

NASA Contractor Report 191009

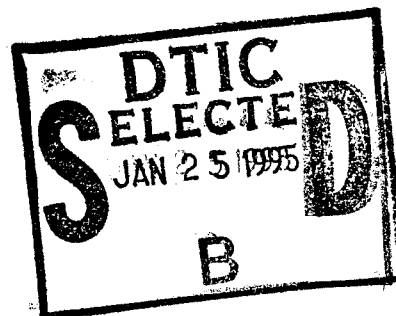
Army Research Laboratory
Contractor Report ARL-CR-121

Manual for Automatic Generation of Finite Element Models of Spiral Bevel Gears in Mesh

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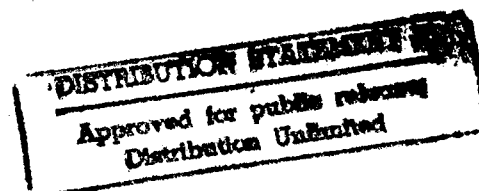
April 1994

Prepared for
Lewis Research Center
Under Grant NAG3-1476



National Aeronautics and
Space Administration

19950123 081



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INTRODUCTION

ABSTRACT

The goal of this research is to develop computer programs that generate finite element models suitable for doing 3D contact analysis of faced milled spiral bevel gears in mesh. A pinion tooth and a gear tooth are created and put in mesh.

There are two programs:

1. Points.f
2. Pat.f

Points.f is based on the equation of meshing for spiral bevel gears. It uses machine tool settings to solve for an $N \times M$ mesh of points on the four surfaces; pinion concave and convex, and gear concave and convex. Points.f creates the file POINTS.OUT, an ASCII file containing $N \times M$ points for each surface. (N is the number of node points along the length of the tooth, and M is nodes on the height.)

Pat.f reads POINTS.OUT and creates the file t1.out. T1.out is a series of PATRAN input commands. In addition to the mesh density on the tooth face, additional user specified variables are the number of finite elements through the thickness, and the number of finite elements along the tooth full fillet. A full fillet is assumed to exist for both the pinion and gear.

This report is based on the theory presented in Army Research Laboratory Report ARL-TR-158 "Contact Stress Analysis of Spiral Bevel Gears Using Nonlinear Finite Element Static Analysis" by G.D. Bibel, A. Kumar and S. Reddy; and AVSCOM Technical Report 91-C-020 "A Method for Determining Spiral-Bevel Gear Tooth Geometry for Finite Element Analysis" by R. F. Handschuh and F. L. Litvin.

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SUMMARY

The goal of this research is to develop computer programs that generate finite element models suitable for doing 3D contact analysis of faced milled spiral bevel gears in mesh. A pinion tooth and a gear tooth are created and put in mesh.

There are two programs:

1. Points.f
2. Pat.f

Points.f is based on the equation of meshing for spiral bevel gears. It uses machine tool settings to solve for an $N \times M$ mesh of points on the four surfaces; pinion concave and convex, and gear concave and convex. Points.f creates the file POINTS.OUT, an ASCII file containing $N \times M$ points for each surface. (N is the number of node points along the length of the tooth, and M is nodes on the height.)

NOTE: For Unix based systems, the program titles are case sensitive. All titles are lower case except POINTS.OUT.

Pat.f reads POINTS.OUT and creates the file t1.out. T1.out is a series of PATRAN input commands. In addition to the mesh density on the tooth face, additional user specified variables are the number of finite elements through the thickness, and the number of finite elements along the tooth full fillet. A full fillet is assumed to exist for both the pinion and gear.

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The following topics are covered in this report:

1. A description of the detailed procedure for generating a finite element model.
2. Instructions for inserting the data.
3. A numerical example of input and output.
4. A listing of the programs.
5. Sample plots.

Finite element analysis of spiral bevel gears can be used to determine contact stresses, bending stresses, stiffness for dynamic analysis, load sharing, contact area, and thermal gradients.

PROCEDURE

1. Prepare the input data for points.f (described elsewhere in this report) for the pinion.
2. Compile and execute points.f
3. During the execution of points.f, the user is prompted for the desired N x M mesh.
4. Execution of points.f creates the file POINTS.OUT. This file will contain N x M points on the pinion concave surface and N x M points on the pinion convex surface. (2 x N x M total points)
5. Prepare the input data for model.f (described elsewhere in this report) for the pinion.
6. Compile and execute model.f.
7. During the execution of model.f, the user is prompted for the desired N x M mesh. These values must be the same used in step 3 above. The user is also prompted for the number of finite elements through the tooth thickness (this must be an even number), and the number of finite elements along the length of 1/2 of the full fillet. Trial and error may be required to obtain finite elements with appropriate aspect ratios.
8. Execution of model.f creates t1.out. This file is suitable for direct input into PATRAN ver 2.5.

NOTE: An 8 x 6 mesh is suggested as a practice mesh. Accuracy is affected with coarser meshes. (The increment is too large for the numerical solution)

NUMERICAL EXAMPLE (SUMMARY)

A 8 x 6 mesh with 4 elements through the tooth thickness and 4 elements in the fillet region will be used as an example.

1. The input data is as shown in the section INPUT DATA: POINTS.F
2. Attachment 1 shows the output from points.f (i. e. the file POINTS.OUT). This file is the X, Y, and Z coordinates of the N x M mesh of points on the four surfaces.
3. The input data from the next step is as shown in the section INPUT DATA: PAT.F
4. Attachment 2 shows the output from Pat.f (i. e. the file t1.out).
5. Attachment 3 shows a typical PATRAN plot after reading t1.out.

INPUT DATA: Points.f

The input data for Points.f is as shown below. (The input data occurs inside of points.f) Each input variable is self explanatory or explained in detail in the reference reports.

The initial guess is very sensitive. The solution technique may converge on another surface if the initial guess is too far from the correct solution.

```
C
C
C
C
C
C-----
C-----
C          DESCRIPTION OF INPUT DATA
C-----
C
C
C          1) RADIUS OF CUTTER, INCHES          (R)
C          2) CRADLE ANGLE, DEGREES            (Q)
C          3) BLADE ANGLE, DEGREES            (PSI)
C          4) CRADLE TO CUTTER DISTANCE, INCHES (S)
C          5) RATIO OF ROLL                    (MCW)
C          6) MACHINE OFFSET, INCHES          (EM)
C          7) VECTOR SUM, INCHES              (LM)
C          8) DEDENDUM ANGLE, DEGREES         (DEDEN)
C          9) PITCH ANGLE, DEGREES           (MU)
C          10) ADDENDUM ANGLE, DEGREES        (ADDAN)
C          11) CLEARANCE, INCHES             (CL)
C          12) MEAN CONE DISTANCE, INCHES     (RL)
C          13) FACE WIDTH, INCHES            (FW)
C          14) INITIAL GUESS FOR SURFACE COORDINATE U ( U(1) )
C          15) INITIAL GUESS FOR SURFACE COORDINATE THETA ( THETA(1) )
C          16) INITIAL GUESS FOR ANGLE OF CRADLE, DEGREES ( PHIC(1) )
C-----
C          INSERT CONCAVE SIDE OF PINION DATA BELOW
C-----
C
C
C          R          = 2.96562137806
C          Q          = 63.9420304635 * PI/180.0
C          PSI        = 161.954330248 * PI/180.0
C          S          = 2.94780202969
C          MCW        = 0.30838512709
```



```

EM      = 0.154575896
LM      = 0.0384999977874
DEDEN   = 1.56666666 * pi/180
MU      = 18.4333333 * pi/180
ADDAN   = 3.8833334 * pi/180
CL      = 0.03
RL      = 3.191
FW      = 1.0
U(1)    = 9.59703
THETA(1) = 126.83544 * PI/180.0
PHIC(1) = -0.85813 * PI/180.0

