DC-TN-2065-1

Sensor and Simulation Notes

Note LII

A Parameter Study of Two Parallel Plate Transmission Line Simulators of EMP Sensor and Simulation Note XXI

by

Terry L. Brown

and

Kenneth D. Granzow

The Dikewood Corporation
1009 Bradbury Drive, S. E.
University Research Park
Albuquerque, New Mexico 87106

April 19, 1968

Abstract

The impedances and field distributions of the symmetrical two-plate transmission lines are given for various ratios of the distance between the plates to the plate length. A computer program that produces the field plots for any ratio between .2 and 100 is described and listed.

I. INTRODUCTION

The purpose of this note is to expand upon certain aspects of Sensor and Simulation Note XXI by Carl E. Baum.* This note deals solely with the two-conductor, finite parallel plate transmission line as described in that article. The plates are parallel to the direction of propagation with dimensions as shown in Figure 1.

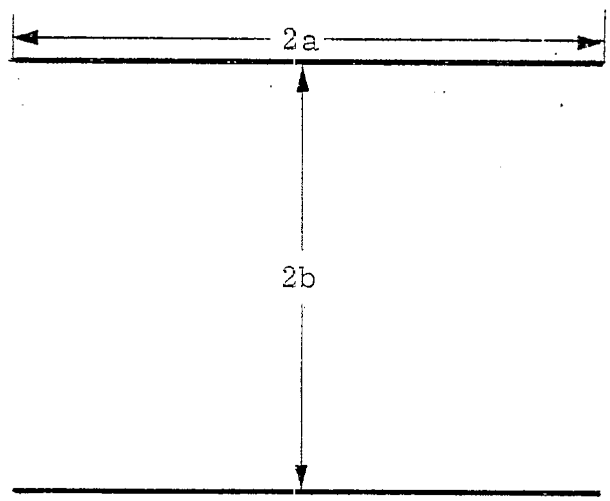


Figure 1

It was our intent to produce graphs of the equipotential and magnetic fields for various fixed ratios and produce a computer code that can be easily used to make such graphs for any other values of b/a. We do not intend to derive the equations given in Note XXI but to use them to produce varying conformal maps. For simplicity, we define $b = 1$.

---

* C. E. Baum, Impedances and Field Distributions for Parallel Plate Transmission Line Simulators, EMP Sensor and Simulation Note XXI, June 6, 1966.

II. OPERATION

General

The plots produced herein are contained in the first quadrant. The x-axis is midway between and parallel to the plates. The y-axis is perpendicular to and bisects the plates. This arrangement is shown in Figure 2. Since the plots are symmetric, reflection across the x and y axes will extend the graph to all four quadrants. With each graph the ratio b/a and the impedance are given (assuming a wave impedance equal to that of free space).

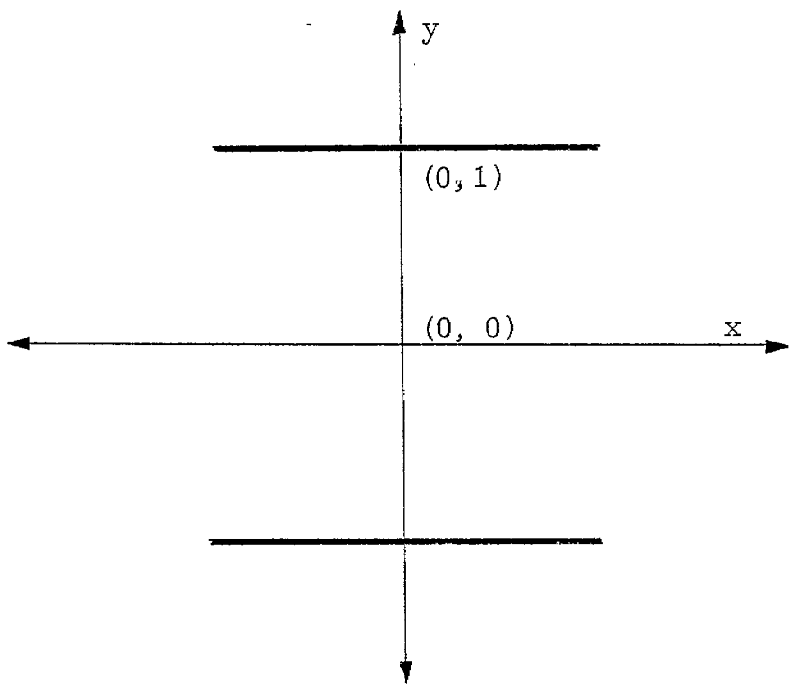


Figure 2

The program used to produce the maps consists, to a large extent, of two programs previously written for Note XXI. The first program produced the geometric factor f_g for a given parameter m, where m is a function of b/a as given below. The second program calculated x and y coordinates from the conformal transformation. These programs have been incorporated into one program that, for a given ratio b/a,

a. by an iterative process gives an approximation of m from which f_g, the geometric factor, is calculated (the approximations are within .001 and .00001 of the true values of m and f_g respectively),

b. generates 100 data points along each of 40 curves,

c. adjusts the data points to the desired size of graph(s),

d. scales, graphs, and labels the conformal map(s) to be produced on the Calcomp plotter.

To reiterate, we list some of the equations found in Note XXI that are of interest.

$$a/b = \frac{2}{\pi} \left[K(m)E(\phi_o | m) - E(m)F(\phi_o | m) \right] \tag{1}$$

$$\phi_o = \arcsin \left[\frac{1}{m} \left(1 - \frac{E(m)}{K(m)} \right) \right]^{1/2} \tag{2}$$

$$f_g = \frac{K(m_1)}{K(m)} \tag{3}$$

From the conformal transformation

$$\bar{z} = \frac{2K(m)}{\pi} Z(w + jK(m) \mid m) + j \tag{4}$$

we have

$$x = \frac{2K(m)}{\pi} \left[E(u \mid m) - \frac{uE(m)}{K(m)} \right.$$

$$\left. + \frac{m\,sn(u \mid m)\, cn\,(u \mid m)\, dn\,(u \mid m)\, sn^2\,(v' \mid m_1)}{1 - dn^2\,(u \mid m)\, sn^2\,(v' \mid m_1)} \right] \quad (5)$$

and

$$y = \frac{2K(m)}{\pi} \left[E(v' \mid m_1) - \frac{v'E(m_1)}{K(m_1)} + \frac{v\pi}{2K(m)K(m_1)} \right.$$

$$\left. - \frac{dn^2\,(u \mid m)\, sn\,(v' \mid m_1)\, cn\,(v' \mid m_1)\, dn\,(v' \mid m_1)}{1 - dn^2\,(u \mid m)\, sn^2\,(v' \mid m_1)} \right] \quad (6)$$

$$v' = v + K(m_1) \quad (7)$$

$$m_1 = 1 - m \quad (8)$$

It might also be noted that

$$A = \frac{A}{B} = \frac{2K(m)Z_{max}}{\pi} \quad (9)$$

gives the abscissa of the edge of the plate where Z_{max} is the maximum value of $Z(u|\, m)$ for a fixed m. (See Figure 3.)

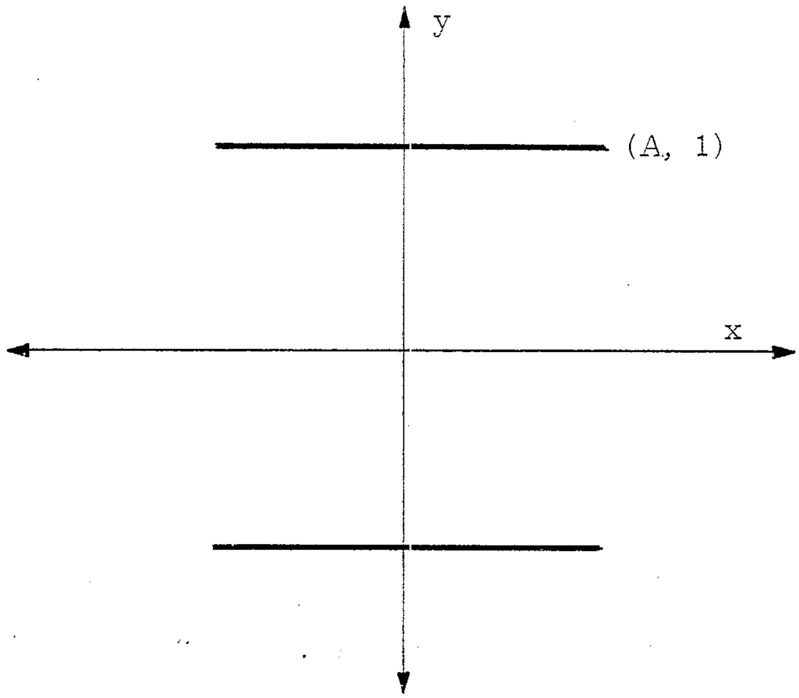


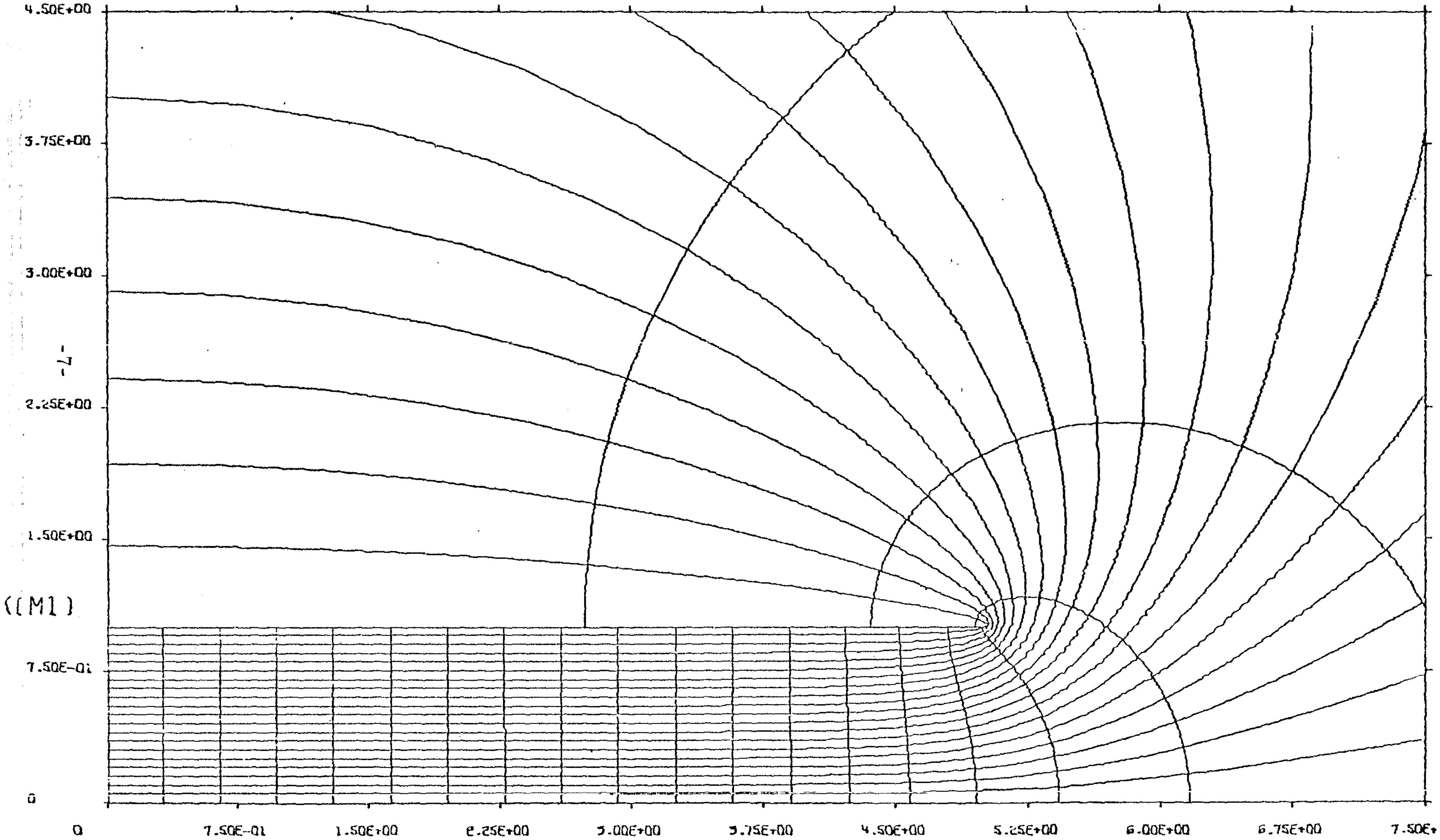
Figure 3

The table below summarizes the plots found in this note.

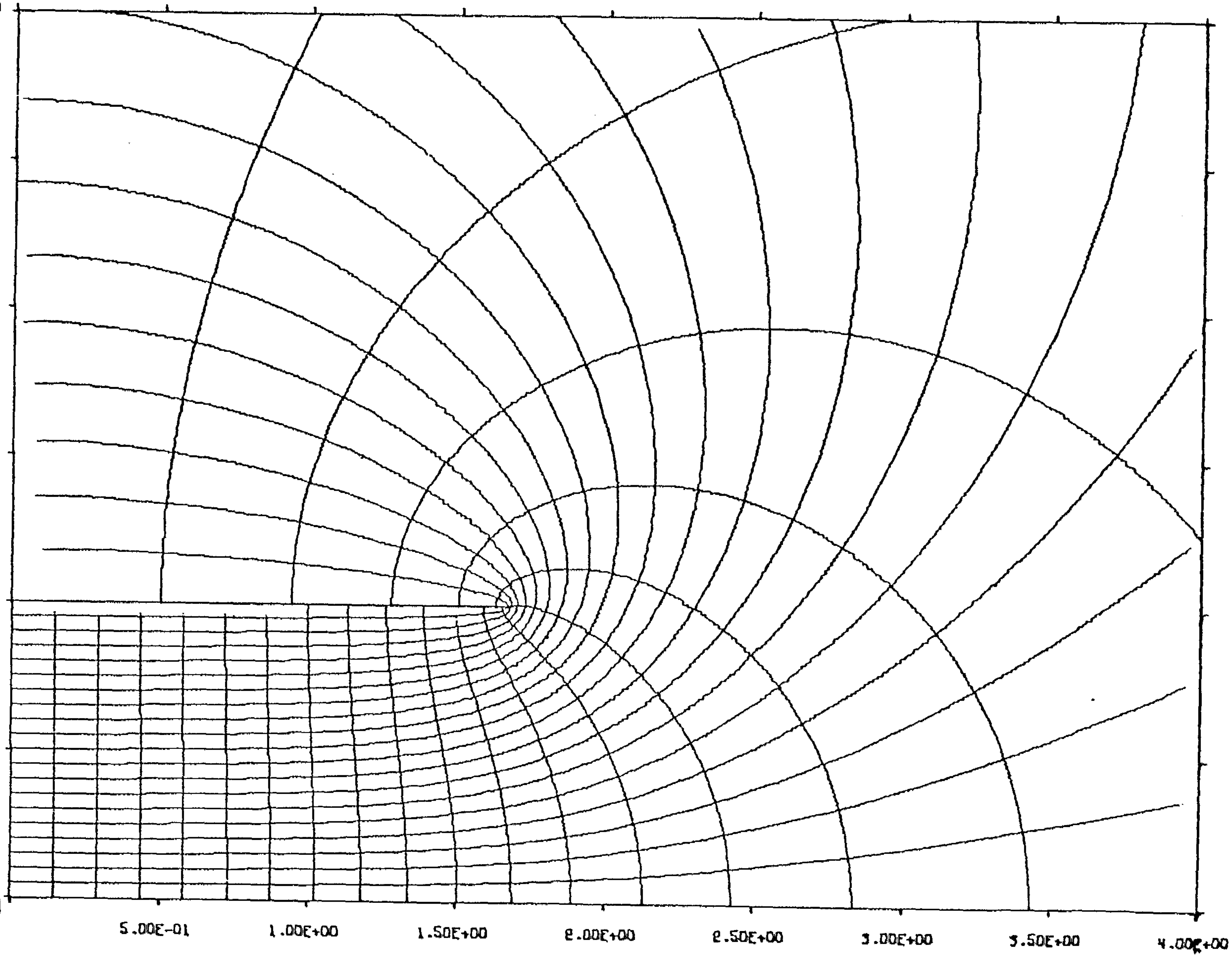
b/a	f_g	Free-space Impedance
0.2	.15376	57.97 ohms
0.6	.34613	130.49 "
0.7	.38204	144.03 "
0.8	.41479	156.37 "
0.9	.44487	167.71 "
1.0	.47264	178.18 "
1.1	.49842	187.90 "
1.2	.52245	196.96 "
1.3	.54495	205.44 "
1.4	.56609	213.41 "
2.0	.67116	253.02 "
5.0	.95514	360.08 "

The following graphs were reproduced directly from the Calcomp plots.

