TECHNICAL MEMORANDUM (NASA) 78

LORAN-C PLOTTING PROGRAM FOR PLOTTING LINES OF POSITION ON STANDARD CHARTS

The Loran-C plotting program was designed to plot Loran-C lines of position on any standard chart and is used in the data-collection system currently in use at Ohio University Avionics Engineering Center.

by

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I. INTRODUCTION

The NASA Tri-University program at Ohio University is currently involved in the development of a low-cost Loran-C navigation receiver for use in general aviation aircraft. This paper describes a set of programs designed to be run on the IBM System/370 computer at Ohio University. These programs are used to plot Loran-C lines of position (LOP) on any common map or standard aviation sectional chart. The Loran-C plotting program JRPLOT FORTRAN uses a standard Calcomp-compatible plotting subroutine package for the Hewlett-Packard 7203A graphic plotter.

This paper gives a general description of the features of the Loran-C plotting program. This program involves a simple add/subtract method to calculate the LOP. Refer to Figure 1. Included is a description on how to use the program and some methods of operation.

II. FEATURES OF THE LORAN-C PLOTTING PROGRAM

The program will accommodate any scale of map desired. (Note: the larger the scale of the map the more distortion will occur.) The program was designed for standard aviation sectional charts; any larger scale than 1:500,000 is not recommended.

Plotting may be done on any size chart within the limitations of the Hewlett-Packard 7203A graphic plotter (10" high by 15" wide).

Four station pairs are calculated in the program's execution where, for the 9960 chain: (Master) control for W, X, Y, and Z is MALONE FL 30° 59' 38.7" N and 85° 10' 09.7" W.

Block address 1 is the W-pair
Grangeville LA 30° 43' 33.0" N and 90° 49' 43.6" W

Block address 2 is the X-pair
Raymondville TX (X) 26° 31' 55.0" N and 97° 50' 0.1" W

Block address 3 is the Y-pair
Jupiter FL (Y) 27° 01' 58.5" N and 80° 06' 53.5" W

and block address 4 is the Z-pair
Carolina Beach NC (Z) 34° 03' 46.0" N and 77° 54' 46.8" W

For best results only plot two LOP sets on a single chart.

The time difference for each line of position is placed to the top or side of the chart, depending on the angle of the LOP, along with the station pair identifier.

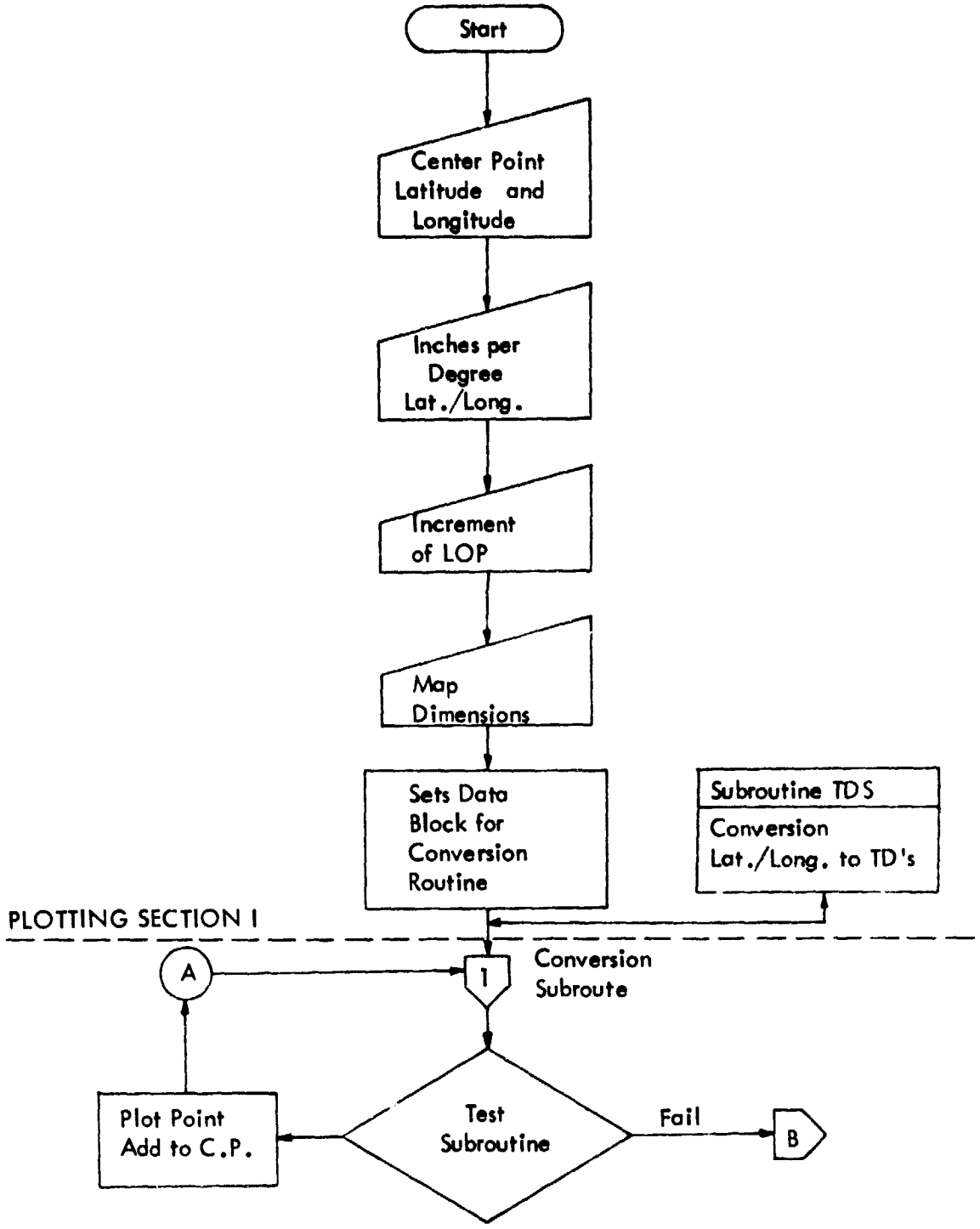

Figure 1. Flow Chart.

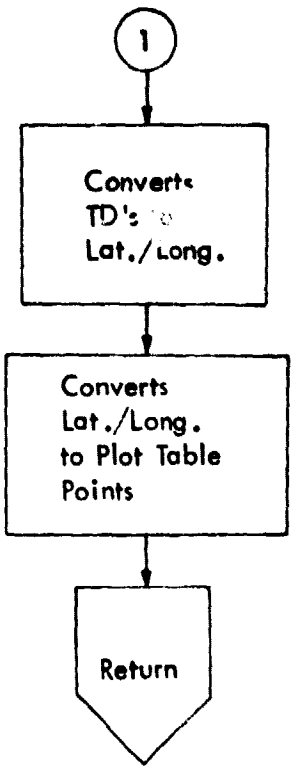

Figure 1. (Continued).

