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Y-1725
Mathematics and Computers

PREPARATION OF CONTROL TAPE FOR AN R-θ INSPECTION MACHINE

C. W. Wilson
W. R. Hensley

MASTER

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the **ATOMIC ENERGY COMMISSION** *under* **U. S. GOVERNMENT Contract W-7405 eng 26**

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Oak Ridge, Tennessee

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ABSTRACT

An APT postprocessor has been written that is suitable for producing control tape for a continuous-path, numerically controlled inspection machine. In addition, geometric construction routines have been written that relate to APT's TABCYL surfaces.

CONTENTS

SUMMARY

An APT postprocessor has been written that is suitable for producing control tape for a continuous-path, numerically controlled inspection machine. In addition, geometric construction routines have been written that relate to APT's TABCYL surfaces.

INTRODUCTION

At present there exists no APT postprocessor for use with continuous-path, numerically controlled inspection machines of the R-θ type. This lack constitutes a severe limitation, particularly when machines with two heads are under consideration. Such machines have two characteristics that make programming inconsistent with existing APT processors:

1. Two heads must be controlled simultaneously with synchronization required in the θ coordinate.

2. "Linear" interpolation of the control unit will create an Archimedes spiral path when applied to R-θ coordinates. In other words, when the machine moves, it follows a spiral path rather than a straight line.

The postprocessor described in this report presents a preliminary technique for R-θ interpolation sufficiently general to take advantage of virtually all capabilities that might be sought in inspection machines of this type. In addition, it will provide a resolution approximately ten times that presently available in the APT system. However, it is recognized that this postprocessor has a number of shortcomings, most notably the following:

1. Conics must be converted to TABCYLS.

2. No provision is made for minimizing the number of interpolations.

3. The transition from one type of contour to another is not conveniently handled.

On-going efforts are directed toward writing a more elegant system.

Several assumptions were made which are basic to this report and to the computer system it describes:

1. The piecewise normalized cubic spline system of curve fitting is used to define the path between the given points. This system is available in the APT system and is described in an earlier report.[a]

(a) Fowler, A. H. and Wilson, C. W.; Cubic Spline, A Curve Fitting Routine, Y-1400 (Rev 1); Union Carbide Corporation-Nuclear Division, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee; June 28, 1966.

2. The radius and the normal to the path must be given for both the inside and outside contours for every value of the θ coordinate.

3. The data are defined in the normal right-handed coordinate system.

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PREPARATION OF THE CONTROL TAPE

GEOMETRIC CONSTRUCTION CONCERNING THE CUBIC SPLINE

Various geometric intersections and tangents relating the gaging ball, the radial line, and a contour defined by piecewise cubic polynominal functions (TABCYL) are required. These construction routines are currently available in the APT system. However, in a number of cases the accuracy limit of the system has been approached. Therefore, these routines were rewritten to provide greater accuracy and a more efficient system. The first approach taken was analytically to solve a set of simultaneous equations describing the particular point desired. However, it became apparent that the resulting equations were quite unwieldy and unpredictable. For example, the problem of locating the center of a circle of given radius on a given line tangent to a given curve defined by piecewise cubic functions reduces to the solution of at least one equation of the tenth degree. The large number of arithmetic calculations required to solve these equations could introduce enough computer round-off error to reduce the accuracy of the result to, at most, six usable digits. Therefore, this approach was discontinued. The second approach was to write iterative routines to do the required geometric construction. The intent was to make them as accurate, efficient, and short as possible. There are no "epsilons" in the programs which restrict the limit of convergence; that is, the iterative process will automatically continue until the accuracy limit of the computer is reached. The programs were written in a form compatible with the APT system as it existed in 1966 so that they could replace the existing programs.

The construction routines consist of the following programs:

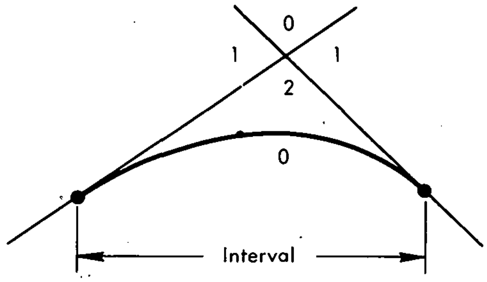
1. CUBICR, which finds the smallest root of a cubic, if any, in a given interval.

2. TABPNT, which finds the intersection of a line and a cubic spline contour.

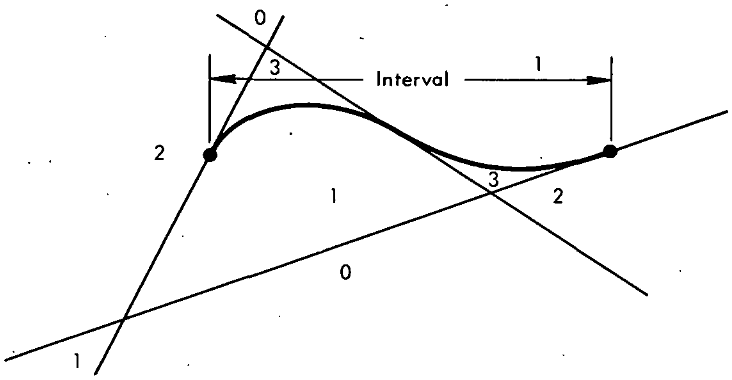
3. TABLIN, which finds a line through a point tangent (perpendicular) to a cubic spline contour.

4. TABCIR, which finds the center of a circle of a given radius tangent to a cubic spline contour. The center may be located on a given line, or the circle may be tangent to the given line.

The TABLIN program is complicated by the fact that frequently more than one tangent (perpendicular) may exist which satisfy the criteria. This problem is illustrated in Figures 1 and 2. Routines CUBICR, TABPNT, and TABCIR are listed in Appendix A as part of the ROCOGA system; TABLIN is listed in Appendix B.



(a) No Inflection Within the Interval



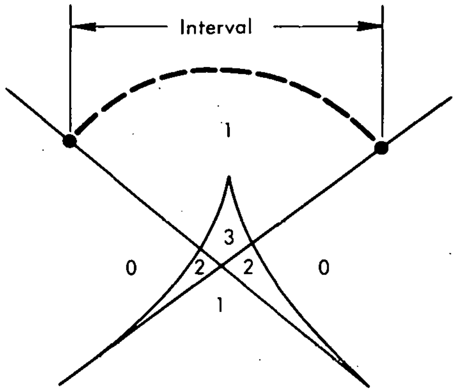
(b) Inflection Within the Interval

Figure 1. TABLIN PROGRAM PROBLEM. (Shown within the regions are the number of lines which can be drawn through a point anywhere within that region and tangent to a cubic within a given interval. Region boundaries are the cubic and the tangents to the cubic at the end points and inflection point.)

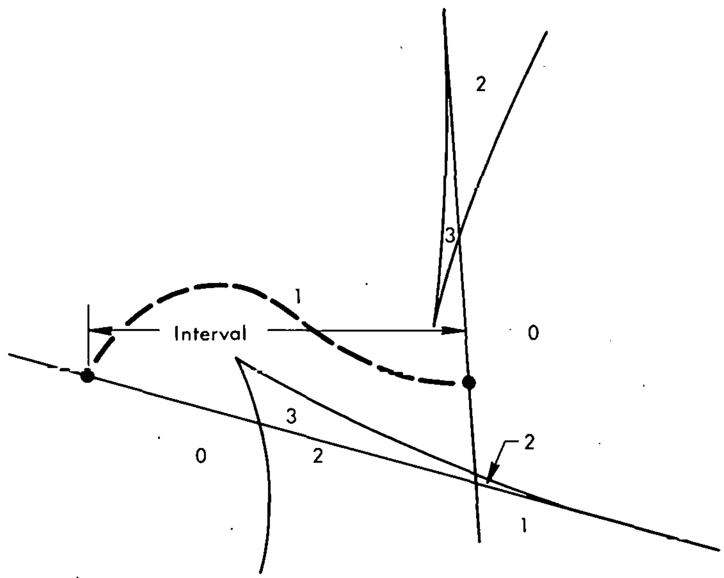
INTERPOLATION

The spiral path that the gage ball follows will not usually coincide with the fitted cubic spline curve. For example, as the gage-ball center moves from Point PC_1 to Point PC_2 (Figure 3), it traces a spiral path. This spiral differs from the fitted cubic defining the contour in that area, thus introducing an error in the gaging data which does not relate to the accuracy of the part being inspected. It is necessary, therefore, to determine this gaging error and to insert sufficient additional points on the contour to reduce it to some given value. Since two points uniquely determine a spiral, it is possible to calculate the gaging error at various intermediate values of the theta coordinate.

The procedure used first adds a point in the center of the interval and then selectively bisects the interval into smaller intervals by adding new points in each of the two adjacent subintervals. The addition of points continues until the difference between the cubic and spiral path at each intermediate point is



(a) No Inflection Within the Interval



(b) Inflection Within the Interval

Figure 2. TABLIN PROGRAM PROBLEM. (Shown within regions are the number of lines which can be drawn through a point anywhere within that region and perpendicular to a cubic within a given interval. Region boundaries are the evolute of the cubic and perpendiculars at the end points.)

less than a specified tolerance or until 31 points have been added. The latter limit of iteration may be reached if the input data points are chosen poorly.

IMPLEMENTATION

Any implementation of ROCOGA will call for additional software since the existing APT system was not designed to handle it. Additional sections have been designed consisting of an APT program with system macros and an interface.

The APT program will provide information on a cutter location file for the post-processor to use in producing an inspection tape for parts with radial or near-

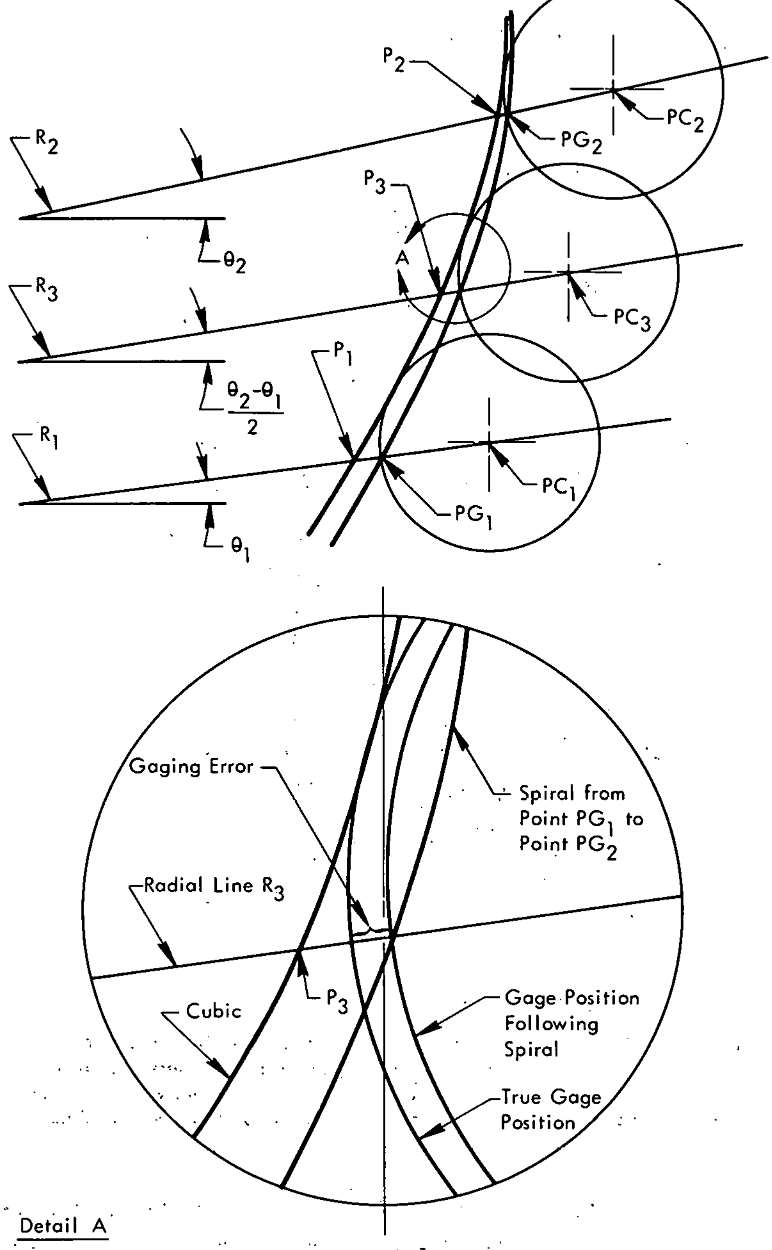


Figure 3. GAGING ERROR RESULTING FROM THE MACHINE MOVING IN A SPIRAL PATH.

radial configurations, Figure 4, such as the HUBCAP described by A. H. Fowler and C. W. Wilson ("An Extension of APT to Obtain Centroid and Inertia Information", Y-1420, Revision 1; Union Carbide Corporation-Nuclear Division, Oak Ridge Y-12 Plant; February 14, 1966). The curve type can vary any number of times on the same part and need not be the same for the inner and outer contours. The point of origin may be offset if desired. The direction of inspection is optional. A new "CALL" statement is required every time either contour

