, lucite, vacuum, lucite, oil and oil).

The center metallic grading ring can be seen to overlap (radially) the other two grading rings but that the outer grading rings do not overlap each other. Thus it is possible to simulate the inner and outer rings on one pair of matrices, and the center ring on a second pair of matrices, so that two pairs of floating electrode matrices are needed. This determines the input constant METAL discussed above.

The rules for deciding which matrix corresponds to which surface are very strict. For a dielectric interface at 45 degrees or less to the axis, the dielectric constant of the pair of matrices below the interface must be that of the dielectric there and the dielectric constant above the interface must correspond to that between the next pair of matrices. If floating electrodes are present, the dielectric constants of adjoining dielectric areas must be correct or the result could be inaccurate.

It should be remembered that the dielectric constants are important only on the interfaces. If an area is made up of only one dielectric, e.g., a vacuum, its dielectric constant is irrelevant.

In the example described here, the dielectric constant between I=1 and 81 and between I=168 and 201 is irrelevant; between 82 and 167 the dielectric constants are critical. As was described above, the relative dielectric constant between the first pair of matrices is 1.0 (vacuum). The first pair of matrices starts at I=1 and extends to I=81, a single dielectric region. The next section starts at I=119 and extends through I=129, the first region that requires a vacuum dielectric and has two lucite sections above it. A similar sort of region occurs between I=138 and 148. A section with one or no lucite sections starts at I=155 and extends to 201.

Note that in all of the above, if one looks out radially from the lower J value (J1), the first surface seen (be it metal, lucite, or floating electrode) is J2.

The second pair of matrices (J3 and J4) covers all regions of the lucite where there is either a second lucite region (radially beyond this region) or there is no other dielectric beyond or only a vacuum dielectric region exists beyond this lucite. The first such region extends from I=100 to 109 where the inner and outer coordinates of the first lucite insulator are given. The remaining sections of J3 and J4 cover the corresponding regions of the other lucite insulators.

The fifth and sixth matrices cover the vacuum dielectric area between the two lucite dielectrics and the regions where there is only a vacuum within the lucite insulator section.

The J7 and J8 matrices cover all the lucite regions that are adjacent to the oil dielectric. This is necessary since the next pair of matrices, J9 and J10, cover an oil dielectric and dielectric interfaces must be consecutive, e.g., J8(I) must equal J9(I) on the interfaces.

J11 and J12 cover the small oil regions outside the metallic grading rings near I=97, 116, and 135.

Two floating electrode matrices are employed for simulation of the grading rings. More than one floating electrode may be simulated on one pair of matrices, but they must not overlap. In this case the center ring overlaps both of the other rings but the two outer rings do not overlap each other. Therefore the outer rings can be put on one pair of matrices and the center ring on a second pair of matrices.

Note that the J coordinates must be selected properly. They are the coordinates of the ring as seen from inside the metal. Note that at I=98, JM1(98)=27 the top (inside end) of the straight rear edge of the ring. Similarly, in column 100 JM2(100)=24, the lower end of the vertical ring surface. There are no restrictions on the shape of these electrodes but it must be remembered that the vertical (radial) surfaces must be handled as special dielectric interfaces with dielectric constants of 101.0 within the metal.

Potential setting along surfaces defined by the matrices above are carried out by the next group of cards. The number of cards to be read and along which matrices the potentials are to be stored is determined from the values along JJV read on the first card. Remembering that each JJV value contains two numbers, i.e., the first two digits refer to one matrix and the last two to the next matrix, the seven JJV values can specify potential setting on all 14 matrices. In this case only the first 12 matrices are employed and JJV(7)=-1 signifies this.

JJV(1)=001 means no potentials are set along J1, and 1 potential is set along J2. This is the first card and it sets the normalized potential 1.0 along the outer electrode from the tip of the insulator to the edge of the matrix. JJV(2)=001 calls for one card setting potentials along J4 and includes some more of the outer electrode and some of the dielectric interface between I=155 and 166.

JJV(4)=3 calls for three sections of J8 to have potentials set. This is primarily the dielectric interface between the lucite and the oil. The reason for setting these values is to give the program something better

than zero to start with. The potentials set are 0.25, 0.5, and 0.75, increasing as the surfaces get closer to the outer, high voltage electrode.

JJV(5)=1 sets potentials on the ramp portion of the outer electrode. Note that two points on the outer grading ring at I=134 and 135 are set by this card and that the next card (specified by JJV(6)) sets the two points on this ramp that are missed.

The next group of cards sets linear distributions of potentials in radial (vertical) columns. The number of such distributions is specified by IVERT on the first data card and is 14 in this case. In this example all of the distributions to be set are in columns where vertical dielectric interfaces occur, again the aim is to provide reasonable potentials for the program to start with. In this case linear potentials between 0.0 and 1.0 are set between the inner and outer cylinders. Specified on each card are the column number I, the lower and upper J limits, and the potentials at the lower and upper ends.

The next two cards are very similar but set logarithmic potentials between the upper and lower limits. These are needed on the left and right edge of the matrix in this case since the axially symmetric configuration will cause this type of potential distribution at the boundaries.

The last of these potential setting cards set potentials along horizontal lines. Specified on each card are the left and right I coordinates, the J row and the left and right end potential values. The first of these cards sets the potential 1.0 in row 81 (the outer cylinder wall). This method was employed because this section of cylinder is covered by several different matrices and by this method all of these potentials are set by a single card. Similarly, a small section of the outer cylinder is set between 163 and 167 in row 46. The remaining cards set initial values over the bulk of the floating electrodes.

Since MU was 2 on the first card, data will be saved and the next card to be read has IBU and IEF on it. In this case IBU=0 so no blowups are called

for, but IEF=1 which calls for the equifield computation and plot. The next cards call for an expanded plot of a portion of the equifield plot. This is a square area between I=71 and 171 and J between 1 and 101. A blank card is employed to terminate this portion of the program.

The next three cards specify the equipotentials to be plotted. In this case the potentials are plotted every 5 percent from the lowest to the highest. Two expanded plots are called for, and one blank card terminates this routine.

Three more blank cards terminate the program.

Output from the program is shown in Table II. Most of the input data is printed out on the first four pages. On the fourth page results of the computations first appear. The first six numbers that appear after the input data are the number of errors that exist on the matrix after each of the major cycles through the program. If there had not been any floating electrodes, there would only be three numbers. In any case the third and last of these numbers should be equal to or less than NVEM given on the first card. If convergence is not obtained, there may be errors in the input data or MM (from the first card) should be made larger.

The comment DATA SAVED UNDER ISN=0 means that data were saved on tape (or disk) with a save number equal to zero. The 0 and 1 printed below this are IBU and IEF.

EMAX is the peak value of electric field computed by the EFIELD routine, and the values printed out below that are the values plotted. The entire electric field matrix is then printed out. At the conclusion of this, the original data are restored in the memory for printing or plotting of the voltages.

At the end of the voltage printout, the equipotential values are printed and the expanded plot areas are listed.

TABLE II

Sample of Printout from the Program for the Data of Table I

FEARS

```
FLOATING ELECTRODE AXISYMMETRIC OR RECTANGULAR SIMULATION

MM= 300,VE=    2,NZ= 201,NR= 101,R0=    0,MU=    2,JJV=    1,    1,    0,    3,    1,    1,  -1,VV=  14,HV=    8,LG=    2,RN=    0,PD=    0
EPSV =    .00004, BETA =    1.80
    2.140  404   96   29   30   101.000  503  100   24   29     3.000  403  117   31   35   101.000  503  119   32   37
    3.000  403  136   39   43   101.000  503  138   40   45     3.000   -0   -0   -0   -0     2.140  404  115   37   38
  101.000   -0   -0   -0   -0     2.140  404  134   45   46   101.000  202  122   22   24     1.000   -0   -0   -0   -0
  101.000  202  141   30   32     1.000   -0   -0   -0   -0   101.000  202  160   38   40     1.000   -0   -0   -0   -0
    3.000  203  129   24   25     1.000   -0   -0   -0   -0     3.000  203  148   32   33     1.000   -0   -0   -0   -0
    3.000  203  167   40   41     1.000   -0   -0   -0   -0     3.000  403   98   23   27   101.000

  J( 1)
 71  71  71  71  71  71  71  71  71  71    71  71  71  71  71  71  71  71  71  71    71  71  71  71  71  71  71  71  71  71
 71  71  71  71  71  71  71  71  71  71    71  71  71  71  71  71  71  71  71  71    71  71  71  71  71  71  69  67  65  63
 61  59  57  55  53  51  49  47  45  43    41  39  37  35  33  31  29  27  25  23    21  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  16  16
 16  16  16  16  16  16  16  16  16  -0    -0  -0  -0  -0  -0  -0  -0  18  18  18    18  18  18  18  18  19  19  19  -0  -0
 -0  -0  -0  -0  20  20  20  21  21  21    21  21  21  22  22  22  22  22  23  23    23  23  23  23  24  24  24  24  24  24
 24  25  25  25  25  25  25  26  26  26    26  26  26  27  27  27  27  27  27  28    28
  J( 2), EPS REL =      1.000
 81  81  81  81  81  81  81  81  81  81    81  81  81  81  81  81  81  81  81  81    81  81  81  81  81  81  81  81  81  81
 81  81  81  81  81  81  81  81  81  81    81  81  81  81  81  81  81  81  81  81    81  81  81  81  81  81  81  81  81  81
 81  81  81  81  81  81  81  81  81  81    81  81  81  81  81  81  81  81  81  81    81  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  22  22
 22  22  24  24  24  24  24  24  24  -0    -0  -0  -0  -0  -0  -0  -0  30  30  30    30  32  32  32  32  32  32  32  -0  -0
 -0  -0  -0  -0  38  38  38  38  38  38    40  40  40  40  40  40  40  46  46  46    46  46  46  46  46  46  46  46  46  46
 46  46  46  45  45  45  45  45  45  44    44  44  44  44  44  43  43  43  43  43    43

  J( 3)
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0    16  16  16  16  16  16  16  16  16  16    -0  -0  -0  -0  -0  -0  -0  -0  24  24
 24  24  24  24  24  24  24  24  -0  -0    -0  -0  -0  -0  -0  -0  -0  32  32  32    32  32  32  32  32  32  32  -0  -0  -0
 -0  -0  -0  -0  40  40  40  40  40  40    40  40  40  40  40  40  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0
  J( 4), EPS REL =      3.000
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0    22  22  22  22  22  21  20  19  18  17    -0  -0  -0  -0  -0  -0  -0  -0  30  30
 30  30  30  30  29  28  27  26  -0  -0    -0  -0  -0  -0  -0  -0  -0  38  38  38    38  38  38  37  36  35  34  -0  -0  -0
 -0  -0  -0  -0  46  46  46  46  46  46    46  46  45  44  43  42  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

  J( 5)
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  21  20  19  18  17    16  16  16  16  16  16  16  16  -0   0
```

Table II continued

```
  0  -0  -0  -0  29  28  27  26  25  16    16  16  17  17  17  17  17  -0  -0   0     0  -0  -0  37  36  35  34  33  19  19
 19  20  20  20  -0  -0  -0  -0  -0   0     0  -0  45  44  43  42  41  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 J( 6), EPS REL =      1.000
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  22  22  22  22  22    22  22  22  22  22  22  22  -0   0
  0  -0  -0  -0  30  30  30  30  30  30    30  30  30  30  30  30  30  -0  -0   0     0  -0  -0  38  38  38  38  38  38  38
 38  38  38  38  -0  -0  -0  -0  -0   0     0  -0  46  46  46  46  46  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 J( 7)
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  16  16  16  16  16  16  16  16  16
 16  16  16  16  16  16  16  16  16  16    24  24  24  24  24  24  24  24  24  24    24  24  24  24  24  24  24  24  -0  32
 32  32  32  32  32  32  32  32  32  32    32  32  32  32  32  32  32  -0  40  40    40  40  40  40  40  40  40  40  40  40
 40  40  40  40  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 J( 8), EPS REL =      3.000
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  22  23  24  25  26  26  26  26  26
 26  26  26  26  26  26  26  23  22  22    30  31  32  33  34  34  34  34  34  34    34  34  34  34  34  34  31  30  -0  38
 39  40  41  42  42  42  42  42  42  42    42  42  42  42  42  39  38  -0  46  47    48  49  50  50  50  50  50  50  -0  50
 50  50  50  50  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 J( 9)
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  22  23  24  25  26  26  26  26  26
 26  26  26  26  26  26  26  31  30  29    30  31  32  33  34  34  34  34  34  34    34  34  34  34  34  39  38  37  38
 39  40  41  42  42  42  42  42  42  42    42  42  42  42  42  47  46  45  46  47    48  49  50  50  50  50  50  50  50  50
 50  50  50  50  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 J(10), EPS REL =      2.140
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  81  81  81  81  81  81  81  81  81
 81  81  81  81  81  29  28  81  81  81    81  81  81  81  81  81  81  81  81  81    81  81  81  81  37  36  81  81  81  81
 81  81  81  81  80  79  78  77  76  75    74  73  72  45  44  69  68  67  66  65    64  63  62  61  60  59  58  57  56  55
 54  53  52  51  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 J(11)
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  30  31  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  38  39  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  46  47  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 J(12), EPS REL =      2.140
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
```

Table II continued

```
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  61  81  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  81  81  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  71  70  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 JM( 1), METAL
  0   0   0   0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  29  28  27  22  22    22  22  22  22  22  22  22  22  22  22    22  22  22  22  22  22  22  22  22  22
 22  22  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  45  44  43  38  38  38  38    38  38  38  38  38  38  38  38  38  38
 38  38  38  38  38  38  38  38  38  38     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 JM( 2)
  0   0   0   0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  30  31  31  30  24    24  24  24  24  24  24  24  24  24  24    24  24  24  24  24  24  24  24  24  24
 24  24  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  46  47  47  46  40  40  40    40  40  40  40  40  40  40  40  40  40
 40  40  40  40  40  40  40  40  40  40     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 JM( 3), METAL
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  37  36  35  30  30  30
 30  30  30  30  30  30  30  30  30  30    30  30  30  30  30  30  30  30  30  30    30  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0

 JM( 4)
  0   0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  38  39  39  38  32  32
 32  32  32  32  32  32  32  32  32  32    32  32  32  32  32  32  32  32  32  32    32  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0
  0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0   0     0
168 201 1.00E+00
155 166 1.00E+00
 82 118 2.50E-01
120 137 5.00E-01
139 154 7.50E-01
121 154 1.00E+00
134 135 1.00E+00

VERTICAL LINEAR VOLTAGES
 96  16  81 0.       1.00E+00
 98  16  81 0.       1.00E+00
100  16  81 0.       1.00E+00
115  16  81 0.       1.00E+00
117  16  81 0.       1.00E+00
119  16  81 0.       1.00E+00
122  16  81 0.       1.00E+00
129  16  76 0.       1.00E+00
134  17  71 0.       1.00E+00
136  17  69 0.       1.00E+00
138  18  67 0.       1.00E+00
141  19  63 0.       1.00E+00
```

```
148  19  57 0.        1.00E+00
160  22  45 0.        1.00E+00

VERTICAL LOG VOLTAGES
  1  71  81 0.        1.00E+00
201  28  43 0.        1.00E+00

HORIZONTAL LINEAR VOLTAGES
  1 201  81 1.00E+00 1.00E+00
163 167  46 1.00E+00 1.00E+00
 91 130  22 2.00E-01 2.00E-01
 91 131  24 2.50E-01 2.50E-01
111 141  30 5.00E-01 5.00E-01
111 151  32 5.50E-01 5.50E-01
131 165  38 7.50E-01 7.50E-01
131 171  40 7.50E-01 7.50E-01

      5271

       609

         1

         0

       703

         2
DATA SAVED UNDER ISN =    0
  0   1
 71 171   1 101

 EMAX =   1.480276E-01

 1.0000E-05  1.4803E-02  2.9606E-02  4.4408E-02  5.9211E-02  7.4014E-02  8.8817E-02  1.0362E-01  1.1842E-01  1.3322E-01
 1.4803E-01
   1
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.
   2
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
```

Table II continued

A second data set is shown in Table 3. This set includes a blowup of a section of the plot shown in Fig. 10. The blowup in this case is expanded by a factor of four. Experience has shown that the accuracy will be improved also by at least a factor of four. The advantage of the blowup comes from the ability to obtain boundary conditions from the larger plot and being able to define electrode shapes on a finer matrix. In this case it was desired to investigate the effects of changes in the gap geometry.

Note that the last card in the potential setting routines sets the potential along the bottom edge of the matrix in the region of the nonzero electrode. This is necessitated by the dielectric shapes above it, and is required in order that the potentials on the electrode be set properly.

Here, as in the first case, data are saved (MU=2 on the first data card) this time for use by the blowup subroutine. IBU is 1 indicating that one blowup area is desired. The expansion factor, IEX, is 4 and the area to be expanded extends from I=71 to 121 and J=1 to 36.

Note that there is only one blank card after the last expanded plot of the equipotential surfaces. The second data set is placed directly after the first. MU is equal to 3 to restore the data saved by the first program and IRN is equal to 1, the number of the expanded plot data saved by the first data set. Also note that the dielectric constants are irrelevant in the blowup case since there are no dielectric interfaces. MU=3 saves the blowup data, in this case to permit an electric field plot. A blowup of the blowup could also be obtained if it were desired at this point.

The plots obtained from these data are shown in Figs. 11 through 15. Figure 11 is the plot for the original data set and Fig. 12 is an expanded plot of the region between the gap. Figure 13 is the blown-up plot of the gap with one side modified and Fig. 14 the expanded plot of the point on the switch. The equifield plot is shown in Fig. 15.