FIELD AND POTENTIAL DISTRIBUTION
FOR PARALLEL, TWO-PLATE TRANSMISSION LINE. 57.97 OHMS
B/A = .20

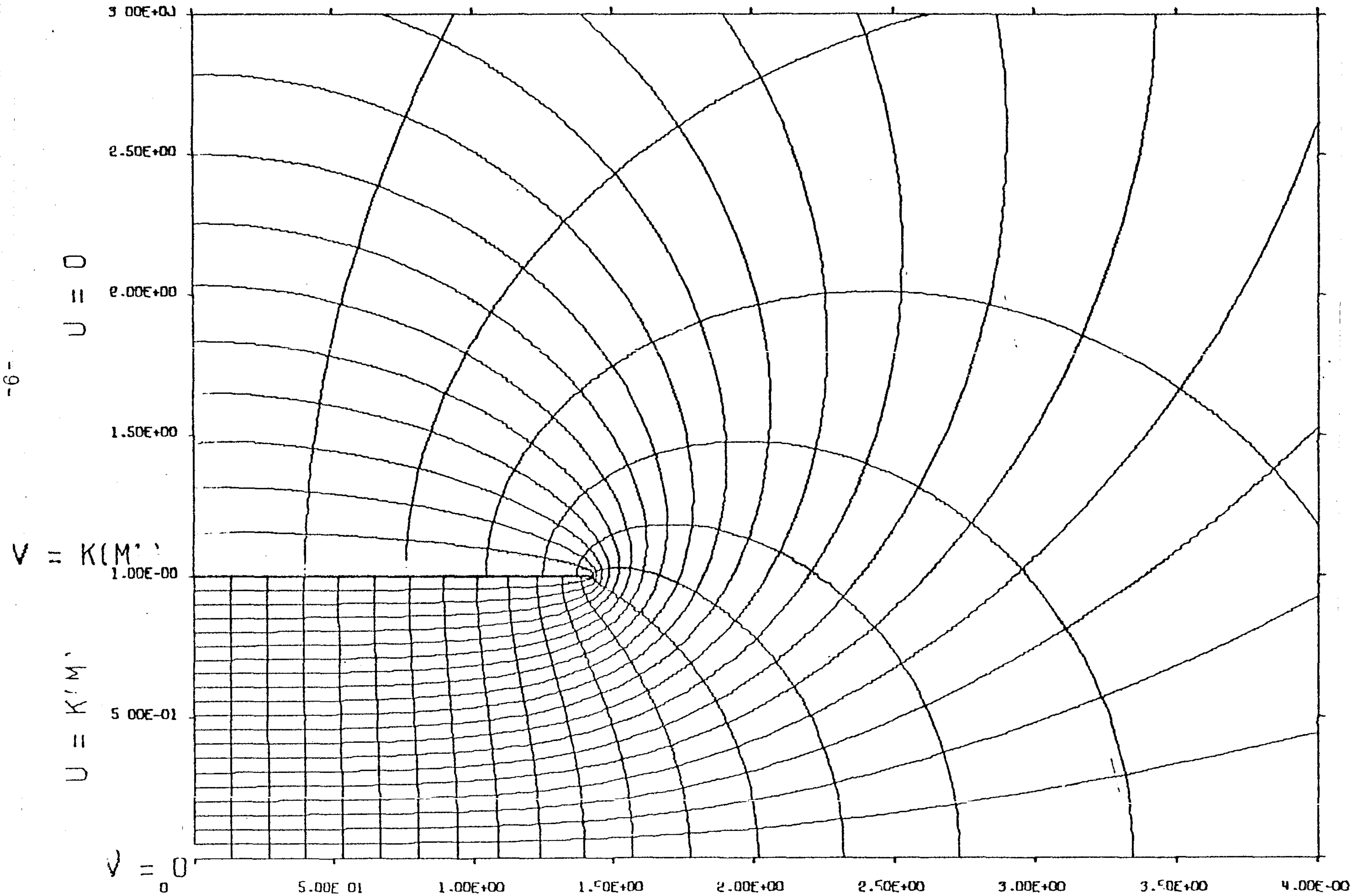


FIELD AND POTENTIAL DISTRIBUTION
FOR PARALLEL, TWO-PLATE TRANSMISSION LINE. 130.49 OHMS
B/A = .60



U = 0
V = K(M1)
U = K(M)
ϑ_0 = U

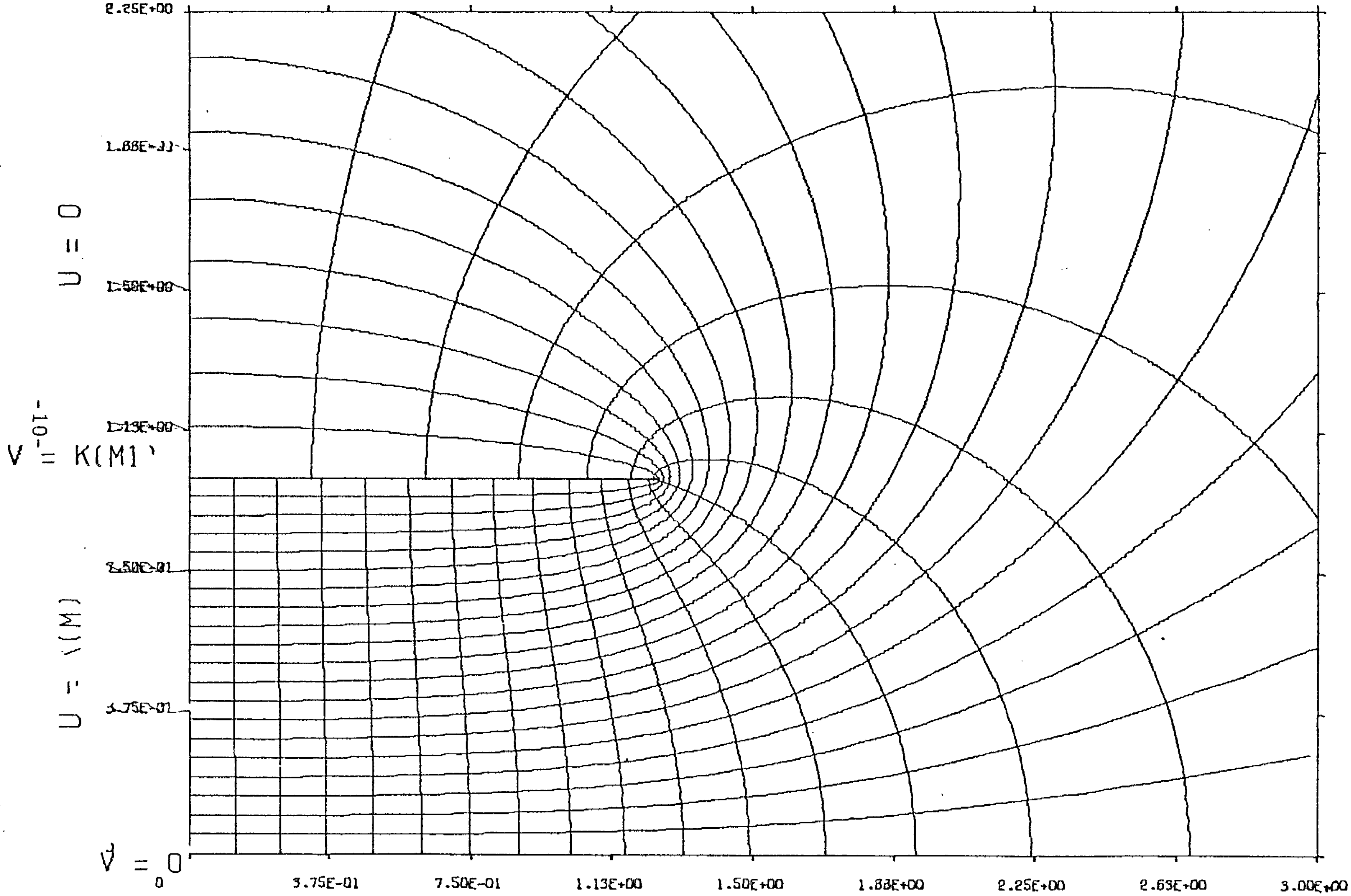
FIELD AND POTENTIAL DISTRIBUTION
FOR PARALLEL, TWO-PLATE TRANSMISSION LINE. 144.03 OHMS
B/A = .70



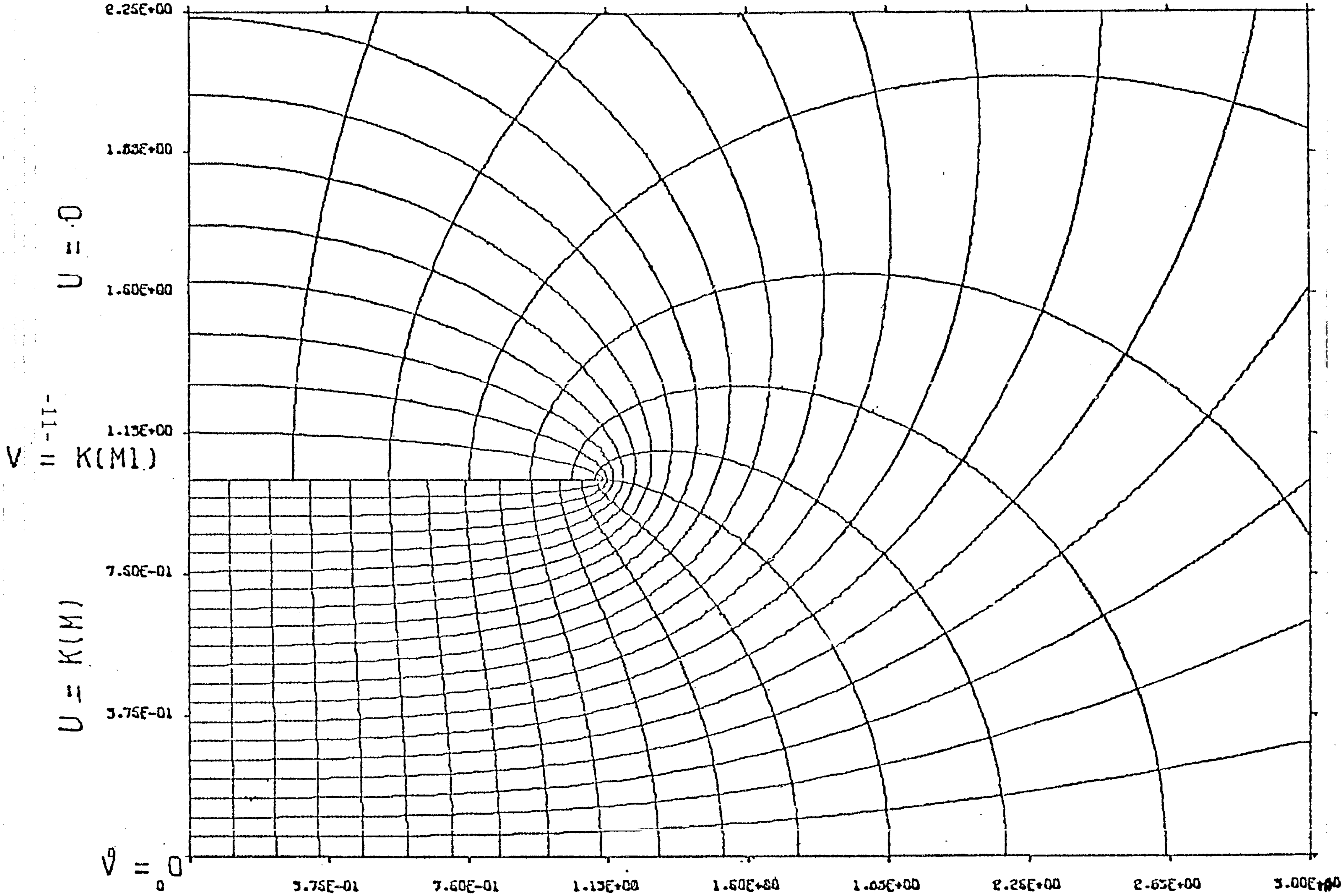
FIELD AND POTENTIAL DISTRIBUTION

FOR PARALLEL, TWO-PLATE TRANSMISSION LINE. 156.37 OHMS

B/A = .80



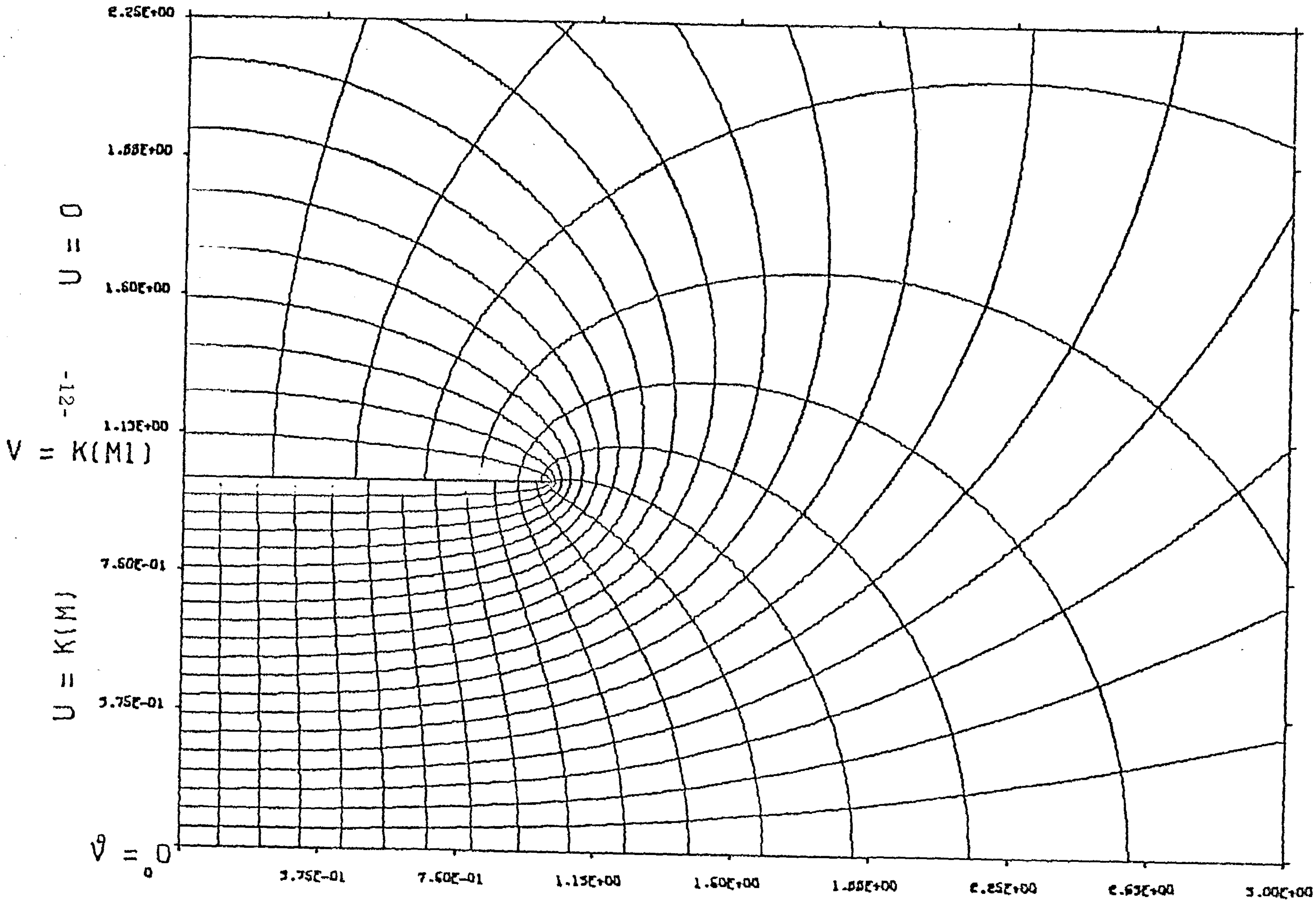
FIELD AND POTENTIAL DISTRIBUTION
FOR PARALLEL, TWO-PLATE TRANSMISSION LINE. 167.71 OHMS
B/A = .90