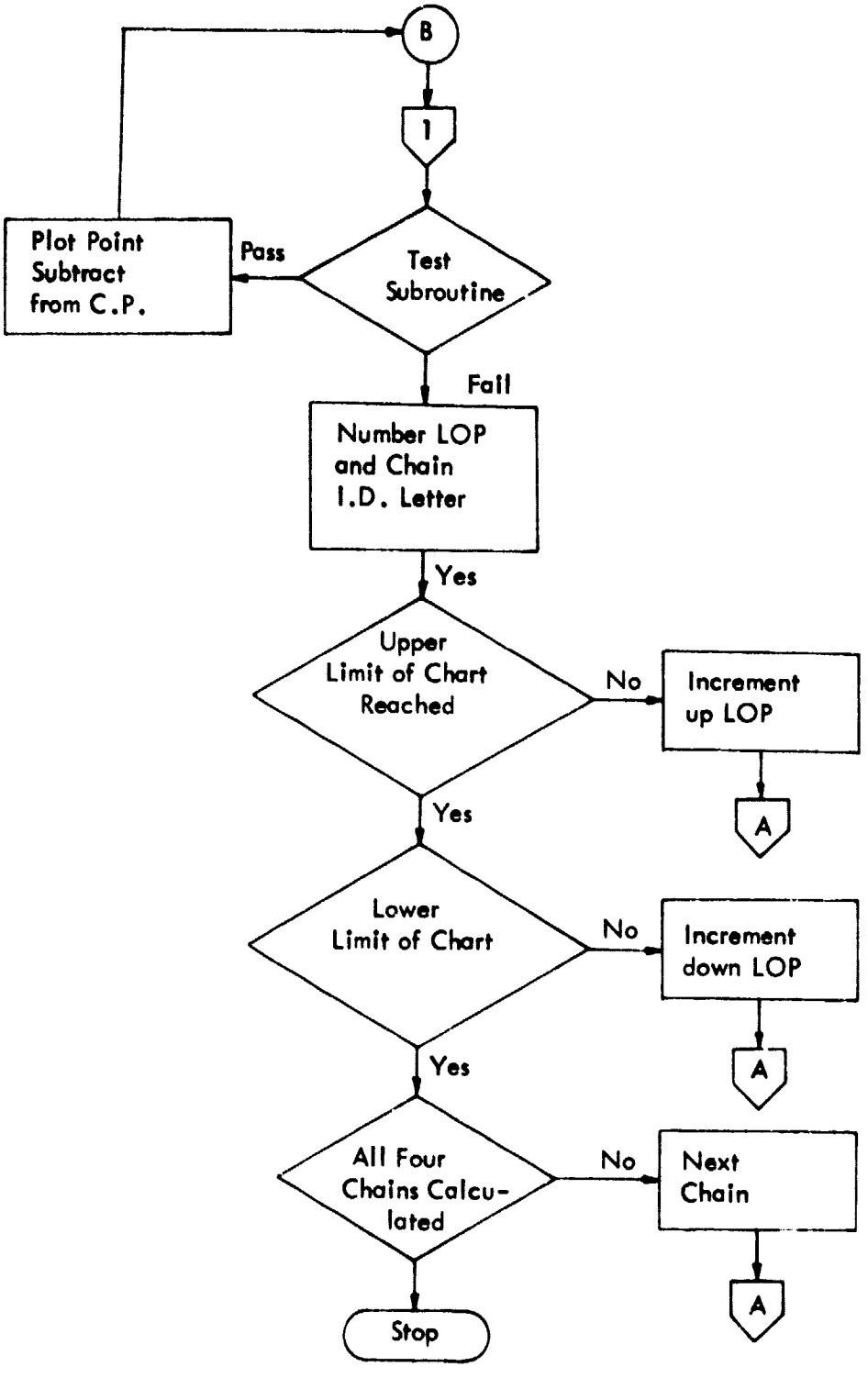

Figure 1. (Continued).

III. ACCURACY

There are two sources of error in the system. Although the latitude/longitude conversion subprogram takes into account the curvature of the earth, the plotting routine is purely linear, therefore, the larger the scale of the chart the greater the percentage of error. The error for large scale sectionals is approximately $\pm$ 10 μsec. The error for small scale geographic survey charts is $\pm$ .5 μ sec. The other source of error is in measurement of the parameters listed below. These errors can be reduced by methods listed in Section IV depending on the accuracy the programmer wishes to achieve.

IV. EXECUTION

1. The center point of the chart must be measured as accurately as possible. Then, the latitude and longitude must be taken from that point. The proper form for entering into the computer is:

integer degrees integer minutes floating point seconds

###$_{space}$##$_{space}$##.#

2. Then measure the number of inches per degree of latitude and measure the number of inches per degree of longitude. See Figure 2.

3. Then enter the increment that the lines of position should be spaced apart.

Recommended increments are:

50.0 for standard sectional charts

2.0 for geographic survey charts.

4. Enter the actual dimensions of the chart to be plotted (see Figure 2). The chart should be no larger than 11 x 15 inches and no smaller than 5 x 5 inches. These are the practical limitations of the Hewlett-Packard 7203A plotter. When the program is finished executing, the chains will be located as follows:

Block Address	Station Pair
1	W
2	X
3	Y
4	Z

It is recommended to plot all four chains on a blank sheet of paper the same size as the chart. This procedure will help the operator
the actual chart.

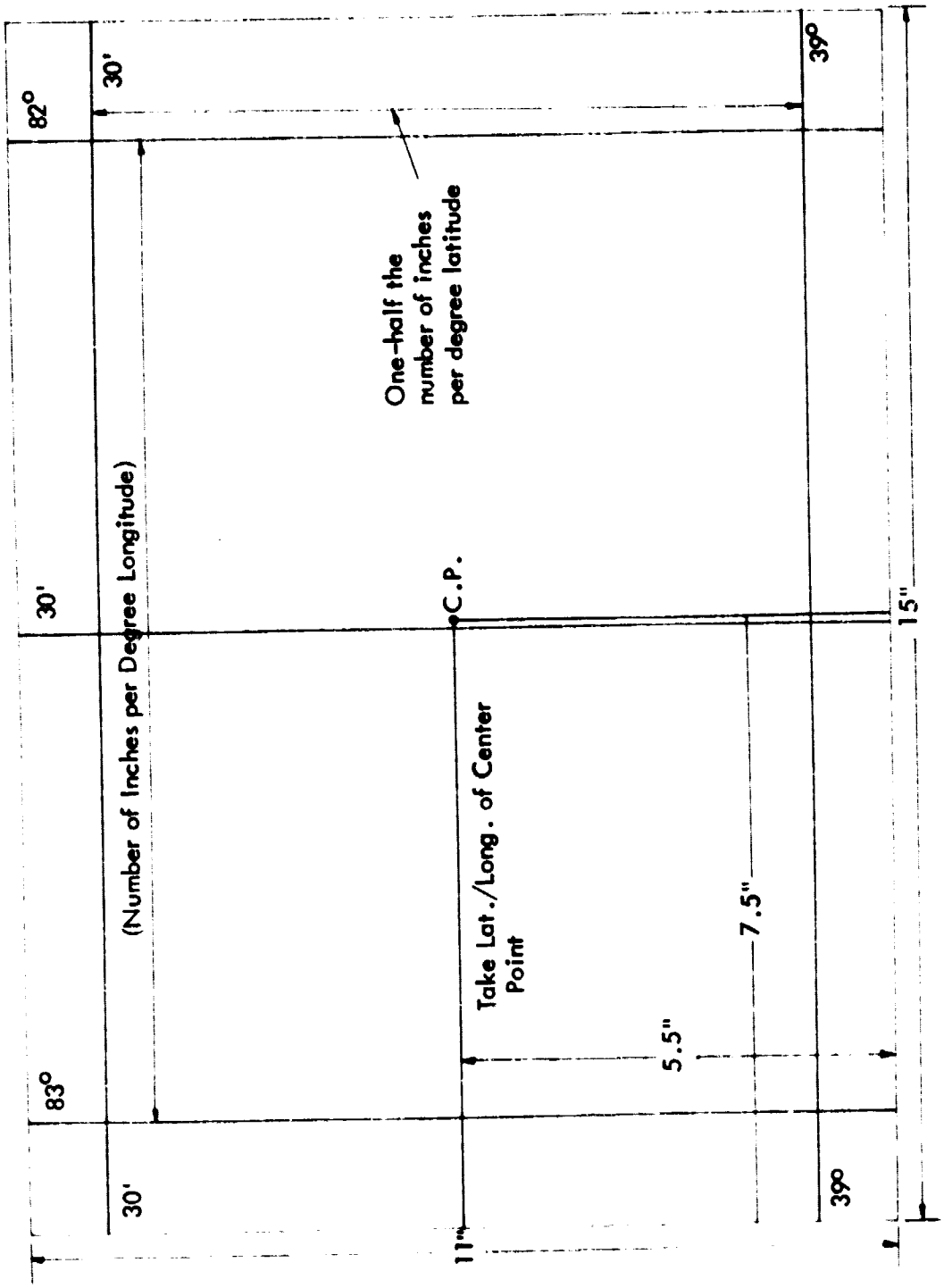

Figure 2. Sample Chart for Measurements.

V. IMPROVING ACCURACY

This procedure should be necessary only when there is a need for extreme accuracy. To make the Loran-C plotting program more accurate, three time difference positions are needed before execution of the program: the time difference of the center point, the time differences for a point left of center, and the time differences for a point right of center. Then it is a simple matter to align the grid with the known time-difference positions. By adding or subtracting from the latitude position of the center point, the grid will shift north or south respectively. By adding or subtracting from the longitude center point position, the grid will shift west or east respectively. Another method of adjusting the grid would be to add or subtract from the inches per degree parameters. Then the grid may be expanded or contracted respectively.

VI. SUMMARY

The Loran-C plotting program is a system of plotting routines and conversion subprograms. The program is designed to accommodate a wide range of mapping needs. The program may be easily modified to meet the specific needs of the current experiment.