Significant parts of the output from the program are shown in Table 4. The first two pages of the first data section and the first page of the second

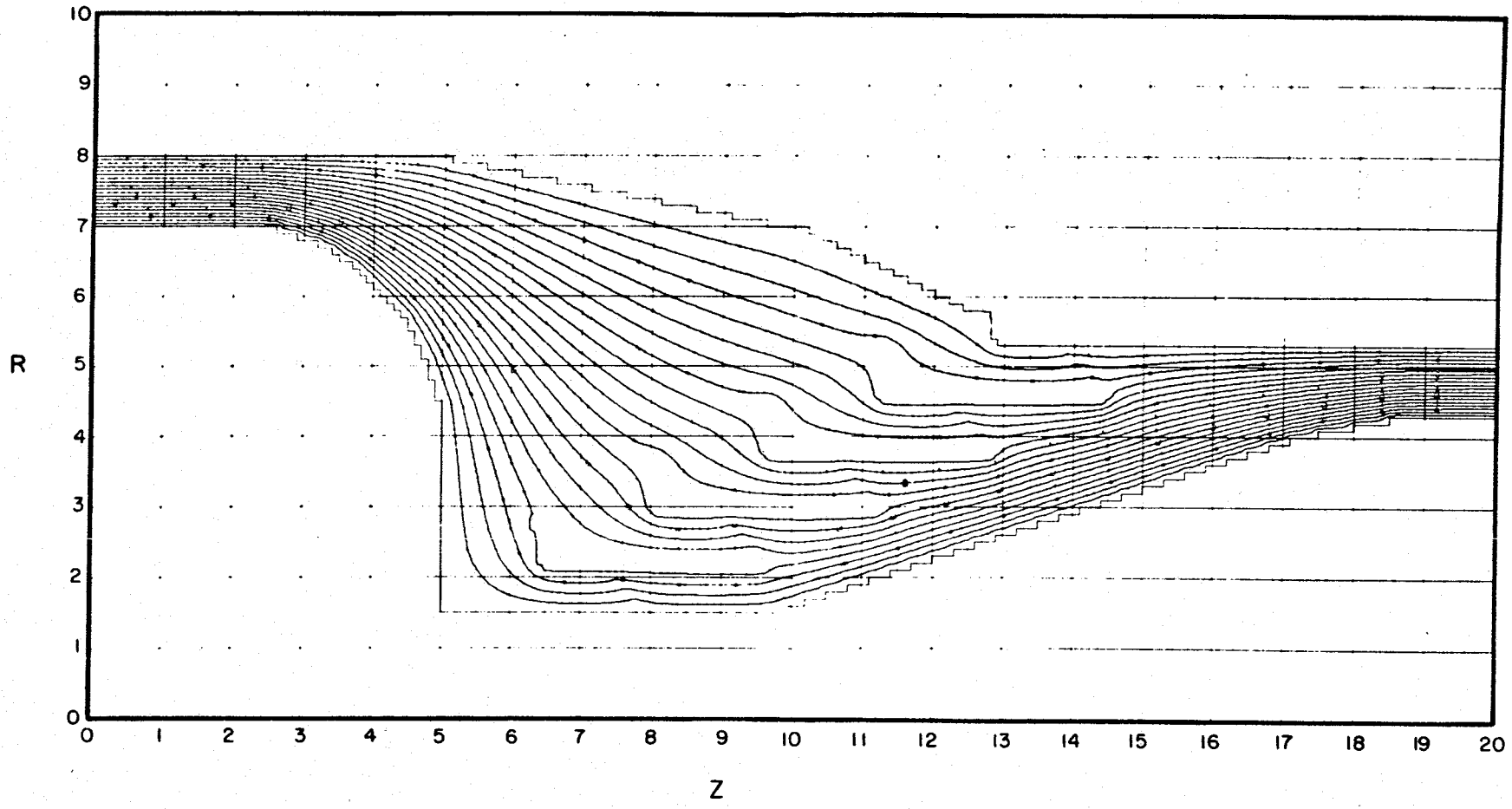


Figure 10. Equipotential Plot of Improved Insulator Design

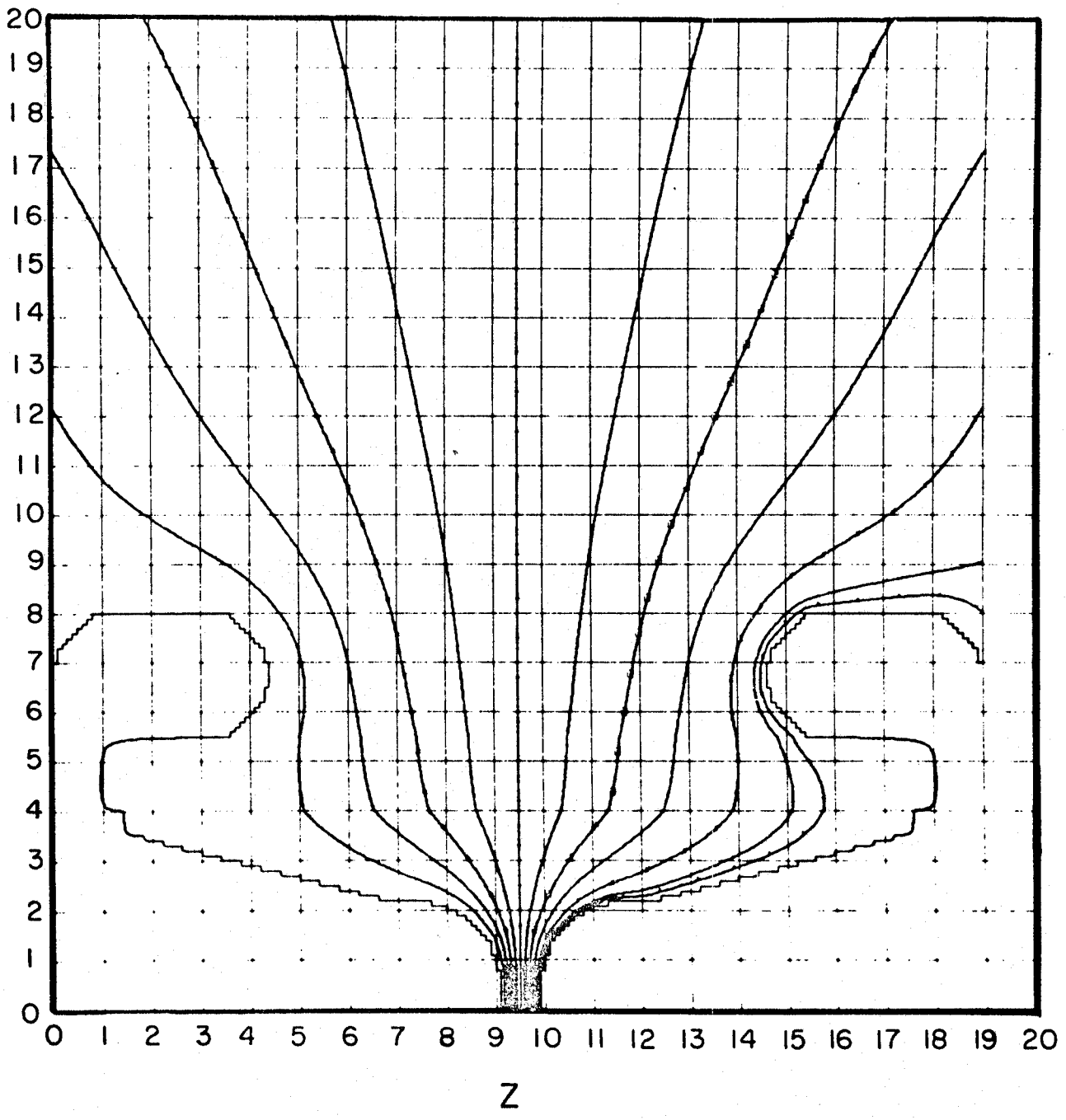


Figure 11. Equipotentials for High Voltage Switch Configuration

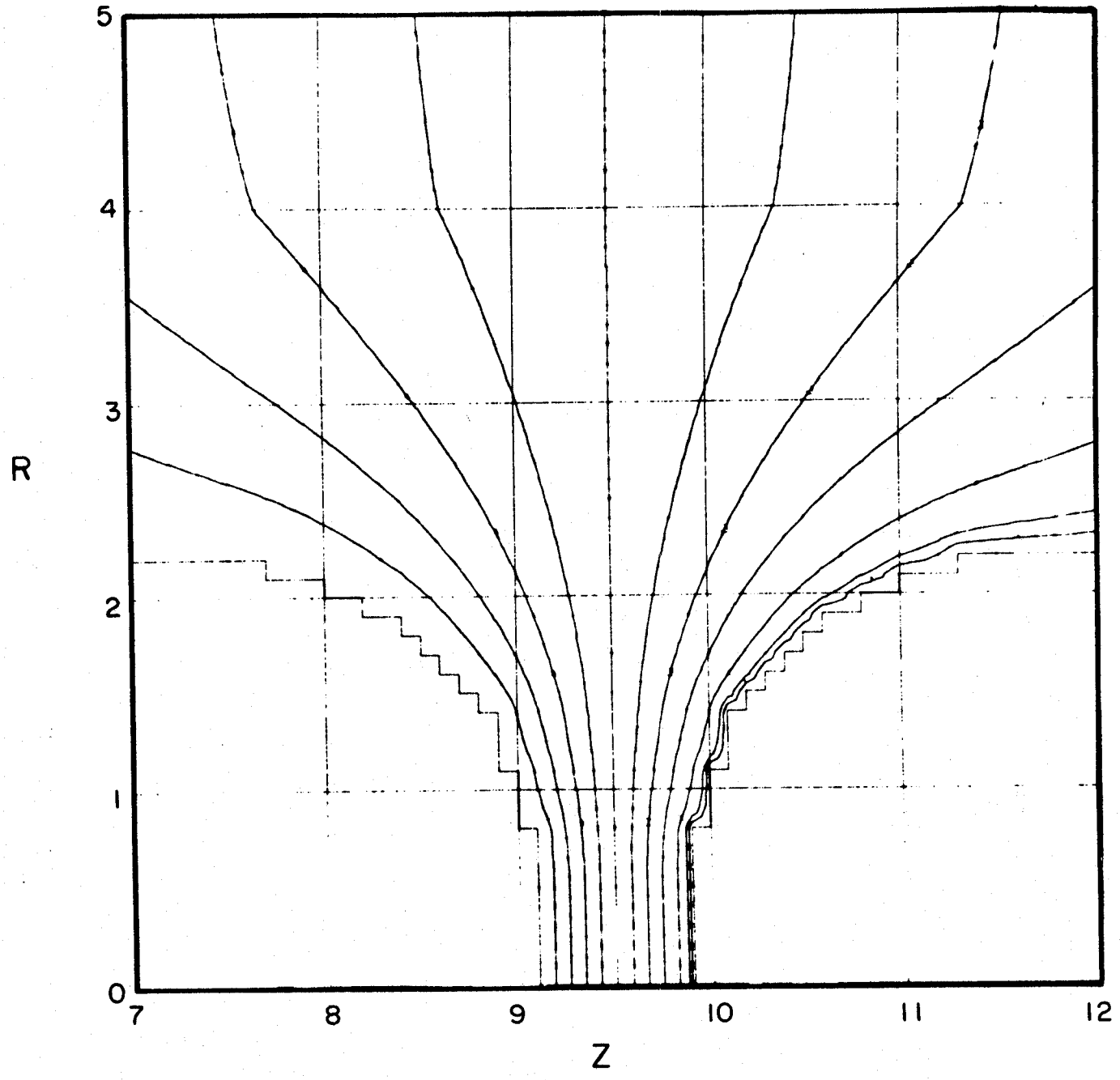


Figure 12. Blowup of Gap Region of Fig. 11

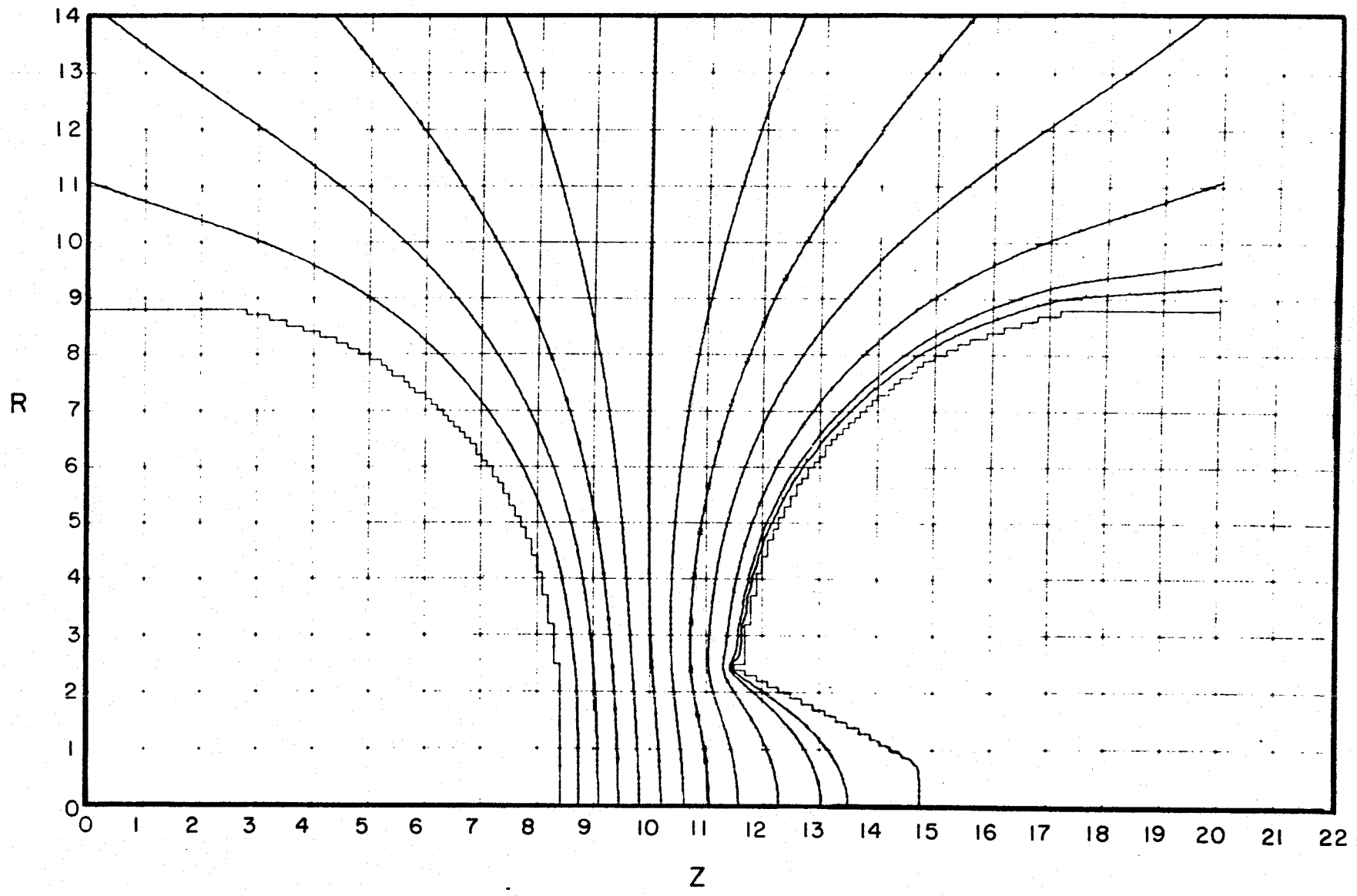


Figure 13. Expanded Plot of Gap with Improved Accuracy and Greater Detail

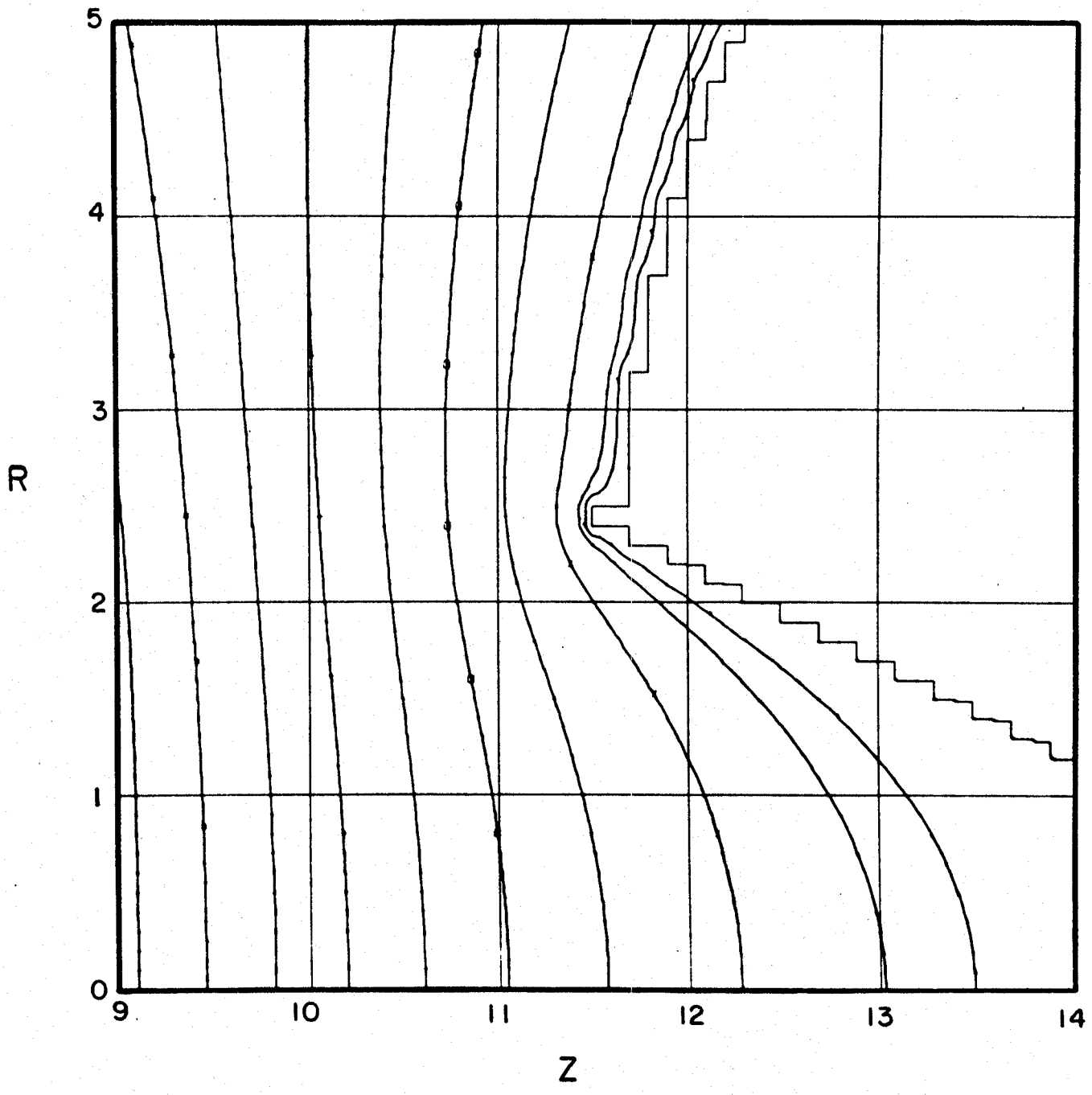


Figure 14. Blowup of Section of the Expanded Plot

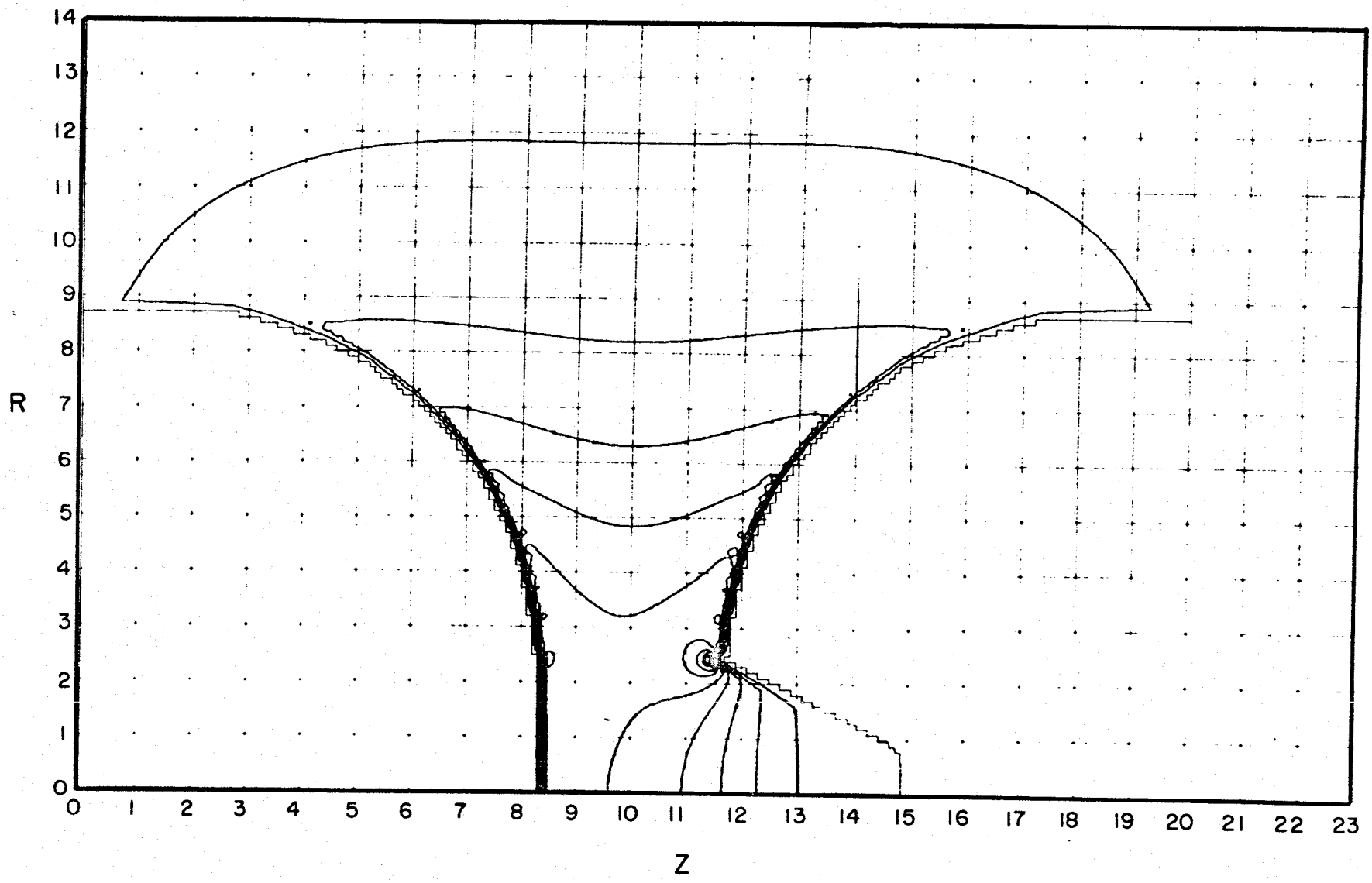


Figure 15. Equifield Plot of Expanded Plot Shown in Fig. 13.

TABLE III

Input Data for a Simulation Including an Expanded Plot and Equifield Plots

```
200    2 191 201    0    2 100 101 101 100   -1    0    0    4    5    0    0    0
  0.0001       1.8        1.0        3.0        1.0        1.0
    0.0
 0    0
71 74 75 76 77 78 79 80 81 81                36 36 36 36 35
35 35 35 34 34 34 34 33 33 33 33 32 32 32 32 31 31 31 31 30
30 30 30 29 29 29 29 28 28 28 28 27 27 27 27 26 26 26 26 25
25 25 25 24 24 24 24 23 23 23 23 23 23 23 23 23 23 23 22 22
22 21 21 20 20 19 18 17 16 15 12  9  0  0  0  0  0  0  0  9
12 15 16 17 18 19 20 20 21 21 22 22 22 23 23 23 23 23 23 23
23 23 23 23 24 24 24 24 25 25 25 25 26 26 26 26 27 27 27 27
28 28 28 28 29 29 29 29 30 30 30 30 31 31 31 31 32 32 32 32
33 33 33 33 34 34 34 34 35 35 35 35 36 36 36 36
   81 81 80 79 78 77 76 75 74 71
201201201201201201201201201201               41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
  201201201201201201201201201201
 0  0                          41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41
41                              0
 0  0                          56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56                              0
 0  0                          81 81 81 81 81 81 81 81 81 81
81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56 56
```

```
 56 56 56 56 56 56 56 56 56 56 56 56 56 56 81 81 81 81 81 81
 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81 81
 81                            0
  0  0                        201201201201201201201201201201
201201201201201201201201201201201201201201201201201 57 58 59
 60 61 62 63 66201201201201201201201201201201201201201201201
201201201201201201201201201201201201201201201201201201201201
201201201201201201201201201201201201201201201201201201201201
201201201201201201201201201201201201201201201201201201201201
201201201201201201201201201201201201201201201201201201201201
201201201201201201 66 63 62 61 60 59 58 57201201201201201201
201201201201201201201201201201201201201201201201201201201201
201                            0
  0  0                                                     0
  0                                                 80 79 78
 77 76 75 74 71                                            0
  0                                                        0
  0                                                        0
  0                                                        0
  0                                                        0
  0                  71 74 75 76 77 78 79 80               0
  0                                                        0
  0                             0
  0  0                                                     0
  0                                                201201201
201201201201201                                            0
  0                                                        0
  0                                                        0
  0                                                        0
  0                                                        0
  0                  201201201201201201201201              0
  0                                                        0
  0                             0
 100 191        1.0
 176 181        1.0
 155 181        1.0
 155 181        1.0
 147 154        1.0
 147 154        1.0
  11  42  55      .0001      .0001
  13  42  55      .0001      .0001
   1  71 201        0.0        .25
 191  71 201        1.0        .75
   1 191 201        .25        .75
  15 177  41        0.0        1.0
  37 155  56        0.0        1.0
  92 100   1        0.0        1.0
 100 191   1        1.0        1.0
   1
   4  71 121    1   36
     .0001      .1         .2         .3         .4         .5         .6         .7
        .8      .9         .96        .98       .9999
      0.0
  71 121    1   51
```

Table III continued

```
200   2 201 141   0   3 201 100  -1                           1
    .0004       1.8       1.0
      0.0
  0   0
 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89
 89 89 89 89 89 89 89 89 89 88 88 88 88 87 87 87 86 86 86 85
 85 85 84 84 84 83 83 82 82 81 81 80 80 79 78 77 77 76 75 74
 74 73 72 71 70 69 68 67 66 65 63 62 61 59 58 56 54 52 50 48
 45 42 38 33 26  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0                                                        0
  0                      80 80 81 81 82 82 83 83 84 84 84 85
 85 85 86 86 86 87 87 87 88 88 88 88 89 89 89 89 89 89 89 89
 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89
 89
141141141141141141141141141141141141141141141141141141141141
141141141141141141141141141141141141141141141141141141141141
141141141141141141141141141141141141141141141141141141141141
141141141141141141141141141141141141141141141141141141141141
141141141141141141141141141141141141141141141141141141141141
141141141141141141141141141141141141141141141 25 25 25 25 25
 25 25 24 24 24 24 23 23 23 23 22 22 22 22 21 21 21 21 20 20
 20 20 19 19 19 19 18 18141141141141141141141141141141141141
141141141141141141141141141141141141141141141141141141141141
141141141141141141141141141141141141141141141141141141141141
141
  0  0                                                     0
  0                                                        0
  0                                                        0
  0                                                        0
  0                                                        0
  0                                           26 26 33 38 42
 45 48 50 52 54 56 58 59 61 62 63 65 66 67 68 69 70 71 72 73
 74 74 75 76 77 77 78 79                                   0
  0                                                        0
  0                                                        0
  0
  0  0                                                     0
  0                                                        0
  0                                                        0
  0                                                        0
  0                                                        0
  0                                          141141141141141
141141141141141141141141141141141141141141141141141141141141
141141141141141141141141                                   0
  0                                                        0
  0                                                        0
  0
   1  85       0.0
 149 201       1.0
 116 148       1.0
 116 148       1.0
   0   1
```

Table III continued

```
.0001      .1      .2      .3      .4      .5      .6      .7      BLANK
  .8       .9      .96     .98     .9999
  0.0
91 141    1  51

                                                                   BLANK
                                                                   BLANK
                                                                   BLANK