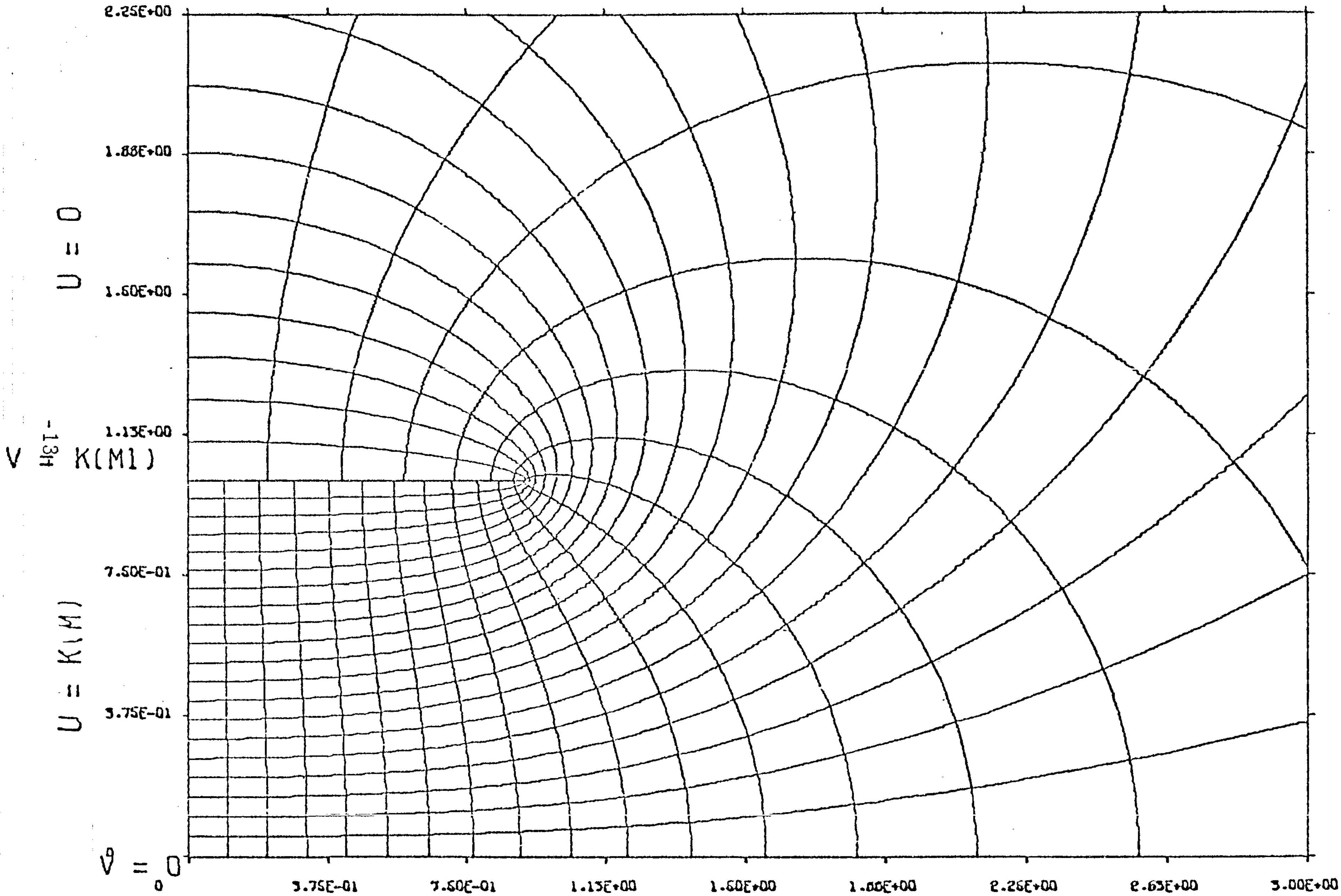
FIELD AND POTENTIAL DISTRIBUTION

FOR PARALLEL. TWO-PLATE TRANSMISSION LINE. 178.18 OHMS

B/A = 1.00



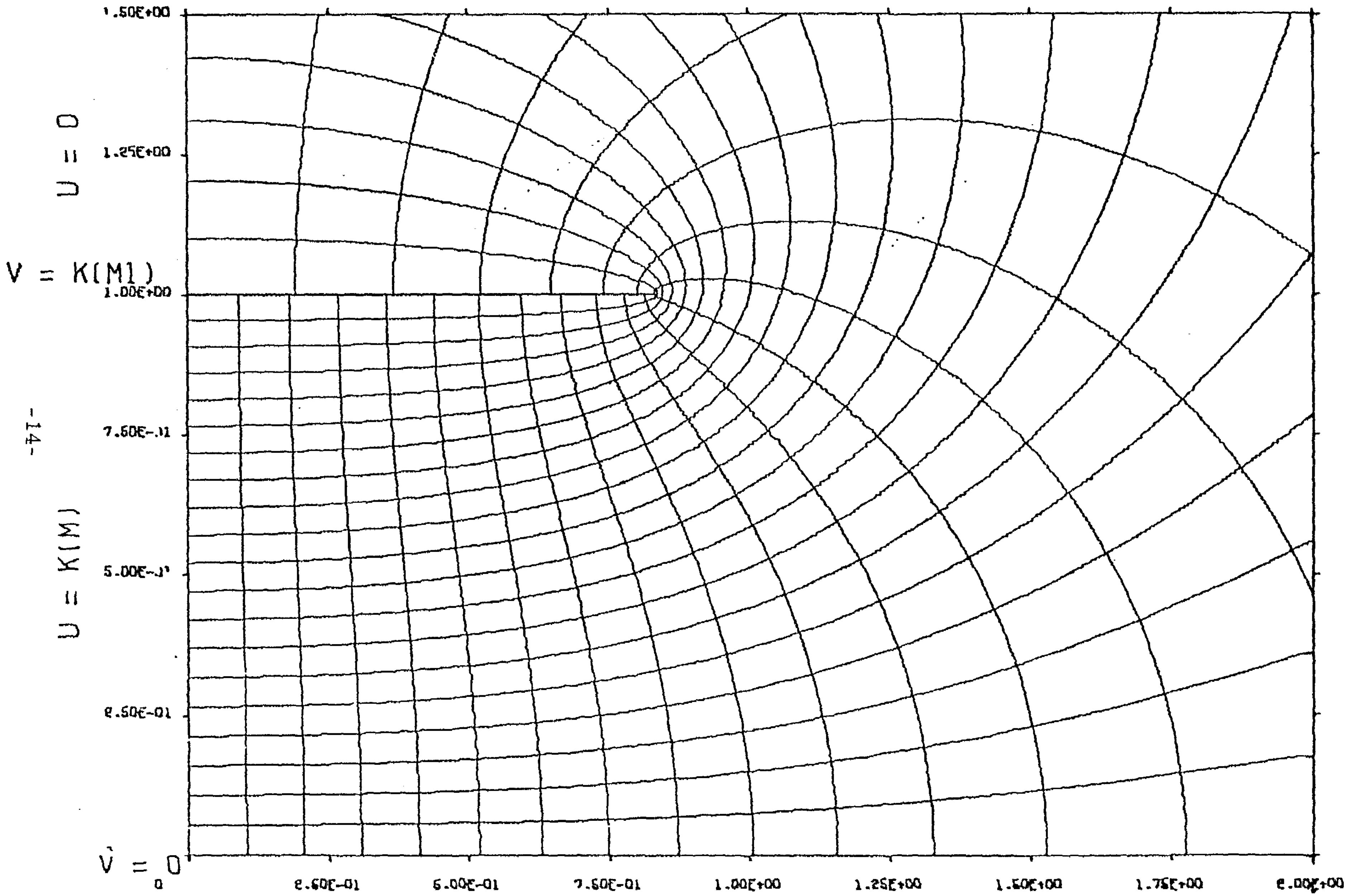
FIELD AND POTENTIAL DISTRIBUTION
FOR PARALLEL, TWO-PLATE TRANSMISSION LINE. 187.90 OHMS
B/A = 1.10



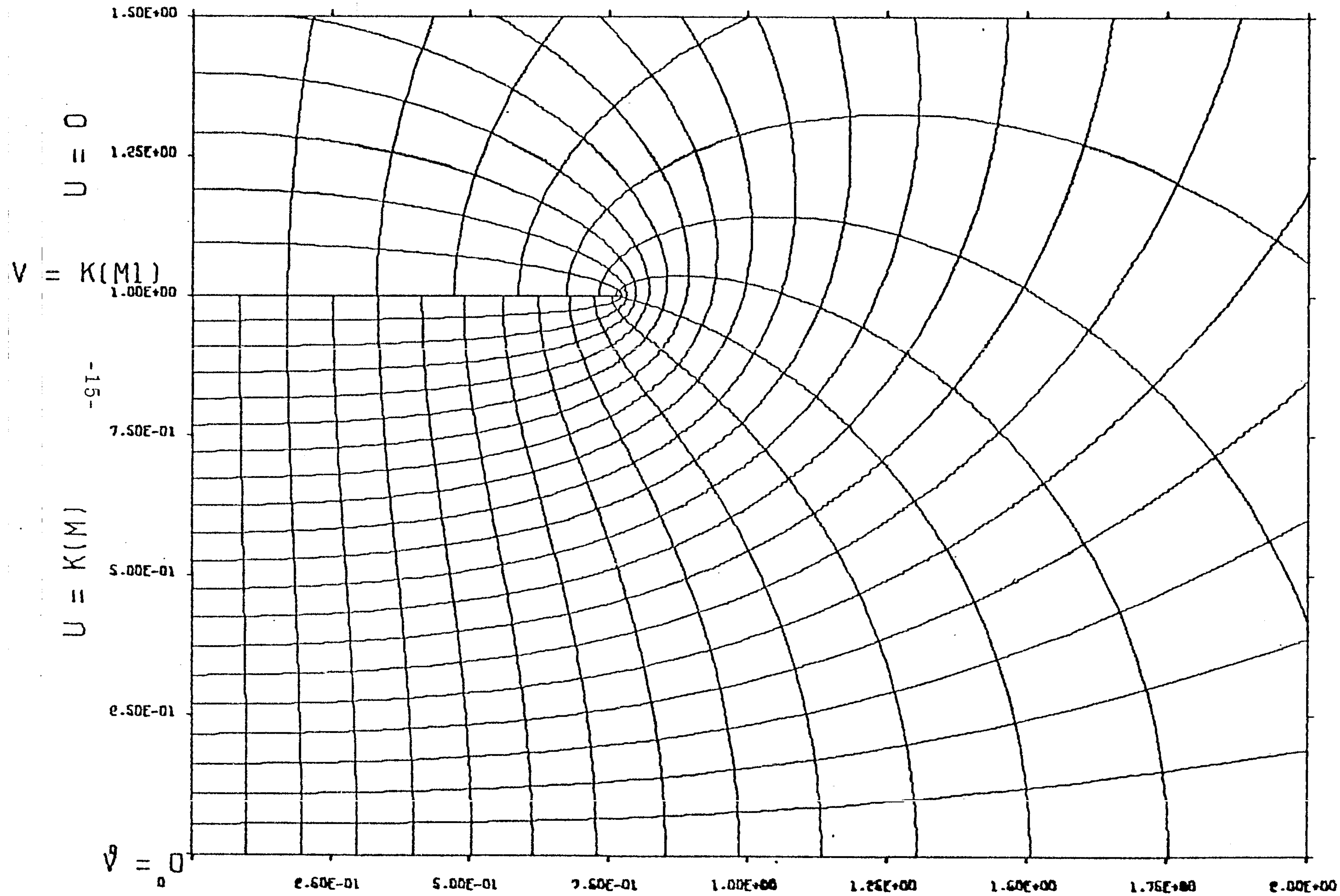
FIELD AND POTENTIAL DISTRIBUTION

FOR PARALLEL, TWO-PLATE TRANSMISSION LINE. 196.96 OHMS

B/A = 1.20



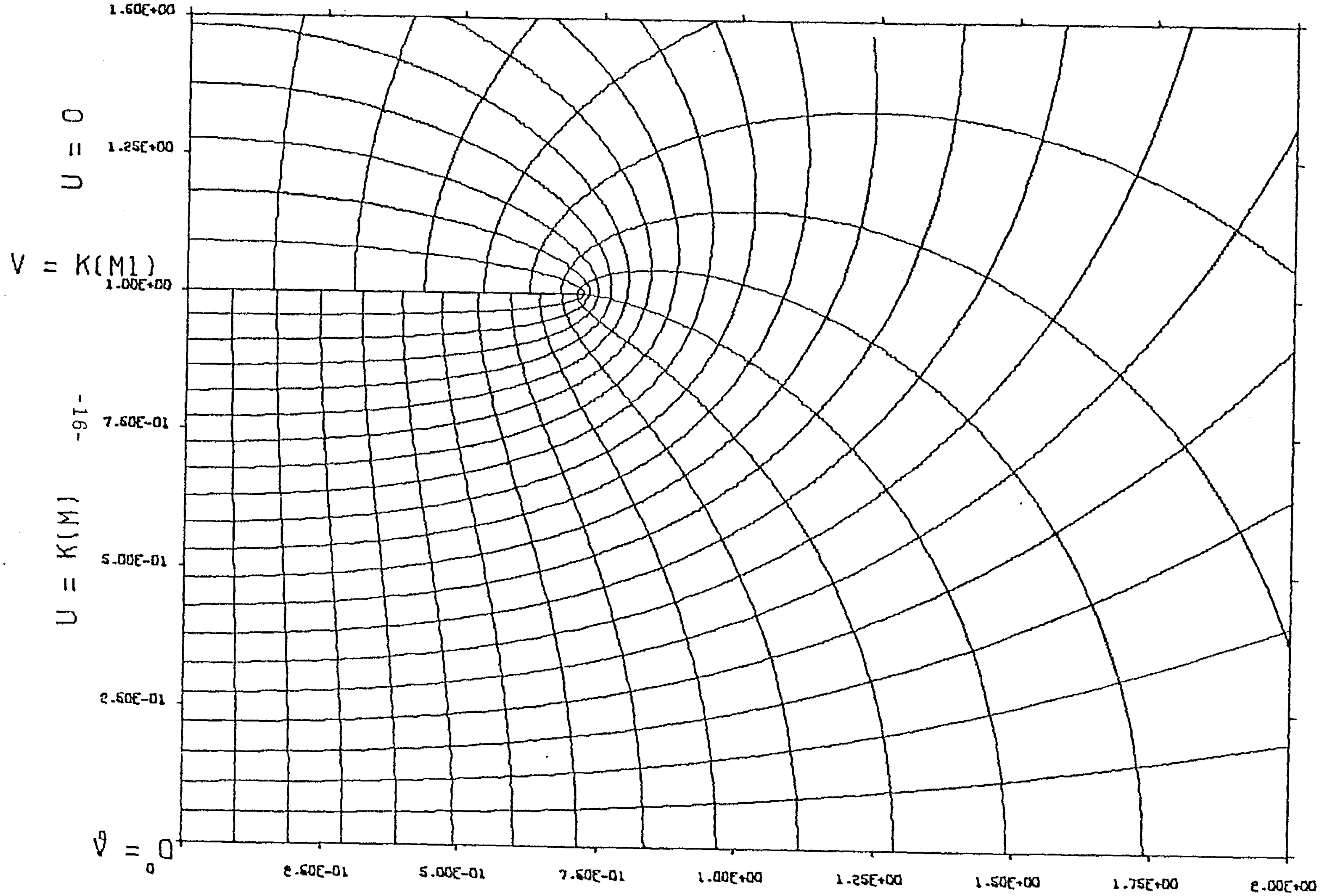
FIELD AND POTENTIAL DISTRIBUTION
FOR PARALLEL, TWO-PLATE TRANSMISSION LINE, 205.44 OHMS
B/A = 1.30