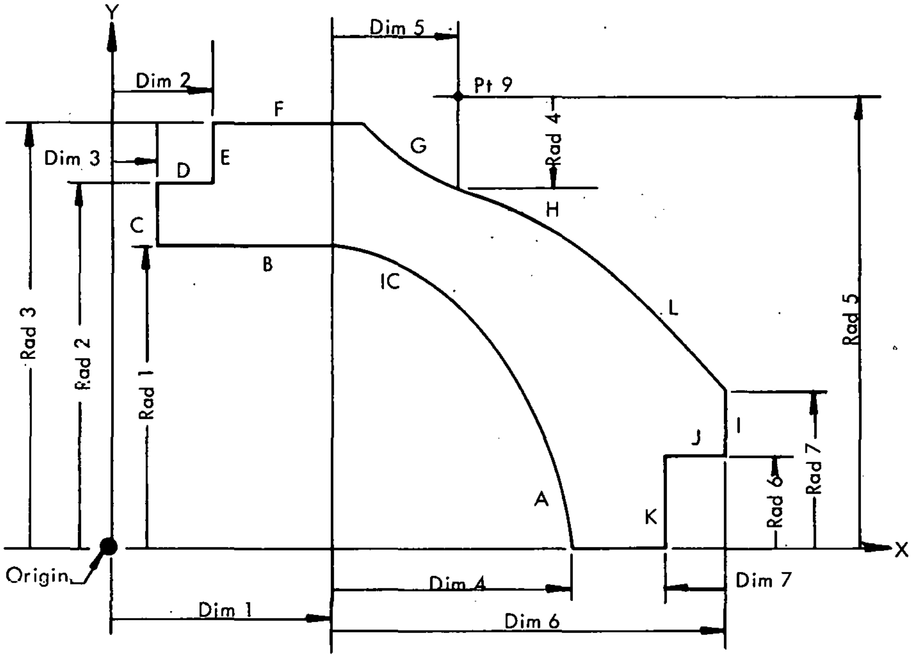


Figure 4. TYPICAL NEAR RADIAL PART.

changes type. The data used by the system are detailed in Appendix C along with general flowcharts of the APT program and system macro which processes it. Appendix D presents examples of preprinted data forms designed to ease the task of entering data. Appendix E describes the system macro.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of A. H. Fowler, now of the University Computing Company, and R. J. Easterday of the Oak Ridge Computer Technology Center. Mr. Fowler, was instrumental in the creation of the ROCOGA postprocessor while an employee at Y-12; Mr. Easterday incorporated the ROCOGA postprocessor and the related programs and macros into the APT system.

EXAMPLE

PROGRAM LIST

```
TAPENO ROCOGA EXAMPLE   WRH    9212                                0102
CHARGE#7350                                                        0104
       MACHIN/SHEFLD.INSP.ROCOGA                                   0106
       OPTION/30.3                                                 0108
       SEQNO/1.INCR.1                                              0110
       MULTAX                                                      0112
       CUTTER/.15625                                               0114
       SPINDL/1.0                                                  0116
       FEDRAT/6.0                                                  0118
       LINTOL/1                                                    0120
       CLPRNT                                                      0122
       WPO#POINT/0.0                                               0124
       YIF#.1                                                      0202
       XIF#.1                                                      0204
       MI#MATRIX/TRANSL.XIF.YIF.0                                  0206
       REFSYS/MI                                                   0208
RAD1   #4                                                          0210
DIM1   #1                                                          0212
DIM2   #.5                                                         0214
DIM3   #.25                                                        0216
RAD2   #4.5                                                        0218
RAD3   #5                                                          0220
RAD4   #.5                                                         0302
RAD5   #6                                                          0304
RAD6   #.25                                                        0306
RAD7   #.5                                                         0308
DIM4   #4                                                          0310
DIM5   #1                                                          0312
DIM6   #6                                                          0314
DIM7   #1                                                          0316
ORIG   #POINT/0.0.0                                                0318
X      #LINE/ORIG.ATANGL.0                                         0320
Y      #LINE/ORIG.ATANGL.90                                        0322
SURFA  #ELLIPS/CENTER.(POINT/DIM1.0.0).RAD1.$                      0902
       DIM4.90                                                     0904
SURFB  #LINE/PARLEL.X.YLARGE.RAD1                                  0906
SURFC  #LINE/PARLEL.Y.XLARGE.DIM3                                  0908
SURFD  #LINE/PARLEL.X.YLARGE.RAD2                                  0910
SURFE  #LINE/PARLEL.Y.XLARGE.DIM2                                  0912
SURFF  #LINE/PARLEL.X.YLARGE.RAD3                                  0914
PT9    #POINT/(DIM1+DIM5).RAD5                                     0916
SURFG  #CIRCLE/CENTER.PT9.RADIUS.RAD4                              0918
SURFH  #CIRCLE/CENTER.(POINT/DIM1.0).($                            0920
       POINT/(DIM1+DIM5).(RAD5-RAD4))                              0922
SURFI  #LINE/PARLEL.Y.XLARGE.(DIM1+DIM6)                           0924
SURFJ  #LINE/PARLEL.X.YLARGE.RAD6                                  1002
SURFK  #LINE/PARLEL.SURFI.XSMALL.DIM7                              1004
SURFL  #LINE/(POINT/(DIM1+DIM6).$                                  1006
       RAD7).RIGHT.TANTO.SURFH                                     1008
       OBTAIN.ELLIPS/SURFA.IA.IB..ID...$                           1010
       IH.IP.IQ.                                                   1012
ICCN   #Q ADRIC/CANON.IA.IB.0.ID.0.0.IH.IP.IQ.0                    1014
       WPTI0#POINT/RTHETA.XYPLAN.5.1.0                             0404
       WPTI2#POINT/RTHETA.XYPLAN.5.077777.2                        0406
       WPTI4#POINT/RTHETA.XYPLAN.5.055555.4                        0408
       WPTI6#POINT/RTHETA.XYPLAN.5.033333.6                        0410
       WPTI8#POINT/RTHETA.XYPLAN.5.011111.8                        0412
       WPTI10#POINT/RTHETA.XYPLAN.4.988888.10                      0414
       WPTI12#POINT/RTHETA.XYPLAN.4.966666.12                      0416
       WPTI14#POINT/RTHETA.XYPLAN.4.944444.14                      0418
```

```
        WPTI16#POINT/RTHETA.XYPLAN.4.922222.16                    0420
        WPTI18#POINT/RTHETA.XYPLAN.4.899999.18                    0422
        WPTI20#POINT/RTHETA.XYPLAN.4.877777.20                    0424
        WPTI22#POINT/RTHETA.XYPLAN.4.855555.22                    0502
        WPTI24#POINT/RTHETA.XYPLAN.4.833333.24                    0504
        WPTI26#POINT/RTHETA.XYPLAN.4.811111.26                    0506
        WPTI28#POINT/RTHETA.XYPLAN.4.788888.28                    0508
        WPTI30#POINT/RTHETA.XYPLAN.4.766666.30                    0510
        WPTI32#POINT/RTHETA.XYPLAN.4.744444.32                    0512
        WPTI34#POINT/RTHETA.XYPLAN.4.722222.34                    0514
        WPTI36#POINT/RTHETA.XYPLAN.4.699999.36                    0516
        WPTI38#POINT/RTHETA.XYPLAN.4.677777.38                    0518
        WPTI40#POINT/RTHETA.XYPLAN.4.655555.40                    0520
        WPTI42#POINT/RTHETA.XYPLAN.4.633333.42                    0522
        WPTI44#POINT/RTHETA.XYPLAN.4.611111.44                    0524
        WPTI46#POINT/RTHETA.XYPLAN.4.588888.46                    0602
        WPTI48#POINT/RTHETA.XYPLAN.4.566666.48                    0604
        WPTI50#POINT/RTHETA.XYPLAN.4.544444.50                    0606
        WPTI52#POINT/RTHETA.XYPLAN.4.522222.52                    0608
        WPTI54#POINT/RTHETA.XYPLAN.4.499999.54                    0610
        WPTI56#POINT/RTHETA.XYPLAN.4.477777.56                    0612
        WPTI58#POINT/RTHETA.XYPLAN.4.455555.58                    0614
        WPTI60#POINT/RTHETA.XYPLAN.4.433333.60                    0616
        WPTI62#POINT/RTHETA.XYPLAN.4.411111.62                    0618
        WPTI64#POINT/RTHETA.XYPLAN.4.388888.64                    0620
        WPTI66#POINT/RTHETA.XYPLAN.4.366666.66                    0622
        WPTI68#POINT/RTHETA.XYPLAN.4.344444.68                    0624
        WPTI70#POINT/RTHETA.XYPLAN.4.322222.70                    0702
        WPTI72#POINT/RTHETA.XYPLAN.4.299999.72                    0704
        WPTI74#POINT/RTHETA.XYPLAN.4.277777.74                    0706
        WPTI76#POINT/RTHETA.XYPLAN.4.255555.76                    0708
        WPTI78#POINT/RTHETA.XYPLAN.4.233333.78                    0710
        WPTI80#POINT/RTHETA.XYPLAN.4.211111.80                    0712
        WPTI82#POINT/RTHETA.XYPLAN.4.188888.82                    0714
        WPTI84#POINT/RTHETA.XYPLAN.4.166666.84                    0716
        WPTI86#POINT/RTHETA.XYPLAN.4.144444.86                    0718
        WPTI88#POINT/RTHETA.XYPLAN.4.122222.88                    0720
        WPTI90#POINT/RTHETA.XYPLAN.4.1.90                         0722
        REFSYS/NOMORE
IC     #TABCYL/NOZ.SPLINE.$                                       0801
        WPTI0.WPTI2.WPTI4.WPTI6.WPTI8.WPTI10.$                    0803
        WPTI12.WPTI14.WPTI16.WPTI18.WPTI20.WPTI22.$               0805
        WPTI24.WPTI26.WPTI28.WPTI30.WPTI32.WPTI34.$               0807
        WPTI36.WPTI38.WPTI40.WPTI42.WPTI44.WPTI46.$               0809
        WPTI48.WPTI50.WPTI52.WPTI54.WPTI56.WPTI58.$               0811
        WPTI60.WPTI62.WPTI64.WPTI66.WPTI68.WPTI70.$               0813
        WPTI72.WPTI74.WPTI76.WPTI78.WPTI80.WPTI82.$               0815
        WPTI84.WPTI86.WPTI88.WPTI90                               0817
        NSPECT/ON                                                 1102
        CALL/NSPROC.WCIN#ICCN.WCOUT#$                             1104
        SURFL.WSTA#20.WENA#40.WDELA#$                             1106
        10.WNSPO#NSPLN.WNSPI#NSPCN                                1108
        CYCLE/SWEEP.1.0                                           1110
        CALL/NSPROC.WCIN#IC.WCOUT#SURFH.$                         1112
        WSTA#50.WENA#60.WDELA#10.$                                1114
        WNSPO#NSPCR .WNSPI#NSPTBI                                 1116
        CYCLE/OFF                                                 1118
```

```
ROCOGA EXAMPLE   WRH   9212                                                   CARD NO.    0102 TAPE NO.     2
MACHIN/SHEFLD INSP      0.0                                                   CARD NO.    0106 TAPE NO.     4
                                                                              CARD NO.    0108 TAPE NO.     6
 OPTION/  30.0000   3.0000
                                                                              CARD NO.    0110 TAPE NO.     8
  SEQNO/   1.0000   INCR   1.0000
MULTAX/                                                                       CARD NO.    0112 TAPE NO.    10
CUTTER/   0.1562
                                                                              CARD NO.    0114 TAPE NO.    12
                                                                              CARD NO.    0116 TAPE NO.    14
 SPINDL/   1.0000
                                                                              CARD NO.    0118 TAPE NO.    16
 FEDRAT/   6.0000
                                                                              CARD NO.    0120 TAPE NO.    18
 LINTOL/   1.0000
                                                                              CARD NO.    1102 TAPE NO.    20
 NSPECT/     ON
                                                                 CALL CARD NO.      1104 TAPE NO.   21
                                                                 CALL CARD NO. 00001270 TAPE NO.   22
                                                                 CALL CARD NO. 00001290 TAPE NO.   23
 DS IS                                                                        CARD NO.00001310 TAPE NO.    25
              X                Y                 Z                 I                J                K
          20.000000         5.057893         30.933751        6.662449        26.565050        0.
                                                                 CALL CARD NO. 00001270 TAPE NO.   26
                                                                 CALL CARD NO. 00001290 TAPE NO.   27
 DS IS                                                                        CARD NO.00001310 TAPE NO.    29
              X                Y                 Z                 I                J                K
          30.000000         4.975695         47.328234        6.630673        26.565050        0.
                                                                 CALL CARD NO. 00001270 TAPE NO.   30
                                                                 CALL CARD NO. 00001290 TAPE NO.   31
 DS IS                                                                        CARD NO.00001310 TAPE NO.    33
              X                Y                 Z                 I                J                K
          40.000000         4.856930         62.507087        6.804984        26.565050        0.
```

```
                                                                        CARD NO.     1110 TAPE NO.     35
  CYCLE/ SWEEP     1.0000
                                                              CALL CARD NO.      1112 TAPE NO.   36
                                                              CALL CARD NO. 00001270 TAPE NO.    37
                                                              CALL CARD NO. 00001290 TAPE NO.    38

 DS IS                                                                  CARD NO.00001310 TAPE NO.      40
             X               Y               Z               I               J               K

        50.000000       4.683583       58.131962        6.319386       58.003815       0.
                                                              CALL CARD NO. 00001270 TAPE NO.    41
                                                              CALL CARD NO. 00001290 TAPE NO.    42
 DS IS                                                                  CARD NO.00001310 TAPE NO.      44
             X               Y               Z               I               J               K
        60.000000       4.564522       68.653951        6.153419       69.292052       0.
                                                                        CARD NO.     1118 TAPE NO.     46
  CYCLE/     OFF
FINI                                                                    CARD NO.     1122 TAPE NO.     48
```

ROCOGA OUTPUT

ROCOGA EXAMPLE WRH 9212

SEQ	THETA	R(I)	WALL	R(O)	X	U	TILT	TABLE
	20.0000	5.056529	1.606436	6.662964				
1	25.0000	5.029948	1.591311	6.621259	0.026580	0.015125	6.	1.
1	30.0000	4.972308	1.658506	6.630814	0.057640	0.067195	6.	1.
2	35.0000	4.927413	1.764581	6.691994	0.044895	0.106075	6.	1.
2	40.0000	4.850768	1.956196	6.806964	0.076645	0.191615	6.	1.
3	45.0000	4.741353	1.931206	6.672559	0.109415	0.024990	6.	1.
3	50.0000	4.682773	1.637516	6.320289	0.058580	0.293690	6.	1.
SWEEP								1.
4	55.0000	4.623788	1.616156	6.239944	0.058985	0.021360	6.	1.
4	60.0000	4.563623	1.590821	6.154444	0.060165	0.025335	6.	1.
SWEEP								1.
SWEEP								1.