                                                                   BLANK
END
```

TABLE IV

Output from the Program for the Data of Table III

FEARS

FLOATING ELECTRODE AXISYMMETRIC OR RECTANGULAR SIMULATION

```
MM= 200,VE=   2,NZ= 191,NR= 201,R0=   0,MU=   2,JJV= 100, 101, 101, 100,  -1,   0,   0,VV=   4,HV=   5,LG=   0,RN=   0,PD=   0
EPSV =   .00010, BETA =   1.80


  J( 1)
 71  74  75  76  77  78  79  80  81  81     1   1   1   1   1  36  36  36  36  35    35  35  35  34  34  34  34  33  33  33
 33  32  32  32  32  31  31  31  31  30    30  30  30  29  29  29  29  28  28  28    28  27  27  27  27  26  26  26  26  25
 25  25  25  24  24  24  24  23  23  23    23  23  23  23  23  23  23  23  22  22    22  21  21  20  20  19  18  17  16  15
 12   9   0   0   0   0   0   0   0   9    12  15  16  17  18  19  20  20  21  21    22  22  22  23  23  23  23  23  23  23
 23  23  23  23  24  24  24  24  25  25    25  25  26  26  26  26  27  27  27  27    28  28  28  28  29  29  29  29  30  30
 30  30  31  31  31  31  32  32  32  32    33  33  33  33  34  34  34  34  35  35    35  35  36  36  36  36   1   1   1   1
  1  81  81  80  79  78  77  76  75  74    71

  J( 2), EPS REL =      1.000
201 201 201 201 201 201 201 201 201 201     2   2   2   2   2  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41   2   2   2   2
  2 201 201 201 201 201 201 201 201 201   201


  J( 3)
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41    41  41  41  41  41  41  41  41  41  41
 41  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0

  J( 4), EPS REL =      3.000
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56
 56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56
 56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56    56  58  56  56  56  56  56  56  56  56
 56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56
 56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56
 56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56
 56  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0


  J( 5)
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    81  81  81  81  81  81  81  81  81  81    81  81  81  81  81  81  81  81  81  81
 81  81  81  81  81  81  81  56  56  56    56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56
 56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56
 56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56
 56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56    56  56  56  56  56  56  56  56  56  56
 56  56  56  56  81  81  81  81  81  81    81  81  81  81  81  81  81  81  81  81    81  81  81  81  81  81  81  81  81  81
 81  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0

  J( 6), EPS REL =      1.000
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0   201 201 201 201 201 201 201 201 201 201   201 201 201 201 201 201 201 201 201 201
```

```
201 201 201 201 201 201 201  57  58  59    60  61  62  63  66 201 201 201 201 201   201 201 201 201 201 201 201 201 201 201
201 201 201 201 201 201 201 201 201 201   201 201 201 201 201 201 201 201 201 201   201 201 201 201 201 201 201 201 201 201
201 201 201 201 201 201 201 201 201 201   201 201 201 201 201 201 201 201 201 201   201 201 201 201 201 201 201 201 201 201
201 201 201 201 201 201 201 201 201 201   201 201 201 201 201 201 201 201 201 201   201 201 201 201 201 201  66  63  62  61
 60  59  58  57 201 201 201 201 201 201   201 201 201 201 201 201 201 201 201 201   201 201 201 201 201 201 201 201 201 201
201  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0


   J( 7)
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  80  79  78    77  76  75  74  71  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  71  74  75  76
 77  78  79  80  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0

   J( 8), EPS REL =     1.000
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0 201 201 201   201 201 201 201 201  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0 201 201 201 201
201 201 201 201  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0
100 191 1.00E+00
176 181 1.00E+00
155 181 1.00E+00
155 181 1.00E+00
147 154 1.00E+00
147 154 1.00E+00
 11  42  55 1.00E-04 1.00E-04
 13  42  55 1.00E-04 1.00E-04
  1  71 201 0.       2.50E-01
191  71 201 1.00E+00 7.50E-01
  1 191 201 2.50E-01 7.50E-01
 15 177  41 0.       1.00E+00
 37 155  56 0.       1.00E+00
 92 100   1 0.       1.00E+00
100 191   2 1.00E+00 1.00E+00

     5008

        2

        0
DATA SAVED UNDER ISN =   0
DATA SAVED UNDER ISN =   1
    0 RESTORED
   1
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
0.          0.          1.25219E-01 2.50309E-01 3.75221E-01 5.00007E-01 6.24793E-01 7.49701E-01 8.74787E-01 1.00000E+00
1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
```

Table IV continued

FEARS

FLOATING ELECTRODE AXISYMMETRIC OR RECTANGULAR SIMULATION

```
MM= 200,VE=   2,NZ= 201,NR= 141,R0=   0,MU=   4,JJV= 201, 100,  -1,  -0,  -0,  -0,  -0,VV=  -0,HV=  -0,LG=  -0,RN=   1,PD=  -0
EPSV =   .00040, BETA =   1.80


  J( 1)
 89  89  89  89  89  89  89  89  89  89    89  89  89  89  89  89  89  89  89  89    89  89  89  89  89  89  89  89  89  88
 88  88  88  87  87  87  86  86  86  85    85  85  84  84  84  83  83  82  82  81    81  80  80  79  78  77  77  76  75  74
 74  73  72  71  70  69  68  67  66  65    63  62  61  59  58  56  54  52  50  48    45  42  38  33  26   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0     0   0   0   0   0   0   0   0   0   0     0   0   0   0   0   0   0   0   0   0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  80  80
 81  81  82  82  83  83  84  84  84  85    85  85  86  86  86  87  87  87  88  88    88  88  89  89  89  89  89  89  89  89
 89  89  89  89  89  89  89  89  89  89    89  89  89  89  89  89  89  89  89  89    89

  J( 2), EPS REL =      1.000
141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141
141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141
141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141
141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141   141 141 141 141 141  25  25  25  25  25
 25  25  24  24  24  24  23  23  23  23    22  22  22  22  21  21  21  21  20  20    20  20  19  19  19  19  18  18 141 141
141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141
141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141   141


  J( 3)
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  26  26  33  38  42
 45  48  50  52  54  56  58  59  61  62    63  65  66  67  68  69  70  71  72  73    74  74  75  76  77  77  78  79  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0

  J( 4), EPS REL =     -0.000
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0 141 141 141 141 141
141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141 141 141   141 141 141 141 141 141 141 141  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0
 -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0  -0  -0  -0  -0  -0  -0  -0  -0  -0    -0
   1 RESTORED
  1  85 0.
149 201 1.00E+00
116 148 1.00E+00
116 148 1.00E+00

    2202

       1

       0
DATA SAVED UNDER ISN =   2
   1
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
```

part of the data are reproduced here. The second page has the two comments DATA SAVE UNDER ISN=0,1 printed. The data set 0 is the one which was just solved, data set 1 is the boundary conditions for the blowup. ISN=2 on the second data set is saving the blowup data for the equifield plot. If a second blowup were called for, the boundary data would be saved under ISN=3.

Appendix B

Data Sheets for FFEARS

The following sheets have been laid out in the formats needed for the input to the FFEARS program.