VII. ACKNOWLEDGEMENTS

The subprogram TDPOS is a program written by Joseph P. Fischer of the Ohio University Avionics Engineering Center. The program was originally written for use in Loran-C data reduction. The subprogram TDS is a modification of a program also written by Mr. Fischer. This work is supported by the National Aeronautics and Space Administration.

VIII. BIBLIOGRAPHY

Loran-C User Handbook, United States Coast Guard, May 1980.

IX. APPENDIX

A. Listing of JRPLOT Program

```
CCCCCCCCCCCCC PLOTTING LORAN-C CURVES ON SECTIONAL CHARTS CCCCCCC        JRP00010
      DIMENSION TD(4),TH(4),DRPOS(2),POS(2)                             JRP00020
      DIMENSION IRCD(2),X2(2,200),Y2(2,200)                             JRP00030
      DIMENSION BUF(1)                                                  JRP00040
      REAL*8 PHIR,GAMR                                                  JRP00050
      COMMON PHIR,GAMR                                                  JRP00060
      COMMON/CHAIND/DEL(2),AS,AS,AD(8),DM(8),CS(8)                      JRP00070
CCCCCCCCCCCCCCCCCCCCC INPUT SECTION CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC JRP00080
      WRITE(6,11)                                                       JRP00090
11    FORMAT('+',' ENTER LATITUDE OF CENTER POINT FORM ### ## ##.# ')   JRP00100
      READ(5,4)IDEG,MIN,SEC                                             JRP00110
      WRITE(6,12)                                                       JRP00120
12    FORMAT(' ',' ENTER LONGITUDE OF CENTER POINT')                    JRP00130
      READ(5,4)IDEG1,MIN1,SEC1                                          JRP00140
4     FORMAT(I3,1X,I2,1X,F3.1)                                          JRP00150
      WRITE(6,13)                                                       JRP00160
13    FORMAT(' ',' ENTER NUMBER OF INCHES PER DEGREE LATITUDE')         JRP00170
      READ(5,5)A                                                        JRP00180
      WRITE(6,14)                                                       JRP00190
14    FORMAT(' ',' ENTER NUMBER OF INCHES PER DEGREE LONGITUDE')        JRP00200
      READ(5,5)B                                                        JRP00210
5     FORMAT(F7.4)                                                      JRP00220
      WRITE(6,15)                                                       JRP00230
15    FORMAT('+',' INPUT INCREMENT BETWEEN L.O.P..')                    JRP00240
      READ(5,5)XINC                                                     JRP00250
      XINC2=XINC                                                        JRP00260
      IF(XINC.GT.10.0)XINC2=10.0                                        JRP00270
      B=B*(-1.0)                                                        JRP00280
      XIP=IDEG+(MIN+SEC/60.0)/60.0                                      JRP00290
      XIP1=IDEG1+(MIN1+SEC1/60.0)/60.0                                  JRP00300
      CALL PLOTS(BUF,1,11)                                              JRP00310
CCCCCCCCCCCCCCCCC MAP DIMENSIONS CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC JRP00320
      WRITE(6,1)                                                        JRP00330
1     FORMAT('+',' ENTER HORIZONTAL DIMENSION')                         JRP00340
      READ(5,2)XLAT                                                     JRP00350
2     FORMAT(F6.2)                                                      JRP00360
      WRITE(6,3)                                                        JRP00370
3     FORMAT('+',' ENTER VERTICAL DIMENSION')                           JRP00380
      READ(5,2)XLONG                                                    JRP00390
      XLAT=XLAT-0.375                                                   JRP00400
      XLONG=XLONG-1.0                                                   JRP00410
      PHIR=(IDEG+(MIN+SEC/60.)/60.)*3.14159265/180.                     JRP00420
      GAMR=(IDEG1+(MIN1+SEC1/60.)/60.)*3.14159265/180.                  JRP00430
      XCP=XLAT/2.0                                                      JRP00440
      XCP1=XLONG/2.0                                                    JRP00450
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC JRP00460
CCCCCCCCCCCCCCCCCCCCC CONVERSION TO TIME DIFF. CCCCCCCCCCCCCCCCCCCCC JRP00470
      CALL TOS(TD)                                                      JRP00480
      DRPOS(1)=IDEG+(MIN+SEC/60.)/60.                                   JRP00490
      DRPOS(2)=IDEG1+(MIN1+SEC1/60.)/60.                                JRP00500
      WRITE(6,10)IDEG,MIN,SEC,IDEG1,MIN1,SEC1                          JRP00510
10    FORMAT(' ',' LATITUDE= ',I2,' ',I2,' ',F5.2,' LONGITUDE=',I2     JRP00520
     >,' ',I2,' ',F5.2)                                                JRP00530
      IF(A.GT.20.0)GOTO 45                                              JRP00540
      DO 40 K=1,4,1                                                     JRP00550
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      K1=TD(K)/10                                                       JRP00560
      K1=K1*10                                                          JRP00570
      C=TD(K)-K1                                                        JRP00580
      IF(C-5.0)20,30,30                                                 JRP00590
20    TD(K)=TD(K)-C                                                     JRP00600
      GOTO 40                                                           JRP00610
30    TD(K)=TD(K)+(10.0-C)                                              JRP00620
40    CONTINUE                                                          JRP00630
45    WRITE(6,50)(TD(K),K=1,4)                                          JRP00640
50    FORMAT(' ','TDS=',4F15.2)                                         JRP00650
      DO 2000 I7=1,5,1                                                  JRP00660
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC JRP00670
CCCCCCCCCCCCCCCC DATA ALLOCATION CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC JRP00680
      IF(I7.GE.5)GOTO 3000                                              JRP00690
      J7=0                                                              JRP00700
      IF(I7-2)90,100,110                                                JRP00710
90    I=1                                                               JRP00720
      J=2                                                               JRP00730
      I2=1                                                              JRP00740
      J2=2                                                              JRP00750
      CALL DATAWX                                                       JRP00760
      GOTO 130                                                          JRP00770
100   I=2                                                               JRP00780
      J=1                                                               JRP00790
      I2=2                                                              JRP00800
      J2=1                                                              JRP00810
      CALL DATAWX                                                       JRP00820
      GOTO 130                                                          JRP00830
110   IF(I7.EQ.4)GOTO 120                                               JRP00840
      I=3                                                               JRP00850
      J=2                                                               JRP00860
      I2=2                                                              JRP00870
      J2=1                                                              JRP00880
      CALL DATAXY                                                       JRP00890
      GOTO 130                                                          JRP00900
120   I=4                                                               JRP00910
      J=3                                                               JRP00920
      I2=2                                                              JRP00930
      J2=1                                                              JRP00940
      CALL DATAY2                                                       JRP00950
130   IF(DPOS(2).GT.76.0)CALL NEWDAT(I7,I,I2,J,J2)                      JRP00960
      IC=0                                                              JRP00970
      I9=0                                                              JRP00980
      TH(I2)=TD(I)                                                      JRP00990
      TH(J2)=TD(J)                                                      JRP01000
      IPEN=3                                                            JRP01010
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC JRP01020
CCCCCCCCCCCCCCCCCCCCCCCC PLOTTING SECTION ! CCCCCCCCCCCCCCCCCCCCCCCCCC JRP01030
140   CALL CONVER(TH,DPOS,DPOS,IERROR,YCP,YCP1,YIP,YIP1,X,Y,R,A)        JRP01040
      IC=IC+1                                                           JRP01050
      Y2(1,IC)=Y                                                        JRP01060
      X2(1,IC)=X                                                        JRP01070
      I3=0                                                              JRP01080
      CALL TEST(XLAT,XLONG,X,Y,I3,IERROR)                               JRP01090
      IF(I3.GE.1)GOTO 140                                               JRP01100
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      CALL PLOT(X,Y,IPEN)                                                    JPP01110
      TH(J2)=TH(J2)+XINC2                                                    JPP01120
      IPEN=2                                                                 JPP01130
140   IF(I3-1)140,900,900                                                    JPP01140
CCCCCCCCCCCCCCCCCCCCCCCC PLOTTING SECTION 2 CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJPP01150
900   I3=0                                                                   JPP01160
      DPPOS(1)=IDEG+(MIN+SEC/60.0)/60.0                                      JPP01170
      DPPOS(2)=IDEG1+(MIN1+SEC1/60.0)/60.0                                   JPP01180
      TH(J2)=TO(J)                                                           JPP01190
      IPEN=3                                                                 JPP01200
      GOTO 915                                                               JPP01210
910   TH(J2)=TH(J2)-XINC2                                                    JPP01220
915   CALL CONVER(TH,POS,DPPOS,IERROR,YCR,YCR1,YIR,XIR1,X,Y,R,A)             JPP01230
      IR=IR+1                                                                JPP01240
      Y2(2,IR)=Y                                                             JPP01250
      X2(2,IR)=X                                                             JPP01260
      I3=0                                                                   JPP01270
      CALL TEST(XLAT,XLONG,X,Y,I3,IERROR)                                    JPP01280
      IF(I3.GE.1)GOTO 930                                                    JPP01290
      CALL PLOT(X,Y,IPEN)                                                    JPP01300
      IPEN=2                                                                 JPP01310
930   IF(I3-1)910,1000,1000                                                  JPP01320
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJPP01330
CCCCCCCCCCCCCCCCCCCCCCCC NUMBERING SECTION CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJPP01340
1000  HEIGHT=0.1                                                             JPP01350
      IF(IC.LT.20)GOTO 1005                                                  JPP01360
      GOTO 1006                                                              JPP01370
1005  DELTAX=X2(2,(IR/2))-X2(2,(IR/3))                                       JPP01380
      DELTAY=Y2(2,(IR/2))-Y2(2,(IR/3))                                       JPP01390
      IR=2                                                                   JPP01400
      GOTO 1007                                                              JPP01410
1006  DELTAX=X2(1,(IC/2))-X2(1,(IC/3))                                       JPP01420
      DELTAY=Y2(1,(IC/2))-Y2(1,(IC/3))                                       JPP01430
      IR=1                                                                   JPP01440
1007  ANGLE=ATAN2(DELTAY,DELTAX)                                             JPP01450
      ANGLE=ABS((ANGLE*180.)/3.14159265)                                     JPP01460
      IF(((ANGLE.LE.45.).OR.(ANGLE.GE.315.)).OR.((ANGLE.GE.135.)             JPP01470
     >.AND.(ANGLE.LE.225.)))IPOS1=1                                          JPP01480
      IF(((ANGLE.GT.45.).AND.(ANGLE.LT.135.)).OR.((ANGLE.GT.225.)            JPP01490
     >.AND.(ANGLE.LT.315.)))IPOS1=2                                          JPP01500
1008  NPLACE=0                                                               JPP01510
      ANGLE=1.0                                                              JPP01520
      NCHAR=0                                                                JPP01530
      ENUM=TH(I2)                                                            JPP01540
      IPOS(1)=101+I7                                                         JPP01550
      IF(IPOS1-2)1020,1011,1011                                              JPP01560
1011  XDOWN=1.0                                                              JPP01570
      CALL NUMBER(X2(1,IC),(XLAT-XDOWN),HEIGHT,ENUM,ANGLE,NPLACE)            JPP01580
      CALL SYMBOL((X2(1,IC)+0.2),(XLAT-(XDOWN-0.2)),HEIGHT,IPOS(1),ANGLE,    JPP01590
     >,NCHAR)                                                                JPP01600
      GOTO 1030                                                              JPP01610
1020  CALL NUMBER(0.2,Y2(2,IR),HEIGHT,ENUM,ANGLE,NPLACE)                     JPP01620
      CALL SYMBOL(0.2,Y2(2,IR),HEIGHT,IPOS(1),ANGLE,NCHAR)                   JPP01630
1030  IC=0                                                                   JPP01640
      IR=0                                                                   JPP01650
```

```
      IF(J7.EQ.1)GOTO 2010                                                    JRP01660
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJRP01670
CCCCCCCCCCCCCCCCCCCCCC INCREMENT UP CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJRP01680
1010  TH(I2)=TH(I2)+XINC                                                      JRP01690
      TH(J2)=TD(J)                                                            JRP01700
      IPEN=3                                                                  JRP01710
      CALL CONVER(TH,POS,ORPOS,IERROR,YCP,XCP1,YIP,XIP1,X,Y,B,A)              JRP01720
      I3=0                                                                    JRP01730
      CALL TEST(XLAT,XLONG,X,Y,I3,IERROR)                                     JRP01740
      IF(I3-1)140,2000,2000                                                   JRP01750
CCCCCCCCCCCCCCCCCCCCCCCC INCREMENT DOWN CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJRP01760
2000  TH(I2)=TD(I)                                                            JRP01770
      J7=1                                                                    JRP01780
      I3=0                                                                    JRP01790
2010  TH(I2)=TH(I2)-XINC                                                      JRP01800
      TH(J2)=TD(J)                                                            JRP01810
      IPEN=3                                                                  JRP01820
      CALL CONVER(TH,POS,ORPOS,IERROR,YCP,XCP1,YIP,XIP1,X,Y,B,A)              JRP01830
      I3=0                                                                    JRP01840
      CALL TEST(XLAT,XLONG,X,Y,I3,IERROR)                                     JRP01850
      IF(I3-1)140,2999,2999                                                   JRP01860
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJRP01870
2999  CALL PLOT(0.0,0.0,-3)                                                   JRP01880
3000  CALL PLOT(0.0,0.0,999)                                                  JRP01890
      STOP                                                                    JRP01900
      END                                                                     JRP01910
      SUBROUTINE TDS(TD)                                                      JRP01920
CCCCCCCCCCCCCCCCCCCCC DATA FOR TIME DIFF. CONVERSION CCCCCCCCCCCCCCCCCCCCCCJRP01930
      DIMENSION TD(4)                                                         JRP01940
      REAL*8 PHIM,GAMM,PHIW,GAMW,PHIX,GAMX,PHIY,GAMY,PHIZ,GAMZ                JRP01950
      DATA PHIM,GAMM/0.7455002761,1.3408707241/                               JRP01960
      DATA PHIW,GAMW/0.8169691590,1.1855593031/                               JRP01970
      DATA PHIX,GAMX/0.7200063971,1.2213450981/                               JRP01980
      DATA PHIY,GAMY/0.5945057338,1.3598403191/                               JRP01990
      DATA PHIZ,GAMZ/0.6955476439,1.5269280091/                               JRP02000
      DATA CORW/1.379724E4/                                                   JRP02010
      DATA CORX/2.696991E4/                                                   JRP02020
      DATA CORY/4.222161E4/                                                   JRP02030
      DATA CORZ/5.716205E4/                                                   JRP02040
      TDM=ARC(PHIM,GAMM)                                                      JRP02050
      TD(1)=CORW+ARC(PHIW,GAMW)-TDM                                           JRP02060
      TD(2)=CORX+ARC(PHIX,GAMX)-TDM                                           JRP02070
      TD(3)=CORY+ARC(PHIY,GAMY)-TDM                                           JRP02080
      TD(4)=CORZ+ARC(PHIZ,GAMZ)-TDM                                           JRP02090
      RETURN                                                                  JRP02100
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJRP02110
CCCCCCCCCCCCCCCCCCCC TESTING ROUTINE CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJRP02120
      END                                                                     JRP02130
      SUBROUTINE TEST(XLAT,XLONG,X,Y,I3,IERROR)                               JRP02140
      IF(Y.GE.(XLAT-1.5))I3=1                                                 JRP02150
      IF(Y.LE.1.375)I3=1                                                      JRP02160
      IF(X.GE.(XLONG-1.0))I3=1                                                JRP02170
      IF(X.LE.1.5)I3=1                                                        JRP02180
      IF(IERROR.EQ.-1)I3=2                                                    JRP02190
      RETURN                                                                  JRP02200
```