```

C

ELSEIF (INT .EQ. 2) THEN

C

INSERT CONVEX SIDE OF PINION DATA BELOW

C

```

R      = 3.071306157
Q      = 53.9259945467 * PI/180.0
PSI    = 24.337423854 * PI/180.0
S      = 2.80104946
MCW    = 0.3220428536
EM     = -0.17426159493
LM     = -0.0518138227
DEDEN  = 1.56666666 * pi/180
MU     = 18.4333333 * pi/180
ADDAN  = 3.8833334 * pi/180
CL     = 0.03
RL     = 3.191
FW     = 1.0
U(1)   = 7.42534
THETA(1) = 124.43689 * PI/180.0
PHIC(1) = -11.38663 * PI/180.0

```

C

ELSEIF (INT .EQ. 3) THEN

C

INSERT CONCAVE SIDE OF GEAR DATA BELOW

C

```

R      = 3.0325
Q      = 59.2342023 * PI/180.0
PSI    = 158.0 * PI/180.0
S      = 2.85995004691
MCW    = 0.9508646
EM     = 0.0
LM     = 0.0
DEDEN  = 3.8833333333 * pi/180
MU     = 71.5666666 * pi/180
ADDAN  = 1.5666666 * pi/180
CL     = 0.0366
RL     = 3.191
FW     = 1.0
U(1)   = 8.12602
THETA(1) = 233.98994 * PI/180.0
PHIC(1) = -0.35063 * PI/180.0

```

C

C

C

C

C

ELSE

C

C

INSERT CONVEX SIDE OF GEAR DATA BELOW

C

R = 2.9675
Q = 59.2342023 * PI/180.0
PSI = 22.0 * PI/180.0
S = 2.85995004691
MCW = 0.9508646
EM = 0.0
LM = 0.0
DEDEN = 3.8833333333 * pi/180
MU = 71.5666666 * pi/180
ADDAN = 1.5666666 * pi/180
CL = 0.0366
RL = 3.191 *
FW = 1.0
U(1) = 7.89156 *
THETA(1) = 234.95451 * PI/180.0
PHIC(1) = -12.3384 * PI/180.0

INPUT DATA: Pat. f.

The input data for Model.f is as shown below. Some of the data is redundant with Points.f The new variables are as follows:

1. "ROTCON". ROTCON is the rotation of each convex surface required to obtain the desired top land thickness.
2. "ROTINT". ROTINT is the rotation of the pinion required to eliminate interference with the gear.
3. "ROGEAR". ROGEAR is the rotation of the gear required to place the gear in mesh with the pinion. For the general case, the gear tooth is rotated $360/(\text{Number of gear teeth}) + 180$ degrees CW about the Z axis (the gear's axis of rotation).

```
C
C-----
C              DESCRIPTION OF INPUT DATA FOR PINION
C-----
C
C      1. DEDENDUM, DEGREES                (DEDEN)
C      2. PITCH ANGLE, DEGREES            (MU)
C      3. ROTATION OF CONVEX SURFACE TO
C          CREATE TOP LAND                (ROTCON)
C      4. ROTATION OF PINION TO ELIMINATE
C          INTERFERENCE                    (ROTINT)
C      5. PINION ID, INCHES                (RI)
C      6. CLEARANCE, INCHES               (CL)
C      7. NUMBER OF PINION TEETH          (NTPIN)
C-----
C
C-----
C              INPUT THE PINION DATA BELOW
C-----
C      DEDEN = 1.56666666 * PI/180.0
C      MU    = 18.43333333 * PI/180.0
C      ROTCON = 2.275
C      ROTINT = -3.56
C      RI    = 0.609375
C      CL    = 0.03
C      NTPIN = 12
C-----
```

```

C
C
C
ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
C
C
C-----
C   DESCRIPTION OF INPUT DATA FOR THE GEAR
C-----
C
C       1. DEDENDUM, DEGREES           (DEDEN)
C       2. PITCH ANGEL, DEGREES       (MU)
C       3. ROTATION OF CONVEX SURFACE TO
C           CREATE TOP LAND           (ROTCON)
C       4. ROTATION OF GEAR TO PUT IN MESH (ROGEAR)
C       5. CLEARANCE, INCHES *        (CL)
C       6. ID OF GEAR BASE             (R1)
C       7. OD OF GEAR BASE             (R2)
C       8. NUMBER OF GEAR TEETH       (NTGE)
C-----
C
C-----
C           INPUT THE GEAR DATA BELOW
C-----
C           DEDEN = 3.883333333 * PI/180.0
C           MU    = 71.56666666 * PI/180.0
C           ROTCON = -8.49
C           ROGEAR = 190.0
C           CL    = 0.0366
C           R1    = 2.375
C           R2    = 3.250
C           NTGE  = 36
C-----
C

```

OUTPUT FROM POINTS.F

X	Y	Z
0.7948185893337920	0.1518771876505158	2.565573009266192
0.8343433613077650	0.1745810495998836	2.552471190313917
0.8720324096583479	0.2042199804427480	2.539369371362535
0.9077908578945182	0.2394490290397444	2.526267552535221
0.9414155876464360	0.2795805696115394	2.513165735668416
0.9726798641190831	0.3241375989552031	2.500063936000037
0.8472371339193625	7.6106029221588933E-02	2.702284801203873
0.8913330776440134	9.5839030874127040E-02	2.688392059145086
0.9342070276559395	0.1231797235370555	2.674499317051919
0.9756155352323542	0.1566714188085960	2.660606575085474
1.015268047213935	0.1955944000191652	2.646713837702351
1.052870943839311	0.2394597732991732	2.632821147263364
0.8920544861387928	-8.7977041450044701E-03	2.838996593145300
0.9405003839933272	7.3083519719827627E-03	2.824312928070127
0.9884537411081434	3.1630276922439470E-02	2.809629262838540
1.035498881976111	6.2620579641409435E-02	2.794945597192247
1.081249167998568	9.9539397524525785E-02	2.780261940615036
1.125338129677023	0.1418941391352297	2.765578408798671
0.9279228340072788	-0.1023212288383641	2.975708385187462
0.9804198623141954	-9.0488151985839593E-02	2.960233797221159
1.033263802256655	-6.9914280082028490E-02	2.944759208992080
1.085845886896256	-4.2211242335634668E-02	2.929284618267694
1.137675976466795	-8.1252212097733256E-03	2.913810043739986
1.188306404191815	3.1855424697372125E-02	2.898335812878913
0.9534599334795802	-0.2037951651625605	3.112420178263912
1.009630926058035	-0.1968645393407975	3.096154666768726
1.067089798650322	-0.1807700720952332	3.079889156026669
1.125017872008955	-0.1571554097480132	3.063623637059750
1.182815359830648	-0.1267574497917443	3.047358144908540
1.239934504589937	-9.0054618527663610E-02	3.031093686081570
0.9672556523581568	-0.3123758786108948	3.249131977522822
1.026644599586983	-0.3109539641202601	3.232075536925217
1.088352545835276	-0.3000651176158047	3.215019104897882
1.151339425325948	-0.2813479710083238	3.197962650909841
1.214890364286590	-0.2555128377780433	3.180906240112322
1.278297192284771	-0.2230290530267571	3.163853372103641
0.9678796662918135	-0.4270252087603694	3.385843803228283
1.029951520163903	-0.4316883253646147	3.367996407956596
1.095449239626837	-0.4267184461595268	3.350149057378801
1.163106632451191	-0.4137081339625599	3.332301654167603
1.232086458109564	-0.3933218937462701	3.314454332645862
1.301293568935084	-0.3660335888044650	3.296621207705554
0.9538905193238456	-0.5464866609459378	3.522557203760676
1.018031477753651	-0.5577745718372567	3.503917280198983
1.086763175986946	-0.5594158588267257	3.485279016743563
1.158596913336253	-0.5529133643964257	3.466640634659134
1.232554428724539	-0.5388625992810234	3.448002511532153
1.306217203742137	-0.5177479993723693	3.429430372498238
0.7093463178422439	0.3893983454546772	2.565573009266191
0.7570852600711056	0.3917005187907718	2.552471190313766
0.8073029755824992	0.3878249981807325	2.539369371359211
0.8593909679113807	0.3779778338261695	2.526267552392368
0.9128138134481132	0.3622148457047225	2.513165733397398
0.9670614194895887	0.3405352495955354	2.500063914362740
0.7805547654008799	0.3381377633245926	2.702284801203850
0.8313192150683369	0.3355117554273983	2.688392059127966
0.8840811061706690	0.3260622820926806	2.674499317054876
0.9382129090097685	0.3100453874934890	2.660606574980783
0.9931445219848133	0.2875595701230784	2.646713832903523
1.048324166687691	0.2586450939788132	2.632821090805444
0.8483132970638206	0.2760491911215923	2.838996593141508
0.9015956233205106	0.2678053743188284	2.824312927885464
0.9562796868411379	0.2521317789571000	2.809629262692835
1.011723722807169	0.2293346362776858	2.794945597542682
1.067325789653079	0.1995595783460700	2.780261932355890
1.122494542284766	0.1628943693243237	2.765578267158041