MM	NVEM	NZ	NR	NRO	MU	JJV1	JJV2	JJV3	JJV4	JJV5	JJV6	JJV7	IVERT	IHOR	LOG	IRN	IPD	18I4

EPSV	BETA	EP-1	EP-2	EP-3	EP-4	EP-5	EP-6	8E9
EP-7								1E9

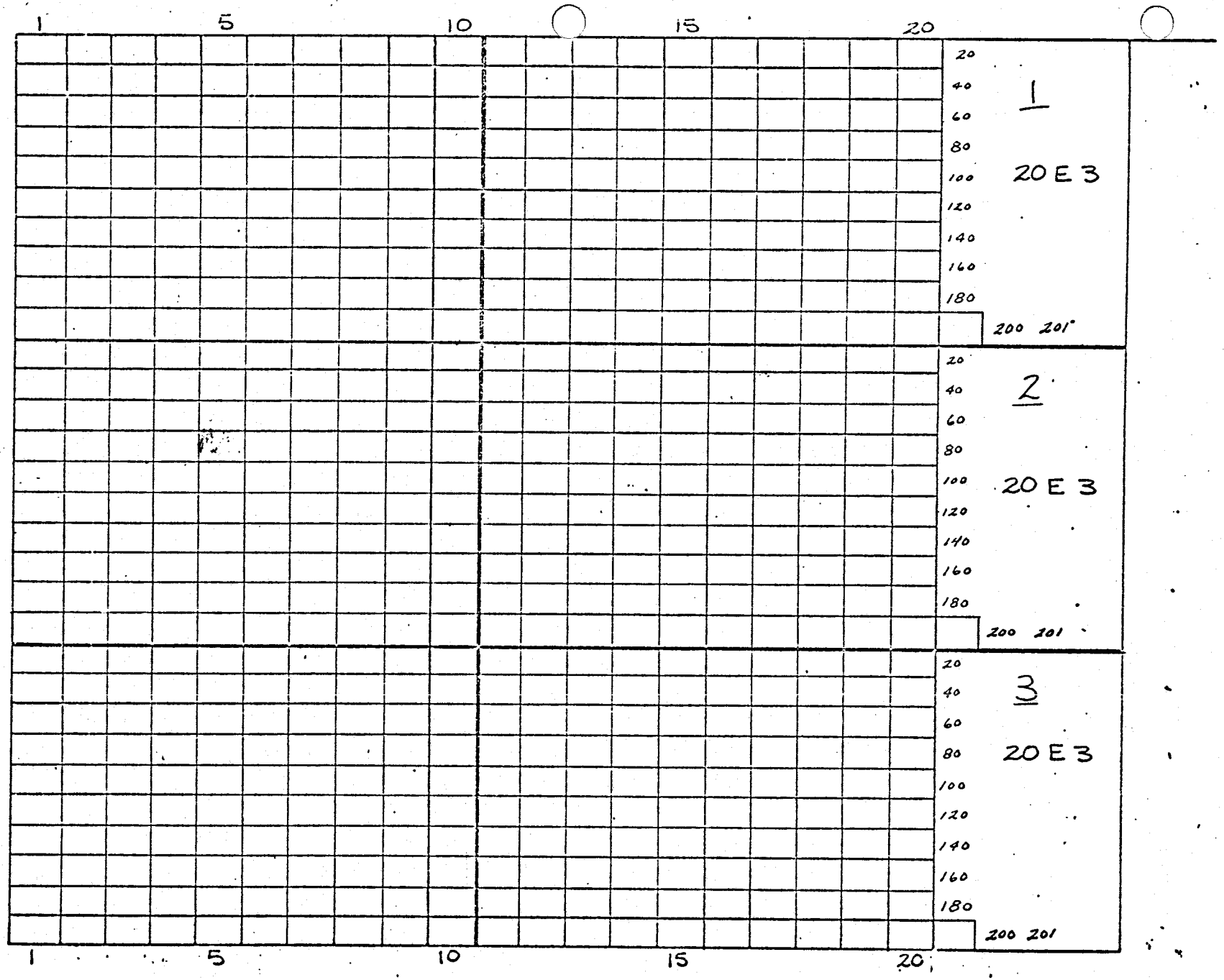
IDI	METAL	I4

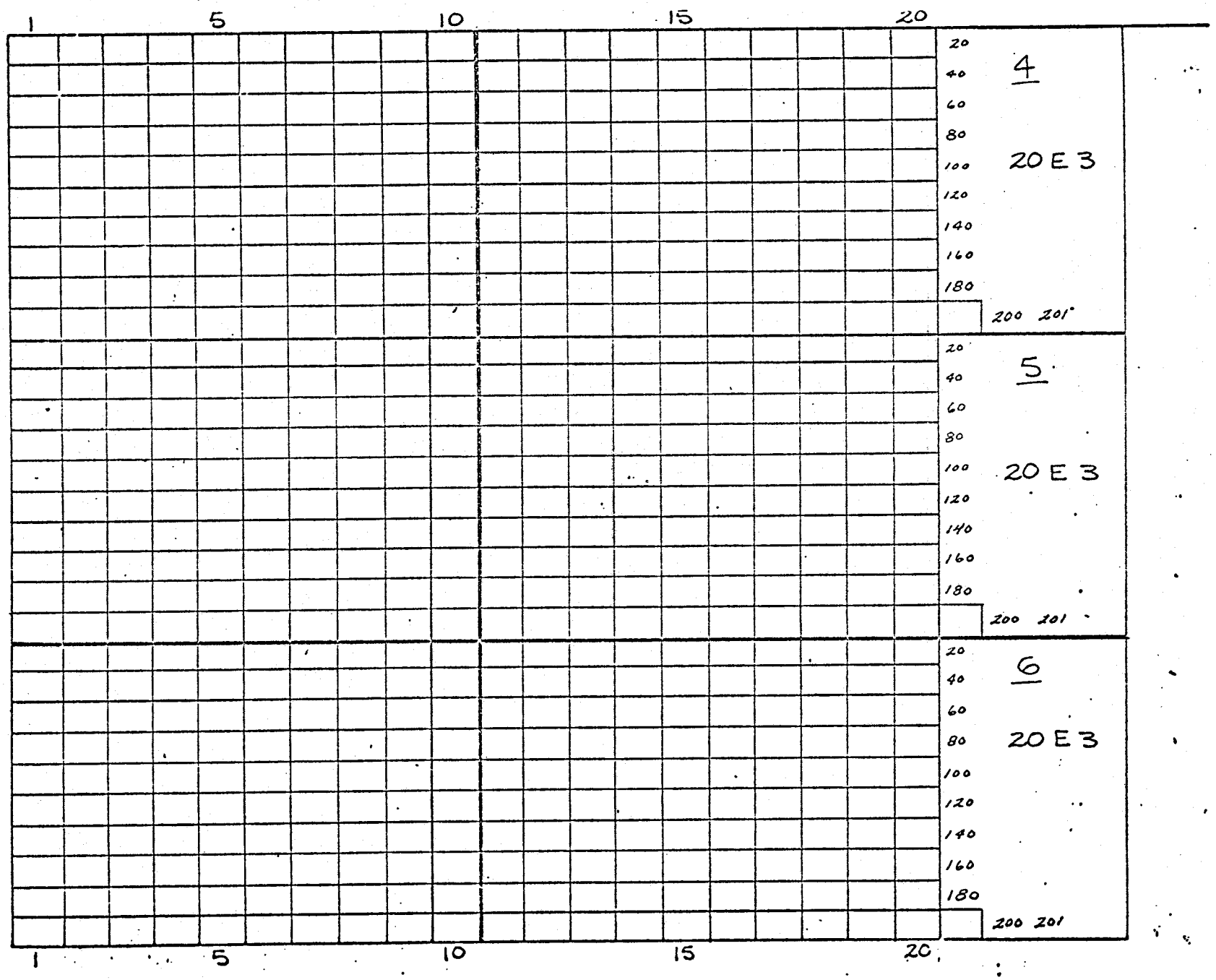
										EPV
										12FG

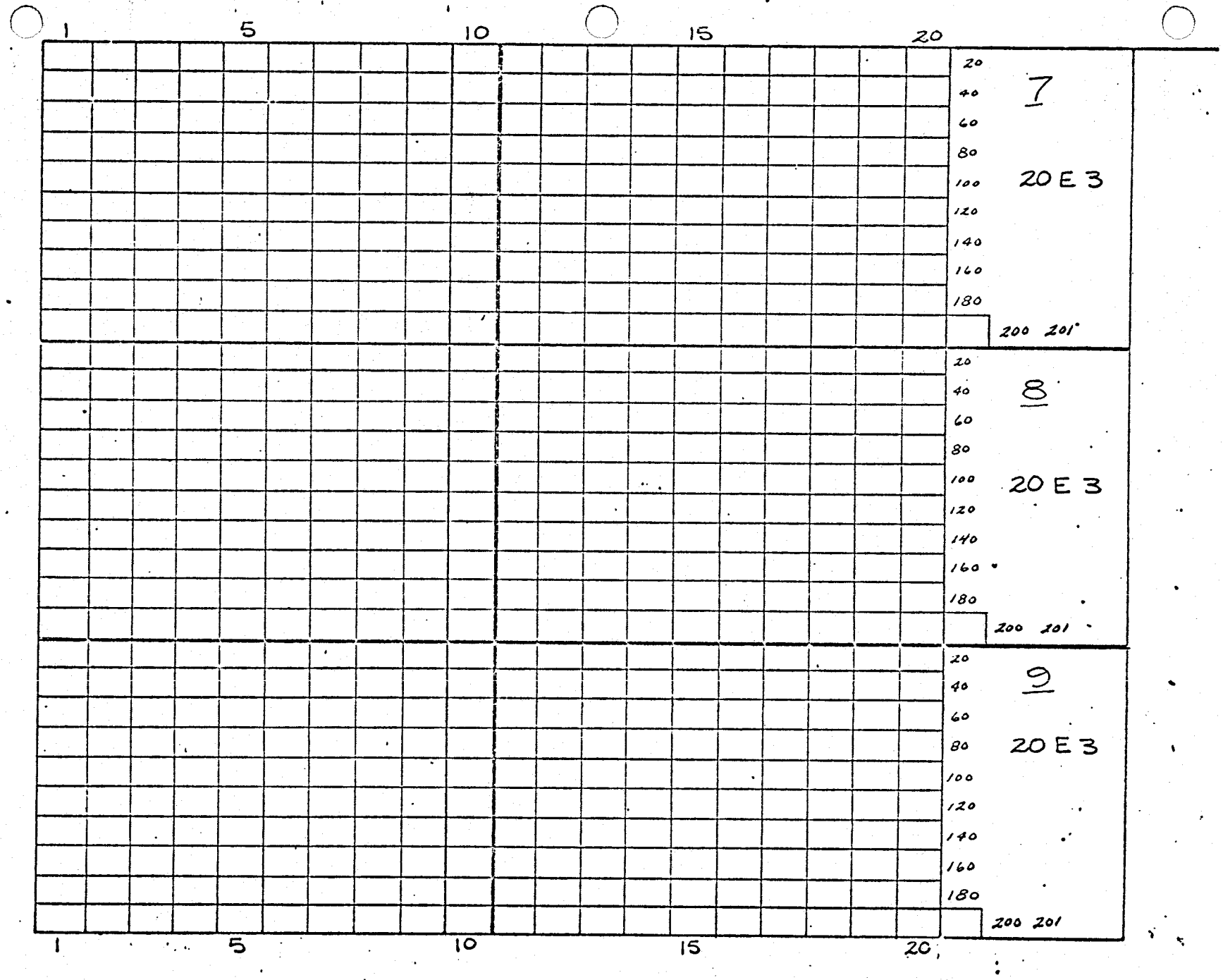
	I	JL	JH		I	JL	JH		I	JL	JH		I	JL	JH		I	JL	JH