NO OF LOWEST LEVEL SECTIONS REQUIRING FURTHER DIVISION WAS 0

TAPE LIST

```
N001X-0026580U-0015125C018000S4M18
X-0057640U0067195C018000
N002X-0044895U0106075C018000
X-0076645U0191615C018000
N003X-0109415U-0024990C018000
X-0058580U-0293690C018000
S0M18
N004X-0058985U-0021360C018000S4M18
X-0060165U-0025335C018000
S0M18
```

APPENDIX A

ROCOGA LISTS

```
*LABEL
CADDPT     ROUTINE FOR ROCOGA TO CALCULATE LOCATION OF AND ERROR AT A POINT
      SUBROUTINE ADDPT (IBX,IFAC,IOK,IA,A,ID,D,EPS,RADGAG)
      EQUIVALENCE (SYSTEM(1700),KOM   (1700),KFLAGS(1692),TAPETB(1622))
      EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
     1  POCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
     2             CORTAP( 9),
     3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
     4  FORTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1))
      DIMENSION SYSTEM(1739)
       COMMON SYSTEM
      COMMON DEFANS,JSUBER
      DIMENSION DEFANS(3)
      DIMENSION D(610,2),ID(610,2),A(33,8),IA(33,8)
      CONV=57.29578
  750 IP1 = IBX-IFAC
      IP2 = IBX+IFAC
      IOK = 0
      IA(IBX,1)=1
       A(IBX,2)= (A(IP1,2) + A(IP2,2)) /2.
      D1=-SINF(A(IBX,2)/CONV)
      D2= COSF(A(IBX,2)/CONV)
      FS=CONV/(A(IP1,2)-A(IP2,2))
      DO 760 I=1,2
      D(4,I)=D1
      D(5,I)=D2
      CALL TABPNT (D(1,I),ID(1,I))
      A(IBX,I+2)=SQRTF(DEFANS(1)**2 + DEFANS(2)**2)
      AS=(A(IP1,I+4) - A(IP2,I+4) )*FS
      BS=(A(IP2,I+4)*A(IP1,2) - A(IP1,I+4)*A(IP2,2)) *FS/CONV
      RS=AS*A(IBX,2)/CONV + BS
      CALL TABCIR (D(1,I),ID(1,I))
      A(IBX,I+4)=SQRTF(DEFANS(1)**2+DEFANS(2)**2)-RADGAG*FLOATF(2*I-3)
      TEMP=A(IBX,I+4)-RS
      IA(IBX,I+6)=1000000.* TEMP+SIGNF(0.5,TEMP)
  745 IF( ABSF(A(IBX,I+4)-RS) - EPS ) 760,760,755
  755 IOK=1
  760 CONTINUE
      RETURN
      END

*LABEL
*FAP
*CUBICR
       COUNT   250
       ENTRY   CUBICR
CUBICR SXA     390A,1
       SXA     390A+1,2
       CLA     1,4
       STA     YFUNC+1
       CLA     2,4
       STA     YFUNC+2
       CLA     3,4
       STA     YFUNC+5
       STA     DERIV+5
       CLA     4,4
       STA     YFUNC+8
```

```
        SXA *+1,4
        AXT **,2
        AXT 4,1
        CLA* 1,2
        SSP
        FSB EPS
        TPL *+2
        STZ* 1,2
        TXI *+1,2,-1
        TIX *-6,1,1
10A     LDQ      R3
        FMP*     1,4 A
        STO      A3
        LDQ      R2
        FMP*     2,4 B
        STO      B2
        STZ      XA
        CLA*     3,4 C
        STO      SA
        CLA*     4,4 D
        STO      VA
        CLA*     5,4 XL
        STO      TEMP
        TSX      YFUNC,2
        STO      Y3
        TSX      DERIV,2
        STO      DY3
        STZ      N1
        STZ      N2
20A     CLA*     1,4 A
        TZE      50A
30A     CLA*     2,4 B
        FDP      A3
        XCA
        CHS
        STO      X2
40A     TZE      50A
        TMI      50A
45A     FSB*     5,4 XL
        TMI      70A
50A     CLA*     5,4 XL
        STO      XB
        CLA      Y3
        STO      VB
        CLA      DY3
        STO      SB
60A     LXD      I1,1
        TRA      75A
70A     CLA      X2
        STO      TEMP
        TSX      YFUNC,2
        STO      Y2
        TSX      DERIV,2
        STO      DY2
        CLA      X2
        STO      XB
        CLA      Y2
        STO      VB
        CLA      DY2
        STO      SB
        LXD      I2,1
75A     CLA      R1
        LDQ      SA
        LLS      0
```

```
        STO     SIGNSA
        LDQ     VA
        LLS     0
        STO     SIGNVA
77A     CLA     VA
        TZE     380A
80A     XCA
        FMP     VB
        TZE     300A
        TMI     300A
85A     CLA     SA
        TZE     190A
90A     LDQ     SIGNSA
        FMP     SB
        TZE     190A
        TPL     190A
95A     STZ     DXO
100A    CLA     VA
        FDP     SA
        XCA
        CHS
        STO     DX
        CLA     N1
        ADD     I1
        STO     N1
        SUB     I100
        TZE     400A
110A    CLA     DX
        TZE     380A
        TMI     190A
115A    FSB     DXO
        TZE     380A
120A    CLA     XA
        FAD     DX
        STO     XA
130A    FSB     XB
        TPL     190A
140A    CLA     XA
        STO     TEMP
        TSX     YFUNC,2
        STO     VA
150A    XCA
        FMP     SIGNVA
        TZE     380A
        TMI     380A
160A    TSX     DERIV,2
        STO     SA
170A    XCA
        FMP     SIGNSA
        TZE     190A
        TMI     190A
180A    CLA     DX
        STO     DXO
        TRA     100A
190A    TXL     210A,1,1
200A    CLA     X2
        STO     XA
        CLA     DY2
        STO     SA
        CLA     Y2
        STO     VA
        CLA*    5,4 XL
        STO     XB
        CLA     DY3
        STO     SB
```

```
         CLA      Y3
         STO      VB
         TRA      60A
210A     CLA      DY3
         FDP      Y3
         STQ      TEMP
         CLA*     3,4 C
         FDP*     4,4 D
         XCA
         FAD      TEMP
220A     TZE      240A
         TPL      240A
230A     CLA      R1
         STO*     1,4 A
         TRA      390A
240A     CLS      R1
         STO*     1,4 A
         TRA      390A
300A     CLA      XB
         FSB      XA
         STO      TEMP
         CLA      VB
         FSB      VA
         FDP      TEMP
         XCA
         SSP
         STO      TEMP
         CLA      SA
         SSP
         FSB      TEMP
         TZE      330A
         TMI      330A
310A     CLA      VA
         FDP      SA
         XCA
         CHS
         STO      DX
320A     TZE      380A
         TPL      340A
330A     CLA      XB
         STO      XA
         CLA      VB
         STO      VA
         CLA      SB
         STO      SA
         CLS      R1
         STO      X2
         STZ      DXO
         TRA      360A
340A     CLA      R1
         STO      X2
350A     LDQ      X2
         FMP      DX
         FAD      XA
         STO      XA
         STO      TEMP
         TSX      YFUNC,2
         STO      VA
         TSX      DERIV,2
         STO      SA
         CLA      DX
         STO      DXO
360A     CLA      X2
         FDP      SA
         FMP      VA
```

```
         CHS
         STO      DX
         CLA      N2
         ADD      I1
         STO      N2
         SUB      I100
         TZE      400A
370A     CLA      DX
         TZE      380A
         TMI      380A
375A     FSB      DXO
         TNZ      350A
380A     CLA      XA
         STO*     2,4 B
         STZ*     1,4 A
390A     AXT      **,1
         AXT      **,2
         TRA      6,4
400A     CLA      R2
         STO*     1,4 A
         TRA      390A
YFUNC    LDQ      TEMP
         FMP      ** A
         FAD      ** B
         XCA
         FMP      TEMP
         FAD      ** C
         XCA
         FMP      TEMP
         FAD      ** D
         TRA      1,2
DERIV    LDQ      TEMP
         FMP      A3
         FAD      B2
         XCA
         FMP      TEMP
         FAD      ** C
         TRA      1,2
 EPS     DEC    .000001
R1       DEC      1.
R2       DEC      2.
R3       DEC      3.
I1       OCT      1000000
I2       OCT      2000000
I100     OCT      144000000
N1
N2
TEMP
A3
B2
DXO
DX
DY3
DY2
SA
SB
SIGNSA
SIGNVA
VA
VB
X2
XA
XB
Y2
Y3
         END
```

```
*LABEL
CFINISH
       SUBROUTINE FINISH
       EQUIVALENCE (SYSTEM(1700),KOM    (1700),KFLAGS(1692),TAPETB(1622))
       EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
      1  POCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
      2              CORTAP( 9),
      3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
      4  FORTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1))
       DIMENSION SYSTEM(1739)
        COMMON SYSTEM
       COMMON DEFANS,JSUBER
       DIMENSION KFLAGS(50)
B      AA=606060606060
       CALL PUNCHA(-1,AA,1,0)
       CALL SETUP(1)
       CALL PUNCHA(-1,AA,1)
       CABCTR=KFLAGS(50)
       CABON=CABCTR*.6+12.0
       JCAB=CABON
       CALL PRTON(1,JCAB)
       KFLAGS(39)=KFLAGS(39)+JCAB
       KFLAGS(50)=0
       CALL DESPAT
       RETURN
       END

*LIST
*LABEL
CROCOGA    CONTINUOUS PATH ROTARY CONTOUR GAGE
       SUBROUTINE ROCOGA
       DIMENSION SCODT(10),AMCODT(10),           V(250),INCOD(10),IPECOD(3,
      1200),SPECOD(3,200),D(610,2),ID(610,2),Q(10,102),IQ(10,102),
      2STP(3),IA(33,8),A(33,8),PUN(8),           IV(250),IW(2)
       DIMENSION DEFANS(3)
       EQUIVALENCE (SYSTEM(1700),KOM    (1700),KFLAGS(1692),TAPETB(1622))
       EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
      1  POCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
      2              CORTAP( 9),
      3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
      4  FORTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1))
       DIMENSION SYSTEM(1739)
        COMMON SYSTEM
       COMMON DEFANS,JSUBER
       COMMON INP,IOT,ICL,IPN,IZR,ICLFLG,ID1,ID2
       EQUIVALENCE (IPECOD(1),SPECOD(1)),(ID(1),D(1)),(IQ(1),Q(1)),
      1(IA(1),A(1)),(IV(1),VV(1),TAPSTO(4)),(IT1,TAPSTO(2))
      2,(IT2,TAPSTO(3)),(V(1),TAPSTO(6))
       EQUIVALENCE(TAPSTO(1),IRECNO)
       DIMENSION KFLAGS(1)
       DIMENSION BUFP(20),VV(3)
       EQUIVALENCE(FIW,IW(1))
       SMALF(Z1)=SIGNF(MAX1F(ABSF(Z1),1.E-12),Z1)
       TANF(Z1) = SINF(Z1/CONV)/SMALF(COSF(Z1/CONV))
       TANMF(Z1,Z2) = (Z1-Z2)/SMALF(1.+Z1*Z2)
       IOUTAP=6
B      SP=606060606060
B      SM=406060606060
  100 CONV = 57.29578
       DO 101 J=1,12
  101 DEFANS(J)=0.
       PID8=45./CONV
       SCODT( 1) = 60.
       SCODT( 2) = 30.
       SCODT( 3) = 16.
```

```
          SCODT( 4) = 10.
          SCODT( 5) =  8.
          SCODT( 6) =  6.
          SCODT( 7) =  4.
          SCODT( 8) =  2.
          SCODT( 9) =  1.
          SCODT(10) =  0.
          AMCODT( 1) = 9.
          AMCODT( 2) = 8.
          AMCODT( 3) = 7.
          AMCODT( 4) = 6.
          AMCODT( 5) = 5.
          AMCODT( 6) = 4.
          AMCODT( 7) = 3.
          AMCODT( 8) = 2.
          AMCODT( 9) = 1.
          AMCODT(10) = 0.
          INCOD(1) = 1019
          INCOD(2) = 1009
          INCOD(3) = 1031
          INCOD(4) =    2
          INCOD(5) =    3
          INCOD(6) = 1006
          INCOD(7) = 1064
          INCOD(8) = 1052
          INCOD(9) = 1067
          INCOD(10)= 1
B         STP(1) = 440000536060
B         STP(2) = 440001536060
B         STP(3) = 440300536060
  150     NP     = 0
          ISCODP =-1
          MPRE   =-1
          ICYCLE=0
          ISCOD  = 9
          IMCOD  = 26
          NVAL   = 0
          NDEL   = 1
          NSC    = 0
          IDATA=0
          TOLER  = .000025*4.