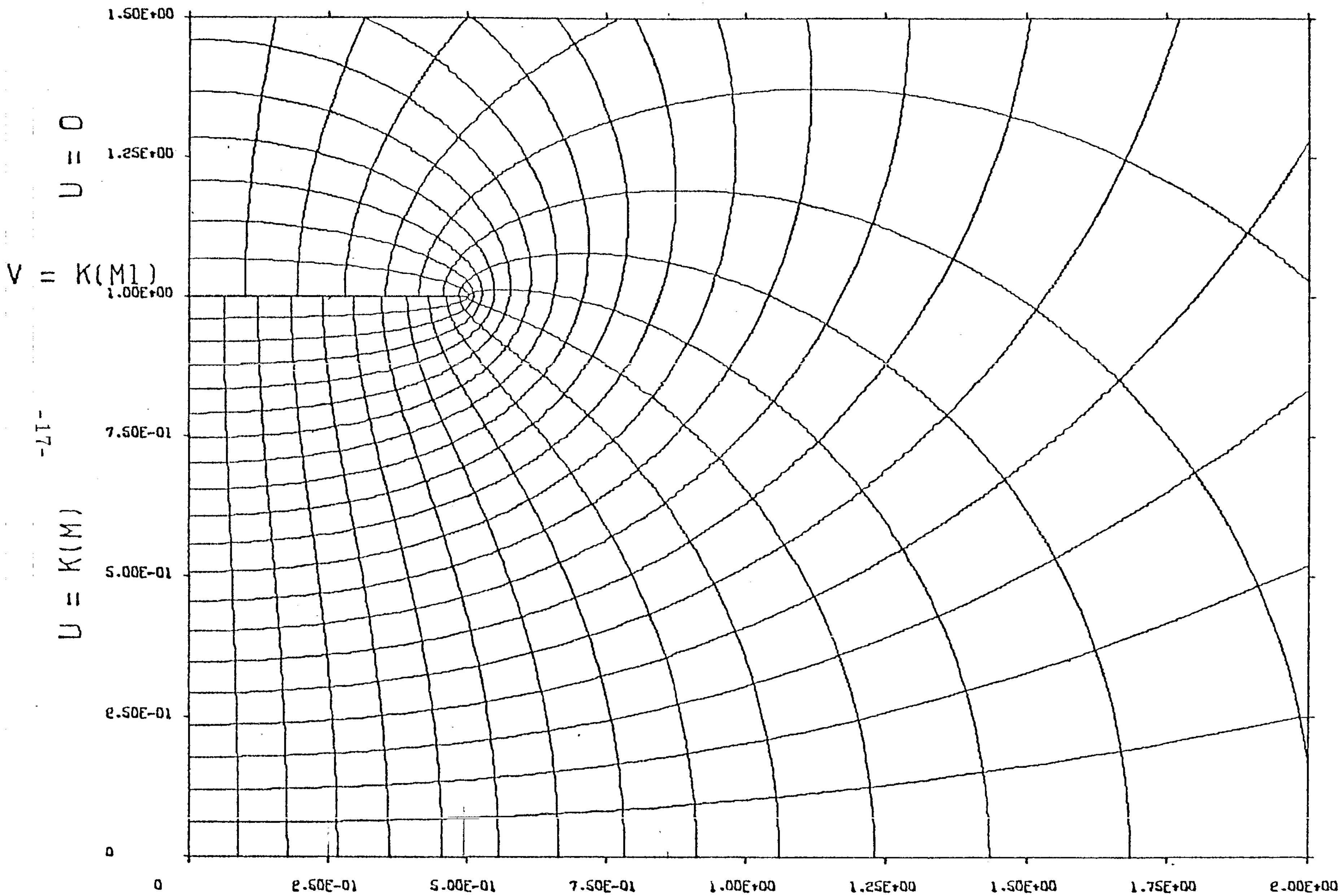
FIELD AND POTENTIAL DISTRIBUTION

FOR PARALLEL, TWO-PLATE TRANSMISSION LINE. 213.41 OHMS

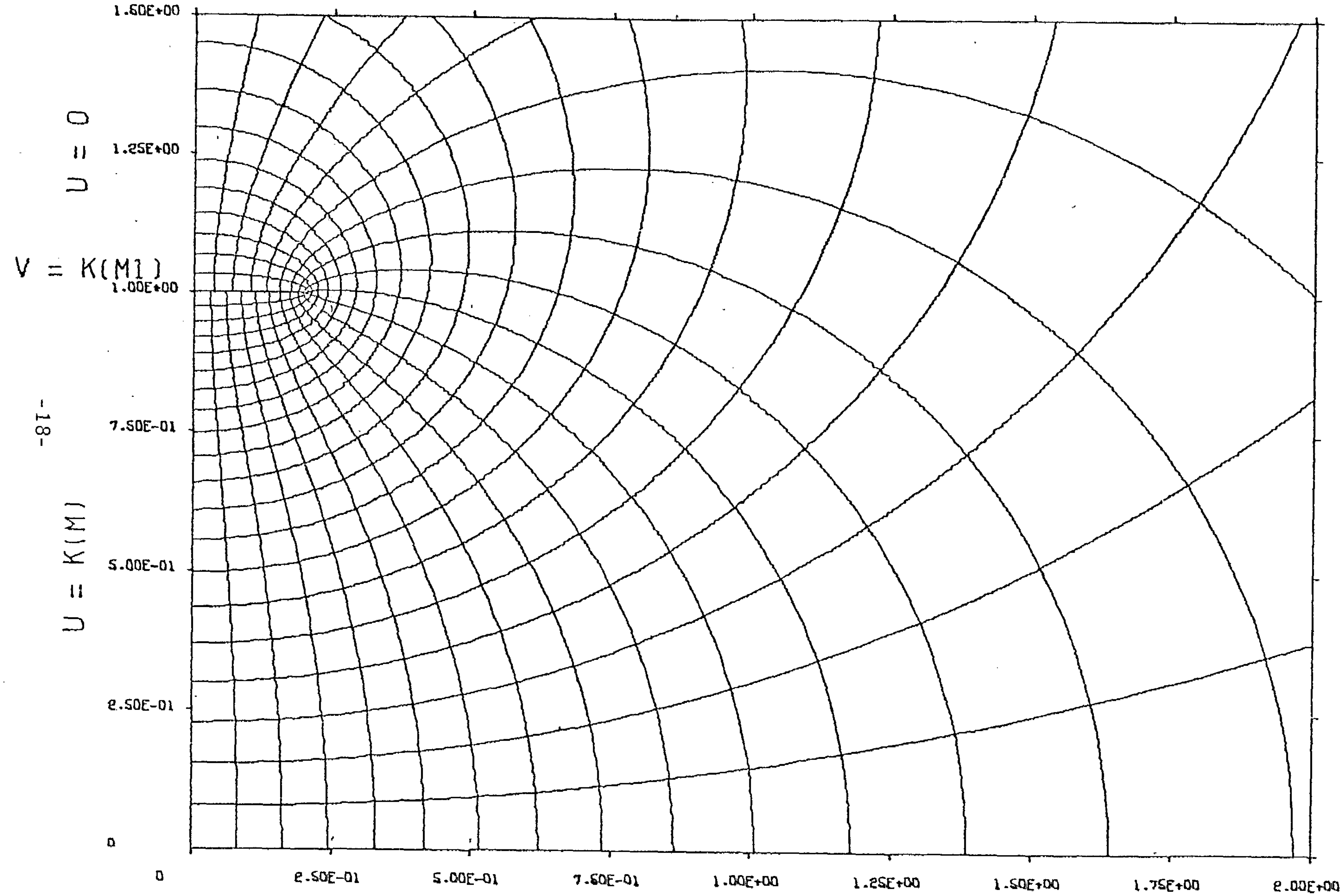
B/A = 1.40



FIELD AND POTENTIAL DISTRIBUTION
FOR PARALLEL, TWO-PLATE TRANSMISSION LINE, 253.02 OHMS
B/A = 2.00



FIELD AND POTENTIAL DISTRIBUTION
FOR PARALLEL, TWO-PLATE TRANSMISSION LINE. 360.08.OHMS
B/A = 5.00



Program EXTEND

Input From Data Card

Variable Name	Column	Type	Format	Use
BA	1-14	Real	E14.8	Ratio of the distance between the plates to plate length.
NDO	20	Integer	I1	Value that determines the scale of graph(s) produced.

Program EXTEND accepts any ratio $.2 \leq b/a \leq 100$ as data. The program reads the particular b/a in an E14.8 format, one number (i.e., one ratio b/a) per card. At least two data cards are required. The last card must contain a negative number in the same format to stop the reading cycle. Any b/a, not within the stated limits, read in will cause the program to exit with the following message printed: "ERROR. B/A = XXXXXXXX IS OUT OF RANGE," where XXXXXXXX is b/a in an E8.2 format. The lower bound of b/a is the limit to which the program can accurately calculate f_g. The upper bound is the limit to which an acceptable graph is produced. The upper bound, however, could be extended with some modifications.

There exists an option of having the program return combinations of four graphs of the conformal map depending upon the "magnification" wanted. The option consists of the same size graph (except for Graph 1) with only the unit of measure changed. The different units of measure and sizes are as follows:

a. Graph 1: 1 unit (inch) = 0.75 (6 by 10 inches)

b. Graph 2: 1 unit (inch) = 0.5 (6 by 8 inches)

c. Graph 3: 1 unit (inch) = 0.375 (6 by 8 inches)

d. Graph 4: 1 unit (inch) = 0.25 (6 by 8 inches)

It is recommended that graph number 1 be reserved for ratios of b/a < .4.

To utilize this option, add to the data card in Column 20 any integer one through nine, according to the graph(s) desired. Graphs are drawn according to the following chart.

Number in Col. 20	1	2	3	4	5	6	7	8	9
Graphs produced	No. 1	No. 1 No. 2	No. 2	No. 2 No. 3	No. 2 No. 3 No. 4	No. 2 No. 4	No. 3 No. 4	No. 3	No. 4

The default option (i.e., no punch in Column 20) is one graph according to the size of b/a as follows:

Range of the ratio b/a	Graph produced
$2 \leq b/a \leq 100$	No. 4
$.1 < b/a < 2.$	No. 3
$.4 \leq b/a \leq 1.$	No. 2
$.2 \leq b/a < .4$	No. 1

The subroutines that draw the graphs are quite flexible, and various sizes as well as various scales can be employed with minimum alterations. (IL, IH, XM, and YM determine the height, length, maximum value of x, and maximum value of y, respectively.)

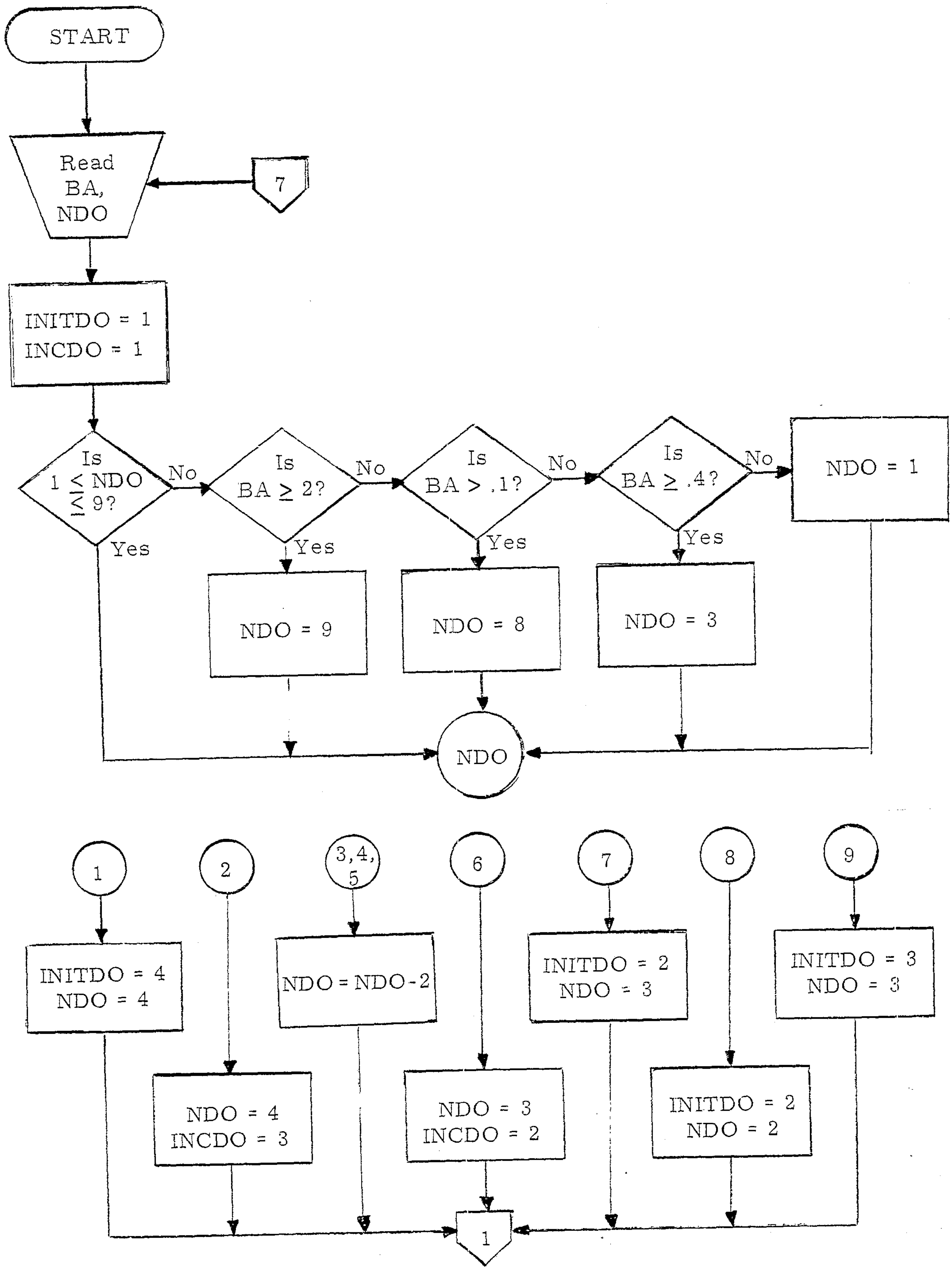
One 1/2-inch plot tape is required. The instructions to the Calcomp Plotter are written on this tape, and it must be specified as a low density tape (200 BPI). The logical designation for this tape is 10 and must appear as such in the control cards.

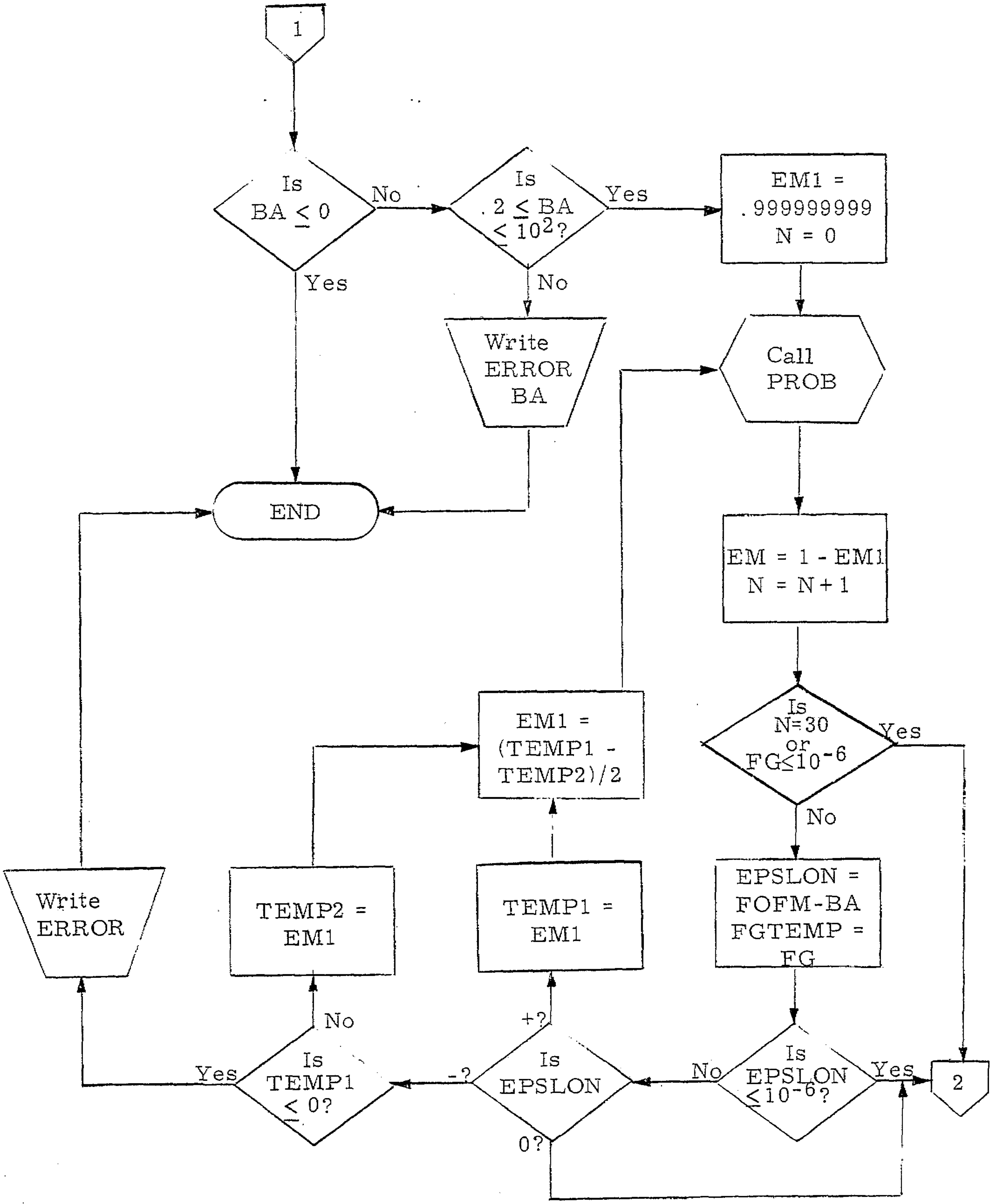
CPU time to produce each graph varied from approximately 180 seconds for b/a = 5.0 to approximately 730 seconds for b/a = .2. However, once the values have been calculated, each additional graph requires only about 30 seconds. A field length of 56000_8 is sufficient for loading and execution. These figures are based on the use of a CDC 6600 computer.