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CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCJRP02210
CCCCCCCCCCCCCCCCCCCCCCCC DATA FOR LAT. , LONG CONVERSION CCCCCCCCCCCCCCCCCJRP02220
      END                                                                   JRP02230
      SUBROUTINE DATAWX                                                     JRP02240
      COMMON/CHAIND/DEL(2),A5,A6,AD(8),DM(8),CS(8)                          JRP02250
      DEL(1)=11.0E3                                                         JRP02260
      DEL(2)=25.0E3                                                         JRP02270
      A5=2.1275406E4                                                        JRP02280
      A6=2.1203281E4                                                        JRP02290
      AD(1)=42.0                                                            JRP02300
      AD(2)=76.0                                                            JRP02310
      AD(3)=46.0                                                            JRP02320
      AD(4)=67.0                                                            JRP02330
      AD(5)=42.0                                                            JRP02340
      AD(6)=76.0                                                            JRP02350
      AD(7)=41.0                                                            JRP02360
      AD(8)=69.0                                                            JRP02370
      DM(1)=42.0                                                            JRP02380
      DM(2)=49.0                                                            JRP02390
      DM(3)=49.0                                                            JRP02400
      DM(4)=55.0                                                            JRP02410
      DM(5)=42.0                                                            JRP02420
      DM(6)=49.0                                                            JRP02430
      DM(7)=15.0                                                            JRP02440
      DM(8)=59.0                                                            JRP02450
      CS(1)=50.47                                                           JRP02460
      CS(2)=34.44                                                           JRP02470
      CS(3)=27.86                                                           JRP02480
      CS(4)=39.16                                                           JRP02490
      CS(5)=50.47                                                           JRP02500
      CS(6)=34.44                                                           JRP02510
      CS(7)=11.98                                                           JRP02520
      CS(8)=40.51                                                           JRP02530
      RETURN                                                                JRP02540
      END                                                                   JRP02550
      SUBROUTINE DATAXY                                                     JRP02560
      COMMON/CHAIND/DEL(2),A5,A6,AD(8),DM(8),CS(8)                          JRP02570
      DEL(1)=25.0E3                                                         JRP02580
      DEL(2)=39.0E3                                                         JRP02590
      A5=2.128260E4                                                         JRP02600
      A6=2.1210456E4                                                        JRP02610
      AD(1)=42.0                                                            JRP02620
      AD(2)=76.0                                                            JRP02630
      AD(3)=41.0                                                            JRP02640
      AD(4)=69.0                                                            JRP02650
      AD(5)=42.0                                                            JRP02660
      AD(6)=76.0                                                            JRP02670
      AD(7)=34.0                                                            JRP02680
      AD(8)=77.0                                                            JRP02690
      DM(1)=42.0                                                            JRP02700
      DM(2)=49.0                                                            JRP02710
      DM(3)=15.0                                                            JRP02720
      DM(4)=59.0                                                            JRP02730
      DM(5)=42.0                                                            JRP02740
      DM(6)=49.0                                                            JRP02750
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      DM(7)=3.0                                                          JRP02760
      DM(8)=54.0                                                         JRP02770
      CS(1)=50.47                                                        JRP02780
      CS(2)=34.44                                                        JRP02790
      CS(3)=11.99                                                        JRP02800
      CS(4)=40.51                                                        JRP02810
      CS(5)=50.47                                                        JRP02820
      CS(6)=33.44                                                        JRP02830
      CS(7)=45.61                                                        JRP02840
      CS(8)=47.20                                                        JRP02850
      RETURN                                                             JRP02860
      END                                                                JRP02870
      SUBROUTINE DATAY7                                                  JRP02880
      COMMON/CHAIND/DEL(2),A5,A6,AD(8),DM(8),CS(8)                       JRP02890
      DEL(1)=39.0E3                                                      JRP02900
      DEL(2)=54.0E3                                                      JRP02910
      A5=2.129260E4                                                      JRP02920
      A6=2.121045E4                                                      JRP02930
      AD(1)=42.0                                                         JRP02940
      AD(2)=76.0                                                         JRP02950
      AD(3)=34.0                                                         JRP02960
      AD(4)=77.0                                                         JRP02970
      AD(5)=42.0                                                         JRP02980
      AD(6)=76.0                                                         JRP02990
      AD(7)=39.0                                                         JRP03000
      AD(8)=87.0                                                         JRP03010
      DM(1)=42.0                                                         JRP03020
      DM(2)=49.0                                                         JRP03030
      DM(3)=03.0                                                         JRP03040
      DM(4)=54.0                                                         JRP03050
      DM(5)=42.0                                                         JRP03060
      DM(6)=49.0                                                         JRP03070
      DM(7)=51.0                                                         JRP03080
      DM(8)=29.0                                                         JRP03090
      CS(1)=50.47                                                        JRP03100
      CS(2)=34.44                                                        JRP03110
      CS(3)=45.96                                                        JRP03120
      CS(4)=46.76                                                        JRP03130
      CS(5)=50.47                                                        JRP03140
      CS(6)=34.44                                                        JRP03150
      CS(7)=07.46                                                        JRP03160
      CS(8)=12.14                                                        JRP03170
      RETURN                                                             JRP03180
      END                                                                JRP03190
      SUBROUTINE NEWDAT(I7,I,I2,J,J2)                                    JRP03200
      COMMON/CHAIND/DEL(2),A5,A6,AD(8),DM(8),CS(8)                       JRP03210
      IF(I7-2)10,20,30                                                   JRP03220
10    I=1                                                                JRP03230
      J=2                                                                JRP03240
      I2=1                                                               JRP03250
      J2=2                                                               JRP03260
      CALL DATAWX                                                        JRP03270
      GOTO40                                                             JRP03280
20    I=2                                                                JRP03290
      J=3                                                                JRP03300
```