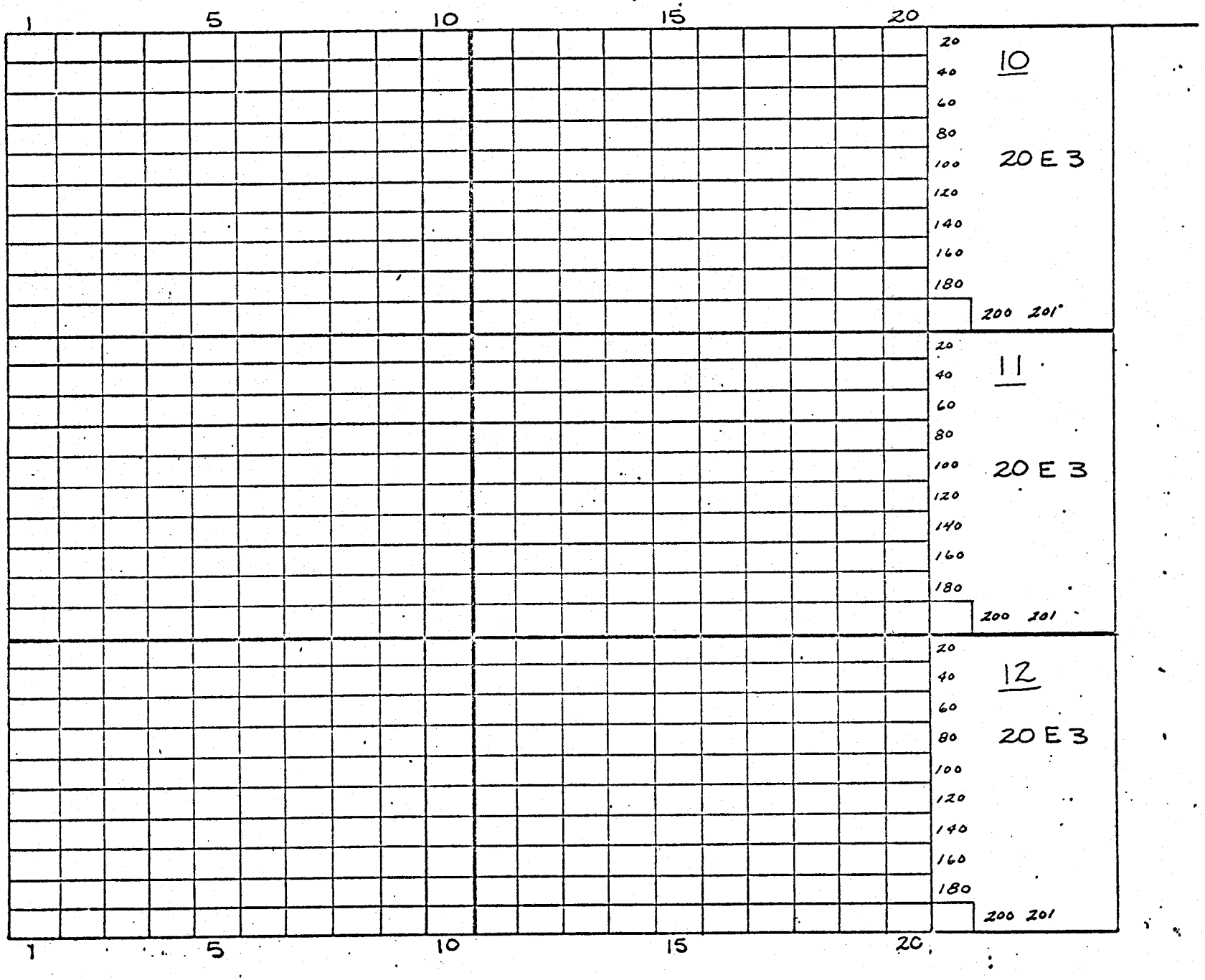
20I4

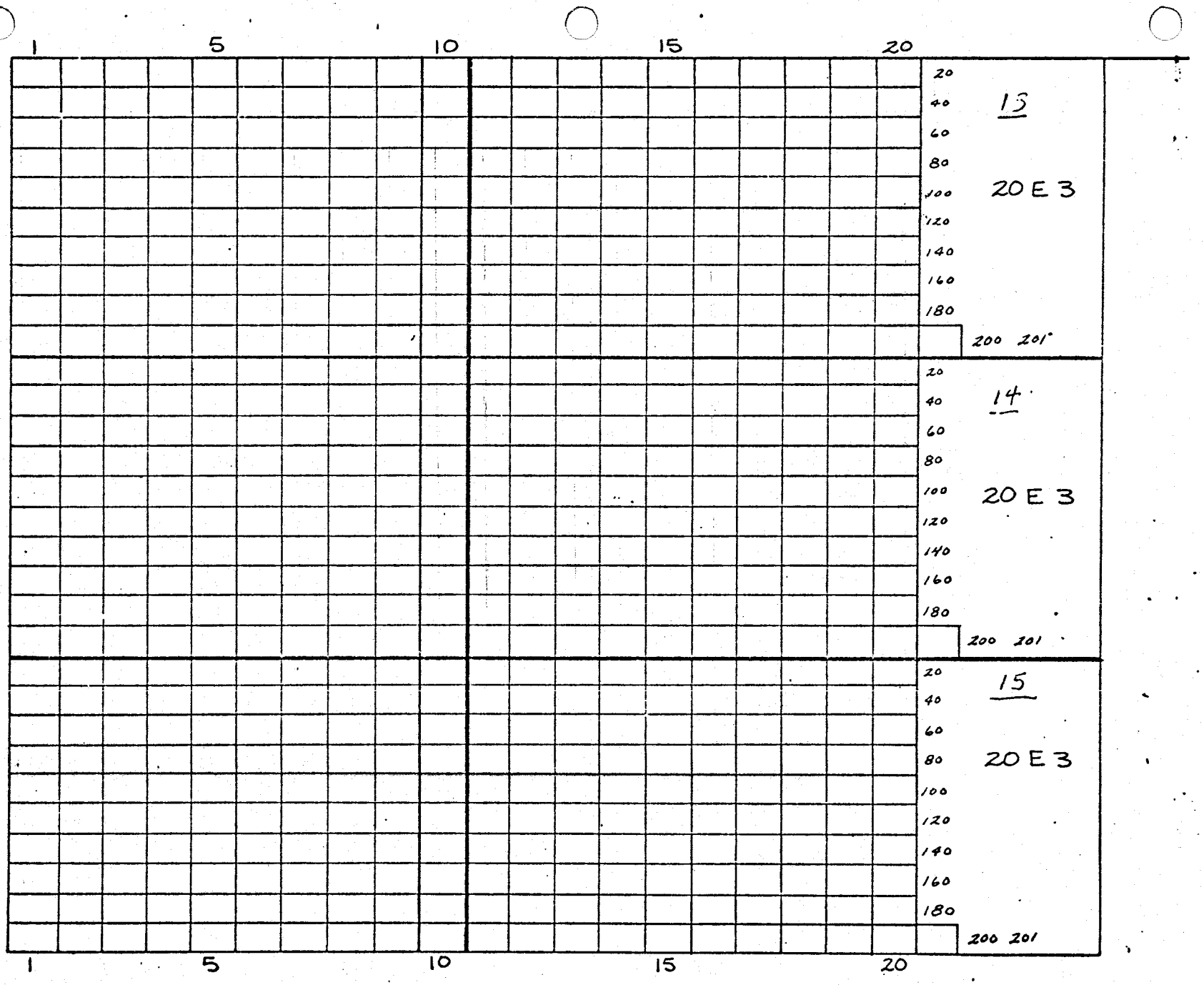
FFEARS DATA SHEETS

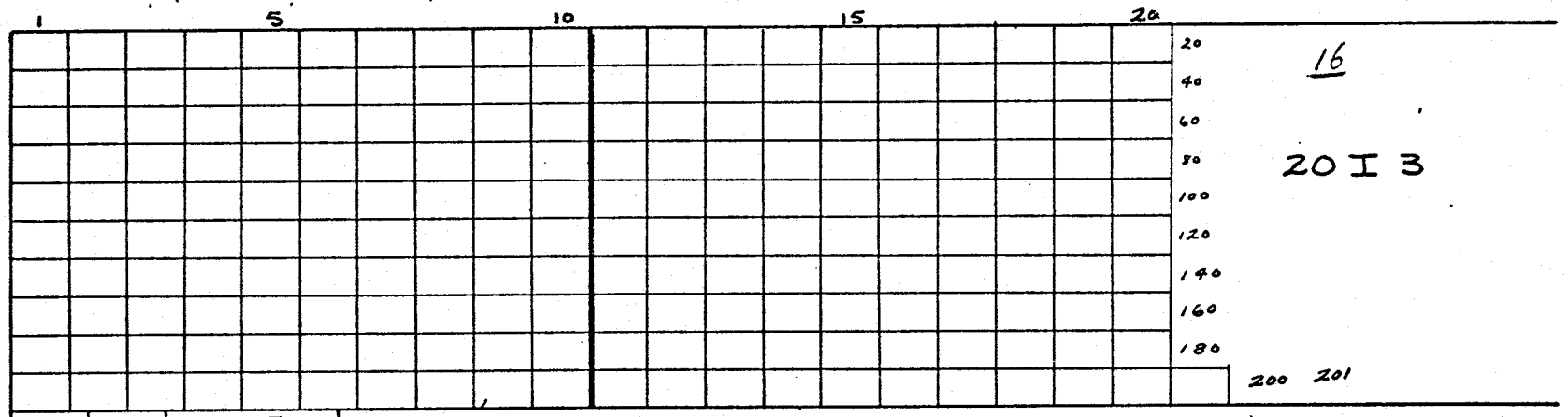

1
5
10
15
20
20
40
60
80
100
120
140
160
180
200 201
1
20 E 3
2
20 E 3
3
20 E 3


1
5
10
15
20
20
40
60
80
100
120
140
160
180
200 201
4
20 E 3
5
20 E 3
6
20 E 3


1
5
10
15
20
20
40
60
80
100
120
140
160
180
200 201
7
20 E 3
8
20 E 3
9
20 E 3


1
5
10
15
20
20
40
60
80
100
120
140
160
180
200 201
10
20 E 3
11
20 E 3
12
20 E 3


1
5
10
15
20
20
40
60
80
100
120
140
160
180
200 201
15
20 E 3
14
20 E 3
15
20 E 3



16

20 I 3

JL	JH	V-SET

I	JL	JH	VL	VH

LINEAR RADIAL
3I4 , 2E9

I	JL	JH	VL	VH

I	JL	JH	VL	VH

LOG RADIAL
3I4 , 2E9

I	JL	JH	VL	VH

IL	IH	J	VL	VH

LINEAR AXIAL
3I4 , 2E9

IL	IH	J	VL	VH

IBU	IEF

2I4

IEX	IL	IH	JL	JH

EXPANDED AREAS 5I4

IL	IH	JL	JH

E FIELD BLOWUP 4I4

								8E9 VCON

IL	IH	JL	JH

EXPANDED PLOTS 4I4

Appendix C

FFEARS and Subroutine Listings

The program consists of a main program called FFEARS, which performs the relaxation of the potentials, and several subroutines which do the blowups, field computations, plotting, saving of data and restoring of data.

The subroutine BLOWUP saves the data needed to produce expanded, solutions for areas of an original solution. BLOWUP saves the boundary data of a specified rectangular region and lays this data out on a finer matrix, interpolating for values between those of the original solution.

Subroutine EFIELD computes either the electric field (E), or its square (E^2). Second order differences are employed to compute the electric field at every point on the matrix.

Plotting is carried out by the subroutines EQPLOT, CDPLOT, SCAN, TRACE, CALC and PILINE. EQPLOT is in overall charge of the plotting while SCAN, TRACE, and CALC do the equipotential (or equifield) computations. CDPLOT sorts the data for the various sections of the plotted output, e.g., the enlarged sections. PILINE transmits points to the plotting subroutines.

The North American Aviation Subroutines for the Stromberg-Carlson 4020 as modified for the CDC 6600 computer at Sandia Laboratories, Albuquerque, are employed. Tape No. 10 is specified as the plot output tape.

Should the program be employed on another system, the plotting routines may have to be modified. The contour information is transmitted from the subroutine TRACE to CDPLOT via the R and Z matrices. CDPLOT would need to be rewritten for the plot routines available on the particular machine employed.

Saving and restoring of data are accomplished by WTTAPE and RDTAPE, respectively. As the program is listed here the disk files are employed to simulate a tape (IST=4) for storing data. If a physical tape is to be used, the binary number 999 must be written on it before the program employs it and the WRITE TAPE IST, ISTP statement should be removed from the program.