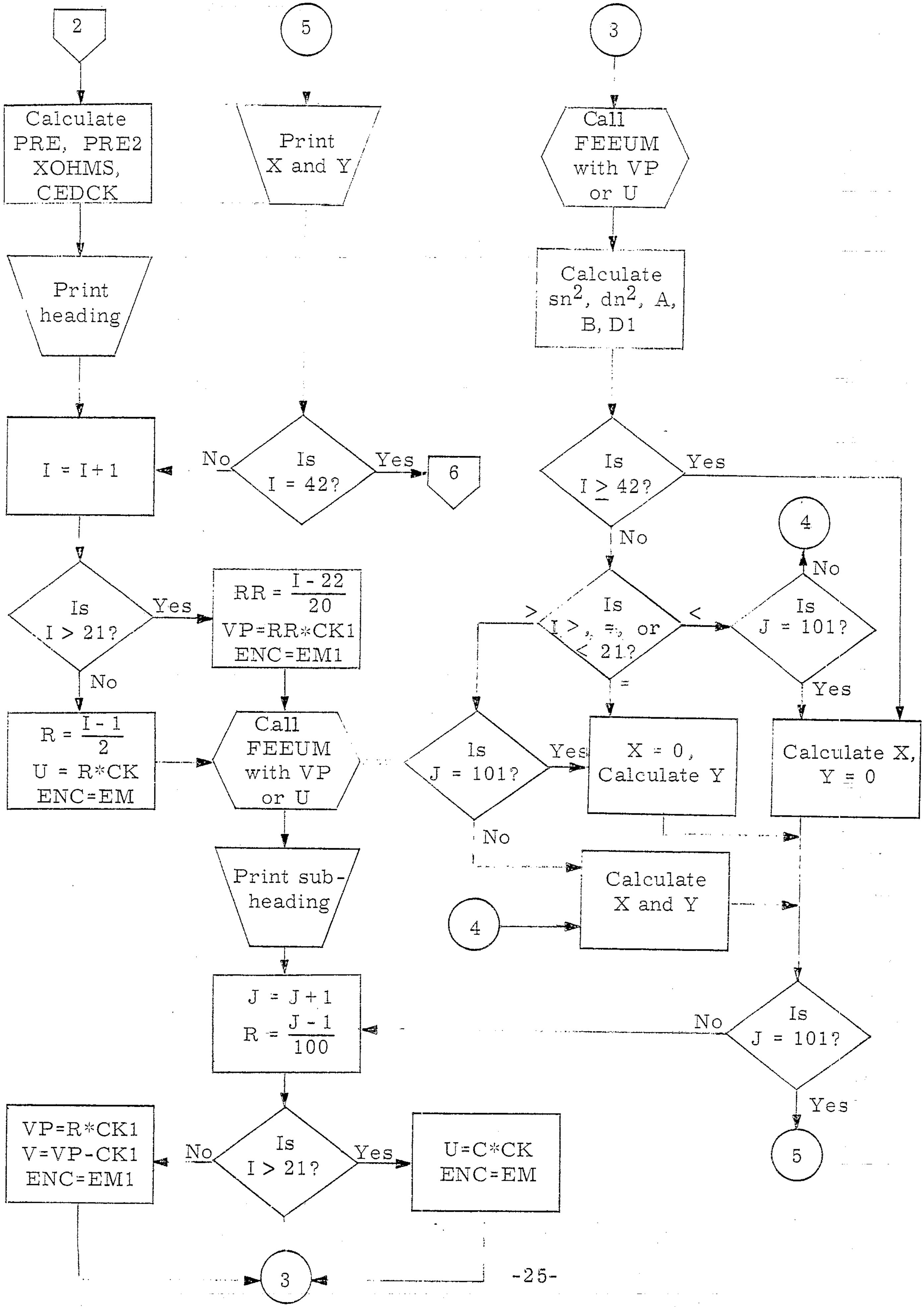
Appendix A

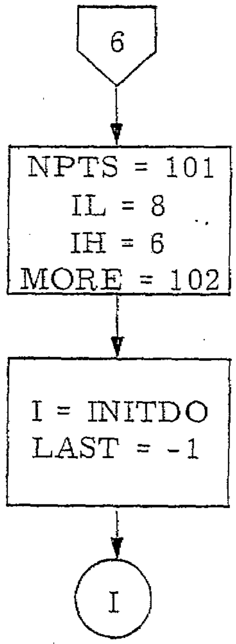
FLOW CHARTS FOR EXTEND, ADJUST, EDGE, AND DRAW

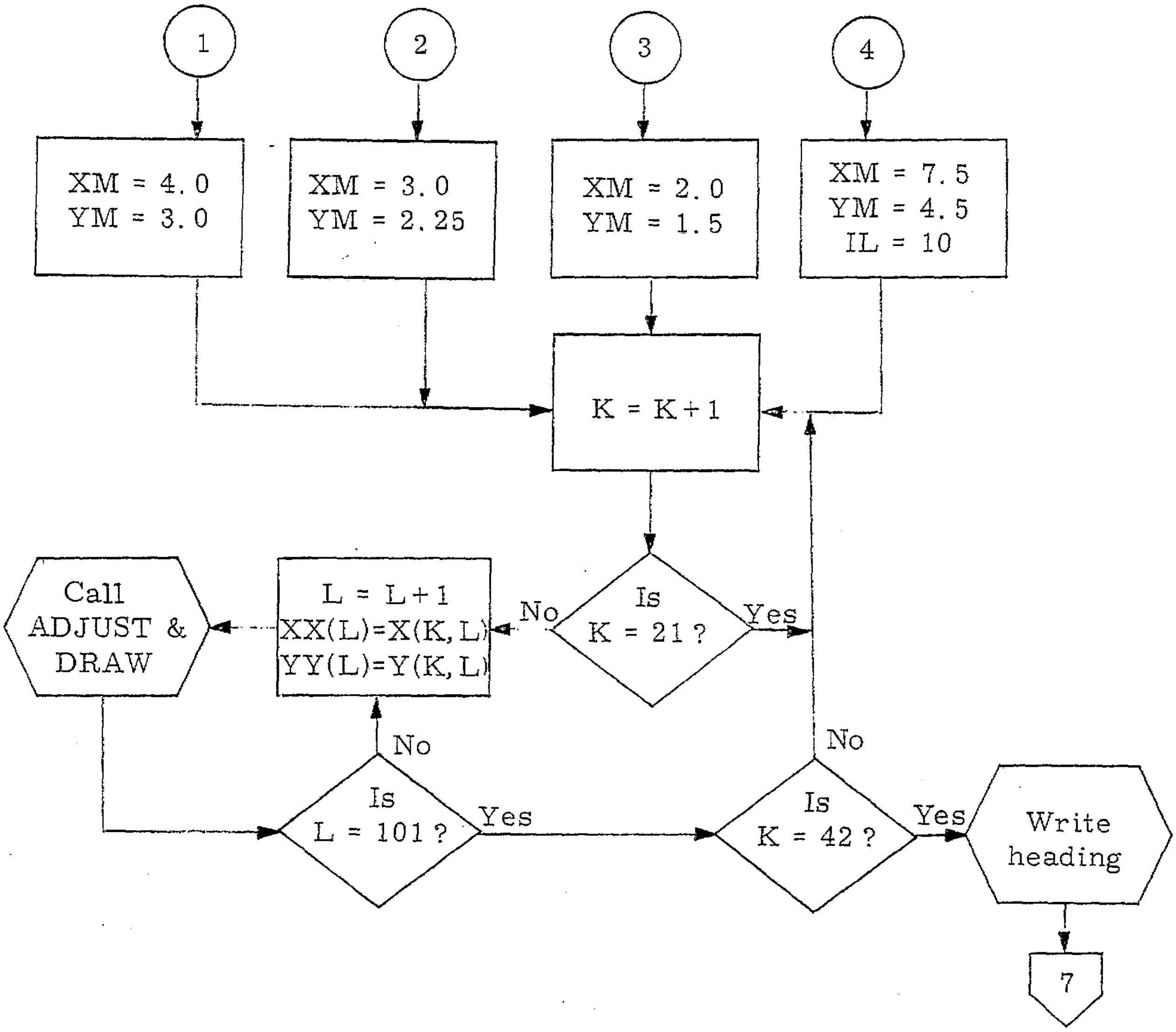
Flow Chart for Program EXTEND (Main Program)



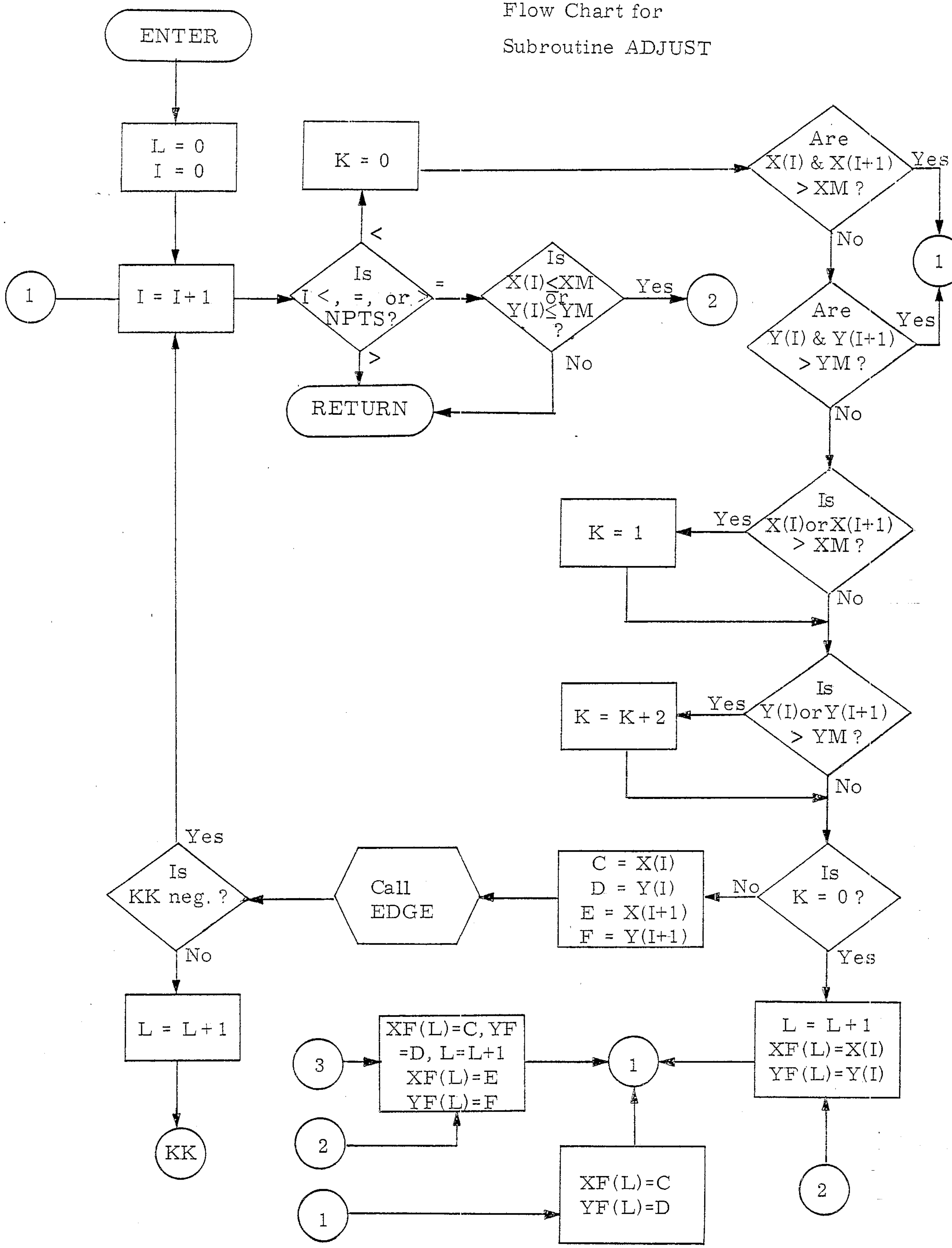

1
Is
BA ≤ 0
No
Yes
Is
.2 ≤ BA
≤ 10²?
Yes
No
EM1 =
.999999999
N = 0
Write
ERROR
BA
Call
PROB
END
EM = 1 - EM1
N = N + 1
Is
N=30
or
FG≤10⁻⁶
Yes
No
EM1 =
(TEMP1 -
TEMP2)/2
EPSLON =
FOFM-BA
FGTEMP =
FG
Write
ERROR
TEMP2 =
EM1
TEMP1 =
EM1
No
+?
Yes
Is
TEMP1
≤ 0?
-?
Is
EPSLON
No
Is
EPSLON
≤10⁻⁶?
Yes
2
0?


2
5
3
Calculate PRE, PRE2 XOHMS, CEDCK
Print X and Y
Call FEEUM with VP or U
Calculate sn2, dn2, A, B, D1
Print heading
I = I+1
No
Is I = 42?
Yes
6
Is I ≥ 42?
Yes
No
4
No
Is I > 21?
Yes
RR = (I - 22)/20
VP=RR*CK1
ENC=EM1
>
Is I >, =, or < 21?
<
Is J = 101?
No
Yes
=
R = (I - 1)/2
U = R*CK
ENC=EM
Call FEEUM with VP or U
Is J = 101?
Yes
X = 0, Calculate Y
Calculate X, Y = 0
No
Print sub-heading
Calculate X and Y
4
J = J+1
R = (J - 1)/100
No
Is J = 101?
Yes
5
VP=R*CK1
V=VP-CK1
ENC=EM1
No
Is I > 21?
Yes
U=C*CK
ENC=EM
3


6
NPTS = 101
IL = 8
IH = 6
MORE = 102
I = INITDO
LAST = -1
I

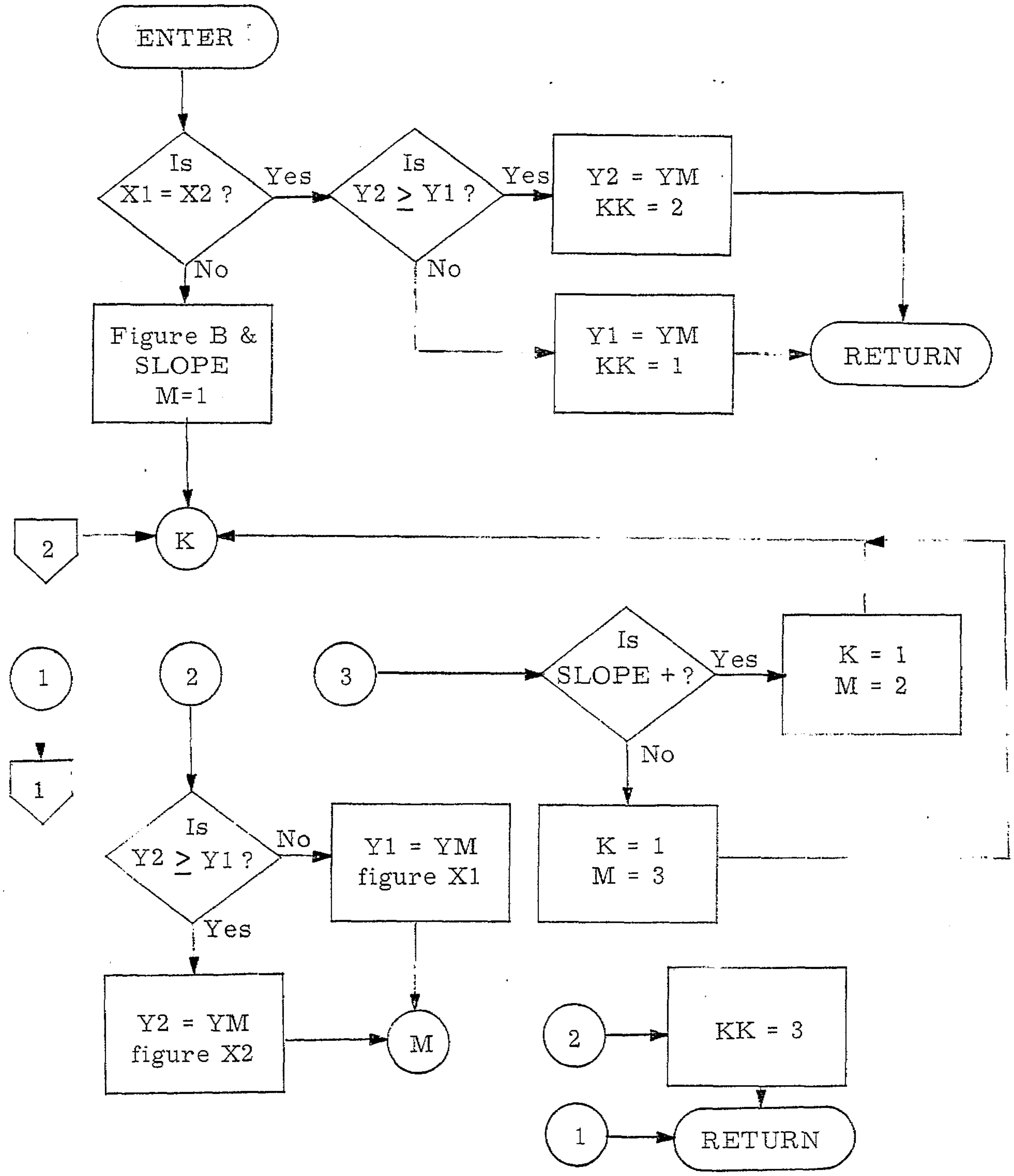

1
2
3
4
XM = 4.0
YM = 3.0
XM = 3.0
YM = 2.25
XM = 2.0
YM = 1.5
XM = 7.5
YM = 4.5
IL = 10
K = K+1
Is
K = 21 ?
Yes
No
L = L+1
XX(L)=X(K,L)
YY(L)=Y(K,L)
Call
ADJUST &
DRAW
No
Is
L = 101 ?
Yes
No
Is
K = 42 ?
Yes
Write
heading
7