0.9112000448284689	0.2030391581389535	2.975708385079163
0.9663724749316263	0.1885085186004414	2.960233796271262
1.022236225128360	0.1659976000986125	2.944759207797051
1.078139321839011	0.1358626773835785	2.929284619894748
1.133450935693196	9.8300989821880069E-02	2.913810031777249
1.187542779161388	5.3454488313127157E-02	2.898335443486139
0.9676895991379796	0.1191435063835695	3.112420177016817
1.023995422930553	9.7691650985565203E-02	3.096154663323241
1.080168552957352	6.7782050056511611E-02	3.079889150748298
1.135549961729417	2.9820889650890691E-02	3.063623641171534
1.189482972857256	-1.5938341746537521E-02	3.047358130942706
1.241305512978413	-6.9292504478944305E-02	3.031092619792399
1.016149494629492	2.4546941529382415E-02	3.249131968954469
1.072693870906420	-4.4094230428219916E-03	3.232075526708658
1.128170570501692	-4.2209828439173868E-02	3.215019087512731
1.181915774012974	-8.8397895323604203E-02	3.197962659109970
1.233250099226129	-0.1426588841462646	3.180906229149712
1.281481427875818	-0.2047210348378159	3.163849795972270
1.054836149594651	-8.0393756502517454E-02	3.385843760892120
1.110576450723173	-0.1173673033750138	3.367996381370604
1.164207315546032	-0.1634608596042426	3.350149009219072
1.215061572522443	-0.2181667004477261	3.332301668710605
1.262440437691158	-0.2811032336663852	3.314454324809642
1.305626160434559	-0.3519220612269351	3.296606971745099
1.081890093168536	-0.1951217417487592	3.522555552829777
1.135625698876967	-0.2405311921112059	3.503917217031341
1.186109140444834	-0.2952059400453120	3.485278897558544
1.232670689693987	-0.3585843827438959	3.466640659723548
1.274595758431425	-0.4302115809299476	3.448002414715995
1.311146184992092	-0.5096536842811183	3.429364146542768
2.474433967420987	-0.3395653327372070	0.9856358798469023
2.487839996829133	-0.3593061900500794	0.9465879479135923
2.500980732115327	-0.3799719362136913	0.9075400160259967
2.513847962185435	-0.4014972153625989	0.8684920851879474
2.526433333215689	-0.4238257450684864	0.8294441631803695
2.538728501263516	-0.4469082097766504	0.7903962834276070
2.615744367457404	-0.2713527297527838	1.039882343666109
2.630668874615893	-0.2921776971646133	0.9983126342013517
2.645336856855221	-0.3140021877370152	0.9567429270473953
2.659736900244837	-0.3367554455147062	0.9151732405016411
2.673857752554951	-0.3603767778219593	0.8736036480711737
2.687688379068866	-0.3848131384418187	0.8320343503411255
2.755122082966633	-0.1939252488334882	1.094128807487018
2.771646356120490	-0.2158264544757134	1.050037320781535
2.787926437149529	-0.2388005015425003	1.005945850025553
2.803947251406170	-0.2627715238015491	0.9618544915078790
2.819694200468521	-0.2876746263983043	0.9177635422435383
2.835153088849297	-0.3134531506865259	0.8736736400533243
2.892115805626759	-0.1070309492253978	1.148375271344924
2.910326750723583	-0.1300043557812005	1.101762007915943
2.928309186669705	-0.1541221288023844	1.055148803591732
2.946043871332245	-0.1793036410217184	1.008535978909207
2.963512305696952	-0.2054800085262900	0.9619243699325180
2.980696572015054	-0.2325910821084665	0.9153154443440815
3.026234802111897	-1.0397603116659048E-02	1.202621735548316
3.046226387571472	-3.4443711328922432E-02	1.153486695724431
3.066008199637873	-5.9703409974563026E-02	1.104351817871708
3.085556228980730	-8.6091707633022540E-02	1.055217942501711
3.104847356582463	-0.1135359377283138	1.006086988192335
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PATCH,	38, QUAD,,	45/	46/	94/	93
PATCH,	39, QUAD,,	46/	47/	95/	94
PATCH,	40, QUAD,,	47/	48/	96/	95
HPAT,	1,2P,,	1,	6		
HPAT,	2,2P,,	2,	7		
HPAT,	3,2P,,	3,	8		
HPAT,	4,2P,,	4,	9		
HPAT,	5,2P,,	5,	10		
HPAT,	6,2P,,	6,	11		
HPAT,	7,2P,,	7,	12		
HPAT,	8,2P,,	8,	13		
HPAT,	9,2P,,	9,	14		
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 GRID, 203,, 0.609145/ 0.016728/ 2.702285
 LINE, 26,ARC,5(0)/1/ 20.56433, 203
 GRID, 205,, 0.607796/ -0.043834/ 2.838997
 LINE, 27,ARC,5(0)/1/ 20.86543, 205
 GRID, 207,, 0.600388/ -0.104272/ 2.975708
 LINE, 28,ARC,5(0)/1/ 21.12931, 207
 GRID, 209,, 0.586856/ -0.164129/ 3.112420
 LINE, 29,ARC,5(0)/1/ 21.35904, 209
 GRID, 211,, 0.567137/ -0.222920/ 3.249132
 LINE, 30,ARC,5(0)/1/ 21.55671, 211
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 LINE, 33,ARC, 0.80851/ 0.03345/0/ 0.80851/ 0.03345/1.0/ 170.22185, 1
 LINE, 49/ 50,BR,.5, 33
 LINE, 34 ,ARC,0/0/0/0/0/1/ -9.778, 201
 LINE, 81/ 82,BR,.5, 34
 LINE, 65,ST,, 193, 220
 LINE, 97,ST,, 218, 220
 LINE, 105,ST,, 49, 202
 LINE, 113,ST,, 217, 219
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 LINE, 35,ARC, 0.84937/-0.04667/0/ 0.84937/-0.04667/1.0/ 170.56433, 7
 LINE, 51/ 52,BR,.5, 35
 LINE, 36 ,ARC,0/0/0/0/0/1/ -9.436, 203
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 LINE, 99,ST,, 226, 228
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LINE, 39,ARC, 0.90467/-0.23039/0/ 0.90467/-0.23039/1.0/ 171.12931, 19
 LINE, 55/ 56,BR,.5, 39
 LINE, 40 ,ARC,0/0/0/0/0/1/ -8.871, 207
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 LINE, 100,ST,, 230, 232
 LINE, 108,ST,, 67, 208
 LINE, 116,ST,, 229, 231
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 LINE, 41,ARC, 0.91651/-0.33260/0/ 0.91651/-0.33260/1.0/ 171.35904, 25
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 LINE, 42 ,ARC,0/0/0/0/0/1/ -8.641, 209
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 LINE, 101,ST,, 234, 236
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 LINE, 43,ARC, 0.91605/-0.44046/0/ 0.91605/-0.44046/1.0/ 171.55671, 31
 LINE, 59/ 60,BR,.5, 43
 LINE, 44 ,ARC,0/0/0/0/0/1/ -8.443, 211
 LINE, 91/ 92,BR,.5, 44
 LINE, 70,ST,, 198, 240
 LINE, 102,ST,, 238, 240
 LINE, 110,ST,, 79, 212
 LINE, 118,ST,, 237, 239
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 LINE, 46 ,ARC,0/0/0/0/0/1/ -8.276, 213
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 LINE, 71,ST,, 199, 244
 LINE, 103,ST,, 242, 244
 LINE, 111,ST,, 85, 214
 LINE, 119,ST,, 241, 243
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 LINE, 47,ARC, 0.87288/-0.66830/0/ 0.87288/-0.66830/1.0/ 171.85998, 43
 LINE, 63/ 64,BR,.5, 47
 LINE, 48 ,ARC,0/0/0/0/0/1/ -8.140, 215
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 PA, 57,EDGE,, 82/ 113/ 50/ 97
 PA, 42,EDGE,, 12/ 106/ 122/ 66
 PA, 50,EDGE,, 11/ 66/ 98/ 51
 PA, 58,EDGE,, 84/ 114/ 52/ 98
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 PA, 59,EDGE,, 86/ 115/ 54/ 99
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 NAME,PI 1
 SET,ACTIVE,NONE
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 PATCH, 69, QUAD,, 101/ 102/ 150/ 149
 PATCH, 70, QUAD,, 103/ 104/ 152/ 151
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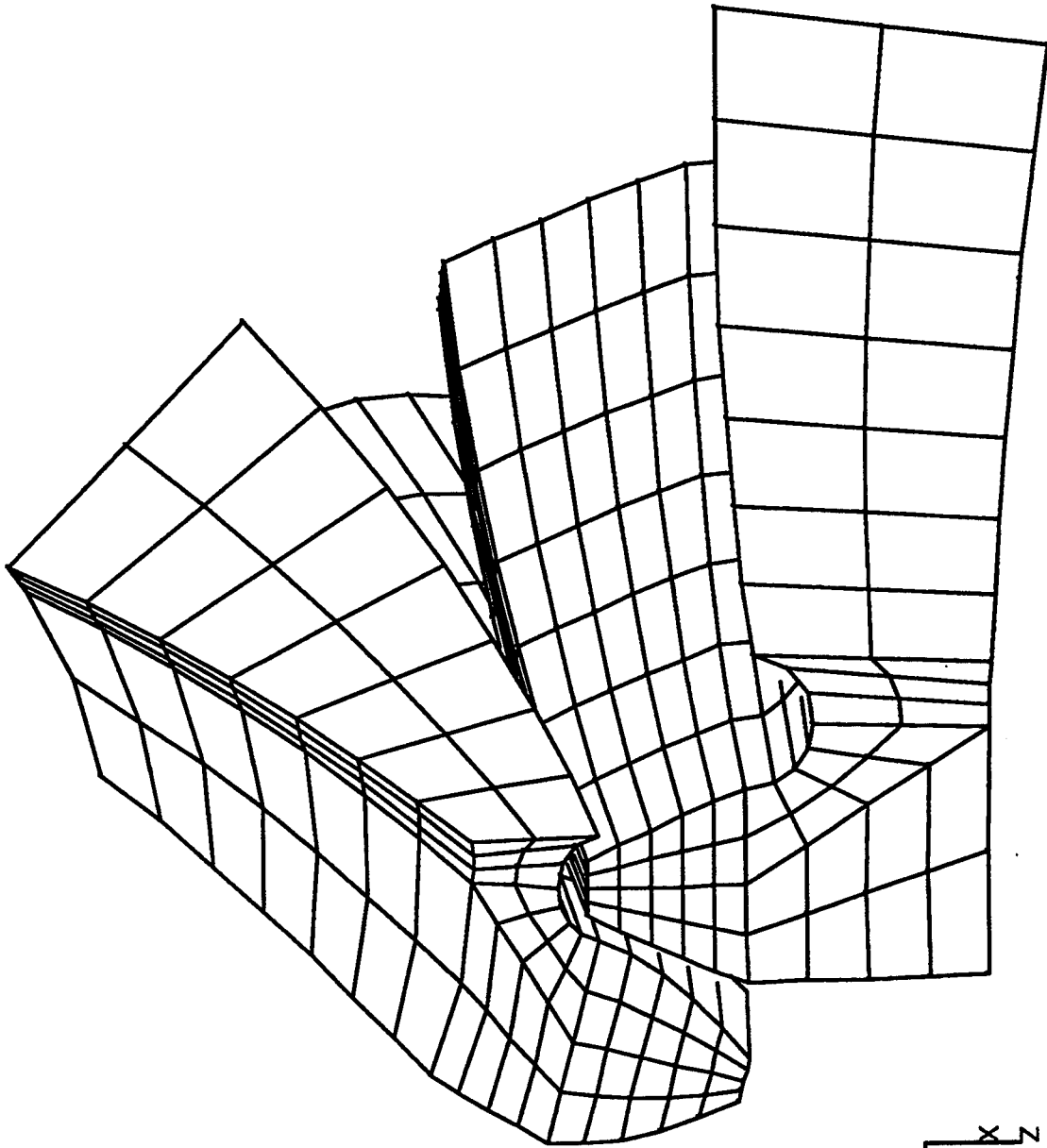
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PATCH,	102,	QUAD,,	141/	142/	190/	189
PATCH,	103,	QUAD,,	142/	143/	191/	190
PATCH,	104,	QUAD,,	143/	144/	192/	191
HPAT,	57,2P,,	65,	70			
HPAT,	58,2P,,	66,	71			
HPAT,	59,2P,,	67,	72			
HPAT,	60,2P,,	68,	73			
HPAT,	61,2P,,	69,	74			
HPAT,	62,2P,,	70,	75			
HPAT,	63,2P,,	71,	76			
HPAT,	64,2P,,	72,	77			
HPAT,	65,2P,,	73,	78			
HPAT,	66,2P,,	74,	79			
HPAT,	67,2P,,	75,	80			
HPAT,	68,2P,,	76,	81			
HPAT,	69,2P,,	77,	82			
HPAT,	70,2P,,	78,	83			
HPAT,	71,2P,,	79,	84			
HPAT,	72,2P,,	80,	85			
HPAT,	73,2P,,	81,	86			
HPAT,	74,2P,,	82,	87			
HPAT,	75,2P,,	83,	88			
HPAT,	76,2P,,	84,	89			
HPAT,	77,2P,,	85,	90			
HPAT,	78,2P,,	86,	91			
HPAT,	79,2P,,	87,	92			
HPAT,	80,2P,,	88,	93			
HPAT,	81,2P,,	89,	94			
HPAT,	82,2P,,	90,	95			
HPAT,	83,2P,,	91,	96			
HPAT,	84,2P,,	92,	97			
HPAT,	85,2P,,	93,	98			
HPAT,	86,2P,,	94,	99			
HPAT,	87,2P,,	95,	100			
HPAT,	88,2P,,	96,	101			
HPAT,	89,2P,,	97,	102			
HPAT,	90,2P,,	98,	103			
HPAT,	91,2P,,	99,	104			
GRID,	257,,	-2.373271/	-0.090597/	1.284378		
LINE,	153	,ARC,5(0)/1.0/	-5.8802	, 257		
GRID,	259,,	-2.493672/	-0.177761/	1.356060		
LINE,	154	,ARC,5(0)/1.0/	-5.9681	, 259		
GRID,	261,,	-2.610745/	-0.273191/	1.427743		
LINE,	155	,ARC,5(0)/1.0/	-6.0447	, 261		
GRID,	263,,	-2.724029/	-0.377049/	1.499426		
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GRID,	265,,	-2.833021/	-0.489508/	1.571109		
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GRID,	267,,	-2.937172/	-0.610756/	1.642791		
LINE,	158	,ARC,5(0)/1.0/	-6.2174	, 267		
GRID,	269,,	-3.035876/	-0.740999/	1.714474		
LINE,	159	,ARC,5(0)/1.0/	-6.2584	, 269		