```
      I2=1                                                                  JRP03310
      J2=2                                                                  JRP03320
      CALL DATAXY                                                           JRP03330
      GOTO 40                                                               JRP03340
30    IF(I2.EQ.4)GOTO 35                                                    JRP03350
      I=3                                                                   JRP03360
      J=4                                                                   JRP03370
      I2=1                                                                  JRP03380
      J2=2                                                                  JRP03390
      CALL DATAYZ                                                           JRP03400
      GOTO 40                                                               JRP03410
35    I=4                                                                   JRP03420
      J=3                                                                   JRP03430
      I2=2                                                                  JRP03440
      J2=1                                                                  JRP03450
      CALL DATAYZ                                                           JRP03460
40    RETURN                                                                JRP03470
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC JRP03480
CCCCCCCCCCCCCCCCCC CONVERSION ROUTINE CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC JRP03490
      END                                                                   JRP03500
      SUBROUTINE CONVER(TH,PDS,DRPDS,IERROR,YCP,YCP1,YIP,XIP1,X,Y,B,A)      JRP03510
      DIMENSION TH(4),PDS(2),DRPDS(2)                                       JRP03520
      CALL TDPDS(TH,PDS,DRPDS,IERROR)                                       JRP03530
      DO 10 K=1,2,1                                                         JRP03540
10    DRPDS(K)=PDS(K)                                                       JRP03550
      X=((PDS(2)-XIP1)*B)+YCP1                                              JRP03560
      Y=((PDS(1)-YIP)*A)+YCP                                                JRP03570
20    RETURN                                                                JRP03580
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC JRP03590
      END                                                                   JRP03600
```

B. Listing of TDPOS Program

```
      SUBROUTINE TDDDS(TM,DDS,DRDDS,IERROR)                              TDD00010
      DIMENSION TOSV(2),DSV(2),ANG(8),AD(8),DM(8),CS(8),DDS(2),ZIWD(2),ETDD00020
     :WM(2),DEL(2),IDD(2),IRD(2),DRM(2),TM(2),A(11),B(11),C(11),D(11),E(TDD00030
     :11),CC(11),TM(2),RLEM(2),REDEL(2),RADD(2),BETA(2),DWG(2),TWO(2),IDTDD00040
     :DD(2),DRDDS(2)                                                    TDD00050
C -                                                                     TDD00060
      DATA A1/24.0305/,A2/-0.40758/,A3/3.467746E-3/,A4/0.510483/,B2/-0.01TDD00070
     :1402/,B3/0.001760/,BD/1.745329E-2/,BM/2.908882E-4/,BS/4.848137E-6/TDD00080
     :,PI/3.141592/,A4/2.296912E2/                                      TDD00090
C -                                                                     TDD00100
      COMMON/CHAIND/DEL,A5,A6,AD,DM,CS                                  TDD00110
C -                                                                     TDD00120
C - BEGIN TIME DIFFERENCE TO POSITION CONVERSION.                       TDD00130
C -                                                                     TDD00140
      DO 1 I=1,2                                                        TDD00150
      IDD(I)=DRDDS(I)                                                   TDD00160
      DD(I)=IDD(I)                                                      TDD00170
    1 DRM(I)=(DRDDS(I)-DD(I))*60.0                                      TDD00180
      IERROR=1                                                          TDD00190
      A10=(A5*A5-A6*A6)/(A5*A5)                                         TDD00200
      A14=1.0-A6/A5                                                     TDD00210
      A50=(1.0+A14+A14*A14)                                             TDD00220
      A51=(A50-1.0)                                                     TDD00230
      A52=(A14*A14)/2.0                                                 TDD00240
      A53=-A51/2.0                                                      TDD00250
      A54=(A14*A14)/16.0                                                TDD00260
      A55=(A14*A14)/8.0                                                 TDD00270
      A56=A14*A14                                                       TDD00280
      A57=A56*1.25                                                      TDD00290
      A58=A56/4.0                                                       TDD00300
      DO 128 K=1,8                                                      TDD00310
      IF(AD(K))124,126,126                                              TDD00320
  124 ANG(K)=BD*AD(K)-BM*DM(K)-BS*CS(K)                                 TDD00330
      GO TO 128                                                         TDD00340
  126 ANG(K)=BD*AD(K)+BM*DM(K)+BS*CS(K)                                 TDD00350
  128 CONTINUE                                                          TDD00360
      A12=(ANG(1)-ANG(5)+ANG(2)-ANG(6))                                 TDD00370
      A12=ABS(A12)                                                      TDD00380
      IF(A12-3.000011)7,7,8                                             TDD00390
    7 A11=-1.0                                                          TDD00400
      GO TO 9                                                           TDD00410
    8 A11=1.0                                                           TDD00420
C -                                                                     TDD00430
C - APPROXIMATE POSITIONS AND STATION COORDINATES.                      TDD00440
C -                                                                     TDD00450
    9 E(1)=ANG(1)                                                       TDD00460
      E(2)=ANG(2)                                                       TDD00470
      CC(1)=ANG(3)                                                      TDD00480
      CC(2)=ANG(4)                                                      TDD00490
      E(3)=SIN(E(1))                                                    TDD00500
      E(4)=COS(E(1))                                                    TDD00510
      E(5)=E(3)/E(4)                                                    TDD00520
      E(9)=(E(5))*(1.0-A14)                                             TDD00530
      A62=ATAN(E(9))                                                    TDD00540
      E(6)=SIN(A62)                                                     TDD00550
```