          RADGAG=0.
  180 CALL TAPERD(CLTAPE,IRETN,NWPR,1,TAPSTO,0)
          IF(IRETN)182,181,181
  181 WRITE OUTPUT TAPE IOUTAP,3000
          GO TO 976
  182 IF(IT1-2000)180,200,190
  190 IF( IT1 - 5000 ) 180, 300, 380
  200 DO 210 I = 1,10
  205 IF( INCOD(I) - IT2 ) 210,215,210
  210 CONTINUE
          GO TO 180
C               SEQNO,FEDRAT,SPINDL,STOP,OPSTOP,REWIND,CYCLE
  215 GOTO (220,  225,    240,    290, 290,    290,    270
C         NSPECT,LINTOL,END
       1,296,    216,   405),I
C LINTOL
  216 TOLER=VV(1)*4.
          GO TO 180
C 220-SEQNO
  220 IF(IV(2)-66)222,221,222
  221 NDEL=VV(3)
          GO TO 223
  222 NDEL=1
```

```
  223 NVAL = XINTF(VV(1)+.5)-NDEL
      GO TO 180
C 225-FEDRAT
  225 DO 230 I = 1,8
      IF(VV(1) - SCODT(I) ) 230,235,235
  230 CONTINUE
      I = 9
  235 ISCOD = 10-I
      GO TO 180
C 240-SPINDL
  240 DO 245 I = 1,8
      IF(VV(1) - AMCODT(I) ) 245,260,260
  245 CONTINUE
      IF(VV(1) ) 255,250,255
  250 IMCOD = 17
      GO TO 180
  255 I = 9
  260 IMCOD = 27-I
      GO TO 180
C0270 CYCLE
 0270 IF(IV(1) - 72   ) 271,290,271
  271 IF(IV(1)-239)180,275,180
 0275 DO 280 J=1,8
      IF(VV(2) - AMCODT(J) ) 280,285,285
 0280 CONTINUE
      J=9
 0285 ICV=27-J
      GO TO 295
C 290-STOP-OPSTOP-REWIND
  290 ICV=0
  295 NSC = NSC + 1
      IPECOD(1,NSC) = I-3
      IPECOD(2,NSC) = ICV
      IPECOD(3,NSC) = IRECNO
      GO TO 180
C NSPECT
  296 IF(IV(1)-71)180,297,298
  297 IDATA=1
      GO TO 180
  298 IF(IV(1)-72)180,299,180
  299 IDATA=0
      GO TO 180
C 300-GOTO-DATA
  300 NP = NP+1
      N = 6*NP +17
      F1 = COSF(V(1)/CONV)
      N=N
      D(N,1) = V(2)*F1
      D(N,2) = V(4)*F1
      F1 = SINF( V(1)/CONV)
      N=N
      NP=NP
      D(N+1,1) = V(2)*F1
      D(N+1,2) = V(4)*F1
  310 DO 315 I = 1,5
  315 Q(I,NP) = V(I)
      IF(IDATA)318,317,318
  317 IQ(6,NP)=0
      GO TO 319
  318 NVAL=NVAL+NDEL
      IQ(6,NP) = NVAL
  319 IQ(7,NP) = ISCOD
      IQ(8,NP) = IMCOD
      IQ(9,NP) = IRECNO
      Q(10,NP) = TOLER
```

```
  320 IF( NP - 2 ) 180,325,365
  325 DO 360 I = 1,2
      D(22,I) =(Q(2*I+1,1) - SIGNF(90.,Q(2*I+1,1)) )/CONV
  340 DX = 10.*COSF(D(22,I))
      DY = 10.*SINF(D(22,I))
      II=I
  345 IF( DX*(D(23,II)-D(29,II)) + DY*(D(24,II)-D(30,II)) ) 350,355,355
  350 DX = -DX
      DY = -DY
  355 D(17,II) = DX + D(23,II)
      D(18,II) = DY + D(24,II)
  360 CONTINUE
      N=N
  365 DO 375 I = 1,2
  370 DX = D(N,I)-D(N-6,I)
      DY = D(N+1,I)-D(N-5,I)
      SS = DY/SMALF(DX)
      XL = SQRTF(DX*DX+DY*DY)
      NP=NP
      S3 = -1./SMALF(TANF(Q(2*I+1,NP)))
      NP=NP
      S2 = -1./SMALF(TANF(Q(2*I+1,NP-1)))
      TA = TANMF(S2,SS)
      TB = TANMF(S3,SS)
      N=N
      D(N-4,I) = (TA+TB)/(XL*XL)
      D(N-3,I) = -(2.*TA+TB)/XL
      D(N-2,I) = TA
      D(N-1,I) = ATANF(SS)
  375 CONTINUE
      GO TO 180
  380 IF( IT1-6000) 180,385,400
  385 IF( IT2- 6  )180,395,180
C 395 CUTTER
  395 RADGAG=VV(1)/2.
      GO TO 180
C 400-FINI-END
  400 IF(IT1-14000)180,405,180
  405 ID(1,1) = NP+2
      ID(1,2) = ID(1,1)
      DO 435  I = 1,2
      NP=NP
      D(N+5,I) =(Q(2*I+1,NP) - SIGNF(90.,Q(2*I+1,NP)) )/CONV
  415 DX = 10.*COSF(D(N+5,I))
      N=N
      DY = 10.*SINF(D(N+5,I))
      N=N
  420 IF( DX*(D(N,I)-D(N-6,I)) + DY*(D(N+1,I)-D(N-5,I)) ) 425,430,430
  425 DX = -DX
      DY = -DY
  430 D(N+6,I) = DX + D(N,I)
      D(N+7,I) = DY + D(N+1,I)
  435 CONTINUE
  440 NSCN = 1
  450 KFLAGS(50)=0
      CALL SETUP(0)
      NSEGTD = NP
      NERR=0
      DO 491 NSEGB=1,NP
      IF( IQ(6,NSEGB) ) 491,491,492
  491 CONTINUE
  492 NSEGB=NSEGB+1
      NSCN=NSCN
  460 IF( NSCN - NSC ) 465,465,490
  465 IF( IPECOD(3,NSCN) - IQ(9,NSEGB-1) ) 470,490,490
```

```
470 IF( IPECOD(1,NSCN) - 4 ) 475,480,480
475 I = IPECOD(1,NSCN)
    CALL PUNCHA (-3,STP(I),0)
    GO TO 485
480 ICYCLE = IPECOD(2,NSCN)
485 NSCN = NSCN + 1
    GO TO 460
490 DO 950 NSEG=NSEGB,NSEGTO
    IF( IQ(6,NSEG) ) 955,955,499
499 K=6*NSEG+11
500 DO 505 I = 1,33
    IA(I,7)=0
    IA(I,8)=0
505 IA(I,1) = 0
510 D(2,1) = D(K,1)
    D(2,2) = D(K,2)
    D(3,1) = D(K+1,1)
    D(3,2) = D(K+1,2)
515 IA(1,1) = 1
     A(1,2) = Q(1,NSEG-1)
     A(1,3) = Q(2,NSEG-1)
     A(1,4) = Q(4,NSEG-1)
    IA(33,1) = 1
     A(33,2) = Q(1,NSEG)
     A(33,3) = Q(2,NSEG)
     A(33,4) = Q(4,NSEG)
    EPS = Q(10,NSEG)
530 DO 550 I=1,2
    D(12,I)=RADGAG
    D( 6,I)=0.
    ID(9,I)=71
    IF( ABSF(D(K+5,I)) - PID8) 545,545,540
540 ID(11,I)=33-I
    GO TO 550
545 ID(11,I)=37-I
550 CONTINUE
555 DO 560 J=1,33,32
    JJ=J
    D1=-SINF(A(JJ,2)/CONV)
    JJ=JJ
    D2= COSF(A(JJ,2)/CONV)
    DO 560 I=1,2
    D(4,I)=D1
    D(5,I)=D2
    CALL TABCIR (D(1,I),ID(1,I))
    JJ=JJ
    II=I
560 A(JJ,II+4)=SQRTF(DEFANS(1)**2+DEFANS(2)**2) -RADGAG*FLOATF(2*II-3)
    IF( NSEG-NSEGB ) 570,570,690
570 SUMDX=A(1,5)
    SUMDU=A(1,6)-A(1,5)
    CALL HEAD (0,V)
    WRITEOUTPUTTAPE IOUTAP,4003
    LINES=48
    WRITEOUTPUTTAPE IOUTAP,4002,A(1,2),SUMDX,SUMDU,A(1,6)
690 DO 805 I0 = 1,1
    IB00 = 17
    CALL ADDPT (IB00,16,IOK,IA,A,ID,D,EPS,RADGAG)
695 IF( IOK ) 805,805,700
700 DO 800 I1 = 1,2
    IB01 = IB00 + 16*I1 - 24
    CALL ADDPT (IB01, 8,IOK,IA,A,ID,D,EPS,RADGAG)
705 IF( IOK ) 800,800,710
710 DO 795 I2 = 1,2
    IB02 = IB01 +8*I2 - 12
    CALL ADDPT (IB02, 4,IOK,IA,A,ID,D,EPS,RADGAG)
```

```
  715 IF( IOK ) 795,795,720
  720 DO 790 I3 = 1,2
      IB03 = IB02 + 4*I3 - 6
      CALL ADDPT (IB03, 2,IOK,IA,A,ID,D,EPS,RADGAG)
  725 IF( IOK ) 790,790,730
  730 DO 785 I4 = 1,2
      IB04 = IB03 + 2*I4 - 3
      CALL ADDPT (IB04, 1,IOK,IA,A,ID,D,EPS,RADGAG)
  735 IF( IOK ) 785,785,740
  740 NERR = NERR + 1
  785 CONTINUE
  790 CONTINUE
  795 CONTINUE
  800 CONTINUE
  805 CONTINUE
  810 IF( ICYCLE ) 820,820,815
  815 CYCLE=ICYCLE
      CALL CONBCD(CYCLE,IW(2),2,0)
B     FIW=620044606060
      CALL PUNCHA (-12,IW,0)
      ISCODP=-1
      MPRE=-1
      IF( LINES ) 816,816,817
  816 LINES=49
      CALL HEAD (-1,V)
      CALL HEAD (0,V)
      WRITEOUTPUTTAPE IOUTAP,4003
  817 I=27-ICYCLE
      TABLE=AMCODT(I)
      WRITEOUTPUTTAPE IOUTAP,4000,TABLE
      LINES=LINES-1
  820 IF( NSCN-NSC ) 825,825,850
  825 NSEG=NSEG
      NSCN=NSCN
      IF( IPECOD(3,NSCN) - IQ(9,NSEG) ) 830,850,850
  830 IF( IPECOD(1,NSCN) - 4 ) 835,840,840
  835 I=IPECOD(1,NSCN)
      CALL PUNCHA (-3,STP(I),0)
      ISCODP=-1
      MPRE=-1
      GO TO 845
  840 ICYCLE=IPECOD(2,NSCN)
  845 NSCN = NSCN + 1
      GO TO 820
  850 NP = 1
      DO 945 NPT = 2,33
      IF( IA(NPT,1) ) 945,945,855
  855 DELX=A(NPT,5)-SUMDX
      DXP=5.*INTF(DELX*200000.+SIGNF(.5,DELX))
      SUMDX=SUMDX+DXP/1000000.
      DELU=A(NPT,6)-SUMDX-SUMDU
      DUP=5.*INTF(DELU*200000.+SIGNF(.5,DELU))
      SUMDU=SUMDU+DUP/1000000.
      DELR=MAX1F(ABSF(DXP),ABSF(DUP))/1000000.
      DELC =(A(NPT,2)-A(NP,2))*3600.
      IF( DELR) 851,851,852
  851 DELTM=60.
      GO TO 853
  852 DELTM=ABSF(DELC/(2000.*DELR))
  853 I=10-IQ(7,NSEG)
      SVALCA= MIN1F(60.,SCODT(I),DELTM)
      SX=SP
      IF( DXP ) 856,857,857
  856 SX=SM
```

```
  857 DXP=ABSF(DXP)
      SU=SP
      IF( DUP ) 858,859,859
  858 SU=SM
  859 DUP=ABSF(DUP)
      DO 860 I=1,8
      IF( SVALCA - SCODT(I) ) 860,865,865
  860 CONTINUE
      I=9
  865 ISP=10-I
      MO=0
      IF( IQ(8,NSEG) - MPRE ) 870,875,870
  870 MPRE = IQ(8,NSEG)
      MPP=MPRE+100
      MO=1
  875 ISO=0
      IF( ISP    - ISCODP ) 880,885,880
  880 ISCODP=ISP
      ISO=1
  885 ISQN=IQ(6,NSEG-1) +1000
      SXU=SUMDX+SUMDU
      DXP1=DXP/1000000.
      DUP1=DUP/1000000.
      I=10-ISP
      TILT=SCODT(I)
      I=27-MPRE
      TABLE=AMCODT(I)
      IF( LINES ) 886,886,887
  886 CALL HEAD (-1,V)
      CALL HEAD (0,V)
      WRITEOUTPUTTAPE IOUTAP,4003
      LINES=49
  887 WRITEOUTPUTTAPE IOUTAP,4001,IQ(6,NSEG-1),A(NPT,2),SUMDX,SUMDU,
     1SXU,DXP1,DUP1,TILT,TABLE
      LINES=LINES-1
      FSQN=ISQN
      FSP=ISP
      FMPP=MPP
      CALL CONBCD(FSQN,PUN(1),3,0)
      FDXP=DXP/1000.
      FDUP=DUP/1000.
      CALL CONBCD(FDXP,PUN(2),7,3)
      CALL CONBCD(FDUP,PUN(4),7,3)
      CALL CONBCD(DELC,PUN(6),6,0)
      CALL CONBCD( FSP,PUN(7),1,0)
      CALL CONBCD(FMPP,PUN(8),2,0)
      DO 888 JJ=1,20
  888 BUFP(JJ)=SP
      IF(DXP-.5)890,890,889
B 889 BUFP(20)=536060606060
B     BUFP( 3)=676060606060
      BUFP( 4)=SX
      BUFP( 5)=PUN(2)
      BUFP( 6)=PUN(3)
  890 IF(DUP-.5)892,892,891
B 891 BUFP( 7)=646060606060
      BUFP( 8)=SU
      BUFP( 9)=PUN(4)
      BUFP(10)=PUN(5)
  892 IF(DELC-.5)894,894,893
B 893 BUFP(11)=236060606060
      BUFP(12)=PUN(6)
  894 IF( NP-1 ) 910,895,910
B 895 BUFP( 1)=456060606060
      BUFP( 2)=PUN(1)
      IF( MO ) 910,910,896
```

```
B 896 BUFP(13)=626060606060
      BUFP(14)=PUN(7)
B     BUFP(15)=446060606060
      BUFP(16)=PUN(8)
      IF( ISO) 905,905,940
  905 BUFP(13)=SP
      BUFP(14)=SP
      GO TO 940
B 910 BUFP(13)=626060606060
      BUFP(14)=PUN(7)
      IF( ISO ) 905,905,940
  940 CALL PUNCHA(-120,BUFP,0)
      NP=NPT
  945 CONTINUE
  950 CONTINUE
  955 IF(ICYCLE)959,959,956
  956 CYCLE=ICYCLE
      CALL CONBCD(CYCLE,IW(2),2,0)
B     FIW=620044606060
      CALL PUNCHA (-12,IW,0)
      ISCODP=-1
      MPRE=-1
      IF( LINES ) 957,957,958
  957 LINES-49
      CALL HEAD (-1,V)
      CALL HEAD (0,V)
      WRITEOUTPUTTAPE IOUTAP,4003
  958 I=27-ICYCLE
      TABLE=AMCODT(I)
      WRITEOUTPUTTAPE IOUTAP,4000,TABLE
      LINES=LINES-1
  959 IF( NSCN-NSC ) 960,960,975
  960 IF( IPECOD(1,NSCN)-4) 965,970,970
  965 I=IPECOD(1,NSCN)
      CALL PUNCHA (-3,STP(I),0)
  970 NSCN=NSCN+1
      GO TO 955
  975 WRITEOUTPUTTAPE IOUTAP,2001,NERR
  976 CALL FINISH
 9999 RETURN
 3000 FORMAT(18HOCLTAPE READ ERROR)
 3002 FORMAT(I3,3F8.0,I1,I2)
 3003 FORMAT(A3,A6,A1,1X,A6,A1,2X,A6,1X,A1,A2)
 3004 FORMAT(1HN,A3,1HX,A1,A6,A1,1HU,A1,A6,A1,1HC,A6,1HS,A1,1HM,A2)
 3005 FORMAT(6A6)
 3006 FORMAT(1HN,A3,1HX,A1,A6,A1,1HU,A1,A6,A1,1HC,A6,1HM,A2)
 3007 FORMAT(1HN,A3,1HX,A1,A6,A1,1HU,A1,A6,A1,1HC,A6)
 3008 FORMAT(1HN,A3,1HX,A1,A6,A1,1HU,A1,A6,A1,1HC,A6,1HS,A1)
 3009 FORMAT(1HX,A1,A6,A1,1HU,A1,A6,A1,1HC,A6)
 3010 FORMAT(1HX,A1,A6,A1,1HU,A1,A6,A1,1HC,A6,1HS,A1)
 2001 FORMAT(60HONO OF LOWEST LEVEL SECTIONS REQUIRING FURTHER DIVISION
     1WAS ,I4)
 4000 FORMAT(6H SWEEP,68X,F10.0)
 4001 FORMAT(1H ,I3,F10.4,5F10.6,2F10.0)
 4002 FORMAT(1H ,3X,F10.4,3F10.6)
 4003 FORMAT(85H SEQ  THETA      R(I)      WALL      R(O)       X
     1 U            TILT      TABLE  )
      END

*LABEL
CHEAD          HEADINGS FOR ROCOGA LISTS
      SUBROUTINE HEAD (IC,ITITL)
      DIMENSION ITITL(11),ITIT(11),DEFANS(3)
      EQUIVALENCE (SYSTEM(1700),KOM   (1700),KFLAGS(1692),TAPETB(1622))
      EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
```

```
     1  POCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
     2              CORTAP( 9),
     3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
     4  FORTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1))
      DIMENSION SYSTEM(1739)
       COMMON SYSTEM
      COMMON DEFANS,JSUBER
      COMMON INP,IOT,ICL,IPN,IZR,ICLFLG,ID1,ID2
      IF( IC ) 230,100,10
   10 DO 15 I=1,11
   15 ITIT(I)=ITITL(I)
  100 WRITEOUTPUTTAPE IOUTAP,2000,ITIT
  230 RETURN
 2000 FORMAT(1H1,11A6)
      END

*LABEL
CSCHTB
      SUBROUTINE SCHTB (N,D,ID)
      DIMENSION D(1),ID(1),DEFANS(3)
      EQUIVALENCE (SYSTEM(1700),KOM    (1700),KFLAGS(1692),TAPETB(1622))
      EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
     1  POCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
     2              CORTAP( 9),
     3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
     4  FORTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1))
      DIMENSION SYSTEM(1739)
       COMMON SYSTEM
      COMMON DEFANS,JSUBER
      N2= 6*ID(1) + 11
   20 DO 50 N=23,N2,6
   30 IF( ABSF(D(2)-D(N)) - .005) 40,40,50
   40 IF( ABSF(D(3)-D(N+1)) - .005) 70,70,50
   50 CONTINUE
   60 WRITE OUTPUT TAPE IOUTAP,1000
 1000 FORMAT(26HOTABCYL INTERVAL NOT FOUND)
      N=0
   70 RETURN
      END

*LABEL
CSETUP
      SUBROUTINE SETUP(L)
      EQUIVALENCE (SYSTEM(1700),KOM    (1700),KFLAGS(1692),TAPETB(1622))
      EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
     1  POCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
     2              CORTAP( 9),
     3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
     4  FORTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1))
      DIMENSION SYSTEM(1739)
       COMMON SYSTEM
      COMMON DEFANS,JSUBER
      DIMENSION AA(15),PNOFLG(14)
      EQUIVALENCE(PNOFLG(1),SYSTEM(1715))
      IF(L)200,100,200
B 100 BLNK=606060606060
      DO 101 JJ=1,12
  101 AA(JJ)=BLNK
B     AA( 9)=606044000053
B     AA(10)=606044000053
B     AA(11)=440000757575
      N=-72
      J=0
      K=1
      CALL PUNCHA(N,AA,J,K)
```

```
      N=-6
      CALL PUNCHA(N,AA(10),J,K)
      N=-12
      CALL PUNCHA(N,AA(11),J,K)
B 200 AA(1)=623025264324
B     AA(2)=733145624773
B     AA(3)=514623462746
B     AA(4)=606060606060
      K=14
      DO 201 J=5,15
      K=K-1
  201 AA(J)=PNOFLG(K)
      CALL HEAD(1,AA(5))
      AA(14)=BLNK
      CALL DATE(AA(14))
      PNOFLG(14)=AA(1)
      N=-90
      CALL PARNOM(N,AA)
      IF(L)400,300,400
  300 M=-60
      DO 301 LL=1,9
B 301 AA(LL)=343434343434
B     AA(10)=343434341353
      J=0
      K=1
      CALL PUNCHA(M,AA,J,K)
  400 RETURN
      END

*LABEL
CTABCIR
      SUBROUTINE TABCIR (D,ID)
      YFUNCF(X)=X*(X*(X*A+B)+C)
      DERIVF(X)=X*(X*AT3+BT2)+C
      YFUNOF(X)=X*(X*(X*AO+BO)+CO)+DO
      DERIOF(X)=X*(X*AO*3.+BO*2.)+CO
      DIMENSION D(1),ID(1),DEFANS(3)
      EQUIVALENCE (SYSTEM(1700),KOM   (1700),KFLAGS(1692),TAPETB(1622))
      EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
     1  POCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
     2              CORTAP( 9),
     3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
     4  FORTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1))
      DIMENSION SYSTEM(1739)
       COMMON SYSTEM
      COMMON DEFANS,JSUBER
      DIMENSION DV(4,2)
   10 DV(1,1) =  1.
      DV(2,1) = -1.
      DV(3,1) =  0.
      DV(4,1) =  0.
      DV(1,2) =  0.
      DV(2,2) =  0.
      DV(3,2) =  1.
      DV(4,2) = -1.
      JSUBER=0
   20 CALL SCHTB (N,D,ID)
   30 IF(N) 40,960,40
   40 CALL TABDIR (N,ID(1),0.)
   50 IF(D(6)) 60,70,70
   60 D(4)=-D(4)
      D(5)=-D(5)
      D(6)=-D(6)
   70 IF( ID(9)-27 ) 80,90,80
C     27 IS FOR CIRCLE TANGENT TO LINE
```

```
 80 RCL=0.
    GO TO 130
 90 IF( ID(10) -34) 110,100,100
100 IDCL= ID(10)-32
    GO TO 120
110 IDCL=ID(10)-30
120 DCL=SIGNF(1.,D(4)*DV(IDCL,1) + D(5)*DV(IDCL,2) )
    RCL= D(12)*DCL
130 IF( ID(11)-34 ) 150,160,160
150 IDCT=ID(11)-30
    GO TO 170
160 IDCT=ID(11)-32
170 A=D(N+2)
    B=D(N+3)
    C=D(N+4)
    AT3=3.*A
    BT2=2.*B
    D2=D(6)+RCL
    DX=D(N+6)-D(N)
    DY=D(N+7)-D(N+1)
    XLSQ=DX*DX+DY*DY
    XL=SQRTF(XLSQ)
    F1=DX/XL
    F2=DY/XL
    AL=D(4)*F1 + D(5)*F2
    BL=D(5)*F1 - D(4)*F2
    DLP= D2 - D(4)*D(N) - D(5)*D(N+1)
    U1=0.
    V1=0.
    S1=C
    IDIR=0
200 DCT=SIGNF(1.,DX*DV(IDCT,2)-DY*DV(IDCT,1))
    RCT= D(12)*DCT
210 IF(A) 220,260,220
220 UI=-B/AT3
230 IF( UI ) 260,260,240
240 IF( UI-XL ) 250,260,260
250 U2=UI
    V2=YFUNCF(U2)
    ND=1
    GO TO 270
260 U2=XL
    V2=0.
    ND=0
270 S2=DERIVF(U2)
    NI=0
280 U4=0.
    V4=0.
    DIS=1.E20
    F3=SQRTF(1.+S1*S1)
    A1=1./F3
    B1=S1/F3
    F3=SQRTF(1.+S2*S2)
    A2=1./F3
    B2=S2/F3
290 U1P=U1-B1*RCT
    V1P=V1+A1*RCT
    DL=DLP-AL*U1P
300 IF( DL ) 310,320,320
310 AL=-AL
    BL=-BL
    DL=-DL
320 U2P=U2-B2*RCT
    V2P=V2+A2*RCT
    U1PO=U1P
```

```
330 DX=U2P-U1P
    DX1I=U1P-U1PO
    AO=(S1+S2-2.*(V2P-V1P)/DX) / (DX*DX)
    BO=(S2-S1-3.*((U2P-U1PO)**2-DX1I**2)*AO) / (2.*DX)
    CO=S1-DX1I*(3.*AO*DX1I + 2.*BO)
    DO=V1P-DX1I*(DX1I*(DX1I*AO+BO)+CO)
340 IF( IDIR ) 350,350,360
350 U1PO=U1P
    DXP=DX
360 IF( BL ) 380,370,380
370 D2=DL
    GO TO 500
380 D1=AO
    D2=BO
    D3=CO+AL/BL
    D4=DO-DL/BL
    DXPE=DXP+.000001
390 CALL CUBICR (D1,D2,D3,D4,DXPE)
400 IF( D1 ) 430,500,410
410 IF( D1-2. ) 430,900,430
430 IF( ND ) 440,450,440
440 U1=U2
    V1=V2
    S1=S2
    GO TO 260
450 CALL TABDIR (N,ID(1),D1)
460 IF( N ) 170,970,170
500 VC=YFUNOF(D2)
    UC=D2+U1PO
505 IF( IDIR ) 506,506,510
506 IF( UC-XL/2. ) 507,507,508
507 IDIR=1
    GO TO 530
508 IDIR=2
    GO TO 530
510 DIS=SQRTF((UC-UCP)**2+(VC-VCP)**2)
515 IF( DIS ) 800,800,520
520 IF( DIS-DISP ) 530,525,525
525 UC=UCP
    VC=VCP
    GO TO 800
530 UCP=UC
    VCP=VC
    DISP=DIS
    SC=DERIOF(D2)
    F3=SQRTF(1.+SC*SC)
    A3=1./F3
    B3=SC/F3
    D3=A3*UC+B3*VC
540 IF( B3 ) 550,545,550
545 U3=D3
    GO TO 590
550 D1=A
    D2=B
    D3P=C+A3/B3
    D4=-D3/B3
    XLE=XL+.000001
560 CALL CUBICR (D1,D2,D3P,D4,XLE)
570 IF( D1 ) 910,580,575
575 IF( D1-2. ) 910,920,910
580 U3=D2
590 V3=YFUNCF(U3)
    S3=DERIVF(U3)
    F3=SQRTF(1.+S3*S3)
```

```
      A4=1./F3
      B4=S3/F3
  600 U4=U3-B4*RCT
      V4=V3+A4*RCT
      IF( (U4-UC)**2+(V4-VC)**2 - 1.E-11 ) 800,800,680
  680 IF( IDIR - 1 ) 700,700,720
  700 U1P=U4
      V1P=V4
      S1=S3
      GO TO 740
  720 U2P=U4
      V2P=V4
      S2=S3
  740 NI=NI+1
      IF( NI-100 ) 330,330,920
  800 DEFANS(1)=UC*F1-VC*F2+D(N)
      DEFANS(2)=VC*F1+UC*F2+D(N+1)
      DEFANS(3)=0.
      GO TO 999
  900 WRITE OUTPUT TAPE IOUTAP,1000
 1000 FORMAT(26HOCUBICR FAILED TO CONVERGE )
  910 WRITE OUTPUT TAPE IOUTAP,1001,NI
 1001 FORMAT(31HOTAB CIRCLE NOT FOUND /NO.ITER=,I3)
      I1=N+7
      WRITEOUTPUTTAPE 6,1004,N,(D(I),I=N,I1)
 1004 FORMAT(I5,8F12.6)
      GO TO 960
  920 WRITE OUTPUT TAPE IOUTAP,1002
 1002 FORMAT(30HOTAB CIRCLE FAILED TO CONVERGE )
  960 JSUBER=1
  970 WRITEOUTPUTTAPE IOUTAP,1003
 1003 FORMAT(35H TABCIR NOT FOUND IN NEARBY SEGMENT)
  999 RETURN
      END

*LABEL
CTABDIR
      SUBROUTINE TABDIR (J,N,DIR)
   10 IF( DIR ) 30,20,70
   20 IRIGHT = 0
      LEFT   = 0
      INTJ   = J
      N2= 6*N+11
      GO TO 120
   30 LEFT = LEFT + 6
   40 IF( LEFT - 18 ) 50,50,110
   50 J = INTJ - LEFT
   60 IF( J-17) 70,120,120
   70 IRIGHT = IRIGHT + 6
   80 IF( IRIGHT - 18 ) 90,90,110
   90 J = INTJ + IRIGHT
  100 IF( J - N2 ) 120,120,30
  110 J = 0
  120 RETURN
      END

*LABEL
CTABPNT
      SUBROUTINE TABPNT (D,ID)
      DIMENSION D(1),ID(1),DEFANS(3)
      EQUIVALENCE (SYSTEM(1700),KOM   (1700),KFLAGS(1692),TAPETB(1622))
      EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
     1  POCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
     2              CORTAP( 9),
     3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
```

```
  4  FORTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1))
     DIMENSION SYSTEM(1739)
      COMMON SYSTEM
     COMMON DEFANS,JSUBER
 10  JSUBER= 0
 20  CALL SCHTB (N,D,ID)
 30  IF( N ) 40,330,40
 40  CALL TABDIR (N,ID(1),0.)
 50  B3= D(6) - D(4)*D(N) - D(5)*D(N+1)
 60  IF( B3 ) 80,70,80
 70  DEFANS(1)=D(N)
     DEFANS(2)=D(N+1)
     GO TO 280
 80  F1=D(N+6)-D(N)
     F2=D(N+7)-D(N+1)
     XLSQ=F1*F1+F2*F2
     XL = SQRTF(XLSQ)
     F1=F1/XL
     F2=F2/XL
     B1= D(4)*F1 + D(5)*F2
     B2= D(5)*F1 - D(4)*F2
     F3 = B1 + B2*D(N+4)
     ND=N+7
 90  IF( ABSF(B3)    XL ) 110,110,100
100  D1 = SIGNF(1.,B1*B3)
     GO TO 300
110  IF( F3 ) 120,180,120
120  U = B3/F3
     E = XLSQ/1.E4
130  IF( D(N+3) ) 140,150,140
140  E = MIN1F(1.E-6/ABSF(D(N+3)),E)
150  IF( U*U - E ) 160,160,180
160  V = U*D(N+4)
     GO TO 270
180  IF( ABSF(B2) - 1.E-3 ) 230,230,190
190  D1 = D(N+2)
     D2 = D(N+3)
     D3 = D(N+4) + B1/B2
     D4 = -B3/B2
200  CALL CUBICR (D1,D2,D3,D4,XL)
210  IF( D1 ) 300,220,215
215  IF( D1-2.) 300,325,300
220  U=D2
     GO TO 260
230  U = B3/B1
240  IF( U ) 290,250,250
250  V = U*(U*(U*D(N+2) + D(N+3) ) +D(N+4) )
     DV = U*(U*3.*D(N+2) + 2.*D(N+3) ) + D(N+4)
     U = (B3 - B2*(V-DV*U)) / (B1 + B2*DV)
260  V = U*(U*(U*D(N+2) + D(N+3) ) +D(N+4) )
270  DEFANS(1) = U*F1 - V*F2 + D(N)
     DEFANS(2) = V*F1 + U*F2 + D(N+1)
280  DEFANS(3)=0.
     GO TO 340
290  D1 = -1.
300  CALL TABDIR (N,ID(1),D1)
310  IF( N )320,320,50
320  WRITE OUTPUT TAPE IOUTAP,1000
1000 FORMAT(36HOTABCYL INTERSECTION POINT NOT FOUND)
     GO TO 330
325  WRITE UUIPUT TAPE IOUTAP,1001
1001 FORMAT(26HOCUBICR FAILED TO CONVERGE)
330  JSUBER = 1
340  RETURN
     END
```

```
*FAP
        ENTRY   PERROR
PERROR  SXA     BACK,4
        CALL DESPAT
  BACK  AXT     **,4
        TRA     1,4
        END

*       FAP
*LABEL
*4500       PRTON
        ENTRY   PRTON
 PRTON  CLA*    1,4
        STO     N
        ARS     18
        XCA
        PXD     0,0
        MPY     N6
        XCA
        ADD     ADR
        STA     DO
        SXA     B,4
        CLA*    2,4
        STO     BB
        AXT     0,4
 DO     CLA     0,4
        STO     PRT+5,4
        TXI     *+1,4,1
        TXL     DO,4,5
        CALL    (SPH),PRT
        CALL    (FIL)
        LFTM
        CALL    (SPH),ACC
        LDQ     BB
        STR
        CALL    (FIL)
        LFTM
        LXA     B,4
        TRA     3,4
 B      PZE     0
 BB     PZE     0
 N      PZE     0
 ACC    BCI     6,(19H LENGTH OF TAPE IS I5,6H  FEET)
 N6     OCT     6
 ADR    PZE     E1-1
 PRT    BSS     6
 E1     BCI     6,(30HOPUNCHED TAPE  FOR ROCOGA      )
        BSS     6
        END
```