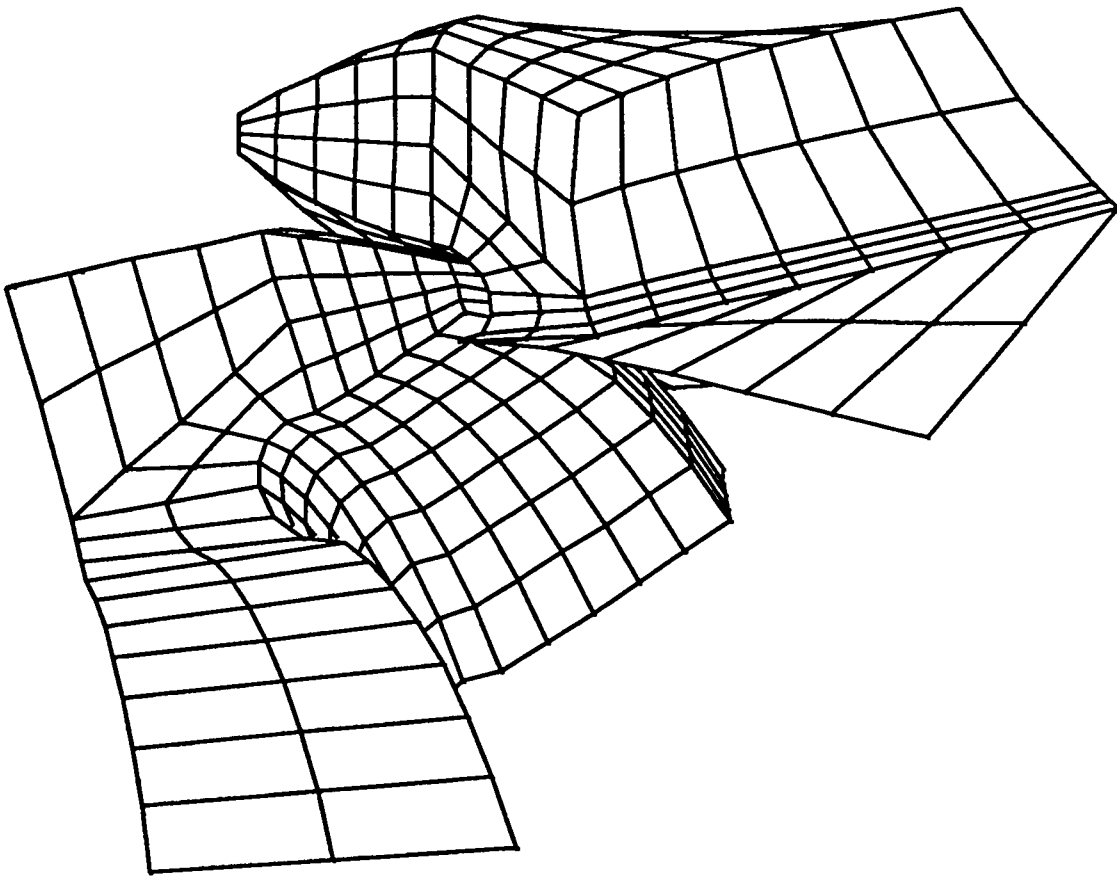
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 LINE, 160 ,ARC,5(0)/1.0/ -6.2918 , 271
 LINE, 161,ARC,0/0/0/-2.4908/-0.1849/ 0.985636/-175.880, 97
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 LINE, 243,ST,, 151, 260
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 LINE, 163,ARC,0/0/0/-2.7354/-0.3821/ 1.094129/-176.045, 109
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 LINE, 167,ARC,0/0/0/-3.1695/-0.8842/ 1.311115/-176.258, 133
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 LINE, 240,ST,, 298, 300
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 LINE, 256,ST,, 297, 299
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 LINE, 168,ARC,0/0/0/-3.2630/-1.0334/ 1.365361/-176.292, 139