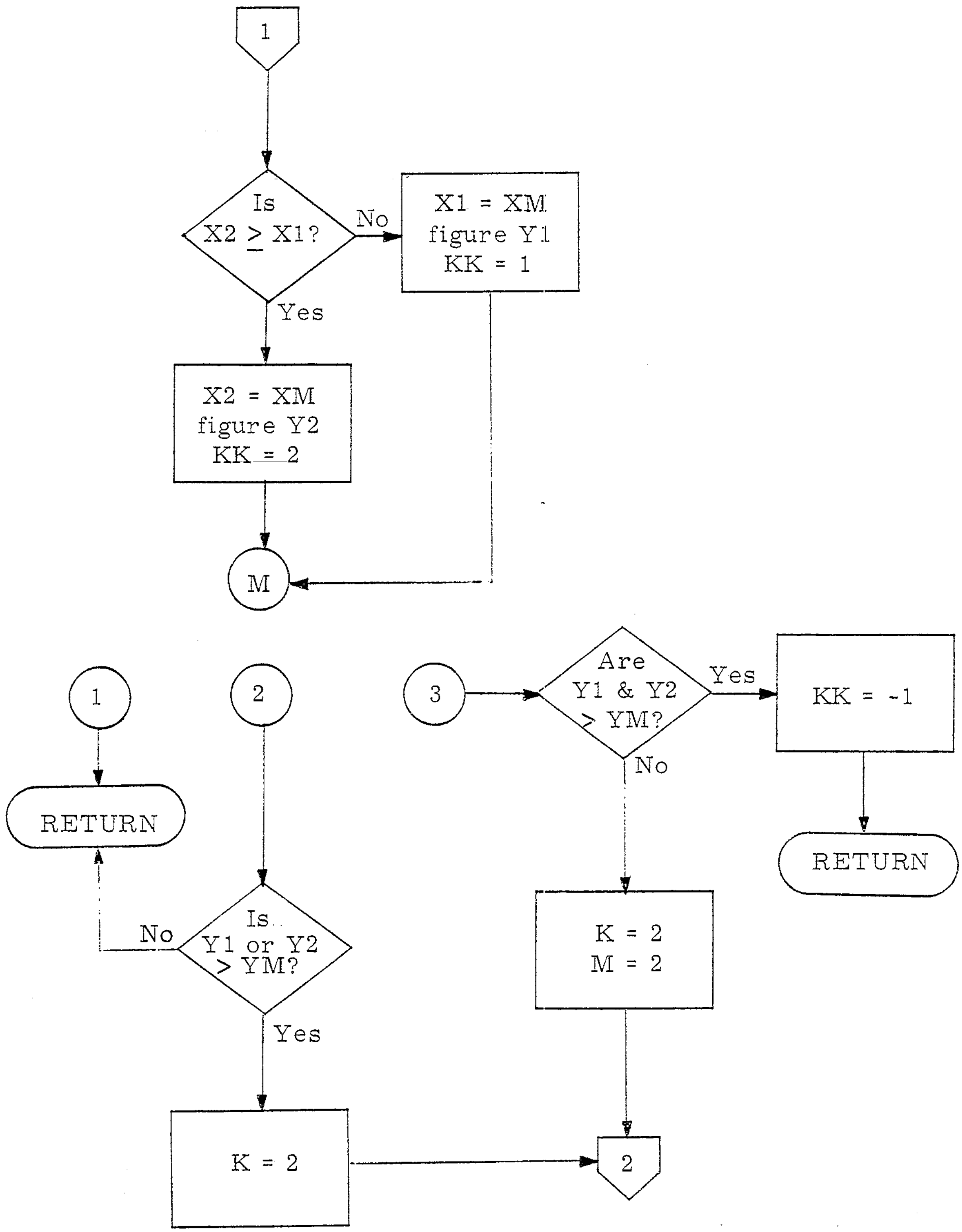
Flow Chart for Subroutine ADJUST

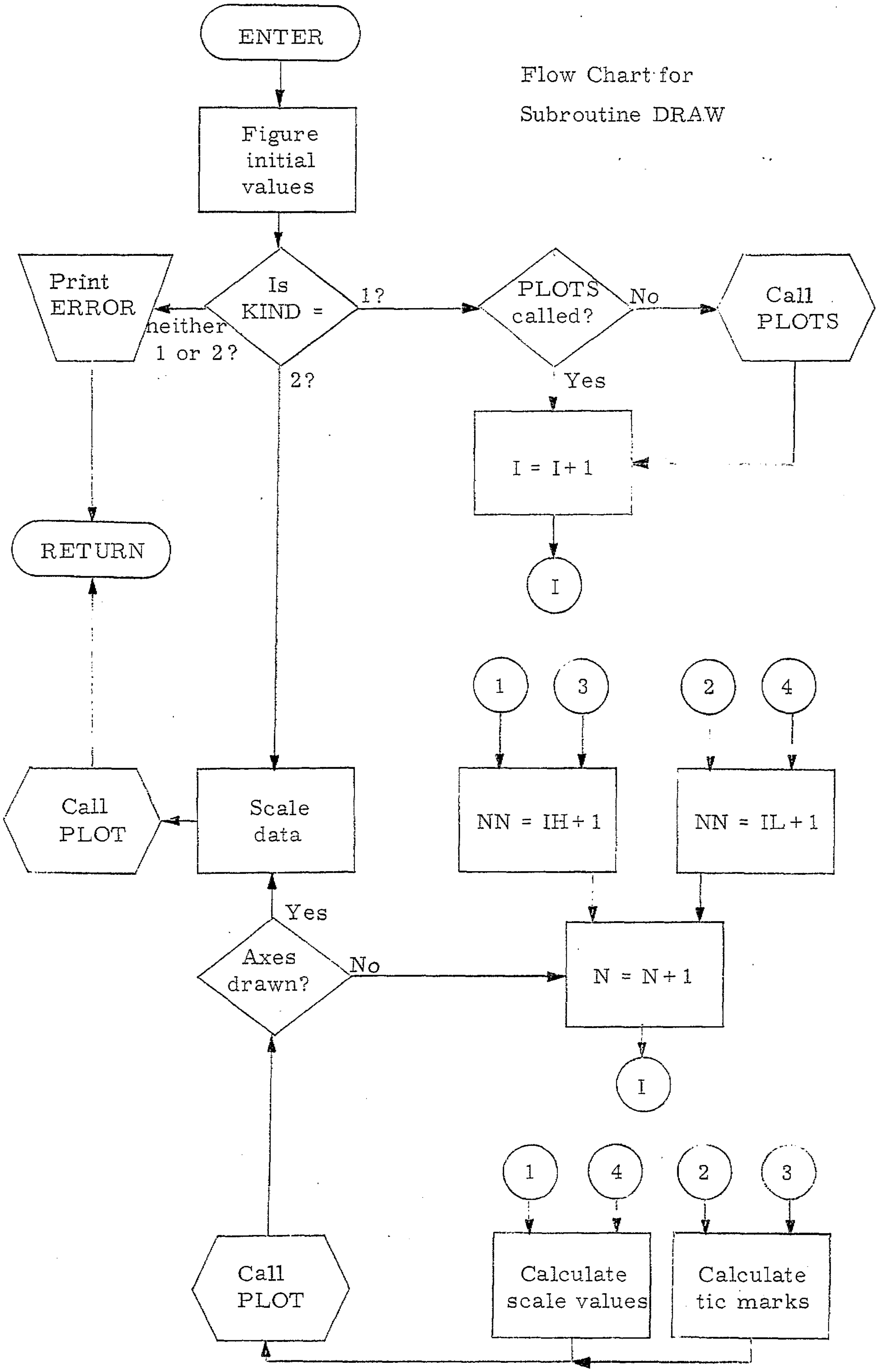


Flow Chart for

Subroutine EDGE




1
Is
X2 ≥ X1?
No
X1 = XM
figure Y1
KK = 1
Yes
X2 = XM
figure Y2
KK = 2
M
1
RETURN
2
Is
Y1 or Y2
> YM?
No
Yes
K = 2
3
Are
Y1 & Y2
> YM?
Yes
KK = -1
RETURN
No
K = 2
M = 2
2


Flow Chart for
Subroutine DRAW
ENTER
Figure initial values
Is KIND =
1?
2?
neither 1 or 2?
Print ERROR
RETURN
PLOTS called?
No
Yes
Call PLOTS
I = I+1
I
1
3
2
4
NN = IH+1
NN = IL+1
N = N+1
I
Call PLOT
Scale data
Yes
Axes drawn?
No
1
4
2
3
Calculate scale values
Calculate tic marks
Call PLOT