APPENDIX B

TABLIN LIST

```
*LABEL
CTABLIN
      SUBROUTINE TABLIN
      YFUNCF(X)#X*(X*(X*A+B)+C)
      DERIVF(X)#X*(X*A3+B2)+C
      DIMENSION KOM(1),DEFANS(1),DEFTAB(1),IDFTAB(1),ZSUR(1),D(1),ID(1)
      EQUIVALENCE (DEFANS(331),IDFTAB(1334),DEFTAB(1334),ID(1333),
     1D(1333),ZSUR(172),JSUBER(235),KOM(9834)),(KOM(95),IOUTAP)
      COMMON KOM
   10 N#17
      N1#6*(ID(17)-1)+22
      JSUBER#0
   20 CALL SCHTB (N,D(N1),D(N1+1))
   30 IF( N ) 40,830,40
   40 CALL TABDIR (N,17,0.)
   50 F1#COSF(D(N+5))
      F2#SINF(D(N+5))
      UP#(D(2)-D(N))*F1 + (D(3)-D(N+1))*F2
      VP#(D(3)-D(N+1))*F1 - (D(2)-D(N))*F2
      XLSQ#(D(N+6)-D(N))**2 + (D(N+7)-D(N+1))**2
      XL#SQRTF(XLSQ)
      A#D(N+2)
      B#D(N+3)
      C#D(N+4)
      A3#3.*A
      B2#2.*B
      N1#0
   60 IF( ID(5) - 18 ) 70,200,70
   70 IF( UP + 1.E-5 ) 120,80,80
   80 IF( UP - XL - 1.E-5 ) 90,90,120
   90 VUP#YFUNCF(UP)
  100 IF( ABSF(VUP-VP) - 1.E-5 ) 110,110,120
  110 VP#VUP
      SP#DERIVF(UP)
      U1#UP
      V1#VP
      GO TO 160
  120 D1#2.*A
      D2#B-A3*D(2)
      D3#-2.*D(2)*B
      D4#D(3) - D(2)*C
  130 CALL CUBICR (D1,D2,D3,D4,XL)
  140 IF( D1 ) 800,150,800
  150 U1#D2
      V1#YFUNCF(U1)
      SP#(VP-V1)/(UP-U1)
  160 B2#1./SQRTF(1.+SP*SP)
      A2#-B2*SP
      D2#A2*UP+B2*VP
      GO TO 900
  200 F3#SQRTF(1.+C*C)
      AL#1./F3
      BL#C/F3
```

```
      DL#0.
      FL#AL*UP+BL*VP
  210 IF( FL ) 220,230,230
  220 DI#-1.
      GO TO 810
  230 SB#A*XLSQ - C
      F3#SQRTF(1.+SB*SB)
      AR#1./F3
      BR#SB/F3
      DR#AR*XL
      FR#AR*UP+BR*VP-DR
  240 IF( FR ) 260,260,250
  250 DI#+1.
      GO TO 810
  260 IF( FL ) 270,265,270
  265 A2#AL
      B2#BL
      D2#DL
      GO TO 900
  270 IF( FR ) 280,275,280
  275 A2#AR
      B2#BR
      D2#DR
      GO TO 900
  280 XA#0.
      VA#0.
      SA#C
  290 IF( A ) 310,300,310
  300 IF( B ) 380,305,380
  305 A2#1.
      B2#0.
      D2#UP
      U1#UP
      V1#YFUNCF(U1)
      GO TO 900
  310 X2#-B/A3
  320 IF( X2 ) 380,380,330
  330 IF( X2-XL ) 340,380,380
  340 XB#X2
      VB#YFUNCF(XB)
      SB#DERIVF(XB)
      ARS#AR
      BRS#BR
      DRS#DR
      F3#SQRTF(1.+SB*SB)
      AR#1./F3
      BR#SB/F3
      DR#AR*XB+BR*VB
      FR#AR*UP+BR*VP-DR
  350 IF( FR ) 390,275,370
  370 AL#AR
      BL#BR
      DL#DR
      AR#ARS
      BR#BRS
      DR#DRS
      XA#XB
      VA#VB
      SA#SB
  380 XB#XL
      VB#0.
      SB#DERIVF(XB)
```

```
390 F3#AR*BL-AL*BR
400 IF( F3 ) 410,305,410
410 UC#(BL*DR-BR*DL)/F3
    VC#-(AL*DR-AR*DL)/F3
    UIP#-1.
    PUSTEP#1.E+30
    PASTEP#1.E+30
    AC#AR
    BC#BR
420 DU#UP-UC
    DV#VP-VC
    F3#SQRTF(DU*DU + DV*DV)
430 IF( F3 ) 450,880,450
450 AC#DV/F3
    BC#-DU/F3
460 IF( ABSF(BC) - 1.E-10) 470,470,480
470 U1#UP
    GO TO 530
480 D1#A
    D2#B
    D3#C+AC/BC
    D4#-(AC*UP+BC*VP)/BC
490 CALL CUBICR (D1,D2,D3,D4,XL)
500 IF( D1 ) 505,520,510
505 U1#XA
    GO TO 530
510 IF( D1-2. ) 515,805,515
515 U1#XB
    GO TO 530
520 U1#D2
530 V1#YFUNCF(U1)
    S1#DERIVF(U1)
540 IF( N1 - 2 ) 570,570,545
545 USTEP#ABSF(U1-U1P)
550 IF( USTEP - PUSTEP ) 555,884,884
555 PUSTEP#USTEP
    ASTEP#ABSF(AC*S1-BC)
560 IF( ASTEP-PASTEP ) 565,885,885
565 PASTEP#ASTEP
570 F4#SQRTF(1.+S1*S1)
    U1P#U1
    ACP#AC
    BCP#BC
    AC#1./F4
    BC#S1/F4
    F3#6.*A*U1+B2
580 IF( F3 ) 600,590,600
590 DU#((UP-U1)+S1*(VP-V1))/F4
    U1#U1+DU
    USTEP#ABSF(DU)
    GO TO 545
600 F3#(F4**3)/F3
    UC#U1-BC*F3
    VC#V1+AC*F3
620 N1#N1+1
    IF( N1 - 100 ) 420,640,640
640 WRITE OUTPUT TAPE IOUTAP,1000
1000 FORMAT(33H0TABLINE ROUTINE DID NOT CONVERGE)
    GO TO 820
800 IF( D1-2. ) 810,805,810
```

```
  805 WRITE OUTPUT TAPE IOUTAP,1002
 1002 FORMAT(26H0CUBICR FAILED TO CONVERGE)
      GO TO 820
  810 CALL TABDIR (N,J,DI)
      IF( N ) 50,820,50
  820 WRITE OUTPUT TAPE IOUTAP,1001
 1001 FORMAT(19H0TAB LINE NOT FOUND)
  830 JSUBER#1
      GO TO 999
  880 A2#AC
      B2#BC
      ID(13)#2
      GO TO 890
  884 ID(13)#1
  885 A2#ACP
      B2#BCP
      U1#U1P
      V1#YFUNCF(U1)
  890 D2#A2*UP+B2*VP
  900 DEFANS(1)# A2*F1 - B2*F2
      DEFANS(2)# B2*F1 + A2*F2
      DEFANS(3)# 0.
      DEFANS(4)# D2 + DEFANS(1)*D(N) + DEFANS(2)*D(N+1)
  910 IF( DEFANS(4) ) 920,999,999
  920 DEFANS(1)#-DEFANS(1)
      DEFANS(2)#-DEFANS(2)
      DEFANS(4)#-DEFANS(4)
C 999 RETURN
  999 ID(1)#N1
      D(11)#U1
      D(12)#V1
      RETURN
      END
```

APPENDIX C

INPUT DATA DESCRIPTION

The APT vocabulary which is recognized by the ROCOGA postprocessor from the created CLDATA file is listed in Table C-1.