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 LINE, 215 ,ARC, 0/0/0/0/0/1/ 3.708, 271
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 HPAT, 105 ,2P, , 119, 120
 HPAT, 112 ,2P, , 127, 128
 SET, LINES, 0
 NAME, GE 1
 SET, ACTIVE, NONE
 NAME, PI 1, PL
 MESH, H 1T 35, HEX, N, 1/ 4/1/ 4/1
 MESH, H 36T 49, HEX, N, 2/ 4/ 2/ 4/1
 MESH, H 50T 56, HEX, N, 3/ 2/3/ 2/1
 NAME, PIN
 SET, ACTIVE, NONE
 NAME, GE 1, PLOT
 MESH, H 57T 91, HEX, N, 1/ 4/1/ 4/1
 MESH, H 92T 105, HEX, N, 4/ 2/ 4/ 2/1
 MESH, H 106T 112, HEX, N, 2/3/ 2/3/1

NAME, GEAR
GR, 1T#, DEL
NAME, PINION, RO, 4(0)/1/0/-90, PIN
NAME, PINION, PL

TYPICAL FE MESH





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C                                     POINTS.F
C-----
C      POINTS.F GENERATES N BY M POINTS FOR THE PINION & GEAR SURFACES
C      POINTS.OUT => N BY M POINTS
C      (MAIN PROGRAM)
C
C      COMMON/CONST/PI,R,Q,MU,DEDEN,PSI,S,MCW,LM,EM,INC
C      DIMENSION XYZ(4),U(51),THETA(51),PHIC(51),D(3,3),F(3),Y(3)
C      DIMENSION RBAR(50,50),ZBAR(50,50),X1(50,50),X2(50,50),X3(50,50)
C      DOUBLE PRECISION MU,A1,B1,C1,D1,E1,AA,BB,CC,RV,MCW,Q,PSI,PI
C      DOUBLE PRECISION THETA,D,F,Y,GAMMA,DEDEN,R,S,TAU,EM,LM,PHIC
C      DOUBLE PRECISION XYZ,U,INC,ZBAR,RBAR,X1,X2,X3,LV,ADDAN,CL,RL,FW
C      INTEGER N1,N2,N3,M,UU,T,INT,BBB,CCC,SS
C
C      WRITE(*,(''PLEASE ENTER THE GRID PATTERN REQUIRED.''/
C      *''FOR EXAMPLE: FOR A 7X8 PATTERN, ENTER 7 AND RETURN''/
C      *''THEN ENTER 8 '''))
C
C      READ(*,*)BBB
C      READ(*,*)CCC
C
C      PI      = 4.0 * ATAN(1.0)
C      INC     = 0.1
C      N1      = 11
C      N2      = 3
C      N3      = 4
C      DO 5 INT = 1,4
C
C      IF (INT .EQ. 1) THEN
C
C
C
C-----
C      DESCRIPTION OF INPUT DATA
C-----
C
C      1) RADIUS OF CUTTER, INCHES           (R)
C      2) CRADLE ANGLE, DEGREES             (Q)
C      3) BLADE ANGLE, DEGREES              (PSI)
C      4) CRADLE TO CUTTER DISTANCE, INCHES (S)
C      5) RATIO OF ROLL                      (MCW)
C      6) MACHINE OFFSET, INCHES           (EM)
C      7) VECTOR SUM, INCHES               (LM)
C      8) DEDENDUM ANGLE, DEGREES          (DEDEN)
C      9) PITCH ANGLE, DEGREES             (MU)
C      10) ADDENDUM ANGLE, DEGREES         (ADDAN)
C      11) CLEARANCE, INCHES               (CL)
C      12) MEAN CONE DISTANCE, INCHES     (RL)
C      13) FACE WIDTH, INCHES             (FW)
C      14) INITIAL GUESS FOR SURFACE COORDINATE U ( U(1) )
C      15) INITIAL GUESS FOR SURFACE COORDINATE THETA ( THETA(1) )
C      16) INITIAL GUESS FOR ANGLE OF CRADLE, DEGREES ( PHIC(1) )
C-----
C      INSERT CONCAVE SIDE OF PINION DATA BELOW
C-----
C
C      R      = 2.96562137806
C      Q      = 63.9420304635 * PI/180.0
C      PSI    = 161.954330248 * PI/180.0
C      S      = 2.94780202969
C      MCW    = 0.30838512709