Appendix B

PROGRAM LISTING

```
      PROGRAM EXTEND(INPUT,OUTPUT,TAPE10)
C*****************************************************************************
C                                                                            *
C                            E X T E N S I O N   O F                         *
C                                                                            *
C      S E N S O R   A N D   S I M U L A T I O N   N O T E   N U M B E R   2 1  *
C                                                                            *
C                    EQUIPOTENTIAL AND MAGNETIC FIELD MAPPING                *
C                    FOR PARALLEL TWO-PLATE TRANSMISSION LINE                *
C                                                                            *
C       THIS PROGRAM READS B/A FROM DATA CARDS AND RETURNS M  AND FG (GEOMETRIC  *
C              FACTOR), K(M), K(M1), E(M), E(M1), AND FIELD PLOT             *
C                         (B/A BETWEEN .2 AND 100.)                          *
C                                                                            *
C         NDO = *  GRAPHS PRODUCED        *                                  *
C          1     *    NO1                 *                                  *
C          2     *    NO1, NO2            *    GRAPH NO1   0.750/UNIT        *
C          3     *         NO2            *    GRAPH NO2   0.500/UNIT        *
C          4     *         NO2, NO3       *    GRAPH NO3   0.375/UNIT        *
C          5     *         NO2, NO3, NO4  *    GRAPH NO4   0.250/UNIT        *
C          6     *         NO2,      NO4  *                                  *
C          7     *              NO3, NO4  *    1UNIT = 1 INCH                *
C          8     *              NO3       *                                  *
C          9     *                   NO4  *                                  *
C                                                                            *
C*****************************************************************************
      DIMENSION X(42,101), Y(42,101), XF(110), YF(110), XX(101),
     1YY(101)
      COMMON /SHARE/ ENC,IFLAG,IPICK
      COMMON /HOLD/ CE,CE1,CK,CK1,PHI,ZE,ZF
5     READ 10, BA,NDO
10    FORMAT (E14.8,5X,I1)
      INITDO=1
      INCDO=1
      IF (NDO) 15,15,20
15    IF (BA.GE.2.) NDO=9
      IF (BA.GT..1.AND.BA.LT.2.) NDO=8
      IF (BA.GE..4.AND.BA.LE.1.) NDO=3
      IF (BA.LT..4) NDO=1
20    GO TO (25,30,55,55,55,35,40,45,50), NDO
25    INITDO=4
      NDO=4
      GO TO 60
30    NDO=4
      INCDO=3
      GO TO 60
35    NDO=3
      INCDO=2
      GO TO 60
```

```
40    INITDO=2
      NDO=3
      GO TO 60
45    INITDO=2
      NDO=2
      GO TO 60
50    INITDO=3
      NDO=3
      GO TO 60
55    NDO=NDO-2
60    IF (BA) 310,310,65
65    IF (BA-.2) 75,85,70
70    IF (BA-100.) 85,85,75
75    PRINT 80, BA
80    FORMAT (10X,7HERROR. ,11H B OVER A =,E8.2,17H IS OUT OF RANGE.)
      GO TO 5
85    TEMP1=0.0
      TEMP2=0.0
      EM1=.999999999
      N=0
      FGTEMP=0.0
90    CALL PROB (EM1,C1,FOFM,FG)
      EM=1.0-EM1
      N=N+1
      IF (ABS(FGTEMP-FG)-1.0E-6) 140,140,95
95    IF (N-30) 100,100,140
100   EPSLON=FOFM-BA
      FGTEMP=FG
      IF (ABS(EPSLON)-1.0E-6) 140,140,105
105   IF (EPSLON) 110,140,130
110   IF (TEMP1) 115,115,125
115   PRINT 120, EPSLON
120   FORMAT (55H ERROR.F(M)IS LESS THAN B/A FOR M1=1. THE DIFFERENCE IS
     1,F16.8)
      GO TO 310
125   TEMP2=EM1
      GO TO 135
130   TEMP1=EM1
135   EM1=(TEMP1+TEMP2)*0.5
      GO TO 90
140   CONTINUE
      HALFPI=1.570796326794897
      RPI2=0.6366197723675813
      XOHMS=120.0*3.14159265358979*FG
      PRE=RPI2*CK
      PRE2=CE1/CK1
      PRE3=HALFPI/(CK*CK1)
      CEDCK=CE/CK
      PRINT 145, XOHMS,EM,BA,FG,CK,CK1,CE,CE1
```

```
145   FORMAT (1H1,45X,36H CONFORMAL MAPPING FOR FINITE PLATES/21X,74HFIE
     1LD AND POTENTIAL DISTRIBUTION FOR PARALLEL TWO-PLATE TRANSMISSION
     2LINE.,F8.2,7H  OHMS,/1H0,15X,1HM,12X,3HB/A,14X,2HFG,13X,4HK(M),11X
     3,5HK(M1),12X,4HE(M),11X,5HE(M1)/1H0,10X,F10.8,6E16.7)
      DO 250 I=1,42
      REALI=I
      IF (I-21) 150,150,160
150   R=(REALI-1.)*.05
      U=R*CK
      ENC=EM
      CALL FEEUM (U,EM,SNU,CNU,DNU,EU,XMLAST,ISTOP)
      PRINT 155, U,R,I,I,I,I
155   FORMAT (1H0,49X,2HU=,E14.7,2X,7HU/K(M)=,F5.2/1H0,30X,2HX(,I2,3H,J)
     1,9X,2HY(,I2,3H,J),29X,2HX(,I2,3H,J),9X,2HY(,I2,3H,J))
      GO TO 170
160   RR=(REALI-22.)*.05
      R=-1.0+RR
      VP=RR*CK1
      V=VP-CK1
      ENC=EM1
      CALL FEEUM (VP,EM1,SNV,CNV,DNV,EV1,XMLAST,ISTOP)
      PRINT 165, V,R,I,I,I,I
165   FORMAT (1H0,48X,3HV =,E14.7,2X,8HV/K(M1)=,F5.2/1H0,30X,2HX(,I2,3H,
     1J),9X,2HY(,I2,3H,J),29X,2HX(,I2,3H,J),9X,2HY(,I2,3H,J))
170   DO 235 J=1,101
      REALJ=J
      R=(REALJ-1.)*.01
      IF (I-21) 175,175,180
175   VP=R*CK1
      V=VP-CK1
      ENC=EM1
      CALL FEEUM (VP,EM1,SNV,CNV,DNV,EV1,XMLAST,ISTOP)
      GO TO 185
180   U=R*CK
      ENC=EM
      CALL FEEUM (U,EM,SNU,CNU,DNU,EU,XMLAST,ISTOP)
185   SNVSQ=SNV*SNV
      DNUSQ=DNU*DNU
      A=SNU*CNU*DNU*SNVSQ
      B=DNUSQ*SNV*CNV*DNV
      D1=1.0E0-DNUSQ*SNVSQ
      IF (I-42) 190,200,200
190   IF (I-21) 195,220,215
195   IF (J-101) 205,200,205
200   Y(I,J)=0.0E0
      GO TO 210
205   Y(I,J)=PRE*(EV1-VP*PRE2+PRE3*V-B/D1)
210   X(I,J)=PRE*(EU-U*CEDCK+(EM*A)/D1)
      GO TO 235
```

```
215   IF (J-101) 225,220,225
220   X(I,J)=0.0E0
      GO TO 230
225   X(I,J)=PRE*(EU-U*CEDCK+(EM*A)/D1)
230   Y(I,J)=PRE*(EV1-VP*PRE2+PRE3*V-B/D1)
235   CONTINUE
      PRINT 240, ((X(I,J),Y(I,J),X(I,J+50),Y(I,J+50)),J=1,50)
240   FORMAT (24X,2E16.7,11X,1H*,8X,2E16.7)
      PRINT 245, X(I,101),Y(I,101)
245   FORMAT (76X,2E16.7)
250   CONTINUE
      NPTS=101
      IL=8
      IH=6
      MORE=102
      DO 305 I=INITDO,NDO,INCDO
      LAST=-1
      GO TO (255,265,260,270), I
255   XM=4.0
      YM=3.0
      GO TO 275
260   XM=2.0
      YM=1.5
      GO TO 275
265   XM=3.0
      YM=2.25
      GO TO 275
270   XM=7.5
      YM=4.5
      IL=10
275   DO 300 K=2,41
      IF (K-21) 280,300,280
280   DO 285 L=1,101
      XX(L)=X(K,L)
285   YY(L)=-Y(K,L)
      CALL ADJUST (XX,YY,NPTS,XM,YM,XF,YF,MORE,L)
      IF (K.EQ.41) LAST=1
      IF (K-2) 295,290,295
290   CALL DRAW (XM,YM,IL,IH,L,XF,YF,1,LAST)
      GO TO 300
295   CALL DRAW (XM,YM,IL,IH,L,XF,YF,2,LAST)
300   CONTINUE
      REALL=IL
      REALH=IH
      UP=REALH/YM
      CALL HEADIN (REALH,REALL,BA,UP,XOHMS)
305   CONTINUE
      GO TO 5
310   CONTINUE
```

```
      SUBROUTINE HEADIN (REALH,REALL,BA,UP,XOHMS)                       HD   1
C***********************************************************************
C                                                                      *
C                    THIS SUBROUTINE PRINTS THE HEADING AND            *
C                      CORRESPONDING NUMBERS ON THE GRAPH.             *
C                                                                      *
C***********************************************************************
      BACK=-(REALL+3.0)                                                 HD   2
      RLO2=REALL/2.0                                                    HD   3
      CEN1=RLO2-1.86                                                    HD   4
      CEN2=RLO2-3.26                                                    HD   5
      CEN3=RLO2+1.90                                                    HD   6
      CEN4=RLO2-0.66                                                    HD   7
      CEN5=RLO2-0.06                                                    HD   8
      HI1=REALH+.78                                                     HD   9
      HI2=REALH+.5                                                      HD  10
      HI3=REALH+.22                                                     HD  11
      CALL PLOT (BACK,0.,-3)                                            HD  12
      CALL SYMBOL (CEN2,HI2,.14,54HFOR PARALLEL, TWO-PLATE TRANSMISSION HD  13
     1LINE.          OHMS,0.,54)                                        HD  14
      CALL SYMBOL (CEN1,HI1,.14,32HFIELD AND POTENTIAL DISTRIBUTION,0.,3 HD  15
     12)                                                                HD  16
      CALL NUMBER (CEN3,HI2,.14,XOHMS,0.,4HF6.2)                        HD  17
      CALL SYMBOL (CEN4,HI3,.14,5HB/A =,0.,5)                           HD  18
      CALL NUMBER (CEN5,HI3,.14,BA,0.,4HF6.2)                           HD  19
      UP1=UP/2.0-0.437                                                  HD  20
      UP2=(REALH-UP)/2.0-.281+UP                                        HD  21
      UP=UP+.09                                                         HD  22
      CALL SYMBOL (-0.80,UP1,.14,8HU = K(M),90.0,8)                     HD  23
      CALL SYMBOL (-0.80,UP2,.14,5HU = 0,90.0,5)                        HD  24
      CALL SYMBOL (-1.30,UP,0.14,9HV = K(M1),0.0,9)                     HD  25
      CALL PLOT (REALL+3.0,0.,3)                                        HD  26
      CALL PLOT (REALL+3.0,0.,-3)                                       HD  27
      RETURN                                                            HD  28
      END                                                               HD  29-
```

```
      SUBROUTINE ADJUST (X,Y,NPTS,XM,YM,XF,YF,MORE,L)
C***************************************************************************
C                                                                          *
C      THIS SUBROUTINE ADJUSTS ALL DATA POINTS IN THE FIRST QUADRANT THAT  *
C    OVERFLOW THE GIVEN LIMITS OF THE BOUNDARY TO THE BOUNDARY WITHOUT THE *
C       LOSS OF THE SLOPE FROM THE INTERIOR POINT TO THE EXTERIOR POINT    *
C                                                                          *
C***************************************************************************
      DIMENSION X(NPTS), Y(NPTS), XF(MORE), YF(MORE)
      L=0
      I=0
5     I=I+1
      IF (I-NPTS) 10,35,45
10    K=0
      IF (X(I).GT.XM.AND.X(I+1).GT.XM) GO TO 5
      IF (Y(I).GT.YM.AND.Y(I+1).GT.YM) GO TO 5
      IF (X(I).GT.XM.OR.X(I+1).GT.XM) K=1
      IF (Y(I).GT.YM.OR.Y(I+1).GT.YM) K=K+2
      IF (K) 15,40,15
15    C=X(I)
      D=Y(I)
      E=X(I+1)
      F=Y(I+1)
      CALL EDGE (C,D,E,F,K,KK,XM,YM)
      IF (KK) 5,20,20
20    L=L+1
      GO TO (25,30,30), KK
25    XF(L)=C
      YF(L)=D
      GO TO 5
30    XF(L)=C
      YF(L)=D
      L=L+1
      XF(L)=E
      YF(L)=F
      GO TO 5
35    IF (X(I).LE.XM.AND.Y(I).LE.YM) GO TO 40
      GO TO 45
40    L=L+1
      XF(L)=X(I)
      YF(L)=Y(I)
      GO TO 5
45    RETURN
      END
```

```
      SUBROUTINE EDGE (X1,Y1,X2,Y2,K,KK,XM,YM)
C***********************************************************************
C                                                                      *
C      SUBROUTINE EDGE CALCULATES THE INTERSECTION OF THE LINE ADJOINING *
C                 TWO POINTS AND THE LINES X=XM, Y=YM OR BOTH           *
C                                                                      *
C***********************************************************************
      IF (X1-X2) 5,95,5
5     SLOPE=(Y2-Y1)/(X2-X1)
      B=Y1-SLOPE*X1
      M=1
10    GO TO (15,55,80), K
15    IF (X2-X1) 25,20,20
20    X2=XM
      Y2=SLOPE*XM+B
      KK=2
      GO TO (50,30,40), M
25    X1=XM
      Y1=SLOPE*XM+B
      KK=1
      GO TO (50,30,40), M
30    IF (Y1.GT.YM.OR.Y2.GT.YM) GO TO 35
      RETURN
35    K=2
      M=2
      GO TO 10
40    IF (Y1.GT.YM.AND.Y2.GT.YM) GO TO 45
      K=2
      M=2
      GO TO 10
45    KK=-1
50    RETURN
55    IF (Y2-Y1) 65,60,60
60    Y2=YM
      X2=(YM-B)/SLOPE
      KK=2
      GO TO (75,70), M
65    Y1=YM
      X1=(YM-B)/SLOPE
      KK=1
      GO TO (75,70), M
70    KK=3
75    RETURN
80    IF (SLOPE) 85,90,90
85    K=1
      M=3
      GO TO 10
90    K=1
      M=2
```

```
      GO TO 10
95    IF (Y2-Y1) 1C5,1CC,1C0
1CC   Y2=YM
      KK=2
      RETURN
105   Y1=YM
      KK=1
      RETURN
      END
```

```
      SUBROUTINE DRAW (XM,YM,IL,IH,NPTS,X,Y,KIND,LAST)
C***************************************************************************
C                                                                          *
C     THIS SUBROUTINE SCALES, DRAWS THE AXIS FOR THE GRAPH, AND PLOTS THE  *
C      ADJUSTED DATA WITH ANY NUMBER OF OVERLAYS ON THE CALCOMP PLOTTER.   *
C                                                                          *
C***************************************************************************
      DIMENSION X(NPTS), Y(NPTS)
      DATA IFT/4HE8.2/
      REALH=IH
      REALL=IL
      SCALEX=XM/REALL
      SCALEY=YM/REALH
      RSCALX=1./SCALEX
      RSCALY=1./SCALEY
      IF (KIND-1) 10,20,5
5     IF (KIND-2) 10,95,10
10    PRINT 15, KIND
15    FORMAT (41H  THE KIND OF GRAPH ASKED FOR IS IN ERROR,F8.2)
      RETURN
20    IF (OI-2) 25,30,25
25    CALL PLOTS (TB,TB,10)
      OI=2
30    DO 90 I=1,4
      GO TO (35,40,35,40), I
35    NN=IH+1
      GO TO 45
40    NN=IL+1
45    DO 90 N=1,NN
      REALN=N
      GO TO (50,60,70,80), I
50    R=REALN-1.
      CALL PLOT (-.05,R,2)
      CALL PLOT (0.,R,2)
      YNUM=R*SCALEY
      RR=REALN-1.01
      CALL NUMBER (-.6,RR,.07,YNUM,0.,IFT)
      CALL PLOT (0.,R,3)
      IF (N-NN) 55,90,55
55    CALL PLOT (0.,REALN,2)
      GO TO 90
60    R=REALN-1.
      RR=REALH+.05
      CALL PLOT (R,RR,2)
      CALL PLOT (R,REALH,2)
      IF (N-NN) 65,90,65
65    CALL PLOT (REALN,REALH,2)
      GO TO 90
70    R=REALL+.05
```

```
      RR=REALH-REALN+1.
      CALL PLOT (R,RR,2)
      CALL PLOT (REALL,RR,2)
      IF (N-NN) 75,90,75
75    RRR=RR-1.
      CALL PLOT (REALL,RRR,2)
      GO TO 90
80    R=REALL-REALN+1.
      CALL PLOT (R,-.05,2)
      CALL PLOT (R,0.,2)
      XNUM=R*SCALEX
      RR=R-.25
      CALL NUMBER (RR,-.25,.07,XNUM,0.,IFT)
      CALL PLOT (R,0.,3)
      IF (N-NN) 85,90,85
85    RRR=R-1.
      CALL PLOT (RRR,0.,2)
90    CONTINUE
95    XX=X(1)*RSCALX
      YY=Y(1)*RSCALY
      CALL PLOT (XX,YY,3)
      DO 100 I=1,NPTS
      XX=X(I)*RSCALX
      YY=Y(I)*RSCALY
      CALL PLOT (XX,YY,2)
100   CONTINUE
      IF (LAST) 105,110,110
105   CALL PLOT (0.,0.,3)
      CALL PLOT (0.,0.,-3)
      RETURN
110   R=REALL+3.
      CALL PLOT (R,0.,3)
      CALL PLOT (R,0.,-3)
      RETURN
      END
```

```
      SUBROUTINE PROB (EM1,AB,BA,FG)
C***********************************************************************
C                                                                      *
C        THIS SUBROUTINE CALCULATES THE GEOMETRIC FACTOR AND B OVER A  *
C                                                                      *
C***********************************************************************
      COMMON /SHARE/ EMC,IFLAG,IPICK
      COMMON /HOLD/ CE,CE1,CK,CK1,PHI,ZE,ZF
      EM=1.0-EM1
      PI=3.14159265358979
      RP=0.3183098861837907
      P2=1.570796326794897
      X=SQRT(EM)
      CALL ELLPIN (X,Y,Z)
      CK=Y
      CE=Z
      X=SQRT(EM1)
      CALL ELLPIN (X,Y,Z)
      CK1=Y
      CE1=Z
      CK=(P2-CE*CK1)/(CE1-CK1)
      EMC=EM
      PHI=ASIN(SQRT((1.0-CE/CK)/EM))
      ZF=XKINC(PHI,EMC)
      ZE=EKINC(PHI,EMC)
      AB=(CK*ZE-CE*ZF)/P2
      BA=1.0/AB
      FG=CK1/CK
      RETURN
      END
```

```
      SUBROUTINE FEEUM (VU,XM,SN,CN,DN,E,XMLAST,ISTOP)
C*****************************************************************************
C                                                                            *
C                    CALCULATION OF THE JACOBIAN FUNCTIONS BY                *
C                        THE ARITHMETIC-GEOMETRIC MEAN                       *
C                                                                            *
C*****************************************************************************
      DIMENSION A(1000), B(1000), C(1000)
      IF (XM-XMLAST) 5,20,5
5     SQM=SQRT(1.-XM)
      A(1)=0.5E0*(1.0E0+SQM)
      B(1)=SQRT(SQM)
      C(1)=0.5E0*(1.0E0-SQM)
      DO 10 I=2,1000
      II=I-1
      A(I)=0.5E0*(A(II)+B(II))
      B(I)=SQRT(A(II)*B(II))
      C(I)=0.5E0*(A(II)-B(II))
      IF (ABS(C(I))-1.0E-10) 15,10,10
10    CONTINUE
15    ISTOP=I
20    PHI=2.0E0**ISTOP*A(ISTOP)*VU
      DO 35 I=1,ISTOP
      II=ISTOP+1-I
      ARG=C(II)/A(II)*SIN(PHI)
      IF (ABS(ARG)-1.0E-5) 30,30,25
25    FACT=ASIN(ARG)
      GO TO 35
30    FACT=ARG
35    PHI=0.5E0*(PHI+FACT)
      SN=SIN(PHI)
      CN=COS(PHI)
      DN=SQRT(1.-XM*SN*SN)
      E=EKINC(PHI,XM)
      XMLAST=XM
      RETURN
      END
```

```
      SUBROUTINE ELLPIN (X,EK,EE)
C***************************************************************************
C                                                                          *
C              COMPUTATION OF COMPLETE ELLIPTIC INTEGRALS K, E             *
C                                                                          *
C***************************************************************************
      DIMENSION AKP(50)
      IF (X-1.0E0) 5,75,10
5     IF (X) 10,20,25
10    PRINT 15
15    FORMAT (8H ELLPINT)
      STOP
20    EK=1.5707963267948957
      EE=EK
      RETURN
25    IF (X-.995E0) 30,50,50
30    AK0=X
      DO 35 N=1,50
      AKP(N)=SQRT(1.-AK0*AK0)
      AK0=(1.E0-AKP(N))/(1.E0+AKP(N))
      IF (AK0-1.E-12) 40,40,35
35    CONTINUE
      N=50
40    ER=1.5707963267948957
      AKR=1.5707963267948957
      NM1=N-1
      DO 45 I=1,NM1
      D=1.E0+AKP(N-I)
      TEMP=2.E0*AKR/D
      AKR=TEMP
45    ER=D*ER-TEMP*AKP(N-I)
      EK=AKR
      EE=ER
      RETURN
50    AKP2=1.0E0-X*X
      AKP(1)=SQRT(AKP2)
      U=ALOG(4./AKP(1))
      A1=1.0E0
      FEE1=AKP2*0.25E0
      SUMK=U+(U-A1)*FEE1
      B1=0.5E0
      C1=AKP2*0.5E0
      SUME=1.0E0+(U-B1)*C1
      DO 65 I=2,100
      AI=I
      TWOR=AI+AI
      TWORM1=TWOR-1.0E0
      TWORM3=TWOR-3.0E0
      ANOW=A1+1.E0/(AI*(TWORM1))
```

```
      F=TWORM1/TWOR
      FEE=F*F*AKP2*FEE1
      TERMK=(U-ANOW)*FEE
      SUMK=SUMK+TERMK
      BNOW=B1+(1.0E0/((AI-1.0E0)*(TWORM3))+1.0E0/(AI*(TWORM1)))*0.5E0
      C=((TWORM3)/(TWOR-2.0E0))*F*AKP2*C1
      TERME=(U-BNOW)*C
      SUME=SUME+TERME
      IF (TERMK-1.0E-11) 55,55,60
55    IF (TERME-1.0E-11) 70,70,60
60    C1=C
      B1=BNOW
      A1=ANOW
65    FEE1=FEE
70    EK=SUMK
      EE=SUME
      RETURN
75    EE=1.0E0
      EK=1.0E75
      RETURN
      END
```

```
      SUBROUTINE GQINT (XL1,XL2,E,SUM)
C***********************************************************************
C                                                                      *
C                      INTEGRATION BY GAUSSIAN QUADRATURE              *
C                 DATA SPECIFIES THE ORDER OF G-Q INTEGRATION          *
C                                                                      *
C***********************************************************************
      DIMENSION A(130), ANS(130), X(100), R(100), U(100)
      DATA M/40/
      DATA U/-.998237709710559,-.990726238699457,-.977259949983774,-.957
     1916819213792,-.932812808278677,-.902098806968874,-.865959503212260
     2,-.824612230833312,-.778305651426519,-.727318255189927,-.671956684
     3614180,-.612553889667980,-.549467125095128,-.483075801686179,-.413
     47792043716C5,-.341994090825758,-.268152185007254,-.192697580701371
     5,-.116084070675255,-.387724175060508E-1,+.387724175060508E-1,.1160
     684070675255,.192697580701371,.268152185007254,.341994090825758,.41
     7377920437160S,.483075801686179,.549467125095128,.612553889667980,.
     8671956684614180,.727318255189927,.778305651426519,.824612230833312
     9,.865959503212260,.902098806968874,.932812808278677,.9579168192137
     $92,.977259949983774,.990726238699457,.998237709710559/
      DATA R/.452127709853319E-2,.104982845311528E-1,.164210583819079E-1
     1,.222458491941670E-1,.279370069800234E-1,.334601952825478E-1,.3878
     2216797447200E-1,.438709081856733E-1,.486958076350722E-1,.532278469
     3839368E-1,.574397690993916E-1,.613062424929289E-1,.648040134566010E
     4-1,.679120458152339E-1,.706116473912868E-1,.728865823958041E-1,.74
     5723169057968 3E-1,.761103619006262E-1,.770398181642480E-1,.77505947
     6978424 8E-1,.775059479784248E-1,.770398181642480E-1,.76110361900626
     72E-1,.747231690579683E-1,.728865823958041E-1,.706116473912868E-1,.
     8679120458152339E-1,.648040134566010E-1,.613062424929289E-1,.574397
     9690993916E-1,.532278469839368E-1,.486958076350722E-1,.438709081856
     $733E-1,.387821679744720E-1,.334601952825478E-1,.279370069800234E-1
     $,.222458491941670E-1,.164210583819079E-1,.104982845311528E-1,.4521
     $27709853319E-2/
      CHK=0.0E0
      N=1
      A(1)=XL1
5     XN=N
      SUM=0.0E0
      H=(XL2-XL1)/XN
      DO 10 I=1,N
      XI=I
10    A(I+1)=XL1+XI*H
      DO 25 I1=1,N
      ANS(I1)=0.0E0
      DO 15 J=1,M
      X(J)=(A(I1+1)-A(I1))*U(J)+(A(I1+1)+A(I1))
15    X(J)=X(J)*0.5E0
      DO 20 I=1,M
      XX=X(I)
```

```
      CALL FXEVAL (FX,XX)
20    ANS(I1)=ANS(I1)+FX*R(I)
25    ANS(I1)=(A(I1+1)-A(I1))*0.5E0*ANS(I1)
      DO 30 I=1,N
30    SUM=SUM+ANS(I)
      IF (ABS(SUM-CHK)-E) 40,40,35
35    N=N+N
      ERROR=SUM-CHK
      CHK=SUM
      IF (N-130) 5,5,40
40    RETURN
      END


      FUNCTION EKINC (X,XM)
      COMMON /SHARE/ ENC,IFLAG,IPICK
      IPICK=1
      UPLIM=SIN(X)
5     CALL GQINT (0.0E0,UPLIM,1.E-10,SUM)
      EKINC=SUM
      IPICK=0
      RETURN
      END


      FUNCTION XKINC (X,XM)
      COMMON /SHARE/ ENC,IFLAG,IPICK
      UPLIM=SIN(X)
      IF (UPLIM-.995E0) 10,10,5
5     IFLAG=1
      UPLIM=X
      GO TO 15
10    IFLAG=0
15    CALL GQINT (0.0E0,UPLIM,1.E-10,SUM)
      XKINC=SUM
      RETURN
      END


      SUBROUTINE FXEVAL (FX,X)
      COMMON /SHARE/ XM,IFLAG,IPICK
      IF (IPICK) 20,5,20
5     IF (IFLAG) 15,10,15
10    X2=X*X
      FX=1.0E0/SQRT((1.0-X2)*(1.0-XM*X2))
      RETURN
15    SINX=SIN(X)
      FX=1.0E0/SQRT(1.-XM*SINX*SINX)
      RETURN
20    X2=X*X
      FX=SQRT((1.0-XM*X2)/(1.0-X2))
      RETURN
      END
```

APPENDIX C

of

Sensor and Simulation Note 52

A TABLE OF VALUES OF THE GEOMETRIC IMPEDANCE FACTOR (f_g) FOR VALUES OF THE SIMULATOR CONFIGURATION (b/a)

January 1969

The purpose of this appendix is to include a more comprehensive table of b/a versus f_g. As in Note 52 the simulator configuration b/a is the ratio of the plate separation to the plate length. The geometric factor f_g relates the transmission line impedance to the free space impedance.