```
      F(7)=COS(A62)                                                     TOP00560
      CC(3)=SIN(CC(1))                                                  TOP00570
      CC(4)=COS(CC(1))                                                  TOP00580
      CC(5)=CC(3)/CC(4)                                                 TOP00590
      CC(8)=(CC(5))*(1.0-A14)                                           TOP00600
      A62=ATAN(CC(8))                                                   TOP00610
      CC(6)=SIN(A62)                                                    TOP00620
      CC(7)=COS(A62)                                                    TOP00630
      I=1                                                               TOP00640
      GO TO 530                                                         TOP00650
   15 E(9)=A35                                                          TOP00660
      E(10)=A46                                                         TOP00670
      E(11)=A47                                                         TOP00680
      DO 17 J=1,11                                                      TOP00690
      A(J)=E(J)                                                         TOP00700
   17 B(J)=CC(J)                                                        TOP00710
      E(1)=ANG(5)                                                       TOP00720
      E(2)=ANG(6)                                                       TOP00730
      CC(1)=ANG(7)                                                      TOP00740
      CC(2)=ANG(8)                                                      TOP00750
      E(3)=SIN(E(1))                                                    TOP00760
      E(4)=COS(E(1))                                                    TOP00770
      E(5)=E(3)/E(4)                                                    TOP00780
      E(8)=(E(5))*(1.0-A14)                                             TOP00790
      A62=ATAN(E(8))                                                    TOP00800
      E(6)=SIN(A62)                                                     TOP00810
      E(7)=COS(A62)                                                     TOP00820
      CC(3)=SIN(CC(1))                                                  TOP00830
      CC(4)=COS(CC(1))                                                  TOP00840
      CC(5)=CC(3)/CC(4)                                                 TOP00850
      CC(8)=(CC(5))*(1.0-A14)                                           TOP00860
      A62=ATAN(CC(8))                                                   TOP00870
      CC(6)=SIN(A62)                                                    TOP00880
      CC(7)=COS(A62)                                                    TOP00890
      I=2                                                               TOP00900
      GO TO 530                                                         TOP00910
   19 E(9)=A35                                                          TOP00920
      E(10)=A46                                                         TOP00930
      E(11)=A47                                                         TOP00940
      DO 21 J=1,11                                                      TOP00950
      C(J)=E(J)                                                         TOP00960
   21 D(J)=CC(J)                                                        TOP00970
      TM(1)=A(10)+A(11)                                                 TOP00980
      TM(2)=C(10)+C(11)                                                 TOP00990
      DO 45 M=1,2                                                       TOP01000
      BETA(M)=TM(M)                                                     TOP01010
      BDEL(M)=BETA(M)+DEL(M)                                            TOP01020
   45 BLEM(M)=BETA(M)+BDEL(M)                                           TOP01030
      IOSV(1)=99999                                                     TOP01040
      IOSV(2)=99999                                                     TOP01050
      ITER=0                                                            TOP01060
   82 SDR=DRM(1)+DRM(1)+DRM(2)+DRM(2)                                   TOP01070
      IF(SDR)83,84,83                                                   TOP01080
   83 DO 30 K=1,2                                                       TOP01090
      IF(DRM(K))32,34,34                                                TOP01100
```

```
      32 RADR(K)=RD*DRD(K)-RM*DRM(K)                                    TDDD1110
         GO TO 30                                                       TDDD1120
      34 RADR(K)=RD*DRD(K)+RM*DRM(K)                                    TDDD1130
      30 CONTINUE                                                       TDDD1140
         E(1)=RADR(1)                                                   TDDD1150
         E(2)=RADR(2)                                                   TDDD1160
         A22=-1.0                                                       TDDD1170
      94 E(3)=SIN(E(1))                                                 TDDD1180
         E(4)=COS(E(1))                                                 TDDD1190
         E(5)=E(3)/E(4)                                                 TDDD1200
         E(8)=(E(5))*(1.0-A14)                                          TDDD1210
         A42=ATAN(E(8))                                                 TDDD1220
         E(6)=SIN(A42)                                                  TDDD1230
         E(7)=COS(A42)                                                  TDDD1240
         DO 96 I=1,8                                                    TDDD1250
      96 CC(I)=C(I)                                                     TDDD1260
         I=3                                                            TDDD1270
         GO TO 500                                                      TDDD1280
      90 C1=A35                                                         TDDD1290
         C2=A44                                                         TDDD1300
         C3=A45                                                         TDDD1310
         C101=A47                                                       TDDD1320
         DO 92 I=1,8                                                    TDDD1330
      92 CC(I)=C(I)                                                     TDDD1340
         I=4                                                            TDDD1350
         GO TO 530                                                      TDDD1360
      95 C4=A35                                                         TDDD1370
         C5=A44                                                         TDDD1380
         C6=A45                                                         TDDD1390
         C104=A47                                                       TDDD1400
         DO 50 I=1,8                                                    TDDD1410
      50 CC(I)=B(I)                                                     TDDD1420
         I=5                                                            TDDD1430
         GO TO 540                                                      TDDD1440
      55 C7=A35                                                         TDDD1450
         C8=A44                                                         TDDD1460
         C9=A45                                                         TDDD1470
         C107=A47                                                       TDDD1480
         IF(A11)52,99,53                                                TDDD1490
      53 C10=C7                                                         TDDD1500
         C11=C8                                                         TDDD1510
         C12=C9                                                         TDDD1520
         C110=C107                                                      TDDD1530
         DO 43 I=1,8                                                    TDDD1540
      43 CC(I)=A(I)                                                     TDDD1550
         I=6                                                            TDDD1560
         GO TO 530                                                      TDDD1570
      45 C7=A35                                                         TDDD1580
         C8=A44                                                         TDDD1590
         C9=A45                                                         TDDD1600
         C107=A47                                                       TDDD1610
         C13=TH(2)-C(10)-C(11)-C10+C104-DEL(2)                          TDDD1620
         C17=C13*A4                                                     TDDD1630
         C18=TH(1)-A(10)-A(11)-C112+C107-DEL(1)                         TDDD1640
         C22=C13*A4                                                     TDDD1650
```