Tapes 51 through 60 are scratch tapes and are simulated on the disk files.

```
      PROGRAM FFEARS (INPUT,OUTPUT,TAPE10,TAPE4,TAPE51,TAPE52,TAPE53,
     1 TAPE54,TAPE55,TAPE56,TAPE57,TAPE58,TAPE59,TAPE60)
C
C              FLOATING ELECTRODE AXISYMMETRIC AND RECTANGULAR SIMULATION
C
C                   INCLUDING DIFFERENT DIELECTRICS
C                   BY J E BOERS
C
      DIMENSION V(201,201), JA(201), JB(201), RI(201)
      DIMENSION VCON(24), REC(1200), Z(2000), R(2000), IPT(3,3), INX(8),
     1 INY(8)
      DIMENSION  SV(100), XYM(40), IRIT(10), IZ(2000), IR(2000)
C
      DIMENSION ID(188), EPV(48)
C
      DIMENSION JJV(7), JX(201,14), EP(7), JM(201,6)
C
      EQUIVALENCE (JX(1,1),JA), (JX(1,2),JB)
C
      COMMON NZ,NR,IX,IY,IDX,IDY,ISS,IT,NP,N,PY,REC,CV,R,Z,IPT,INX,INY,
     1 V,XL,YL,S,U,NT,MT,IZX,DX,DY,XMAX,SCALE,YMAX,VCON,JSYM,LSYM,JT
     2 ,SV, XYM, IRIT, NPLOT, IZ,IR, MLNTH, IRB, IRT, IZL, IZR
C
      IZX = 1
      IBU = 0
      ISTP = 999
      IST = 4
      NVR = 40401
      REWIND IST
      WRITE TAPE IST,ISTP
C
    5 READ 1000,MM,NVEM,NZ,NR,NRO,MU,JJV,IVER,IHOR,LOG,IRN,IPD,
     1 EPSV,BETA,EP
C
      IF (NZ) 8,8,11
    8 CALL EXTFLM(0)
      CALL EXIT
C
   11 PRINT 1045
C
      PRINT 1065,MM,NVEM,NZ,NR,NRO,MU,JJV,IVER,IHOR,LOG,IRN,IPD,EPSV
     1 ,BETA
C
      READ 1030 ,IDI,METAL
C
      IF (IDI)  17,17,14
   14 IRD = IDI+1
C
      READ 1035,(EPV(K),K=1,IRD)
C
      IRD = 4*IDI
C
      READ 1040,(ID(K),K=1,IRD)
      PRINT 1105,(EPV(K/4+1),ID(K),ID(K+1),ID(K+2),ID(K+3),K=1,IRD,4),
     1 EPV(IDI+1)
C
      IDIC = IRD-2
C
```

```
   17 CONTINUE
      DO 20 K=1,7
      IF (JJV(K)) 23,20,20
   20 CONTINUE
      K = 7
      GO TO 26
   23 K = K-1
C
C                    READ GEOMETRY MATRICES
C
   26 DO 29 L=1,K
      M = 2*L-1
      READ 1005,(JX(I,M),I=1,NZ)
      PRINT 1060,M,(JX(I,M),I=1,NZ)
      READ 1005,(JX(I,M+1),I=1,NZ)
      N = M+1
      PRINT 1055,N,EP(L),(JX(I,M+1),I=1,NZ)
   29 CONTINUE
      IF (K-7) 32,38,38
   32 DO 35 I=1,NZ
      JX(I,2*K+1) = 0
   35 JX(I,2*K+2) = 0
   38 IF (METAL) 44,44,41
C
C                    FLOATING ELECTRODES
C
   41 DO 43 M=1,METAL
      N = 2*M-1
      READ 1005,(JM(I,N),I=1,NZ)
      PRINT 1095,N,(JM(I,N),I=1,NZ)
      N = N+1
      READ 1005,(JM(I,N),I=1,NZ)
   43 PRINT 1100,N,(JM(I,N),I=1,NZ)
   44 CONTINUE
C
      DO 47 I=1,NVR
   47 V(I) = 0.0
      IF (MU-2) 53,53,50
C
   50 CALL RDTAPE (IST,ISTP,IRN,V,NVR)
C
   53 CONTINUE
C
C                    ELECTRODE POTENTIALS
C
      DO 68 L=1,K
      LL = JJV(L)/100
      LK = JJV(L)-100*LL
      IF (LL) 60,60,56
   56 DO 59 M=1,LL
      READ 1010,IL,IH,VS
      PRINT 1010,IL,IH,VS
      DO 59 I=IL,IH
      J = JX(I,2*L-1)
   59 V(I,J) = VS
   60 IF (LK) 68,68,62
   62 DO 65 M=1,LK
      READ 1010,IL,IH,VS
```

```
      PRINT 1010,IL,IH,VS
      DO 65 I=IL,IH
      J = JX(I,2*L)
   65 V(I,J) = VS
   68 CONTINUE
      LMM = K
C
C                    DIELECTRIC SURFACE CONSTANTS
C
      EPM = 101.0
      DO 77 J=2,NR
      RI(J) = 0.0
      IF (NR0-9999) 71,77,77
   71 RI(J) = 0.125/FLOAT(NR0+J-1)
   77 CONTINUE
      NZ1 = NZ-1
      NZ2 = NZ-2
C
C                      LINEAR VOLTAGES
C
      IF (IVER) 87,87,83
   83 PRINT 1070
      DO 84 K=1,IVER
      READ 1015,I,JL,JH,VSL,VSH
      PRINT 1015,I,JL,JH,VSL,VSH
      V(I,JL) = VSL
      V(I,JH) = VSH
      JL = JL+1
      JH = JH-1
      DV = (VSH-VSL)/FLOAT(JH-JL+2)
      DO 84 J=JL,JH
   84 V(I,J) = V(I,J-1)+DV
C
C                      LOG VOLTAGES
C
   87 IF (LOG) 96,96,90
   90 PRINT 1075
      DO 93 K=1,LOG
      READ 1015 ,I,JL,JH,VSL,VSH
      PRINT 1015,I,JL,JH,VSL,VSH
      V(I,JL) = VSL
      V(I,JH) = VSH
      JL = JL+1
      JH = JH-1
      RO = JL-2+NR0
      RT = JH+NR0
      DV = (VSH-VSL)/ALOG(RT/RO)
      DO 93 J=JL,JH
   93 V(I,J) = VSL+DV*ALOG(FLOAT(J-1+NR0)/RO)
C
C                    HORIZONTAL LINEAR
C
   96 IF (IHOR) 102,102,99
   99 PRINT 1080
      DO 100 K=1,IHOR
      READ 1015,IL,IH,J,VSL,VSH
      PRINT 1015,IL,IH,J,VSL,VSH
      V(IL,J) = VSL
```

```
      V(IH,J) = VSH
      IL = IL+1
      IH = IH-1
      DV = (VSH-VSL)/FLOAT(IH-IL+2)
      DO 100 I=IL,IH
  100 V(I,J) = V(I-1,J)+DV
  102 CONTINUE
C
C                    INITIAL POTENTIALS
C
      IF (MU-2) 106,106,104
  104 IF (IBU) 106,795,106
  106 DO 116 I=2,NZ1
      DO 114 L=1,LMM
      JL = MAXO(JX(I,2*L-1)+1,2)
      JH = JX(I,2*L)-1
      IF (JH-JL) 114,110,110
  110 DV = (V(I,JH+1)-V(I,JL-1))/FLOAT(JH-JL+2)
      DO 112 J=JL,JH
  112 V(I,J) = V(I,J-1)+DV
  114 CONTINUE
  116 CONTINUE
C
C                    ELECTRODE POTENTIALS
C
      DO 760 I=1,NZ
      IF (JX(I,1)-1) 715,715,700
  700 JL = 1
      JH = JX(I,1)-1
      DO 710 J=JL,JH
      IF (V(I,J)) 710,705,710
  705 V(I,J) = V(I,JH+1)
  710 CONTINUE
C
  715 JLL =  MAXO(JX(I,2),1)
      DO 740 K=2,LMM
      L = K+K-1
      IF (JX(I,L)) 740,740,720
  720 JH = JX(I,L)
      JL = JLL
      JLL = JX(I,L+1)
      IF (JH-JL) 740,740,725
  725 VS = V(I,JL)
      DO 735 J=JL,JH
      IF (V(I,J)) 735,730,735
  730 V(I,J) = VS
  735 CONTINUE
  740 CONTINUE
      JH = NR
      JL = JLL
      IF (JH-JL) 760,760,745
  745 DO 755 J=JL,JH
      IF (V(I,J)) 755,750,755
  750 V(I,J) = V(I,JL)
  755 CONTINUE
  760 CONTINUE
C
C                    FIELD RELAXATION
```

```
C
  795 CONTINUE
C
      N = 1
      K = 0
  125 DO 166 I=3,NZ2,2
      IF (JA(I)) 166,130,135
  130 JL = 1
      GO TO 140
  135 JL = 3+(JA(I)/2)*2
  140 JH = JB(I)-2
      IF (JH-JL) 166,142,142
  142 DO 165 J=JL,JH,2
      IF (J-1) 165,145,150
  145 VNU = (V(I+2,J)+V(I-2,J)+4.0*V(I,J+2))/6.0
      GO TO 165
  150 VNU = (V(I+2,J)+V(I-2,J)+V(I,J+2)+V(I,J-2))*0.25+RI(J)*(V(I,J+2)-
     1 V(I,J-2))*2.0
  165 V(I,J) = AMAX1((VNU-V(I,J))*BETA+V(I,J),1.0E-6)
  166 CONTINUE
C
      IF (LMM-1) 195,195,167
  167 DO 190 L=2,LMM
      LL = L+L-1
      LK = LL+1
      DO 185 I=3,NZ2,2
      IF (JX(I,LL)) 185,185,170
  170 JL = 3+(JX(I,LL)/2)*2
      JH = JX(I,LK)-2
      IF (JH-JL) 185,172,172
  172 DO 180 J=JL,JH,2
      VNU = (V(I+2,J)+V(I-2,J)+V(I,J+2)+V(I,J-2))*0.25+RI(J)*(V(I,J+2)-
     1 V(I,J-2))*2.0
  180 V(I,J) = AMAX1((VNU-V(I,J))*BETA+V(I,J),1.0E-6)
  185 CONTINUE
  190 CONTINUE
C
  195 CONTINUE
C
C                    INTERMEDIATE FILL IN
C
      DO 309 I=3,NZ2,2
      DO 306 KK=1,LMM
      L = KK+KK-1
      JL = 2+(JX(I,L)/2)*2
      JU = JX(I,L+1)-1
      IF (JU-JL) 306,300,300
  300 DO 303 J=JL,JU,2
  303 V(I,J) = (V(I,J+1)+V(I,J-1))*0.5
  306 CONTINUE
  309 CONTINUE
C
      DO 321 I=2,NZ2,2
      DO 318 KK=1,LMM
      L = KK+KK-1
      JL = JX(I,L)+1
      JU = JX(I,L+1)-1
      IF (JU-JL) 318,312,312
```

```
  312 DO 315 J=JL,JU
  315 V(I,J) = (V(I+1,J)+V(I-1,J))*0.5
  318 CONTINUE
  321 CONTINUE
C
C                    FINE MATRIX
C
  370 NE = 0
C
      DO  460 I=2,NZ1
      JL = JA(I)+1
      JU = JB(I)-1
      IF (JU-JL) 460,398,398
  398 DO 420 J=JL,JU
      IF (J-1) 400,400,405
  400 VNU = (V(I+1,J)+V(I-1,J)+4.0*V(I,J+1))/6.0
      GO TO 410
  405 VNU = (V(I+1,J)+V(I-1,J)+V(I,J+1)+V(I,J-1))*0.25+RI(J)*(V(I,J+1)-
     1 V(I,J-1))
  410 IF (ABS(V(I,J)/VNU-1.0)-EPSV) 420,420,415
  415 NE = NE+1
  420 V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
  460 CONTINUE
C
C
      DO 1460 I=2,NZ1
      II = NZ1-I+2
      JL = JA(II)+1
      JU = JB(II)-1
      IF (JU-JL) 1460,1398,1398
 1398 DO 1420 J=JL,JU
      JJ = JU-J+JL
      IF (JJ-1) 1400,1400,1405
 1400 VNU = (V(II+1,JJ)+V(II-1,JJ)+4.0*V(II,JJ+1))/6.0
      GO TO 1410
 1405 VNU = (V(II+1,JJ)+V(II-1,JJ)+V(II,JJ+1)+V(II,JJ-1))*0.25+RI(JJ)*
     1 (V(II,JJ+1)-V(II,JJ-1))
 1410 IF (ABS(V(II,JJ)/VNU-1.0)-EPSV) 1420,1420,1415
 1415 NE = NE+1
 1420 V(II,JJ) = (VNU-V(II,JJ))*BETA+V(II,JJ)
 1460 CONTINUE
C
      IF (LMM-1) 450,450,422
  422 DO 445 L=2,LMM
      LL = L+L-1
      LK = LL+1
      DO 442 I=2,NZ1
      IF (JX(I,LL)) 442,442,430
  430 JL = JX(I,LL)+1
      JU = JX(I,LK)-1
      IF (JU-JL) 442,432,432
  432 DO 440 J=JL,JU
      VNU = (V(I+1,J)+V(I-1,J)+V(I,J+1)+V(I,J-1))*0.25+RI(J)*(V(I,J+1)-
     1 V(I,J-1))
      IF (ABS(V(I,J)/VNU-1.0)-EPSV) 440,440,435
  435 NE = NE+1
  440 V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
  442 CONTINUE
```

```
  445 CONTINUE
C
      DO 1445 L=2,LMM
      LL = L+L+1
      LK = LL+1
      DO 1442 I=2,NZ1
      II = NZ1-I+2
      IF (JX(II,LL)) 1442,1442,1430
 1430 JL = JX(II,LL)+1
      JU = JX(II,LK)-1
      IF (JU-JL) 1442,1432,1432
 1432 DO 1440 J=JL,JU
      JJ = JU-J+JL
      VNU = (V(II+1,JJ)+V(II-1,JJ)+V(II,JJ+1)+V(II,JJ-1))*0.25+RI(JJ)*
     1 (V(II,JJ+1)+V(II,JJ-1))
      IF (ABS(V(II,JJ)/VNU-1.0)-EPSV) 1440,1440,1435
 1435 NE = NE+1
 1440 V(II,JJ) = (VNU-V(II,JJ))*BETA+V(II,JJ)
 1442 CONTINUE
 1445 CONTINUE
C
  450 CONTINUE
C
C                    DIELECTRIC INTERFACES
C
      LMM1 = LMM-1
      DO 589 L=1,LMM1
      LL = L+L
      LK = LL+1
      DO 588 I=2,NZ1
      IF (JX(I,LK)) 588,588,505
  505 IF (JX(I,LL)-JX(I,LK)) 588,510,588
  510 J = JX(I,LL)
      IF (JX(I-1,LL)-JX(I-1,LK)) 530,515,530
  515 IF (JX(I+1,LL)-JX(I+1,LK)) 535,520,535
  520 IF (J-JX(I-1,LL)) 540,525,545
  525 IF (J-JX(I+1,LL)) 565,550,570
  530 IF (J-JX(I+1,LL)) 560,550,555
  535 IF (J-JX(I-1,LL)) 555,550,560
  540 IF (J-JX(I+1,LL)) 585,575,555
  545 IF  (J-JX(I+1,LL)) 560,580,586
C                    HORIZONTAL
  550 VNU = ((V(I-1,J)+V(I+1,J))*(EP(L)*(0.5-RI(J))+EP(L+1)*(0.5+RI(J)))
     1 +EP(L+1)*V(I,J+1)*(1.0+4.0*RI(J))+EP(L)*(1.0-4.0*RI(J))*V(I,J-1))
     2/(EP(L)*(2.0-6.0*RI(J))+EP(L+1)*(2.0+6.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 588
C                    DOWN 45
  555 VNU = (V(I-1,J)*EP(L)+V(I+1,J)*EP(L+1)+V(I,J+1)*EP(L+1)*
     1 (1.0+4.0*RI(J))+V(I,J-1)*EP(L)*(1.0-4.0*RI(J)))/
     2 (EP(L)*(2.0-4.0*RI(J))+EP(L+1)*(2.0+4.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 588
C                    UP 45
  560 VNU = (V(I-1,J)*EP(L+1)+V(I+1,J)*EP(L)+V(I,J+1)*EP(L+1)*(1.0+4.0*
     1 RI(J))+V(I,J-1)*EP(L)*(1.0-4.0*RI(J)))/
     2 (EP(L)*(2.0-4.0*RI(J))+EP(L+1)*(2.0+4.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
```

```
      GO TO 588
C                     OVER AND UP
  565 VNU     = (V(I-1,J)*(EP(L)*(0.5-RI(J))+EP(L+1)*(0.5+RI(J)))+
     1 EP(L+1)*V(I,J+1)*(1.0+4.0*RI(J))+EP(L)*V(I+1,J)+EP(L)*V(I,J-1)*
     2 (1.0-4.0*RI(J)))/(EP(L)*(2.5-5.0*RI(J))+EP(L+1)*(1.5+5.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 588
C                     OVER AND DOWN
  570 VNU     = (V(I,J+1)*EP(L+1)*(1.0+4.0*RI(J))+V(I,J-1)*EP(L)*(1.0-4.0
     1 *RI(J))+V(I-1,J)*(EP(L)*(0.5-RI(J))+EP(L+1)*(0.5+RI(J)))+EP(L+1)*
     2 V(I+1,J))/(EP(L)*(1.5-5.0*RI(J))+EP(L+1)*(2.5+5.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 588
C                     DOWN AND OVER
  575 VNU     = (V(I+1,J)*(EP(L)*(0.5-RI(J))+EP(L+1)*(0.5+RI(J)))+EP(L+1)
     1 *V(I,J+1)*(1.0+4.0*RI(J))+EP(L)*V(I-1,J)+V(I,J-1)*EP(L)*(1.0-4.0*
     2 RI(J)))/(EP(L)*(2.5-5.0*RI(J))+EP(L+1)*(1.5+5.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 588
C                     UP AND OVER
  580 VNU     = (V(I,J+1)*EP(L+1)*(1.0+4.0*RI(J))+EP(L)*V(I,J-1)*(1.0-4.0
     1 *RI(J))+EP(L+1)*V(I-1,J)+V(I+1,J)*(EP(L)*(0.5-RI(J))+EP(L+1)*(0.5
     2 +RI(J))))/(EP(L)*(1.5-5.0*RI(J))+EP(L+1)*(2.5+5.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 588
C                     DOWN AND UP
  585 VNU     = (EP(L)*(1.0-4.0*RI(J))*V(I,J-1)+EP(L+1)*(1.0+4.0*RI(J))*
     1 V(I,J+1)+EP(L)*V(I-1,J)+EP(L)*V(I+1,J))/(EP(L)*(3.0-4.0*RI(J))+
     2 EP(L+1)*(1.0+4.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 588
C                     UP AND DOWN
  586 VNU     = (EP(L)*(1.0-4.0*RI(J))*V(I,J-1)+EP(L+1)*(1.0+4.0*RI(J))*
     1V(I,J+1)+EP(L+1)*V(I-1,J)+EP(L+1)*V(I+1,J))/(EP(L)*(1.0-4.0*RI(J))
     2 +EP(L+1)*(3.0+4.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
  588 CONTINUE
  589 CONTINUE
C
C                     VERTICAL INTERFACES
C
      IF (IDI) 868,868,803
  803 DO 854 M=1,IDIC,4
      I = ID(M+1)
      JL = ID(M+2)+1
      JH = ID(M+3)-1
      L = M/4+1
      IF (JH-JL) 807,805,805
  805 DO 806 J=JL,JH
      VNU = (V(I,J+1)*(EPV(L)+EPV(L+1))*(0.5+2.0*RI(J))+V(I-1,J)*EPV(L)+
     1 V(I+1,J)*EPV(L+1) +V(I,J-1)*(EPV(L)+EPV(L+1))*(0.5-2.0*RI(J)))/
     2 (2.0*EPV(L)+2.0*EPV(L+1))
  806 V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
  807 IB = ID(M)/100
      IT = ID(M)-100*IB
      IF(IB) 830,830,809
  809 J = JL-1
      GO TO (812,815,818,821,824,827),IB
```

```
C                    DOWN AND STRAIGHT UP
  812 VNU     = ((V(I-1,J)+V(I+1,J))*EPV(L+1)+V(I,J-1)*EPV(L+1)*(1.0-
     1 4.0*RI(J))+V(I,J+1)*(EPV(L)+EPV(L+1))*(0.5+2.0*RI(J)))/
     2 (EPV(L)*(0.5+2.0*RI(J))+EPV(L+1)*(3.5-2.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 830
C                    OVER AND STRAIGHT UP
  815 VNU     = ((EPV(L)*(0.5+RI(J))+EPV(L+1)*(0.5-RI(J)))*V(I-1,J)+
     1 EPV(L+1)*V(I+1,J)+EPV(L+1)*(1.0-4.0*RI(J))*V(I,J-1)+(EPV(L)+EPV(
     2 L+1))*(0.5+2.0*RI(J))*V(I,J+1))/(EPV(L)*(1.0+3.0*RI(J))+EPV(L+1)*
     3 (3.0-3.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 830
C                    UP AND STRAIGHT UP