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EM = 0.154575896
LM = 0.0384999977874
DEDEN = 1.56666666 * pi/180
MU = 18.4333333 * pi/180
ADDAN = 3.8833334 * pi/180
CL = 0.03
RL = 3.191
FW = 1.0
U(1) = 9.59703
THETA(1) = 126.83544 * PI/180.0
PHIC(1) = -0.85813 * PI/180.0

C

ELSEIF (INT .EQ. 2) THEN

C-----

C

INSERT CONVEX SIDE OF PINION DATA BELOW

C-----

C

R = 3.071306157
Q = 53.9259945467 * PI/180.0
PSI = 24.337423854 * PI/180.0
S = 2.80104946
MCW = 0.3220428536
EM = -0.17426159493
LM = -0.0518138227
DEDEN = 1.56666666 * pi/180
MU = 18.4333333 * pi/180
ADDAN = 3.8833334 * pi/180
CL = 0.03
RL = 3.191
FW = 1.0
U(1) = 7.42534
THETA(1) = 124.43689 * PI/180.0
PHIC(1) = -11.38663 * PI/180.0

C

ELSEIF (INT .EQ. 3) THEN

C-----

C

INSERT CONCAVE SIDE OF GEAR DATA BELOW

C-----

C

R = 3.0325
Q = 59.2342023 * PI/180.0
PSI = 158.0 * PI/180.0
S = 2.85995004691
MCW = 0.9508646
EM = 0.0
LM = 0.0
DEDEN = 3.8833333333 * pi/180
MU = 71.5666666 * pi/180
ADDAN = 1.5666666 * pi/180
CL = 0.0366
RL = 3.191
FW = 1.0
U(1) = 8.12602
THETA(1) = 233.98994 * PI/180.0
PHIC(1) = -0.35063 * PI/180.0

C-----

C

C

C

C

C

ELSE

C

C-----

C

INSERT CONVEX SIDE OF GEAR DATA BELOW

C-----

C

```

C
R      = 2.9675
Q      = 59.2342023 * PI/180.0
PSI    = 22.0 * PI/180.0
S      = 2.85995004691
MCW    = 0.9508646
EM     = 0.0
LM     = 0.0
DEDEN  = 3.8833333333 * pi/180
MU     = 71.5666666 * pi/180
ADDAN  = 1.5666666 * pi/180
CL     = 0.0366
RL     = 3.191
FW     = 1.0
U(1)   = 7.89156
THETA(1) = 234.95451 * PI/180.0
PHIC(1) = -12.3384 * PI/180.0
ENDIF

C
OPEN(UNIT=900,FILE='POINTS.OUT',STATUS='UNKNOWN')
C
DO 10 UU = 1, BBB
DO 20 T = 1, CCC

C
CALL STEPZR(ZBAR, RBAR, UU, T, int, BBB, CCC, deden, mu, addan, cl, rl, fw)
C
SS = BBB - 1
DO 100 M = 1, SS

C
CALL DIFF(U, THETA, PHIC, M, D, N1, N2, UU, T, ZBAR, RBAR, INT)
C
IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
    TAU = (THETA(M)) - Q + (PHIC(M))
    GAMMA = MU - DEDEN
C
ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
    TAU = (THETA(M)) + Q - (PHIC(M))
    GAMMA = MU - DEDEN
ENDIF

C
C
C (THE FIRST EQUATION. (EQUATION OF MESHING FOR LEFT HAND PINION))
C
1 A1 = ((U(M))-R*(COS(PSI)*COS(PSI)/SIN(PSI)))
   *COS(GAMMA)*SIN(TAU)
B1 = S*(MCW-SIN(GAMMA))*COS(PSI)*SIN(THETA(M))
C1 = S*COS(GAMMA)*SIN(PSI)*SIN(Q-(PHIC(M)))
D1 = EM*(COS(GAMMA)*SIN(PSI)+SIN(GAMMA)*COS(PSI)*COS(TAU))
E1 = LM*SIN(GAMMA)*COS(PSI)*SIN(TAU)
IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
    LV = A1 + B1 - C1 + D1 - E1
    AA = LV
ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
    RV = A1 + B1 + C1 - D1 - E1
    AA = RV
ENDIF

C
C
C (THE SECOND EQUATION. ZW - Z = 0)
C
CALL TRANSF(U, THETA, PHIC, M, XYZ, N3, N1, INT)
C
BB = XYZ(3) - ZBAR(UU, T)
C
C
C (THE THIRD EQUATION. R - SQRT( X*X + Y*Y ) = 0)
C
CC = RBAR(UU, T) - SQRT(XYZ(1)*XYZ(1) + XYZ(2)*XYZ(2))

```

```

      F(1) = -AA
      F(2) = -BB
      F(3) = -CC
C
      CALL GAUSS(D,F,Y,N2)
C
      U(M+1) = U(M) + Y(1)
      THETA(M+1) = THETA(M) + Y(2)
      PHIC(M+1) = PHIC(M) + Y(3)
100 CONTINUE
C
      X1(UU,T) = XYZ(1)
      X2(UU,T) = XYZ(2)
      X3(UU,T) = XYZ(3)
C
      WRITE(900,*)X1(UU,T),X2(UU,T),X3(UU,T)
C
20  CONTINUE
10  CONTINUE
C
5   CONTINUE
      CLOSE(900,STATUS='KEEP')
C
      STOP
      END
C
      SUBROUTINE DIFF(X1,X2,X3,M,D,N1,N2,UU,T,ZBAR,RBAR,INT)
C
C      (THE VARIABLES X1,X2,X3; LOCAL TO THIS PROCEDURE; REPRESENT
C      U, THETA AND PHIC. )
C
      COMMON/CONST/PI,R,Q,MU,DEDEN,PSI,S,MCW,LM,EM,INC
      DIMENSION X1(N1),X2(N1),X3(N1),A(5,3),B(5,3),C(5,3),RVAL(5,3)
      DIMENSION XX1(51),XX2(51),XX3(51),D(N2,N2),XYZ(4),ZBAR(50,50)
      DIMENSION RBAR(50,50),LVAL(5,3)
      INTEGER I,J,L,UU,T
      DOUBLE PRECISION RVAL,A,B,C,K,H1,H2,H3,TAU,GAMMA,A1,B1,C1,D1
      DOUBLE PRECISION MU,DEDEN,PI,LM,MCW,X1,X2,X3,XX1,XX2,XX3,D
      DOUBLE PRECISION E1,INC,R,PSI,XYZ,EM,Q,S,ZBAR,RBAR,LVAL
C
C      (H1,H2,H3 ARE THE INCREMENTS ADDED TO THE)
C      (VAR X1,X2,X3 DURING THE NUMERICAL DIFF. )
C      (A1,B1,C1,D1,E1 INTERMEDIATE VALUES FOR EQU. OF MESHING)
C
      DO 201 I = 1,5
          L = I - 3
          K = L/2.0
C
C      (K IS THE MULTIPLIER ON THE INCREMENT "INC".)
C
      DO 205 J = 1,3
C
      IF (J .EQ. 1) THEN
          H1 = INC
          H2 = 0.
          H3 = 0.
      ELSE IF (J .EQ. 2) THEN
          H1 = 0.
          H2 = INC
          H3 = 0.
      ELSE
          H1 = 0.
          H2 = 0.
          H3 = INC
      ENDIF
C