The values in the following table were produced essentially with the same computer program documented in Sensor and Simulation Note 52. However, refinements were required to generate the desired range of values. The incrementing values of b/a were selected to allow interpolation with relative error of no more than one part in one thousand. A third column containing differences of the geometric factors is included to aid interpolation. The range of b/a in the table is from 0.01 to 99.0. These limits allow the approximate values of f_g for small and large values of b/a to be used with a minimum accuracy of four significant digits.

The approximation of f_g for small b/a is

$$f_g = \frac{b}{a}\left\{1 + \frac{b}{\pi a}\left[1 + \ln\left(\frac{2\pi a}{b}\right)\right]\right\}^{-1}$$

and for large b/a

$$f_g = \frac{1}{\pi}\ln\left(4\frac{b}{a}\right)$$

b/a	f_g	(dif)	b/a	f_g	(dif)	b/a	f_g	(dif)
.010	0.009768	.000955	.040	0.037106	.000870	.070	0.062229	.000805
.011	0.010723	.000952	.041	0.037976	.000867	.071	0.063034	.000804
.012	0.011675	.000948	.042	0.038843	.000865	.072	0.063838	.000801
.013	0.012623	.000946	.043	0.039708	.000862	.073	0.064639	.000800
.014	0.013569	.000941	.044	0.040570	.000860	.074	0.065439	.000798
.015	0.014510	.000939	.045	0.041430	.000858	.075	0.066237	.000796
.016	0.015449	.000935	.046	0.042288	.000856	.076	0.067033	.000794
.017	0.016384	.000932	.047	0.043144	.000853	.077	0.067827	.000792
.018	0.017316	.000929	.048	0.043997	.000851	.078	0.068619	.000791
.019	0.018245	.000926	.049	0.044848	.000849	.079	0.069410	.000789
.020	0.019171	.000923	.050	0.045697	.000847	.080	0.070199	.000786
.021	0.020094	.000920	.051	0.046544	.000844	.081	0.070985	.000786
.022	0.021014	.000918	.052	0.047388	.000842	.082	0.071771	.000783
.023	0.021932	.000914	.053	0.048230	.000840	.083	0.072554	.000781
.024	0.022846	.000911	.054	0.049070	.000838	.084	0.073335	.000780
.025	0.023757	.000909	.055	0.049908	.000836	.085	0.074115	.000778
.026	0.024666	.000905	.056	0.050744	.000834	.086	0.074893	.000776
.027	0.025571	.000903	.057	0.051578	.000831	.087	0.075669	.000775
.028	0.026474	.000901	.058	0.052409	.000830	.088	0.076444	.000773
.029	0.027375	.000897	.059	0.053239	.000827	.089	0.077217	.000771
.030	0.028272	.000895	.060	0.054066	.000825	.090	0.077988	.000769
.031	0.029167	.000893	.061	0.054891	.000824	.091	0.078757	.000768
.032	0.030060	.000889	.062	0.055715	.000821	.092	0.079525	.000766
.033	0.030949	.000887	.063	0.056536	.000819	.093	0.080291	.000764
.034	0.031836	.000885	.064	0.057355	.000817	.094	0.081055	.000763
.035	0.032721	.000882	.065	0.058172	.000815	.095	0.081818	.000761
.036	0.033603	.000879	.066	0.058987	.000814	.096	0.082579	.000759
.037	0.034482	.000877	.067	0.059801	.000811	.097	0.083338	.000758
.038	0.035359	.000875	.068	0.060612	.000809	.098	0.084096	.000756
.039	0.036234	.000872	.069	0.061421	.000808	.099	0.084852	.000758

b/a	f_g	(dif)	b/a	f_g	(dif)	b/a	f_g	(dif)
0.10	0.08561	—	0.40	0.26207		0.70	0.38204	
		.00745			.00468			.00341
0.11	0.09306		0.41	0.26675		0.71	0.38545	
		.00731			.00462			.00338
0.12	0.10037		0.42	0.27137		0.72	0.38883	
		.00716			.00456			.00335
0.13	0.10753		0.43	0.27593		0.73	0.39218	
		.00702			.00451			.00331
0.14	0.11455		0.44	0.28044		0.74	0.39549	
		.00689			.00445			.00329
0.15	0.12144		0.45	0.28489		0.75	0.39878	
		.00676			.00441			.00326
0.16	0.12820		0.46	0.28930		0.76	0.40204	
		.00663			.00435			.00323
0.17	0.13483		0.47	0.29365		0.77	0.40527	
		.00653			.00431			.00320
0.18	0.14136		0.48	0.29796		0.78	0.40847	
		.00641			.00425			.00318
0.19	0.14777		0.49	0.30221		0.79	0.41165	
		.00630			.00421			.00314
0.20	0.15407		0.50	0.30642		0.80	0.41479	
		.00619			.00417			.00313
0.21	0.16026		0.51	0.31059		0.81	0.41792	
		.00610			.00411			.00309
0.22	0.16636		0.52	0.31470		0.82	0.42101	
		.00600			.00408			.00307
0.23	0.17236		0.53	0.31878		0.83	0.42408	
		.00591			.00403			.00304
0.24	0.17827		0.54	0.32281		0.84	0.42712	
		.00581			.00399			.00302
0.25	0.18408		0.55	0.32680		0.85	0.43014	
		.00573			.00394			.00299
0.26	0.18981		0.56	0.33074		0.86	0.43313	
		.00564			.00391			.00297
0.27	0.19545		0.57	0.33465		0.87	0.43610	
		.00556			.00386			.00295
0.28	0.20101		0.58	0.33851		0.88	0.43905	
		.00548			.00383			.00292
0.29	0.20649		0.59	0.34234		0.89	0.44197	
		.00540			.00379			.00290
0.30	0.21189		0.60	0.34613		0.90	0.44487	
		.00532			.00375			.00287
0.31	0.21721		0.61	0.34988		0.91	0.44774	
		.00526			.00371			.00285
0.32	0.22247		0.62	0.35359		0.92	0.45059	
		.00518			.00368			.00283
0.33	0.22765		0.63	0.35727		0.93	0.45342	
		.00511			.00364			.00281
0.34	0.23276		0.64	0.36091		0.94	0.45623	
		.00505			.00361			.00279
0.35	0.23781		0.65	0.36452		0.95	0.45902	
		.00497			.00357			.00276
0.36	0.24278		0.66	0.36809		0.96	0.46178	
		.00492			.00354			.00275
0.37	0.24770		0.67	0.37163		0.97	0.46453	
		.00485			.00350			.00272
0.38	0.25255		0.68	0.37513		0.98	0.46725	
		.00479			.00347			.00271
0.39	0.25734		0.69	0.37860		0.99	0.46996	
		.00473			.00344			.00268

b/a	f_g	(dif)	b/a	f_g	(dif)	b/a	f_g	(dif)
1.00	0.47264	.01312	2.50	0.73901	.00608	4.00	0.88498	.00390
1.05	0.48576	.01266	2.55	0.74509	.00596	4.05	0.88888	.00385
1.10	0.49842	.01222	2.60	0.75105	.00586	4.10	0.89273	.00380
1.15	0.51064	.01181	2.65	0.75691	.00576	4.15	0.89653	.00376
1.20	0.52245	.01143	2.70	0.76267	.00566	4.20	0.90029	.00372
1.25	0.53388	.01107	2.75	0.76833	.00556	4.25	0.90401	.00367
1.30	0.54495	.01073	2.80	0.77389	.00547	4.30	0.90768	.00363
1.35	0.55568	.01041	2.85	0.77936	.00538	4.35	0.91131	.00359
1.40	0.56609	.01010	2.90	0.78474	.00530	4.40	0.91490	.00356
1.45	0.57619	.00982	2.95	0.79004	.00521	4.45	0.91846	.00351
1.50	0.58601	.00954	3.00	0.79525	.00512	4.50	0.92197	.00347
1.55	0.59555	.00928	3.05	0.80037	.00505	4.55	0.92544	.00344
1.60	0.60483	.00904	3.10	0.80542	.00497	4.60	0.92888	.00341
1.65	0.61387	.00880	3.15	0.81039	.00490	4.65	0.93229	.00336
1.70	0.62267	.00859	3.20	0.81529	.00482	4.70	0.93565	.00333
1.75	0.63126	.00836	3.25	0.82011	.00475	4.75	0.93898	.00330
1.80	0.63962	.00817	3.30	0.82486	.00469	4.80	0.94228	.00327
1.85	0.64779	.00797	3.35	0.82955	.00461	4.85	0.94555	.00323
1.90	0.65576	.00779	3.40	0.83416	.00456	4.90	0.94878	.00320
1.95	0.66355	.00761	3.45	0.83872	.00449	4.95	0.95198	.00316
2.00	0.67116	.00745	3.50	0.84321	.00443	5.00	0.95514	.00314
2.05	0.67861	.00728	3.55	0.84764	.00436	5.05	0.95828	.00311
2.10	0.68589	.00712	3.60	0.85200	.00431	5.10	0.96139	.00307
2.15	0.69301	.00698	3.65	0.85631	.00426	5.15	0.96446	.00305
2.20	0.69999	.00683	3.70	0.86057	.00420	5.20	0.96751	.00302
2.25	0.70682	.00669	3.75	0.86477	.00414	5.25	0.97053	.00299
2.30	0.71351	.00656	3.80	0.86891	.00410	5.30	0.97352	.00296
2.35	0.72007	.00643	3.85	0.87301	.00404	5.35	0.97648	.00294
2.40	0.72650	.00632	3.90	0.87705	.00399	5.40	0.97942	.00291
2.45	0.73282	.00619	3.95	0.88104	.00394	5.45	0.98233	.00287

b/a	f_g	(dif)
5.50	0.9852	.0029
5.55	0.9881	.0028
5.60	0.9909	.0028
5.65	0.9937	.0028
5.70	0.9965	.0028
5.75	0.9993	.0027
5.80	1.0020	.0027
5.85	1.0047	.0027
5.90	1.0074	.0027
5.95	1.0101	.0026
6.00	1.0127	.0026
6.05	1.0153	.0026
6.10	1.0179	.0026
6.15	1.0205	.0026
6.20	1.0231	.0025
6.25	1.0256	.0025
6.30	1.0281	.0025
6.35	1.0306	.0025
6.40	1.0331	.0025
6.45	1.0356	.0024
6.50	1.0380	.0024
6.55	1.0404	.0025
6.60	1.0429	.0023
6.65	1.0452	.0024
6.70	1.0476	.0024
6.75	1.0500	.0023
6.80	1.0523	.0023
6.85	1.0546	.0023
6.90	1.0569	.0023
6.95	1.0592	.0023
7.00	1.0615	.0022
7.05	1.0637	.0023
7.10	1.0660	.0022
7.15	1.0682	.0022
7.20	1.0704	.0022
7.25	1.0726	.0022
7.30	1.0748	.0021
7.35	1.0769	.0022
7.40	1.0791	.0021
7.45	1.0812	.0021
7.50	1.0833	.0021
7.55	1.0854	.0021
7.60	1.0875	.0021
7.65	1.0896	.0021
7.70	1.0917	.0020
7.75	1.0937	.0021
7.80	1.0958	.0020
7.85	1.0978	.0020
7.90	1.0998	.0020
7.95	1.1018	.0020
8.00	1.1038	.0020
8.05	1.1058	.0019
8.10	1.1077	.0020
8.15	1.1097	.0019
8.20	1.1116	.0020
8.25	1.1136	.0019
8.30	1.1155	.0019
8.35	1.1174	.0019
8.40	1.1193	.0019
8.45	1.1212	.0018
8.50	1.1230	.0019
8.55	1.1249	.0018
8.60	1.1267	.0019
8.65	1.1286	.0018
8.70	1.1304	.0018
8.75	1.1322	.0018
8.80	1.1340	.0018
8.85	1.1358	.0018
8.90	1.1376	.0018
8.95	1.1394	.0018
9.00	1.1412	.0017
9.05	1.1429	.0018
9.10	1.1447	.0017
9.15	1.1464	.0017
9.20	1.1481	.0018
9.25	1.1499	.0017
9.30	1.1516	.0017
9.35	1.1533	.0017
9.40	1.1550	.0016
9.45	1.1566	.0017
9.50	1.1583	.0017
9.55	1.1600	.0016
9.60	1.1616	.0017
9.65	1.1633	.0016
9.70	1.1649	.0017
9.75	1.1666	.0016
9.80	1.1682	.0016
9.85	1.1698	.0016
9.90	1.1714	.0016
9.95	1.1730	.0016

b/a	f_g	(dif)	b/a	f_g	(dif)	b/a	f_g	(dif)
10.0	1.1746	.0303	40.0	1.6155	.0079	70.0	1.7936	.0045
11.0	1.2049	.0276	41.0	1.6234	.0076	71.0	1.7981	.0045
12.0	1.2325	.0255	42.0	1.6310	.0075	72.0	1.8026	.0044
13.0	1.2580	.0235	43.0	1.6385	.0073	73.0	1.8070	.0043
14.0	1.2815	.0219	44.0	1.6458	.0072	74.0	1.8113	.0043
15.0	1.3034	.0206	45.0	1.6530	.0070	75.0	1.8156	.0042
16.0	1.3240	.0192	46.0	1.6600	.0068	76.0	1.8198	.0042
17.0	1.3432	.0182	47.0	1.6668	.0067	77.0	1.8240	.0041
18.0	1.3614	.0172	48.0	1.6735	.0066	78.0	1.8281	.0040
19.0	1.3786	.0163	49.0	1.6801	.0064	79.0	1.8321	.0040
20.0	1.3949	.0156	50.0	1.6865	.0063	80.0	1.8361	.0040
21.0	1.4105	.0148	51.0	1.6928	.0062	81.0	1.8401	.0039
22.0	1.4253	.0141	52.0	1.6990	.0061	82.0	1.8440	.0038
23.0	1.4394	.0135	53.0	1.7051	.0059	83.0	1.8478	.0038
24.0	1.4529	.0130	54.0	1.7110	.0059	84.0	1.8516	.0038
25.0	1.4659	.0125	55.0	1.7169	.0057	85.0	1.8554	.0037
26.0	1.4784	.0120	56.0	1.7226	.0056	86.0	1.8591	.0037
27.0	1.4904	.0116	57.0	1.7282	.0056	87.0	1.8628	.0037
28.0	1.5020	.0112	58.0	1.7338	.0054	88.0	1.8665	.0036
29.0	1.5132	.0107	59.0	1.7392	.0054	89.0	1.8701	.0035
30.0	1.5239	.0105	60.0	1.7446	.0052	90.0	1.8736	.0035
31.0	1.5344	.0101	61.0	1.7498	.0052	91.0	1.8771	.0035
32.0	1.5445	.0098	62.0	1.7550	.0051	92.0	1.8806	.0034
33.0	1.5543	.0095	63.0	1.7601	.0050	93.0	1.8840	.0035
34.0	1.5638	.0092	64.0	1.7651	.0049	94.0	1.8875	.0033
35.0	1.5730	.0090	65.0	1.7700	.0049	95.0	1.8908	.0034
36.0	1.5820	.0087	66.0	1.7749	.0048	96.0	1.8942	.0033
37.0	1.5907	.0085	67.0	1.7797	.0047	97.0	1.8975	.0032
38.0	1.5992	.0082	68.0	1.7844	.0046	98.0	1.9007	.0032
39.0	1.6074	.0081	69.0	1.7890	.0046	99.0	1.9039	