In addition, two simultaneous TABCYL's must be defined or created by the APT program and system macro. Figures C-1 and C-2 show general flow-charts of the APT program and system macro, respectively.

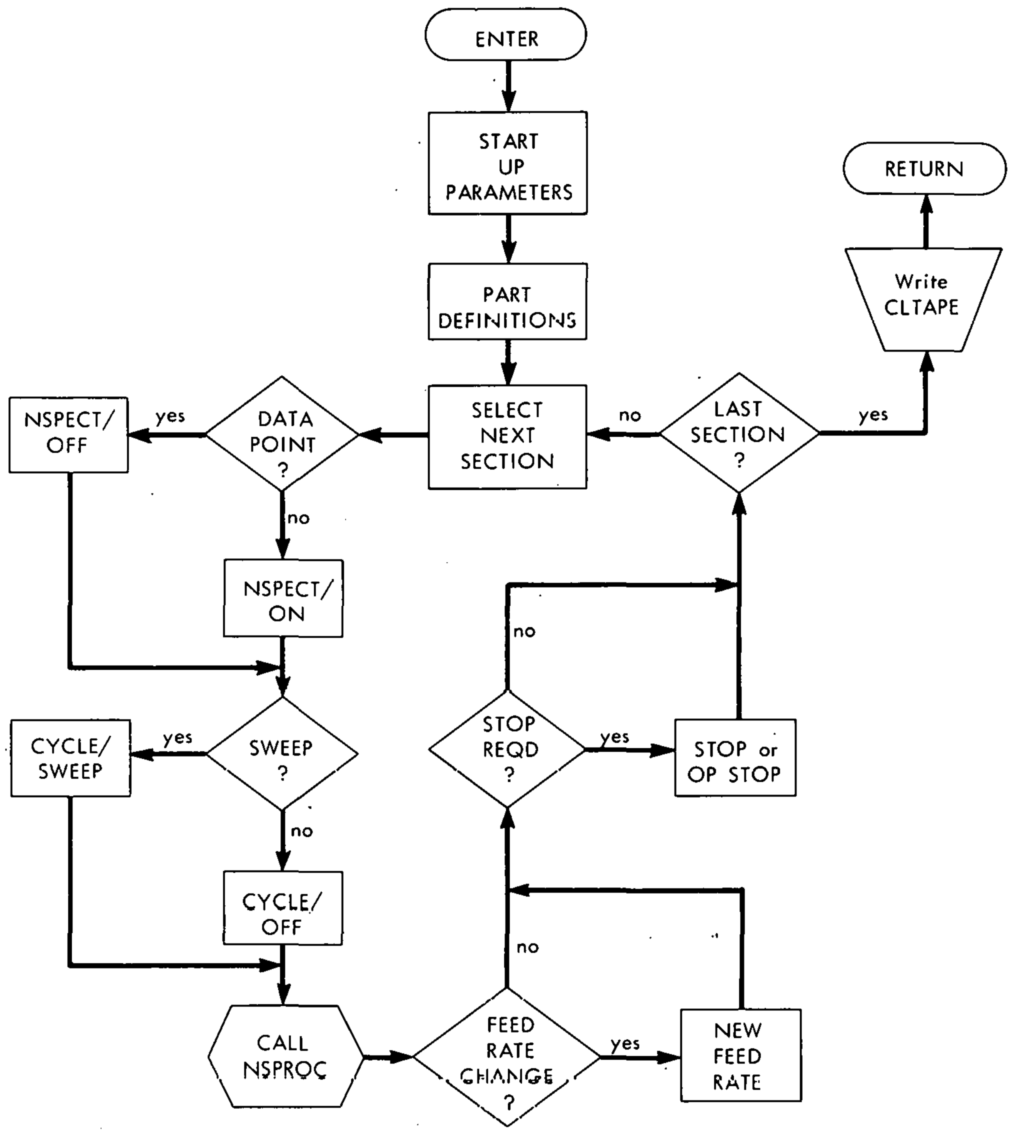


Figure C-1. APT PROGRAM FLOW CHART.

Table C-1

APT VOCABULARY

TAPENO string	CUTTER/n
SPINDL/n	CYCLE/SWEEP, n
FEDRAT/n	CYCLE/OFF
SEQNO/n, INCR, n_2	FINI
OPSTOP	END
STOP	NSPECT/ $\begin{Bmatrix} ON \\ OFF \end{Bmatrix}$
REWIND	LINTOL/n

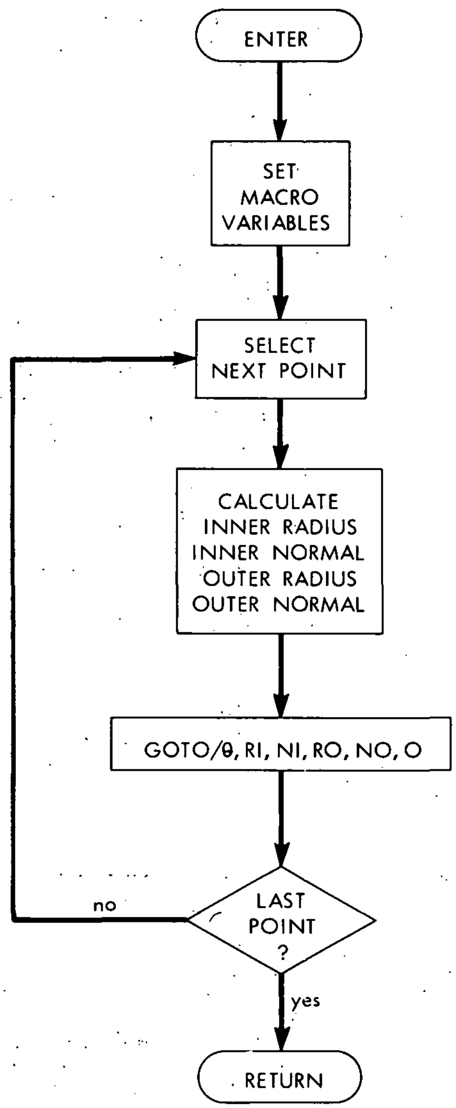


Figure C-2. SYSTEM MACRO.

APPENDIX D

DATA FORMS

The part programmer may assign startup parameters for spindle control, tilt rate, tolerance, and gage ball size by filling in the blanks on a standardized program first page (see Figure D-1). The offsets (designated XOF, YOF, XIF, and YIF on the standard first page) are specified to locate the data origin with respect to the inner and outer contours.

The part is defined in the usual manner, except when defining a TABCYL where a choice of preprinted forms is available (ie, Figures D-2 and D-3). Two types are furnished to allow the part programmer to define the points to be used in either the X-Y or R-θ coordinate systems. Figure D-4 shows the form used to define the TABCYL for the inside contour.

All blanks must be filled, but dummy values can be assigned to any points not required in the TABCYL definition. Only the part of the TABCYL to be inspected needs to be defined. Here, again, the part programmer may make use of a preprinted form and cross off any point not required. After the part programmer decides if data points are desired and determines the proper path to be traversed, the NSPROC macro is called. Following decisions concerning feedrate changes and stops, and after all sections of the contour have been inspected, a CLTAPE is written.

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1 — 6	7	8 — 72	LINE NO. 79 — 80
TAPENØ			01
CHARGE	=		02
			03
MESSAG		BALL (1) DIA (1) ____ (2) REQ (1) ____ (2) REQTR (1)	04
MESSAG		WR (1) ____ (2) BLDG (1) ____ (2) CHECKED (1) BY (1)	05
MESSAG			06
		MACHIN/ , INSP, RØCØGA	07
		ØPTIØN/30, 3	08
		SEQNØ /1, INCR, 1	09
		MULTAX	10
		CUTTER/	11
		SPINDL/	12
		FEDRAT/	13
		LINTØL/	14
		CLPRNT	15
			16
		SYN/P, PØINT, L, LINE, C, CIRCLE, AA, ATANGL, PL, PARLEL, $	17
		XS, XSMALL, XL, XLARGE, YS, YSMALL, YL, YLARGE	18
		WPØ = P/	19
		XØF =	20
		YØF =	21
		XIF =	22
		YIF =	23
		MØ = MATRIX/TRANSL, XØF, YØF, 0	24
		MI = MATRIX/TRANSL, XIF, YIF, 0	25

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Figure D-1. STANDARD FIRST-PAGE FORM.

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1 … 6	7	8 … 72	LINE NO. 79 … 80
			01
		REFSYS/MI	02
			03
		WPTI 0 = PØINT/ ,	04
			05
		WPTI 2 = PØINT/ ,	06
			07
		WPTI 4 = PØINT/ ,	08
			09
		WPTI 6 = PØINT/ ,	10
			11
		WPTI 8 = PØINT/ ,	12
			13
		WPTI 10 = PØINT/ ,	14
			15
		WPTI 12 = PØINT/ ,	16
			17
		WPTI 14 = PØINT/ ,	18
			19
		WPTI 16 = PØINT/ ,	20
			21
		WPTI 18 = PØINT/ ,	22
			23
		WPTI 20 = PØINT/ ,	24
			25

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(12 11-63)

Figure D-2. X-Y TABCYL DATA FORM FOR INSIDE CONTOUR.

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Prepared by________ Date________ 73-76

Checked by________ Date________ Page No. 77-78

1 6	7	8 72	LINE NO. 79 80
			01
		REFSYS/MØ	02
			03
		WPTØ 0 = PØINT/RTHETA, XYPLAN, , 0	04
			05
		WPTØ 2 = PØINT/RTHETA,XYPLAN, , 2	06
			07
		WPTØ 4 = PØINT/RTHETA,XYPLAN, , 4	08
			09
		WPTØ 6 = PØINT/RTHETA,XYPLAN, , 6	10
			11
		WPTØ 8 = PØINT/RTHETA,XYPLAN, , 8	12
			13
		WPTØ 10 = PØINT/RTHETA,XYPLAN, , 10	14
			15
		WPTØ 12 = PØINT/RTHETA,XYPLAN, , 12	16
			17
		WPTØ 14 = PØINT/RTHETA,XYPLAN, , 14	18
			19
		WPTØ 16 = PØINT/RTHETA,XYPLAN, , 16	20
			21
		WPTØ 18 = PØINT/RTHETA,XYPLAN, , 18	22
			23
		WPTØ 20 = PØINT/RTHETA,XYPLAN, , 20	24
			25

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Figure D-3. R-THETA TABCYL DATA FORM FOR OUTSIDE CONTOUR.

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NUMERICAL CONTROL MANUSCRIPT

Prepared by ______ Date ______ 73-76

Checked by ______ Date ______ Page No. ______ 77-78

1 — 6	7	8 — 72	LINE NO. 79 — 80
IC	=	TABCYL/NØZ,SPLINE,$	01
			02
		WPTI0, WPTI2, WPTI4, WPTI6, WPTI8, WPTI10, $	03
			04
		WPTI12, WPTI14, WPTI16, WPTI18, WPTI20, WPTI22, $	05
			06
		WPTI24, WPTI26, WPTI28, WPTI30, WPTI32, WPTI34, $	07
			08
		WPTI36, WPTI38, WPTI40, WPTI42, WPTI44, WPTI46, $	09
			10
		WPTI48, WPTI50, WPTI52, WPTI54, WPTI56, WPTI58, $	11
			12
		WPTI60, WPTI62, WPTI64, WPTI66, WPTI68, WPTI70, $	13
			14
		WPTI72, WPTI74, WPTI76, WPTI78,WPTI80, WPTI82, $	15
			16
		WPTI84, WPTI86, WPTI88, WPTI90	17
			18
			19
			20
			21
			22
			23
			24
			25

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Figure D-4. TABCYL DEFINITION FORM FOR INSIDE CONTOUR.

APPENDIX E

NSPROC - SYSTEM MACRO

NSPROC generates for the CLTAPE the radial distances from the origin to both inner and outer contours at specified angles plus the normals to the curves at those angles. The call statement format is: CALL/NSPROC,WCIN =____, WNSPI = ____, WCOUT = ____, WNSPO = ____, $ WSTA = ____, WENA = ____, WDELA = ____, WXX = XLARGE, WYY = YLARGE

where:

WCIN = Variable name of previously defined inner surface.