```
      C23=C1-C17                                                        TDD01840
      C24=C4                                                            TDD01850
      C25=C7+C23                                                        TDD01860
      C26=C10                                                           TDD01870
      C27=((C3-C5)*(C25-C24)+(C23-C24)*(C11-C9))                        TDD01880
      C28=((C3-C5)*(C12-C9)+(C3-C6)*(C9-C11))                           TDD01890
      C30=C27/C28                                                       TDD01900
      C29=(C23-C24+C30*(C3-C6))/(C5-C2)                                 TDD01910
      GO TO 130                                                         TDD01920
   99 C13=TH(2)-C(10)-C(11)-C101+C104-DEL(2)                            TDD01930
      C17=C13*A6                                                        TDD01940
      C19=TH(1)-A(10)-A(11)-C107+C106-DEL(1)                            TDD01950
      C22=C19*A6                                                        TDD01960
      C23=C1-C17                                                        TDD01970
      C24=C4                                                            TDD01980
      C25=C7-C23                                                        TDD01990
      C27=(C2*(C25-C24)+C23*(C5-C8)+C8*C24-C5*C25)                      TDD02000
      C28=(C2*(C4-C9)+C3*(C8-C5)+C5*C9-C8*C6)                           TDD02010
      C30=C27/C28                                                       TDD02020
      C29=(C23-C24+C30*(C3-C6))/(C5-C2)                                 TDD02030
  130 C31=(A5*A6*(1.0-A13))/(1.0-A10*E(3)*C(31)**1.5                    TDD02040
      C32=(A5*A6)/(1.0-A10*E(3)*E(3))**0.5                              TDD02050
      C33=(C30/C31)                                                     TDD02060
      C34=(-C29/(C32*E(4)))                                             TDD02070
      E(1)=E(1)+C33                                                     TDD02080
      E(2)=E(2)+C34                                                     TDD02090
      IF(A28)132,99,134                                                 TDD02100
  132 A28=1.0                                                           TDD02110
      GO TO 84                                                          TDD02120
C -                                                                     TDD02130
C - CONVERSION DONE, RETURN TO DISTANCE-BEARING ROUTINE.                TDD02140
C -                                                                     TDD02150
  900 IF(DSV(1).NE.TWD(1))GO TO 7713                                    TDD02160
      IF(DSV(2).NE.TWD(2))GO TO 7713                                    TDD02170
      IF(ABS(DSV(1)-EWM(1)).GT.0.1)GO TO 7713                           TDD02180
      IF(ABS(DSV(2)-EWM(2)).GT.0.1)GO TO 7713                           TDD02190
      TDD(1)=TDD(1)*10                                                  TDD02200
      DO 833 I=1,2                                                      TDD02210
      ZTWD(I)=TWD(I)                                                    TDD02220
  833 DDS(I)=ZTWD(I)+EWM(I)/60.0                                        TDD02230
      RETURN                                                            TDD02240
C -                                                                     TDD02250
C - CONTINUE ITERATIONS.                                                TDD02260
C -                                                                     TDD02270
 7713 DO 7717 M=1,2                                                     TDD02280
      DDD(M)=0.0                                                        TDD02290
      DDM(M)=0.0                                                        TDD02300
      DSV(M)=EWM(M)                                                     TDD02310
 7717 DSV(M)=TWD(M)                                                     TDD02320
      ITER=ITER+1                                                       TDD02330
      IF(ITER.LT.100)GO TO 83                                           TDD02340
      IERROR=-1                                                         TDD02350
      RETURN                                                            TDD02360
  134 DMS(1)=E(1)                                                       TDD02370
      DMS(2)=E(2)                                                       TDD02380
```

```
      DO 4840 M=1,2                                                     T0P02210
      W=DWG(M)/90                                                       T0P02220
      IWD(M)=W                                                          T0P02230
      FWD=IWD(M)                                                        T0P02240
      DWD=W-FWD                                                         T0P02250
      EWM=DWD*60.0                                                      T0P02260
      EWM(M)=ABS(EWM)                                                   T0P02270
      IF(EWM(M)-59.9995)4840,4810,4810                                  T0P02280
 4810 EWM(M)=0.0                                                        T0P02290
      IF(IWD(M))4820,4830,4830                                          T0P02300
 4820 IWD(M)=IWD(M)-1                                                   T0P02310
      GO TO 4840                                                        T0P02320
 4830 IWD(M)=IWD(M)+1                                                   T0P02330
 4840 CONTINUE                                                          T0P02340
      GO TO 900                                                         T0P02350
C -                                                                     T0P02360
C - CALCULATION OF INVERSE VARIABLES.                                   T0P02370
C -                                                                     T0P02380
  500 A59=-CC(2)                                                        T0P02390
      A60=-E(2)                                                         T0P02400
      C35=A59-A60                                                       T0P02410
      C36=ABS(C35)                                                      T0P02420
      IF(C36-.1)501,502,502                                             T0P02430
  502 A16=2.0*PI-C36                                                    T0P02440
      GO TO 505                                                         T0P02450
  501 A16=C36                                                           T0P02460
  505 IF(A16)506,507,506                                                T0P02470
  507 A16=0.00000005                                                    T0P02480
  506 A17=SIN(A16)                                                      T0P02490
      A18=COS(A16)                                                      T0P02500
      A19=E(6)*CC(6)                                                    T0P02510
      A20=E(7)*CC(7)                                                    T0P02520
      A21=A19+A20*A18                                                   T0P02530
      A22=((A17*CC(7))**2+(CC(6)*E(7)-E(6)*CC(7)*A18)**2)**0.5          T0P02540
      A23=(A20*A17)/A22                                                 T0P02550
      A24=1.0-A23*A23                                                   T0P02560
      A25=ABSIN(A23)                                                    T0P02570
      A26=A25*A25                                                       T0P02580
      A27=1.0/A22                                                       T0P02590
      A28=A21/A22                                                       T0P02600
      A29=A24*A24                                                       T0P02610
      A30=(A53*A25)+A19*(A51*A22-A52*A26*A27)                           T0P02620
      A31=A24*(A53*A25+A53*A22*A21+A52*A26*A28)                         T0P02630
      A32=A19*A19*(-A52*A21*A22)                                        T0P02640
      A33=A20*(A54*A25+A54*A21*A22-A52*A26*A28-A55*A22*(A21**3))        T0P02650
      A34=A19*A24*(A52*A26*A27+A52*A22*A21*A21)                         T0P02660
      A35=(A30+A31+A32+A33+A34)*A6*A6                                   T0P02670
      A36=(A51*A25*A19*(-A52*A22-A14*A14*A26*A27)                       T0P02680
      A37=A24*(-A57*A25+A58*A22*A21+A14*A14*A24*A28)                    T0P02690
      A38=(A36+A37)*A23+A14                                             T0P02700
      A39=SIN(A38)                                                      T0P02710
      A40=COS(A38)                                                      T0P02720
      A41=(CC(6)*E(7)-A61*E(6)*CC(7))/(A22*CC(7))                       T0P02730
      IF(A41)510,509,510                                                T0P02740
  509 A41=1.00000005                                                    T0P02750
```