  818 VNU     = (EPV(L)*V(I-1,J)+EPV(L+1)*V(I+1,J)+EPV(L+1)*(1.0-4.0*RI(J
     1 ))*V(I,J-1)+V(I,J+1)*(EPV(L)+EPV(L+1))*(0.5+2.0*RI(J)))/
     2 (EPV(L)*(1.5+2.0*RI(J))+EPV(L+1)*(2.5-2.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 830
C                    STRAIGHT DOWN AND DOWN
  821 VNU     = (EPV(L)*V(I-1,J)+EPV(L+1)*V(I+1,J)+EPV(L)*(1.0-4.0*RI(J))
     1 *V(I,J-1)+V(I,J+1)*(EPV(L)+EPV(L+1))*(0.5+2.0*RI(J)))/
     2 (EPV(L)*(2.5-2.0*RI(J))+EPV(L+1)*(1.5+2.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 830
C                    STRAIGHT DOWN AND OVER
  824 VNU     = (EPV(L)*V(I-1,J)+EPV(L)*V(I,J-1)*(1.0-4.0*RI(J))
     1 +(EPV(L)*(0.5-RI(J))+EPV(L+1)*(0.5+RI(J)))*V(I+1,J)+V(I,J+1)*
     2 (EPV(L)+EPV(L+1))*(0.5+2.0*RI(J)))/(EPV(L)*(3.0-3.0*RI(J))+
     3 EPV(L+1)*(1.0+3.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 830
C                    STRAIGHT DOWN AND UP
  827 VNU     = (EPV(L)*(V(I+1,J)+V(I-1,J))+EPV(L)*(1.0-4.0*RI(J))*V(I,J-
     1 1)+V(I,J+1)*(EPV(L)+EPV(L+1))*(0.5+2.0*RI(J)))/(EPV(L)*(3.5-2.0*
     2 RI(J))+EPV(L+1)*(0.5+2.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
  830 IF (IT) 854,854,833
  833 J = JH+1
      GO TO (836,839,842,845,848,851),IT
C                    UP AND STRAIGHT DOWN
  836 VNU     = (EPV(L+1)*(V(I-1,J)+V(I+1,J))+EPV(L+1)*(1.0+4.0*RI(J))*
     1 V(I,J+1)+V(I,J-1)*(EPV(L)+EPV(L+1))*(0.5-2.0*RI(J)))/
     2 (EPV(L)*(0.5-2.0*RI(J))+EPV(L+1)*(3.5+2.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 854
C                    OVER AND STRAIGHT DOWN
  839 VNU     = (EPV(L+1)*V(I+1,J)+V(I-1,J)*(EPV(L)*(0.5-RI(J))+EPV(L+1)
     1 *(0.5+RI(J)))+EPV(L+1)*(1.0+4.0*RI(J))*V(I,J+1)+V(I,J-1)*(EPV(L)+
     2EPV(L+1))*(0.5-2.0*RI(J)))/(EPV(L)*(1.0-3.0*RI(J))+EPV(L+1)*(3.0+
     3 3.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 854
C                    DOWN AND STRAIGHT DOWN
  842 VNU     = (EPV(L)*V(I-1,J)+EPV(L+1)*V(I+1,J)+EPV(L+1)*(1.0+4.0*RI(J
     1 ))*V(I,J+1)+V(I,J-1)*(EPV(L)+EPV(L+1))*(0.5-2.0*RI(J)))/
     1 (EPV(L)*(1.5-2.0*RI(J))+EPV(L+1)*(2.5+2.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
```

```
      GO TO 854
C                     STRAIGHT UP AND UP
  845 VNU     = (EPV(L)*V(I-1,J)+EPV(L+1)*V(I+1,J)+EPV(L)*(1.0+4.0*RI(J))
     1 *V(I,J+1)+V(I,J-1)*(EPV(L)+EPV(L+1))*(0.5-2.0*RI(J)))/
     2 (EPV(L)*(2.5+2.0*RI(J))+EPV(L+1)*(1.5-2.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 854
C                     STRAIGHT UP AND OVER
  848 VNU     = (EPV(L)*V(I-1,J)+EPV(L)*(1.0+4.0*RI(J))*V(I,J+1)+V(I+1,J)
     1 *(EPV(L)*(0.5+RI(J))+EPV(L+1)*(0.5-RI(J)))+V(I,J-1)*(EPV(L)+
     2 EPV(L+1))*(0.5-2.0*RI(J)))/(EPV(L)*(3.0+3.0*RI(J))+EPV(L+1)*(1.0
     3-3.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 854
C                     STRAIGHT UP AND DOWN
  851 VNU     = (EPV(L)*(V(I-1,J)+V(I+1,J))+EPV(L)*(1.0+4.0*RI(J))*V(I,J+
     1 1)+V(I,J-1)*(EPV(L)+EPV(L+1))*(0.5-2.0*RI(J)))/(EPV(L)*(3.5+2.0*
     2 RI(J))+EPV(L+1)*(0.5-2.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
  854 CONTINUE
C
C                     FLOATING ELECTRODES
C
      IF (LMM) 299,299,200
  200 IF (METAL) 299,299,202
  202 DO 297 NN =1,METAL
      M = 2*NN-1
      DO 296 I=2,N71
      IF (JM(I,M)) 296,296,204
  204 IF (JM(I+1,M)) 296,296,206
  206 IF (JM(I-1,M)) 296,296,208
  208 DO 210 L=1,LMM
      LL = L+L
      IF (JM(I,M)-JX(I,LL)) 210,212,210
  210 CONTINUE
      GO TO 238
  212 J = JM(I,M)
      IF (J-JM(I-1,M)) 216,214,218
  214 IF (J-JM(I+1,M)) 226,220,228
  216 IF (J-JM(I+1,M)) 234,230,222
  218 IF (J-JM(I+1,M)) 224,232,236
C                     HORIZONTAL
  220 VNU = ((V(I-1,J)+V(I+1,J))*(EP(L)*(0.5-RI(J))+EPM     *(0.5+RI(J)))
     1 +EPM  *V(I,J+1)*(1.0+4.0*RI(J))+EP(L)*(1.0-4.0*RI(J))*V(I,J-1))/
     2 (EP(L)*(2.0-6.0*RI(J))+EPM     *(2.0+6.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 238
C                     DOWN 45
  222 VNU = (V(I-1,J)*EP(L)+V(I+1,J)*EPM     +V(I,J+1)*EPM     *
     1 (1.0+4.0*RI(J))+V(I,J-1)*EP(L)*(1.0-4.0*RI(J)))/
     2 (EP(L)*(2.0-4.0*RI(J))+EPM     *(2.0+4.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 238
C                     UP 45
  224 VNU = (V(I-1,J)*EPM     +V(I+1,J)*EP(L)+V(I,J+1)*EPM     *(1.0+4.0*
     1 RI(J))+V(I,J-1)*EP(L)*(1.0-4.0*RI(J)))/
     2 (EP(L)*(2.0-4.0*RI(J))+EPM     *(2.0+4.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
```

```
      GO TO 238
C                     OVER AND UP
  226 VNU     = (V(I-1,J)*(EP(L)*(0.5-RI(J))+EPM     *(0.5+RI(J)))+
     1 EPM     *V(I,J+1)*(1.0+4.0*RI(J))+EP(L)*V(I+1,J)+EP(L)*V(I,J-1)*
     2 (1.0-4.0*RI(J)))/(EP(L)*(2.5-5.0*RI(J))+EPM     *(1.5+5.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 238
C                     OVER AND DOWN
  228 VNU     = (V(I,J+1)*EPM     *(1.0+4.0*RI(J))+V(I,J-1)*EP(L)*(1.0-4.0
     1 *RI(J))+V(I-1,J)*(EP(L)*(0.5-RI(J))+EPM     *(0.5+RI(J)))+EPM     *
     2 V(I+1,J))/(EP(L)*(1.5-5.0*RI(J))+EPM     *(2.5+5.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 238
C                     DOWN AND OVER
  230 VNU     = (V(I+1,J)*(EP(L)*(0.5-RI(J))+EPM     *(0.5+RI(J)))+EPM
     1 *V(I,J+1)*(1.0+4.0*RI(J))+EP(L)*V(I-1,J)+V(I,J-1)*EP(L)*(1.0-4.0*
     2 RI(J)))/(EP(L)*(2.5-5.0*RI(J))+EPM     *(1.5+5.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 238
C                     UP AND OVER
  232 VNU     = (V(I,J+1)*EPM     *(1.0+4.0*RI(J))+EP(L)*V(I,J-1)*(1.0-4.0
     1 *RI(J))+EPM     *V(I-1,J)+V(I+1,J)*(EP(L)*(0.5-RI(J))+EPM     *(0.5
     2 +RI(J))))/(EP(L)*(1.5-5.0*RI(J))+EPM     *(2.5+5.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 238
C                     DOWN AND UP
  234 VNU     = (EP(L)*(1.0-4.0*RI(J))*V(I,J-1)+EPM     *(1.0+4.0*RI(J))*
     1 V(I,J+1)+EP(L)*V(I-1,J)+EP(L)*V(I+1,J))/(EP(L)*(3.0-4.0*RI(J))+
     2 EPM     *(1.0+4.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 238
C                     UP AND DOWN
  236 VNU     = (EP(L)*(1.0-4.0*RI(J))*V(I,J-1)+EPM     *(1.0+4.0*RI(J))*
     1V(I,J+1)+EPM     *V(I-1,J)+EPM     *V(I+1,J))/(EP(L)*(1.0-4.0*RI(J))
     2 +EPM     *(3.0+4.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
  238 DO 240 L=1,LMM
      LL = L+L+1
      IF (JM(I,M+1)-JX(I,LL)) 240,242,240
  240 CONTINUE
      GO TO 268
  242 J = JM(I,M+1)
      IF (J-JM(I-1,M+1)) 246,244,248
  244 IF (J-JM(I+1,M+1)) 256,250,258
  246 IF (J-JM(I+1,M+1)) 264,260,252
  248 IF (J-JM(I+1,M+1)) 254,262,266
C                     HORIZONTAL
  250 VNU = ((V(I-1,J)+V(I+1,J))*(EPM  *(0.5-RI(J))+EP(L+1)*(0.5+RI(J)))
     1 +EP(L+1)*V(I,J+1)*(1.0+4.0*RI(J))+EPM*(1.0-4.0*RI(J))*V(I,J-1))/
     2 (EPM  *(2.0-6.0*RI(J))+EP(L+1)*(2.0+6.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 268
C                     DOWN 45
  252 VNU = (V(I-1,J)*EPM  +V(I+1,J)*EP(L+1)+V(I,J+1)*EP(L+1)*
     1 (1.0+4.0*RI(J))+V(I,J-1)*EPM  *(1.0-4.0*RI(J)))/
     2 (EPM  *(2.0-4.0*RI(J))+EP(L+1)*(2.0+4.0*RI(J)))
      V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
      GO TO 268
```

```
C                    UP 45
  254 VNU = (V(I-1,J)*EP(L+1)+V(I+1,J)*EPM  +V(I,J+1)*EP(L+1)*(1.0+4.0*
     1 RI(J))+V(I,J-1)*EPM  *(1.0-4.0*RI(J)))/
     2 (EPM  *(2.0-4.0*RI(J))+EP(L+1)*(2.0+4.0*RI(J)))
       V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
       GO TO 268
C                    OVER AND UP
  256 VNU    = (V(I-1,J)*(EPM  *(0.5-RI(J))+EP(L+1)*(0.5+RI(J)))+
     1 EP(L+1)*V(I,J+1)*(1.0+4.0*RI(J))+EPM  *V(I+1,J)+EPM  *V(I,J-1)*
     2 (1.0-4.0*RI(J)))/(EPM  *(2.5-5.0*RI(J))+EP(L+1)*(1.5+5.0*RI(J)))
       V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
       GO TO 268
C                    OVER AND DOWN
  258 VNU    = (V(I,J+1)*EP(L+1)*(1.0+4.0*RI(J))+V(I,J-1)*EPM  *(1.0-4.0
     1 *RI(J))+V(I-1,J)*(EPM  *(0.5-RI(J))+EP(L+1)*(0.5+RI(J)))+EP(L+1)*
     2 V(I+1,J))/(EPM  *(1.5-5.0*RI(J))+EP(L+1)*(2.5+5.0*RI(J)))
       V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
       GO TO 268
C                    DOWN AND OVER
  260 VNU    = (V(I+1,J)*(EPM  *(0.5-RI(J))+EP(L+1)*(0.5+RI(J)))+EP(L+1)
     1 *V(I,J+1)*(1.0+4.0*RI(J))+EPM  *V(I-1,J)+V(I,J-1)*EPM  *(1.0-4.0*
     2 RI(J)))/(EPM  *(2.5-5.0*RI(J))+EP(L+1)*(1.5+5.0*RI(J)))
       V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
       GO TO 268
C                    UP AND OVER
  262 VNU    = (V(I,J+1)*EP(L+1)*(1.0+4.0*RI(J))+EPM  *V(I,J-1)*(1.0-4.0
     1 *RI(J))+EP(L+1)*V(I-1,J)+V(I+1,J)*(EPM  *(0.5-RI(J))+EP(L+1)*(0.5
     2 +RI(J))))/(EPM  *(1.5-5.0*RI(J))+EP(L+1)*(2.5+5.0*RI(J)))
       V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
       GO TO 268
C                    DOWN AND UP
  264 VNU    = (EPM  *(1.0-4.0*RI(J))*V(I,J-1)+EP(L+1)*(1.0+4.0*RI(J))*
     1 V(I,J+1)+EPM  *V(I-1,J)+EPM  *V(I+1,J))/(EPM  *(3.0-4.0*RI(J))+
     2 EP(L+1)*(1.0+4.0*RI(J)))
       V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
       GO TO 268
C                    UP AND DOWN
  266 VNU    = (EPM  *(1.0-4.0*RI(J))*V(I,J-1)+EP(L+1)*(1.0+4.0*RI(J))*
     1V(I,J+1)+EP(L+1)*V(I-1,J)+EP(L+1)*V(I+1,J))/(EPM  *(1.0-4.0*RI(J))
     2 +EP(L+1)*(3.0+4.0*RI(J)))
       V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
  268 JL = JM(I,M)+1
       JU = JM(I,M+1)-1
       IF (JU-JL) 296,270,270
  270 DO 272 J=JL,JU
       VNU    = (V(I,J+1)+V(I,J-1)+V(I+1,J)+V(I-1,J))*0.25+RI(J)*(V(I,J+1
     1 )-V(I,J-1))
  272 V(I,J) = (VNU-V(I,J))*BETA+V(I,J)
  296 CONTINUE
  297 CONTINUE
  299 CONTINUE
C
  868 K = K+1
  869 IF (K-MM) 872,875,875
  872 IF (NE-NVEM) 875,875,873
  873 IF (N-2) 125,370,370
  875 PRINT 1020,NE
       N = N+1
```

```
      K = 0
C
      IF (N-3) 876,876,878
  876 BETA = 1.0+(1.0-BETA)*0.5*(FLOAT(N)-3.0)
      GO TO 370
  878 IF (METAL) 899,899,879
  879 IF (N-5) 881,882,883
  881 EPM = 1000.0
      EPO = 101.0
      GO TO 884
  882 EPM = 10000.0
      EPO = 1000.0
      GO TO 884
  883 EPM = 100000.0
      EPO = 10000.0
      IF (N-6) 884,884,899
  884 ICK = IDI+1
      DO 886 K=1,ICK
      IF (EPV(K)-EPO) 886,885,886
  885 EPV(K) = EPM
  886 CONTINUE
      K = 0
      GO TO 370
  899 IF (IBU) 905,905,900
  900 IRN = IRN+1
      IBU = IBU-1
      IRO = IRN
  905 IF (MU-4) 910,950,950
  910 IF (MU-2) 950,915,915
C
  915 CALL WTTAPE (IST,ISTP,IRN,V,NVR)
      IRO = IRN
C
      READ 1040,IBU,IEF
C
      PRINT 1040,IBU,IEF
C
      IF (IBU) 925,925,920
  920 CALL BLOWUP (IBU,IRN,IST,ISTP,NVR,IRO)
  925 IF (IEF) 950,950,930
  930 CALL EFIELD (IEF,IST,ISTP,IRN,NVR,IRO)
C
  950 IF (IPD-1) 955,965,955
  955 DO 960 J=1,NR
  960 PRINT 1050,J,(V(I,J),I=1,NZ)
  965 CONTINUE
C
      READ 1025,VCON
      PRINT 1025,VCON
      IF (VCON(1)) 970,5,970
  970 CALL EQPLOT
C
      G O  T O 5
C
C                    FORMATS
C
 1000 FORMAT (18I4/(8E9.2))
 1005 FORMAT (20I3)
```

```
 1010 FORMAT (2I4,E9.2)
 1015 FORMAT (3I4,2E9.2)
 1020 FORMAT (/I10)
 1025 FORMAT (8E9.2)
 1030 FORMAT (2I4)
 1035 FORMAT (12F6.0)
 1040 FORMAT (20I4)
 1045 FORMAT (1H1//58X,5HFEARS//32X,57HFLOATING ELECTRODE AXISYMMETRIC )
     1R RECTANGULAR SIMULATION///)
 1050 FORMAT (I5/(10E12.5))
 1055 FORMAT (/6H     J(,I2,12H), EPS REL =,F10.3/(10I4,2X,10I4,2X,10I4))
 1060 FORMAT (///6H     J(,I2,1H)/(10I4,2X,10I4,2X,10I4))
 1065 FORMAT (/4H MM=,I4,4H,VE=,I4,4H,NZ=,I4,4H,NR=,I4,4H,RO=,I4,4H,MU=,
     1 I4,5H,JJV=,I4,6(1H,I4),       4H,VV=,I4,4H,HV=,I4,4H,LG=,I4,4H,RN=
     2 ,I4,4H,PO=,I4/7H EPSV =,F9.5,8H, BETA =,F7.2)
 1070 FORMAT (25H-VERTICAL LINEAR VOLTAGES)
 1075 FORMAT (22H-VERTICAL LOG VOLTAGES)
 1080 FORMAT(27H-HORIZONTAL LINEAR VOLTAGES)
 1095 FORMAT (//7H     JM(,I2,8H), METAL /(10I4,2X,10I4,2X,10I4))
 1100 FORMAT (/7H     JM(,I2,1H) /(10I4,2X,10I4,2X,10I4))
 1105 FORMAT (4(F10.3,4I5))
C
      END
```

```
      SUBROUTINE BLOWUP (IBU,IRN,IST,ISTP,NVR,IRO)
C
      COMMON NZ,NR,IX,IY,IDX,IDY,ISS,IT,NP,N,PY,REC,CV,R,Z,IPT,INX,INY,
     1 V,XL,YL,S,U,NT,MT,IZX,DX,DY,XMAX,SCALE,YMAX,VCON,JSYM,LSYM,JT
     2 ,SV, XYM, IRIT, NPLOT, IZ,IR, MLNTH, IRB, IRT, IZL, IZR
C
      DIMENSION V(201,201), REC(3,400), Z(2,1000), R(2,1000), IPT(3,3),
     1 INX(8), INY(8), VCON(24)
      DIMENSION  SV(100), XYM(40), IRIT(10), IZ(2000), IR(2000)
      IRO = IRN
C
      DO 50 N=1,IBU
   10 READ 1000,IEX,IL,IH,JL,JH
C
      PRINT 1000,IEX,IL,IH,JL,JH
C
      IF (IEX) 12,12,13
   12 IRN = IRO+1
      RETURN
   13 K = 0
      DO 15 I=IL,IH
      K = K+1
      Z(1,K) = V(I,JL)
   15 Z(2,K) = V(I,JH)
C
      K = 0
      DO 20 J=JL,JH
      K = K+1
      R(1,K) = V(IL,J)
   20 R(2,K) = V(IH,J)
C
      DO 25 K=1,NVR
   25 V(K) = 0.0
      IUP = (IH-IL)*IEX+1
      JUP = (JH-JL)*IEX+1
      K = 0
      DO 30 I=1,IUP,IEX
      K = K+1
      V(I,1) = Z(1,K)
   30 V(I,JUP) = Z(2,K)
      K = 0
      DO 35 J=1,JUP,IEX
      K = K+1
      V(1,J) = R(1,K)
   35 V(IUP,J) = R(2,K)
      IJB = 1+IEX
      IE = IEX-1
      DO 40 I=IJB,IUP,IEX
      DV1 = (V(I,1)-V(I-IEX,1))/FLOAT(IEX)
      DV2 = (V(I,JUP)-V(I-IEX,JUP))/FLOAT(IEX)
      DO 40 K=1,IE
      IK = I-IEX+K
      V(IK,1) = V(IK-1,1)+DV1
   40 V(IK,JUP) = V(IK-1,JUP)+DV2
      DO 45 J=IJB,JUP,IEX
      DV1 = (V(1,J)-V(1,J-IEX))/FLOAT(IEX)
      DV2 = (V(IUP,J)-V(IUP,J-IEX))/FLOAT(IEX)
      DO 45 K=1,IE
```

```
      IK = J-IEX+K