WNSPI = Variable name representing type of inner contour.(b)

WCOUT = Variable name of previously defined outer surface.

WNSPO = Variable name representing type of outer contour.(b)

WSTA = Variable name of first angle to be used for calculations.

(b) Re: WNSPI, WNSPO - The variable name representing the type of contour in this unique system macro actually sets up a subroutine which is a macro within a macro. All variables to the inner macro are preset in the general macro. Therefore, the programmer need not be concerned with the workings of the subroutines. Permissible modifiers for WNSPI and WNSPO are: NSPT, NSPLN, NSPCR, NSPCN, NSPTBI, and NSPTBO, defined as:

NSPT selects the point subroutine.

NSPLN selects the line subroutine.

NSPCR selects the circle subroutine.

NSPCN selects the quadric subroutine.

NSPTBI selects the inner TABCYL subroutine.

NSPTBO selects the outer TABCYL subroutine.

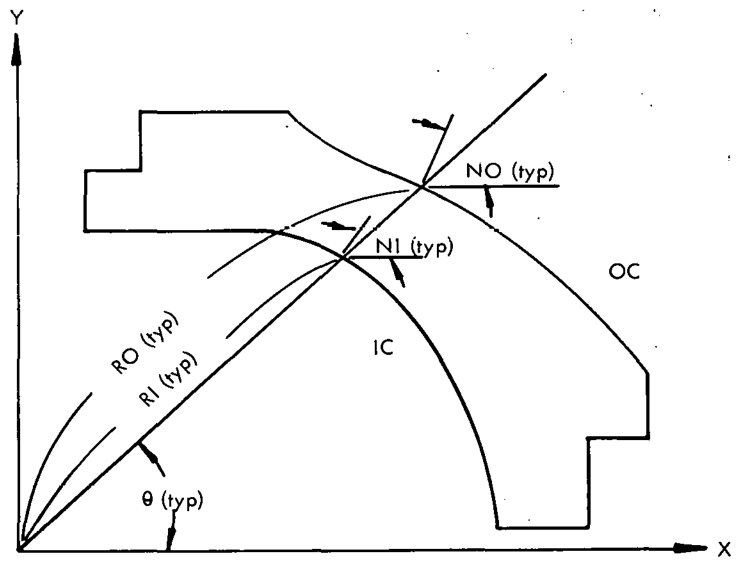
WENA = Variable name of last angle to be used for calculations.

WDELA = Variable name of angle increment to be used for calculations.

WXX = Variable name to designate type of intersection between radial line and contour up to 45 degrees. Permissible modifiers are XLARGE and XSMALL. The normal setting is XLARGE.

WYY = Variable name to designate type intersection between radial line and contour from 45 to 90 degrees. Permissible modifiers are YLARGE and YSMALL. The normal setting is YLARGE.

EXAMPLE:



CALL/NSPROC,WCIN = IC,WNSPI = NSPCR,$

WCOUT = OC,WNSPO = NSPCN,WSTA = 30,$

WENA = 60,WDELA = 10

Execution of the macro by the call statement in the preceding example would output data in the form:

GOTO/θ,RI,NI,RO,NO,0

at 10-degree intervals for a part that is a surface of revolution about the Y axis and has a spherical surface on the inside and an elliptical surface on the outside within the area between 30 and 60 degrees.

The direction of inspection is optional. A negative WDELA angle will inspect from pole to equator. A new call statement is required each time either contour changes types.

The listing of NSPROC is as follows:

```
TAPENO ROCOGA REPORT LIST                WRH
$$      ROCOGA SYSTEM MACROS
NSPLN #MACRO/WC.WR.WN .WX.WY .WTHT
       WR#LNTHF((VECTOR/(POINT/0.0).(POINT/$
       INTOF.(LINE/(POINT/0.0).ATANGL.$
       WTHT).WC)))
       WN#ANGLF((LINE/(POINT/INTOF.$
       (LINE/(POINT/0.0).ATANGL.WTHT).WC).PERPTO.WC))
       TERMAC
NSPCR #MACRO/WC.WR.WN .WX.WY .WTHT
       IF(WTHT-45)WCR1.WCR1.WCR2
WCR1)  WR#LNTHF((VECTOR/(POINT/0.0).$
       (POINT/WX.INTOF.(LINE/$
       (POINT/0.0).ATANGL.WTHT).WC)))
       WN#ANGLF((LINE/(POINT/CENTER.$
       WC).(POINT/WX.INTOF.(LINE/$
       (POINT/0.0).ATANGL.WTHT).WC)))
       JUMPTO/WCR3
WCR2)  WR#LNTHF((VECTOR/(POINT/0.0).$
       (POINT/WY.INTOF.(LINE/$
       (POINT/0.0).ATANGL.WTHT).WC)))
       WN#ANGLF((LINE/(POINT/CENTER.$
       WC).(POINT/WY.INTOF.(LINE/$
       (POINT/0.0).ATANGL.WTHT).WC)))
WCR3)  IF(WN)WCR7.WCR7.WCR4
WCR4)  IF(WN-180)WCR6A.WCR5.WCR7
WCR6A) IF(WN-100)WCR7.WCR7.WCR6
WCR5)  WN#0
       JUMPTO/WCR7
WCR6)  WN#WN-180
WCR7)  CLPRNT
        TERMAC
NSPCN #MACRO/WC.WR.WN.WX.WY .WTHT
       IF(WTHT-45)WCN1.WCN1.WCN2
WCN1)  WR#LNTHF((VECTOR/(POINT/0.0).$
       (POINT/WX.INTOF.(LINE/$
       (POINT/0.0).ATANGL.WTHT).WC)))
       OBTAIN.POINT/(POINT/WX.$
       INTOF.(LINE/(POINT/0.0).ATANGL.$
       WTHT).WC).WX1.WY1
       JUMPTO/WCN3
WCN2)  WR#LNTHF((VECTOR/(POINT/0.0).$
       (POINT/WY.INTOF.(LINE/$
       (POINT/0.0).ATANGL.WTHT).WC)))
       OBTAIN.POINT/(POINT/WY.$
       INTOF.(LINE/(POINT/0.0).ATANGL.$
       WTHT).WC).WX1.WY1
WCN3)  OBTAIN.QADRIC/WC.WA.WB..WD...WH.WP.WQ.
       WN#ATANF((WB*WY1+(2*WH)*WX1+($
       2*WQ))/(WA*WX1+(2*WH)*WY1+($
       2*WP)))
       IF(WTHT-45)WCN4.WCN4.WCN6
WCN4)  IF(WN)WCN9.WCN5.WCN9
WCN5)  WN#0
       JUMPTO/WCN9
WCN6)  IF(WN)WCN8.WCN7.WCN9
WCN7)  WN#90
       JUMPTO/WCN9
```

```
WCN8)   WN#180+WN
WCN9)   CLPRNT
        TERMAC
NSPTBO#MACRO/WC.WR.WN.WX.WY .WTHT
        WPT#POINT/CANON.0.0.0
        OBTAIN.POINT/WPTO84.WXO84.WYO84
        OBTAIN.POINT/WPTO72.WXO72.WYO72
        OBTAIN.POINT/WPTO60.WXO60.WYO60
        OBTAIN.POINT/WPTO48.WXO48.WYO48
        OBTAIN.POINT/WPTO36.WXO36.WYO36
        OBTAIN.POINT/WPTO24.WXO24.WYO24
        OBTAIN.POINT/WPTO12.WXO12.WYO12
        OBTAIN.POINT/WPTOO.WXOO.WYOO
        IF((ANGLF((VECTOR/WPO.WPTO78)))-WTHT)WTO1.WTO2.WTO2
WTO1)   WPT#POINT/WPT.CANON.WXO84.WYO84
        JUMPTO/WTO16
WTO2)   IF((ANGLF((VECTOR/WPO.WPTO66)))-WTHT)WTO3.WTO4.WTO4
WTO3)   WPT#POINT/WPT.CANON.WXO72.WYO72
        JUMPTO/WTO16
WTO4)   IF((ANGLF((VECTOR/WPO.WPTO54)))-WTHT)WTO5.WTO6.WTO6
WTO5)   WPT#POINT/WPT.CANON.WXO60.WYO60
        JUMPTO/WTO16
WTO6)   IF((ANGLF((VECTOR/WPO.WPTO42)))-WTHT)WTO7.WTO8.WTO8
WTO7)   WPT#POINT/WPT.CANON.WXO48.WYO48
        JUMPTO/WTO16
WTO8)   IF((ANGLF((VECTOR/WPO.WPTO30)))-WTHT)WTO9.WTO10.WTO10
WTO9)   WPT#POINT/WPT.CANON.WXO36.WYO36
        JUMPTO/WTO16
WTO10)  IF((ANGLF((VECTOR/WPO.WPTO18)))-WTHT)WTO11.WTO12.WTO12
WTO11)  WPT#POINT/WPT.CANON.WXO24.WYO24
        JUMPTO/WTO16
WTO12)  IF((ANGLF((VECTOR/WPO.WPTO6)))-WTHT)WTO13.WTO14.WTO14
WTO13)  WPT#POINT/WPT.CANON.WXO12.WYO12
        JUMPTO/WTO16
WTO14)  WPT#POINT/WPT.CANON.WXOO.WYOO
WTO16)  WR#LNTHF((VECTOR/(POINT/0.0).(POINT/$
        INTOF.(LINE/(POINT/0.0).ATANGL.$
        WTHT).WC .WPT)) )
        WN#ANGLF((LINE/(POINT/INTOF.$
        (LINE/(POINT/0.0).ATANGL.WTHT).$
        WC.WPT).PERPTO.WC.WPT))
        TERMAC
NSPTBI#MACRO/WC.WR.WN.WX.WY .WTHT
        WPT#POINT/CANON.0.0.0
        OBTAIN.POINT/WPTI84.WXI84.WYI84
        OBTAIN.POINT/WPTI72.WXI72.WYI72
        OBTAIN.POINT/WPTI60.WXI60.WYI60
        OBTAIN.POINT/WPTI48.WXI48.WYI48
        OBTAIN.POINT/WPTI36.WXI36.WYI36
        OBTAIN.POINT/WPTI24.WXI24.WYI24
        OBTAIN.POINT/WPTI12.WXI12.WYI12
        OBTAIN.POINT/WPTIO.WXIO.WYIO
        IF((ANGLF((VECTOR/WPO.WPTI78)))-WTHT)WTI1.WTI2.WTI2
WTI1)   WPT#POINT/WPT.CANON.WXI84.WYI84
        JUMPTO/WTI16
WTI2)   IF((ANGLF((VECTOR/WPO.WPTI66)))-WTHT)WTI3.WTI4.WTI4
WTI3)   WPT#POINT/WPT.CANON.WXI72.WYI72
        JUMPTO/WTI16
WTI4)   IF((ANGLF((VECTOR/WPO.WPTI54)))-WTHT)WTI5.WTI6.WTI6
WTI5)   WPT#POINT/WPT.CANON.WXI60.WYI60
        JUMPTO/WTI16
WTI6)   IF((ANGLF((VECTOR/WPO.WPTI42)))-WTHT)WTI7.WTI8.WTI8
WTI7)   WPT#POINT/WPT.CANON.WXI48.WYI48
        JUMPTO/WTI16
WTI8)   IF((ANGLF((VECTOR/WPO.WPTI30)))-WTHT)WTI9.WTI10.WTI10
WTI9)   WPT#POINT/WPT.CANON.WXI36.WYI36
        JUMPTO/WTI16
WTI10)  IF((ANGLF((VECTOR/WPO.WPTI18)))-WTHT)WTI11.WTI12.WTI12
WTI11)  WPT#POINT/WPT.CANON.WXI24.WYI24
        JUMPTO/WTI16
```

```
WTI12) IF((ANGLF((VECTOR/WPO,WPTI6)))-WTHT)WTI13,WTI14,WTI14
WTI13) WPT#POINT/WPT,CANON,WXI12,WYI12
       JUMPTO/WTI16
WTI14) WPT#POINT/WPT,CANON,WXI0,WYI0
WTI16) WR#LNTHF((VECTOR/(POINT/0,0),(POINT/$
       INTOF,(LINE/(POINT/0,0),ATANGL,$
       WTHT),WC ,WPT)) )
       WN#ANGLF((LINE/(POINT/INTOF,$
       (LINE/(POINT/0,0),ATANGL,WTHT),$
       WC,WPT),PERPTO,WC,WPT))
       TERMAC
NSPROC#MACRO/WCIN,WNSPI,WCOUT,WNSPO,WSTA,$
       WENA,WDELA,WXX#XLARGE,WYY#YLARGE
       WTHTM#WSTA
WRC1)  CALL/WNSPO,WC#WCOUT,WR#WRO,WN#WNO,$
       WX#WXX,WY#WYY,WTHT#WTHTM
       CALL/WNSPI,WC#WCIN,WR#WRI,WN#WNI,$
       WX#WXX,WY#WYY,WTHT#WTHTM
       GOTO/WTHTM,WRI,WNI,WRO,WNO,0
       WTHTM#WTHTM+WDELA
       IF(WENA-WSTA)WRC3,WRC4,WRC2
WRC2)  IF(WENA-WTHTM)WRC4,WRC1,WRC1
WRC3)  IF(WTHTM-WENA)WRC4,WRC1,WRC1
WRC4)  CLPRNT
       TERMAC
```