```
  510 A42=1.0/A41                                                    T0B02740
      A43=ATAN(A42)                                                  T0B02750
      IF(C35)515,514,514                                             T0B02760
  514 IF(C35-2)511,512,512                                           T0B02770
  511 IF(A41)520,521,521                                             T0B02780
  520 A43=PI+A43                                                     T0B02790
      GO TO 521                                                      T0B02800
  512 IF(A41)517,518,518                                             T0B02810
  515 IF(C35+PI)511,511,516                                          T0B02820
  516 IF(A41)517,518,518                                             T0B02830
  517 A43=PI-A43                                                     T0B02840
      GO TO 521                                                      T0B02850
  518 A43=2.0*PI-A43                                                 T0B02860
  521 A43=A43+PI                                                     T0B02870
      A43=A43-2.0*PI                                                 T0B02880
      IF(A43)522,523,523                                             T0B02890
  522 A43=A43+2.0*PI                                                 T0B02900
  523 A44=SIN(A43)                                                   T0B02910
      A45=COS(A43)                                                   T0B02920
      A46=A35/1609.344                                               T0B02930
      IF(A46-100.0)525,526,526                                       T0B02940
  525 A47=PI/(A46+92+93*A46                                          T0B02950
      GO TO 527                                                      T0B02960
  526 A47=A1/(A46+A2+A3*A46                                          T0B02970
  527 A46=A35/A6                                                     T0B02980
      GO TO(15,10,99,95,55,45),I                                     T0B02990
   99 RETURN                                                         T0B03000
      END                                                            T0B03010
```

C. Sample Charts with Lines of Position


Orient
Derby
Commercial Point
Mount Sterling
Darbyville
CLARKS DREAM
Ringgold
Amanda
Williamsport
New Holland
CIRCLEVILLE
Stoutsville
Oakland
Tarlton
Leistville
Laurelville
Clarksburg
ROSS COUNTY
Good Hope
Frankfort
CHILLICOTHE
Jimtown
GREENFIELD
Ratcliffburg
McArthur
Bainbridge
VALLEY VISTA (Pvt)
Richmond Dale
PIKE CO
Byer
WELLSTON
Latham
Piketon
Coalton
JACKSON
Poplar Grove
GIBSON (Pvt)
Beaver
Duke
PEEBLES
Wakefield
Petersburg
RHODES
Vinton
Rodden
Otway
Lucasville
GREAT R PORTSMOUTH REGIONAL
Minford
South Webster
Jones Corner
PORTSMOUTH
West Portsmouth
SHAWNEE STATE LODGE
Friendship
WHEELERSBURG
Saint Paul
Quincy
LANCASTER
ANDERSON
CALDWELL
Pleasantville
New Salem
Somerset
Carroll
Canal Winchester
RICKENBACKER
Bremen
HIDE A WAY
Sugargrove
OWENS
Shawnee
New Straitsville
LOGAN
Rockbridge
Gibsonville
LAZY
Haydenville
NELSONVILLE
Carbon Hill
VINTON CO
Zaleski
Albany
UNIVERSITY
Dexter
Roads
Rio Grande
Centerpoint
Bidwell
Porter
SWANN
Thurman
Oak Hill
GREENE CO SPORT
Gage
Sand Fork
VR1631
VR1633
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39°
FOLDOUT FRAME
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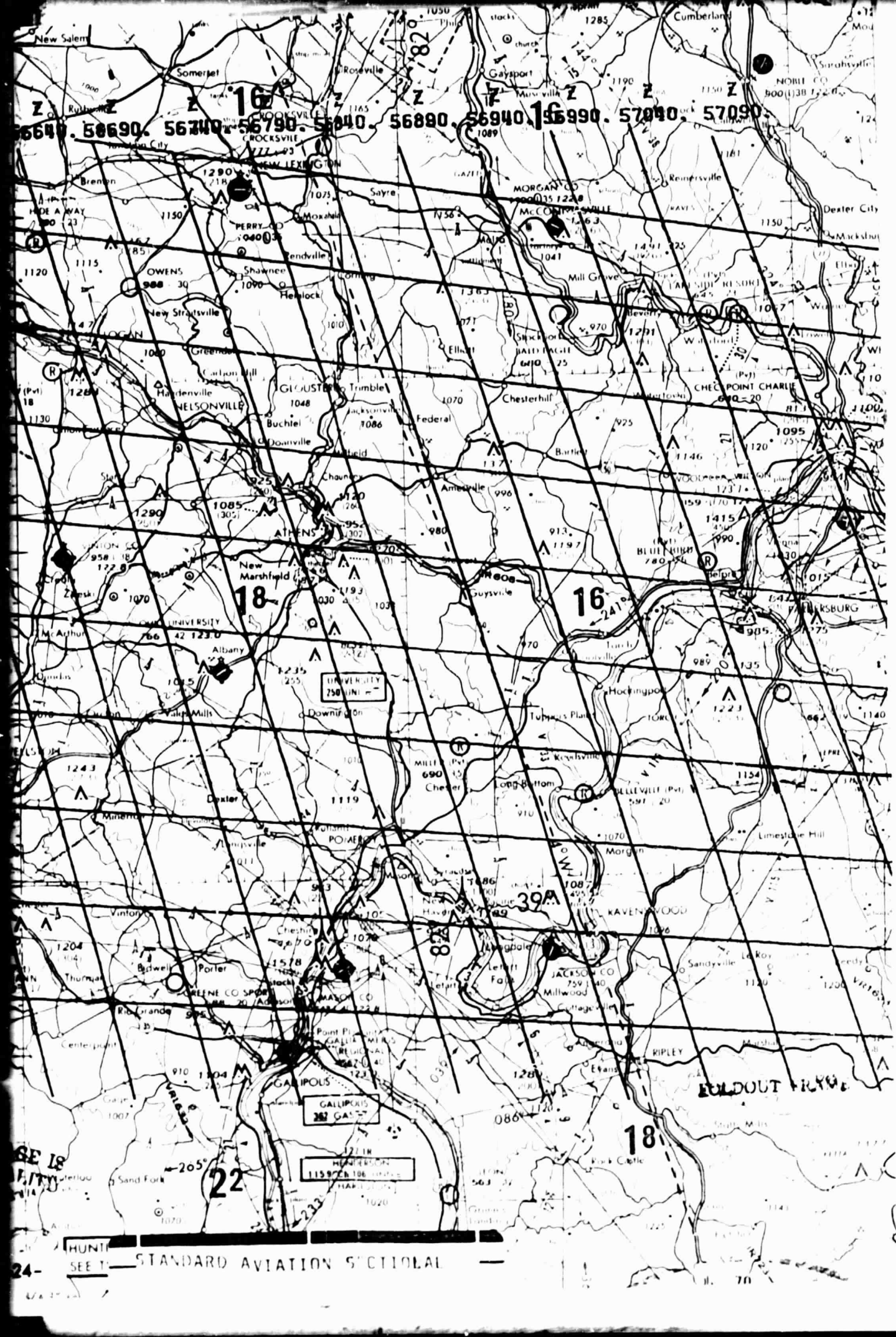
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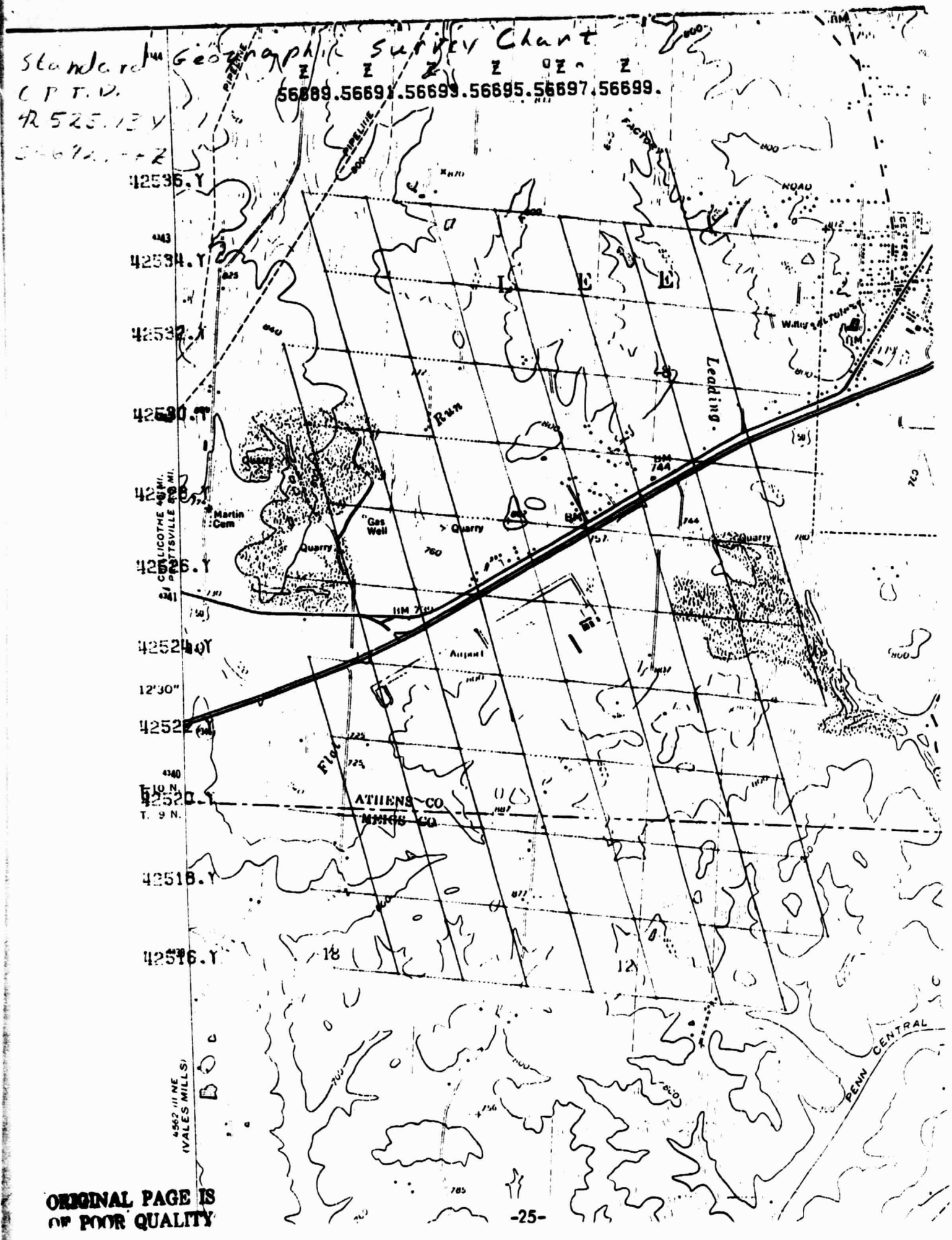

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