      V(1,IK) = V(1,IK-1)+DV1
   45 V(IUP,IK) = V(IUP,IK-1)+DV2
C
      CALL WTTAPE (IST,ISTP,IRN,V,NVR)
      CALL RDTAPE (IST,ISTP,IR0,V,NVR)
C
   50 CONTINUE
      RETURN
 1000 FORMAT (5I4)
      END
```

```
      SUBROUTINE EFIELD(IEF,IST,ISTP,IRN,NVR,IRO)
C
      COMMON NZ,NR,IX,IY,IDX,IDY,ISS,IT,NP,N,PY,REC,CV,R,Z,IPT,INX,INY,
     1 V,XL,YL,S,U,NT,MT,IZX,DX,DY,XMAX,SCALE,YMAX,VCON,JSYM,LSYM,JT
     2 ,SV, XYM, IRIT, NPLOT, IZ,IR, MLNTH, IRB, IRT, IZL, IZR
C
      DIMENSION V(201,201), REC(3,400), Z(2000), R(2000),IPT(3,3),INX(8)
     1,INY(8), VCON(24)
      DIMENSION  SV(100), XYM(40), IRIT(10), IZ(2000), IR(2000)
C
      REWIND 51
      NZ1 = NZ-1
      DO 10 K=2,NZ1
      L = K-1
      LL = K+1
   10 WRITE TAPE 51 ,((V(I,J),J=1,NR),I=L,LL)
      REWIND 51
      READ TAPE 51,((REC(I,J),J=1,NR),I=1,3)
      V(1,1) = (REC(1,1)-REC(1,2))**2+(REC(1,1)-REC(2,1))**2
      NR1 = NR-1
      V(1,NR) = (REC(1,NR)-REC(1,NR-1))**2+(REC(1,NR)-REC(2,NR))**2
      V(2,1) = (REC(2,1)-REC(2,2))**2+((REC(1,1)-REC(3,1))*0.5)**2
      V(2,NR) = (REC(2,NR)-REC(2,NR-1))**2+((REC(1,NR)-REC(3,NR))*0.5)**
     1 2
      DO 15 J=2,NR1
      V(1,J) = (REC(1,J)-REC(2,J))**2+((REC(1,J+1)-REC(1,J-1))*0.5)**2
   15 V(2,J) = ((REC(1,J)-REC(3,J))**2+(REC(2,J+1)-REC(2,J-1))**2)*0.25
      DO 20 K=3,NZ1
      READ TAPE 51,((REC(I,J),J=1,NR),I=1,3)
      V(K,1) = (REC(2,1)-REC(2,2))**2+((REC(1,1)-REC(3,1))*0.5)**2
      V(K,NR) = (REC(2,NR)-REC(2,NR-1))**2+((REC(1,NR)-REC(3,NR))*0.5)**
     12
      DO 20 J=2,NR1
   20 V(K,J) = ((REC(2,J+1)-REC(2,J-1))**2+(REC(1,J)-REC(3,J))**2)*0.25
      V(NZ,1) = (REC(2,1)-REC(3,1))**2+(REC(3,1)-REC(3,2))**2
      V(NZ,NR) = (REC(2,NR)-REC(3,NR))**2+(REC(3,NR)-REC(3,NR-1))**2
      DO 25 J=2,NR1
   25 V(NZ,J) =  (REC(2,J)-REC(3,J))**2+((REC(3,J+1)-REC(3,J-1))*0.5)**2
      GO TO (30,40),IEF
   30 DO 35 J=1,NR
      DO 35 I=1,NZ
   35 V(I,J) = SQRT(V(I,J))
   40 EMAX = 0.0
      DO 45 J=1,NR
      DO  45 I=1,NZ
   45 EMAX = AMAX1(EMAX,V(I,J))
      DE = EMAX/10.0
      VCON(1) = 0.00001
      DO 50 K=2,11
   50 VCON(K) = DE*FLOAT(K-1)
      VCON(12) = 0.0
      CALL EQPLOT
C
      PRINT 1000,EMAX,(VCON(I),I=1,11)
C
      DO 55 J=1,NR
   55 PRINT 1005,J,(V(I,J),I=1,NZ)
C
```

```
C     CALL RDTAPE (IST,ISTP,IRO,V,NVR)
      RETURN
 1000 FORMAT (//8H  EMAX =,E15.6//(10E12.4))
 1005 FORMAT (I5/(10E12.5))
      END
```

```
      SUBROUTINE EQPLOT
      COMMON NZ,NR,IX,IY,IDX,IDY,ISS,IT,NP,N,PY,REC,CV,R,Z,IPT,INX,INY,
     1 V,XL,YL,S,U,NT,MT,IZX,DX,DY,XMAX,SCALE,YMAX,VCON,JSYM,LSYM,JT
     2 ,SV, XYM, IRIT, NPLOT, IZ,IR, MLNTH, IRB, IRT, IZL, IZR
      DIMENSION V(201,201), REC(1200), Z(2000), R(2000),IPT(3,3),INX(8),
     1 INY(8), VCON(24)
      DIMENSION  SV(100), XYM(40), IRIT(10), IZ(2000), IR(2000)
      DIMENSION ISYMT(12)
C
      IF (IZX) 5,6,5
    5 ISYMT(1) = 42
      ISYMT(2) = 44
      ISYMT(3) = 16
      ISYMT(4) = 63
      ISYMT(5) = 55
      ISYMT(6) = 58
      ISYMT(7) = 38
      ISYMT(8) = 42
      ISYMT(9) = 44
      ISYMT(10) = 16
      ISYMT(11) = 63
      ISYMT(12) = 55
      CALL HDCOPY(10)
C
    6 CONTINUE
C
      RNR = 0.1*FLOAT(NR-1)
      K = 0
C
      CALL SMXYV(0,0)
      CALL GRID1V (1,0.0,RNR,0.0,RNR,1.0,1.0,-0,-0,1,1,2,2)
C
      IRB = NYV(0.0)
      IRT = NYV(RNR)
      IZL = NXV (0.0)
      IZR = NXV (RNR)
      IF (NZ-NR) 25,25,10
   10 XYM(1) = RNR
      XYM(2) = RNR+RNR
      XYM(3) = 0.0
      XYM(4) = RNR
      K = K+1
      IF (NZ-NR-NR) 25,25,20
   20 XYM(5) = RNR+RNR
      XYM(6) = 3.0*RNR
      XYM(7) = 0.0
      XYM(8) = RNR
      K = K+1
   25 READ 1000,IL,IW,JB,JT
 1000 FORMAT (4I4)
      IF (IL) 35,35,30
   30 XYM(4*K+1) = FLOAT (IL-1)*0.1
      XYM(4*K+2) = FLOAT (IW-1)*0.1
      XYM(4*K+3) = FLOAT (JB-1)*0.1
      XYM(4*K+4) = FLOAT (JT-1)*0.1
      PRINT 1000,IL,IW,JB,JT
      K = K+1
      GO TO 25
```

```
   35 CONTINUE
C
      NPLOT = K
      DO 36 I=1,NPLOT
      ITP = 50+I
      REWIND ITP
   36 IRIT(I) = 0
C
      II = 1
      DO 115 L=1,24
      IF (VCON(L)) 120,120,100
  100 CV = VCON(L)
      GO TO (105,110),II
  105 JSYM = 0
      LSYM = 0
      II = 2
      GO TO 115
  110 JSYM= 25
      LL = L/2
      LSYM = ISYMT(LL)
      II = 1
  115 CALL SCAN
  120 CONTINUE
C
      K = 0
      IF (NPLOT) 60,60,40
   40 DO 55 I=1,NPLOT
      CALL HOLDIV(1)
      CALL GRID1V (1,XYM(4*K+1),XYM(4*K+2),XYM(4*K+3), XYM(4*K+4),1.0,1.
     1 ,-0,-0,1,1,2,2)
      K = K+1
      IMAX = IRIT(I)
      ITP = I+50
      REWIND ITP
      DO 50 KK=1,IMAX
      READ TAPE ITP,KI,JSYM,LSYM,(IZ(J),IR(J),J=1,KI)
   50 CALL PILINE (IZ,IR,KI,JSYM,LSYM)
   55 CONTINUE
C
   60 RETURN
      END
```

```
      SUBROUTINE CDPLOT
      COMMON NZ,NR,IX,IY,IDX,IDY,ISS,IT,NP,N,PY,REC,CV,R,Z,IPT,INX,INY,
     1 V,XL,YL,S,U,NT,MT,IZX,DX,DY,XMAX,SCALE,YMAX,VCON,JSYM,LSYM,JT
     2 ,SV, XYM, IRIT, NPLOT, IZ,IR, MLNTH, IRB, IRT, IZL, IZR
C
      DIMENSION V(201,201), REC(1200), Z(2000), R(2000),IPT(3,3),INX(8),
     1 INY(8), VCON(24)
      DIMENSION  SV(100), XYM(40), IRIT(10), IZ(2000), IR(2000)
      K = 0
      DO 20 I=1,N
      K = K+1
      IZ(K) = NXV(Z(I))
      IF (IZ(K)) 10,10,15
   10 K = K-1
      GO TO 20
   15 IR(K) = NYV(R(I))
   20 CONTINUE
C
      IF (K) 27,27,23
C
   23 CALL PILINE (IZ,IR,K,JSYM,LSYM)
C
   27 IF (NPLOT) 55,55,28
   28 DO 50 KK=1,NPLOT
      CALL XSCALV(XYM(4*KK-3),XYM(4*KK-2),IZL,1023-IZR)
      CALL YSCALV(XYM(4*KK-1),XYM(4*KK),IRB,1023-IRT)
      K = 0
      DO 40 I=1,N
      K = K+1
      IZ(K) = NXV(Z(I))
      IF (IZ(K)) 30,30,35
   30 K = K-1
      GO TO 40
   35 IR(K) = NYV(R(I))
      IF (IR(K)) 37,37,40
   37 K = K-1
   40 CONTINUE
      IF (K) 50,50,45
   45 IRIT(KK) = IRIT(KK)+1
      ITP = KK+50
      WRITE TAPE ITP,K,JSYM,LSYM,(IZ(I),IR(I),I=1,K)
   50 CONTINUE
      RNR = 0.1*FLOAT(NR-1)
      CALL XSCALV (0.0,RNR,IZL,1023-IZR)
      CALL YSCALV (0.0,RNR,IRB,1023-IRT)
   55 RETURN
      END
```

```
      SUBROUTINE SCAN
C
      COMMON NZ,NR,IX,IY,IDX,IDY,ISS,IT,NP,N,PY,REC,CV,R,Z,IPT,INX,INY,
     1 V,XL,YL,S,U,NT,MT,IZX,DX,DY,XMAX,SCALE,YMAX,VCON,JSYM,LSYM,JT
     2 ,SV, XYM, IRIT, NPLOT, IZ,IR, MLNTH, IRB, IRT, IZL, IZR
C
      DIMENSION V(201,201), REC(1200), Z(2000), R(2000),IPT(3,3),INX(8),
     1 INY(8), VCON(24)
      DIMENSION  SV(100), XYM(40), IRIT(10), IZ(2000), IR(2000)
C
      MLNTH = 201
      NREC = 1200
      NP = 0
      NT = NR
      MT = NZ
      IF (IZX) 10,10,5
    5 IPT(1,1) = 8
      IPT(1,2) = 1
      IPT(1,3) = 2
      IPT(2,1) = 7
      IPT(2,3) = 3
      IPT(3,1) = 6
      IPT(3,2) = 5
      IPT(3,3) = 4
      INX(1) = -1
      INX(2) = -1
      INX(3) = 0
      INX(4) = 1
      INX(5) = 1
      INX(6) = 1
      INX(7) = 0
      INX(8) = -1
      INY(1) = 0
      INY(2) = 1
      INY(3) = 1
      INY(4) = 1
      INY(5) = 0
      INY(6) = -1
      INY(7) = -1
      INY(8) = -1
      IZX = 0
   10 CONTINUE
      DO 15 J=1, NREC
   15 REC(J) = 0.0
      ISS = 0
C
   20 MT1 = MT-1
      DO 40 I=1,MT1
      IF (V(I,1)-CV) 25,40,40
   25 IF (V(I+1,1)-CV) 40,30,30
   30 IF (V(I+1,1)-V(I,1)-1.0) 35,40,35
   35 IX = I+1
      IY = 1
      IDX = -1
      IDY = 0
C
C     CALL TRACE
```

```
   40 CONTINUE
C
      NT1 = NT-1
      DO 60 I=1,NT1
      IF (V(MT,I)-CV) 45,60,60
   45 IF (V(MT,I+1)-CV) 60,50,50
   50 IF (V(MT,I+1)-V(MT,I)-1.0) 55,60,55
   55 IX = MT
      IY = I+1
      IDX = 0
      IDY = -1
      CALL TRACE
   60 CONTINUE
C
   65 DO 85 I=1,MT1
      MT2 = MT-I+1
      IF (V(MT2,NT)-CV) 70,85,85
   70 IF (V(MT2-1,NT)-CV) 85,75,75
   75 IF (V(MT2-1,NT)-V(MT2,NT)-1.0) 80,85,80
   80 IX = MT2-1
      IY = NT
      IDX = 1
      IDY = 0
      CALL TRACE
C
   85 CONTINUE
C
      DO 105 I=1,NT1
      NT2 = NT+1-I
      IF (V(1,NT2)-CV) 90,105,105
   90 IF (V(1,NT2-1)-CV) 105,95,95
   95 IF (V(1,NT2-1)-V(1,NT2)-1.0) 100,105,100
  100 IX = 1
      IY = NT2-1
      IDX = 0
      IDY = 1
C
      CALL TRACE
C
  105 CONTINUE
      ISS = 1
      NT1 = NT-1
      MT1 = MT-1
      DO 140 J=2,NT1
      DO 140 I=1,MT1
      IF (V(I,J)-CV) 110,140,140
  110 IF (V(I+1,J)-CV) 140,115,115
  115 IF (V(I+1,J)-V(I,J)-1.0) 120,140,120
  120 COM = MLNTH*(I+1)+J
      IF (NP) 125,135,125
  125 DO 130 ID = 1,NP
      IF (REC(ID)-COM) 130,140,130
  130 CONTINUE
  135 IX = I+1
      IY = J
      IDX = -1
      IDY = 0
      CALL TRACE
```

```
C  140 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE TRACE
C
      COMMON NZ,NR,IX,IY,IDX,IDY,ISS,IT,NP,N,PY,REC,CV,R,Z,IPT,INX,INY,
     1 V,XL,YL,S,U,NT,MT,IZX,DX,DY,XMAX,SCALE,YMAX,VCON,JSYM,LSYM,JT
     2 ,SV, XYM, IRIT, NPLOT, IZ,IR, MLNTH, IRB, IRT, IZL, IZR
C
      DIMENSION V(201,201), REC(1200), Z(2000), R(2000),IPT(3,3),INX(8),
     1 INY(8), VCON(24)
      DIMENSION  SV(100), XYM(40), IRIT(10), IZ(2000), IR(2000)
C
      PY = 0.0
    5 JT = 0
      N = 0
      IX0 = IX
      IY0 = IY
      ISX = IDX+2
      ISY = IDY+2
      IS = IPT(ISX,ISY)
      JTB = 0
      IS0 = IS
      IF (IS0-8) 15,15,10
   10 IS0 = IS0-8
   15 IT = 0
C
   20 CALL CALC
C
      N = N
C
      IF (IT+JT-1) 30,30,25
   25 XS = Z(N-1)
      YS = R(N-1)
      Z(N-1) = Z(N)
      R(N-1) = R(N)
      Z(N) = XS
      R(N) = YS
   30 IS = IS+1
      JT = IT
   35 IF (IS-9) 45,40,40
   40 IS = IS-8
   45 IDX = INX(IS)
      IDY = INY(IS)
      IX2 = IX+IDX
      IY2 = IY+IDY
      JTB = JTB+1
      IF (JTB-2000) 60,60,50
C
   50 PRINT 1000,CV,Z(N),R(N)
C
 1000 FORMAT(1H0,23HA CONTOUR LINE AT LEVEL,F6.3,21H WAS TERMINATED AT Z
     1=E12.5,3H R=,F7.3,47HBECAUSE IT CONTAINED MORE THAN 2000 PLOT POIN
     2TS)
C
      DO 55 K=1,N
      R(K) = (R(K)-1.0)*0.1
   55 Z(K) = (Z(K)-1.0)*0.1
C
      CALL CDPLOT
C
```

```
      RETURN
   60 IF (ISS) 85,85,65
   65 IF (IX-IX0) 105,70,105
   70 IF (IY-IY0) 105,75,105
   75 IF (IS-IS0) 105,80,105
C
   80 CALL CALC
C
      GO TO 160
   85 IF (IX2) 90,150,90
   90 IF (IX2-MT) 95,95,150
   95 IF (IY2) 100,150,100
  100 IF (IY2-NT) 105,105,150
  105 IF (CV-V(IX2,IY2)) 110,110,20
  110 IF (IDX**2+IDY**2-1) 115,135,115
  115 DCP = (V(IX,IY)+V(IX2,IY)+V(IX,IY2) +V(IX2,IY2))*0.25
      IF (DCP-CV) 20,120,120
  120 IF (INX(IS-1)) 125,130,125
  125 IX = IX+IDX
      IDX = -IDX
      PY = 2.0
C
      CALL CALC
C
      IX = IX+IDX
      GO TO 135
  130 IY = IY+IDY
      IDY = -IDY
      PY = 2.0
C
      CALL CALC
C
      IY = IY+IDY
  135 IF (V(IX-1,IY)-CV) 140,145,145
  140 NP = NP+1
      REC(NP) = MLNTH*IX+IY
  145 IS = IS+5
      IX = IX2
      IY = IY2
      GO TO 35
  150 XT = MT
      IF (V(IX-1,IY)-CV) 155,160,160
  155 NP = NP+1
      REC(NP) = MLNTH*IX+IY
  160 CONTINUE
      DO 165 K=1,N
      Z(K) = (Z(K)-1.0)*0.1
  165 R(K) = (R(K)-1.0)*0.1
      CALL CDPLOT
C
      RETURN
      END
C
```

```
      SUBROUTINE CALC
C
      COMMON NZ,NR,IX,IY,IDX,IDY,ISS,IT,NP,N,PY,REC,CV,R,Z,IPT,INX,INY,
     1 V,XL,YL,S,U,NT,MT,IZX,DX,DY,XMAX,SCALE,YMAX,VCON,JSYM,LSYM,JT
     2 ,SV, XYM, IRIT, NPLOT, IZ,IR, MLNTH, IRB, IRT, IZL, IZR
C
      DIMENSION  SV(100), XYM(40), IRIT(10), IZ(2000), IR(2000)
      DIMENSION V(201,201), REC(1200), Z(2000), R(2000),IPT(3,3),INX(8),
     1 INY(8), VCON(24)
C
      IT = 0
      N = N+1
      IF (IDX**2+IDY**2-1) 30,5,30
    5 IF (IDX) 20,10,20
   10 Z(N) = IX
      W = IY
      IY2 = IY+IDY
      DY = IDY
   15 R(N) = ((V(IX,IY)-CV)/(V(IX,IY)-V(IX,IY2)))*DY+W
      RETURN
   20 R(N) = IY
      W = IX
      DX = IDX
      IX2 = IX+IDX
   25 Z(N) = ((V(IX,IY)-CV)/(V(IX,IY)-V(IX2,IY)))*DX+W
      RETURN
   30 IX2 = IX+IDX
      IY2 = IY+IDY
      W = IX
      U = IY
      DX = IDX
      DY = IDY
      DCP = (V(IX,IY)+ V(IX2,IY)+ V(IX,IY2)+V(IX2,IY2))*0.25
      IF (PY-2.0) 35,40,35
   35 IF (DCP-CV) 40,40,55
   40 AL = V(IX,IY)-DCP
   45 S = 0.5*(AL+DCP-CV)/AL
   50 Z(N) = S*DX+W
      R(N) = S*DY+U
      PY = 0.0
      RETURN
   55 IT = 1
      AL = V(IX2,IY2)-DCP
   60 S = 0.5*(AL+DCP-CV)/AL
   65 Z(N) = -S*DX+W+DX
      R(N) = -S*DY+U+DY
      RETURN
      END
```

```
      SUBROUTINE PILINE (IZ,IR,N,JSYM,LSYM)
      DIMENSION IZ(1), IR(1)
      K = 0
      DO 20 I=2,N
      K = K+1
      IF (K-JSYM) 20,10,20
   10 CALL PLOTV (IZ(I),IR(I),LSYM)
      K = 0
   20 CALL LINEV (IZ(I-1),IR(I-1),IZ(I),IR(I))
      RETURN
      END
```

```
      SUBROUTINE RDTAPE (IST,ISTP,ISN,V,NVR)
      DIMENSION V(1)
      NVR = NVR
      REWIND IST
    5 READ TAPE IST,K
      IF (K-ISTP) 7,20,7
    7 IF (K-ISN) 10,15,10
   10 READ TAPE IST
      GO TO 5
   15 READ TAPE IST, (V(I),I=1,NVR)
      PRINT 1005,ISN
      REWIND IST
      RETURN
   20 PRINT 1000,ISN
      REWIND IST
      CALL EXIT
 1000 FORMAT (I6,22H IS NOT A SAVED NUMBER)
 1005 FORMAT (I6,9H RESTORED)
      END
```

```
      SUBROUTINE WTTAPE (IST,ISTP,ISN,V,NVR)
      DIMENSION V(1)
      NVR = NVR
      REWIND IST
    5 READ TAPE IST,K
      IF (K-ISTP) 10,25,10
   10 IF (K-ISN) 20,15,20
   15 ISN = ISN+1
   20 READ TAPE IST
      GO TO 5
   25 BACKSPACE IST
      WRITE TAPE IST,ISN
      WRITE TAPE IST, (V(I), I=1,NVR)
      PRINT 1000,ISN
 1000 FORMAT (23H DATA SAVED UNDER ISN =,I4)
      WRITE TAPE IST,ISTP
      REWIND IST
      RETURN
      END
```