```



```

C      (* INSERT THE THREE EQUATIONS TO BE DIFFERENTIATED HERE *)
C      ( ADD K*H1, K*H2, K*H3 TO EACH VARIABLE X1,X2,X3 )
C
C      IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
C          TAU = (X2(M)+K*H2) - Q + (X3(M)+K*H3)
C          GAMMA = MU - DEDEN
C      ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
C          TAU = (X2(M)+K*H2) + Q - (X3(M)+K*H3)
C          GAMMA = MU - DEDEN
C      ENDIF
C
C      (THE FIRST EQUATION. (EQUATION OF MESHING FOR LEFT HAND PINION))
C
C      *
C          A1 = ((X1(M)+K*H1)-R*(COS(PSI)*COS(PSI)/SIN(PSI)))
C              *COS(GAMMA)*SIN(TAU)
C          B1 = S*(MCW-SIN(GAMMA))*COS(PSI)*SIN(X2(M)+K*H2)
C          C1 = S*COS(GAMMA)*SIN(PSI)*SIN(Q-(X3(M)+K*H3))
C          D1 = EM*(COS(GAMMA)*SIN(PSI) + SIN(GAMMA)*COS(PSI)*COS(TAU))
C          E1 = LM*SIN(GAMMA)*COS(PSI)*SIN(TAU)
C      IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
C          LVAL(I,J) = A1 + B1 - C1 + D1 - E1
C          A(I,J) = LVAL(I,J)
C      ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
C          RVAL(I,J) = A1 + B1 + C1 - D1 - E1
C          A(I,J) = RVAL(I,J)
C      ENDIF
C
C      (THE SECOND EQUATION. ZW - Z = 0)
C
C          XX1(M) = X1(M) + K*H1
C          XX2(M) = X2(M) + K*H2
C          XX3(M) = X3(M) + K*H3
C
C      CALL TRANSF(XX1, XX2, XX3,M,XYZ,N3,N1,INT)
C
C          B(I,J) = XYZ(3) - ZBAR(UU,T)
C
C      (THE THIRD EQUATION. R - SQRT(X*X + Y*Y) = 0)
C
C          C(I,J) = RBAR(UU,T) - SQRT(XYZ(1)*XYZ(1) + XYZ(2)*XYZ(2))
205      CONTINUE
C
201      CONTINUE
C
      DO 210 I = 1,3
          D(1,I) = -(A(5,I) - 8*A(4,I) - A(1,I) + 8*A(2,I))/(6*INC)
          D(2,I) = -(B(5,I) - 8*B(4,I) - B(1,I) + 8*B(2,I))/(6*INC)
          D(3,I) = -(C(5,I) - 8*C(4,I) - C(1,I) + 8*C(2,I))/(6*INC)
210      CONTINUE
C
      RETURN
      END
C
C      SUBROUTINE TRANSF( X1,X2,X3,M,XYZ,N3,N1,INT)
C
C      COMMON/CONST/PI,R,Q,MU,DEDEN,PSI,S,MCW,LM,EM,INC
C      DIMENSION X1(N1),X2(N1),X3(N1),A(4),REST1(4,4)
C      DIMENSION REST2(4,4),REST3(4,4),REST4(4,4),MSC(4,4),MMS(4,4)
C      DIMENSION MPM(4,4),MAP(4,4),MWA(4,4),XYZ(N3)
C      DOUBLE PRECISION INC,PI,MCW,Q,LM,MU,PSI,MSC,MMS,MPM,MAP,MWA
C      DOUBLE PRECISION REST1,REST2,REST3,REST4,DEDEN,S,R,EM,PHIW
C      DOUBLE PRECISION X1,X2,X3,A,XYZ
C      INTEGER I,J,K
C
C      DO 300 I = 1,4

```

```

C
DO 310 J = 1,4
    REST1(I,J)=0
    REST2(I,J)=0
    REST3(I,J)=0
    REST4(I,J)=0
    MSC(I,J)=0
    MMS(I,J)=0
    MPM(I,J)=0
    MAP(I,J)=0
    MWA(I,J)=0
310 CONTINUE
C
300 CONTINUE
C
    PHIW = X3(M)/MCW
C
C ( THE COORDINATE TRANSFORMATIONS )
C
IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
    MSC(1,1) = 1.0
    MSC(2,2) = COS(Q)
    MSC(2,3) = -SIN(Q)
    MSC(2,4) = -S*SIN(Q)
    MSC(3,2) = +SIN(Q)
    MSC(3,3) = COS(Q)
    MSC(3,4) = S*COS(Q)
    MSC(4,4) = 1.0
C
    MPM(1,1) = COS(DEDEN)
    MPM(1,3) = -SIN(DEDEN)
    MPM(1,4) = -LM*SIN(DEDEN)
    MPM(2,2) = 1.0
    MPM(2,4) = +EM
    MPM(3,1) = SIN(DEDEN)
    MPM(3,3) = COS(DEDEN)
    MPM(3,4) = LM*COS(DEDEN)
    MPM(4,4) = 1.0
C
    MMS(1,1) = 1.0
    MMS(2,2) = COS(X3(M))
    MMS(2,3) = +SIN(X3(M))
    MMS(3,2) = -SIN(X3(M))
    MMS(3,3) = COS(X3(M))
    MMS(4,4) = 1.0
C
    MAP(1,1) = COS(MU)
    MAP(1,3) = SIN(MU)
    MAP(2,2) = 1.0
    MAP(3,1) = -SIN(MU)
    MAP(3,3) = COS(MU)
    MAP(4,4) = 1.0
C
    MWA(1,1) = COS(PHIW)
    MWA(1,2) = +SIN(PHIW)
    MWA(2,1) = -SIN(PHIW)
    MWA(2,2) = COS(PHIW)
    MWA(3,3) = 1.0
    MWA(4,4) = 1.0
C
ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
C
    MSC(1,1) = 1.0
    MSC(2,2) = COS(Q)
    MSC(2,3) = +SIN(Q)
    MSC(2,4) = +S*SIN(Q)

```

```
MSC(3,2) = -SIN(Q)
MSC(3,3) = COS(Q)
MSC(3,4) = S*COS(Q)
MSC(4,4) = 1.0
```

```
C
MPM(1,1) = COS(DEDEN)
MPM(1,3) = -SIN(DEDEN)
MPM(1,4) = -LM*SIN(DEDEN)
MPM(2,2) = 1.0
MPM(2,4) = -EM
MPM(3,1) = SIN(DEDEN)
MPM(3,3) = COS(DEDEN)
MPM(3,4) = LM*COS(DEDEN)
MPM(4,4) = 1.0
```

```
C
MMS(1,1) = 1.0
MMS(2,2) = COS(X3(M))
MMS(2,3) = -SIN(X3(M))
MMS(3,2) = +SIN(X3(M))
MMS(3,3) = COS(X3(M))
MMS(4,4) = 1.0
```

```
C
MAP(1,1) = COS(MU)
MAP(1,3) = SIN(MU)
MAP(2,2) = 1.0
MAP(3,1) = -SIN(MU)
MAP(3,3) = COS(MU)
MAP(4,4) = 1.0
```

```
C
MWA(1,1) = COS(PHIW)
MWA(1,2) = -SIN(PHIW)
MWA(2,1) = +SIN(PHIW)
MWA(2,2) = COS(PHIW)
MWA(3,3) = 1.0
MWA(4,4) = 1.0
```

```
C
ENDIF
```

```
C
C
C ( THE MATRIX MULTIPLICATIONS )
```

```
C
DO 320 I = 1,4
  DO 325 J = 1,4
    DO 330 K = 1,4
      REST1(I,J) = REST1(I,J) + MMS(I,K)*MSC(K,J)
    CONTINUE
  CONTINUE
CONTINUE
```

```
C
DO 335 I = 1,4
  DO 340 J = 1,4
    DO 345 K = 1,4
      REST2(I,J) = REST2(I,J) + MPM(I,K)*REST1(K,J)
    CONTINUE
  CONTINUE
CONTINUE
```

```
C
DO 350 I = 1,4
  DO 355 J = 1,4
    DO 360 K = 1,4
      REST3(I,J) = REST3(I,J) + MAP(I,K)*REST2(K,J)
    CONTINUE
  CONTINUE
CONTINUE
```

```
C
DO 365 I = 1,4
DO 370 J = 1,4
```

```

DO 375 K = 1,4
  REST4(I,J) = REST4(I,J) + MWA(I,K)*REST3(K,J)
375   CONTINUE
370   CONTINUE
365   CONTINUE
C
DO 380 I = 1,4
  XYZ(I) = 0
380   CONTINUE
C
  A(1) = R*COS(PHI)/SIN(PHI)-X1(M)*COS(PHI)
  A(2) = X1(M)*SIN(PHI)*SIN(X2(M))
  A(3) = X1(M)*SIN(PHI)*COS(X2(M))
  A(4) = 1.0
C
DO 385 K = 1,4
  DO 390 I = 1,4
    XYZ(K) = XYZ(K) + REST4(K,I)*A(I)
390   CONTINUE
385   CONTINUE
C
RETURN
END
C
C
SUBROUTINE GAUSS(D,F,Y,N2)
C
DIMENSION D(N2,N2),F(N2),Y(N2)
DOUBLE PRECISION PIVOT,MULT,TOP,D,F,Y
INTEGER I,J,K,N
C
N = 3
C
DO 400 J = 1,N-1
  PIVOT = D(J,J)
C
DO 410 I = J+1,N
  MULT = D(I,J)/PIVOT
C
DO 420 K = J+1,N
  D(I,K) = D(I,K) - MULT * D(J,K)
  F(I) = F(I) - MULT * F(J)
420   CONTINUE
C
410   CONTINUE
C
  Y(N) = F(N)/D(N,N)
DO 430 I = N-1,1,-1
  TOP = F(I)
  DO 440 K = I+1,N
    TOP = TOP - D(I,K) * Y(K)
  Y(I) = TOP/D(I,I)
440   CONTINUE
C
430   CONTINUE
C
400   CONTINUE
C
RETURN
END
C
C
Subroutine stepzr(zbar,rbar,uu,t,int,bbb,ccc,deden,mu,addan
* ,cl,r1,fw)
C
DIMENSION ZBAR(50,50),RBAR(50,50)

```

```

DOUBLE PRECISION ZPITCH,ZROOT1,ZM1,ZMX,ZINC1,ZM,RM,G,G9,Z,R
DOUBLE PRECISION ZBAR,REAR,DEDEN,ADDAN,MU,CL,RL,FW
INTEGER DZ1,DR1,UU,T,BBB,CCC
PI      = 4.0*ATAN(1.0)

```

C

```

ZPITCH = RL - FW/2.0
ZROOT1 = ZPITCH * COS(DEDEN)
ZM1     = ZROOT1 * COS(MU - DEDEN)
ZMX     = (ZROOT1 + FW) * COS(MU - DEDEN)
ZINC1   = (ZMX - ZM1)/(BBB - 1)
Z       = 0.
R       = 0.

```

C

```

DZ1     = (UU - 1)
ZM      = ZM1 + DZ1*ZINC1 - CL * SIN(MU - DEDEN)
RM      = ZM * TAN(MU - DEDEN) + CL/COS(MU - DEDEN)
G       = ZM * TAN(ADDAN + DEDEN)/COS(MU - DEDEN) - CL
G9      = G/(ccc - 1)

```

C

C

```

drl = (T-1)
Zbar(uu,t) = zm - drl*g9*sin(mu-deden)
rbar(uu,t) = rm + drl*g9*cos(mu-deden)

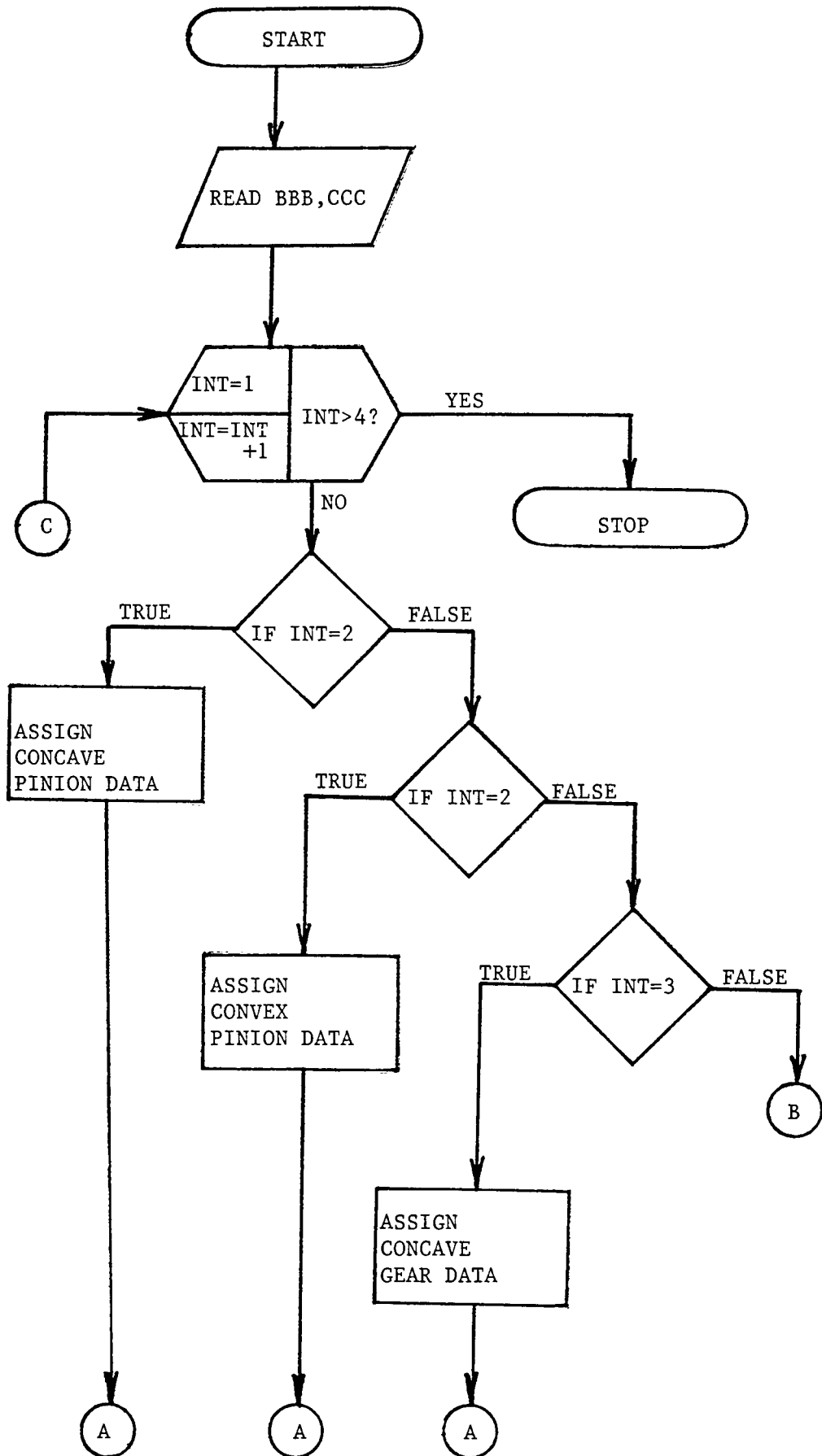
```

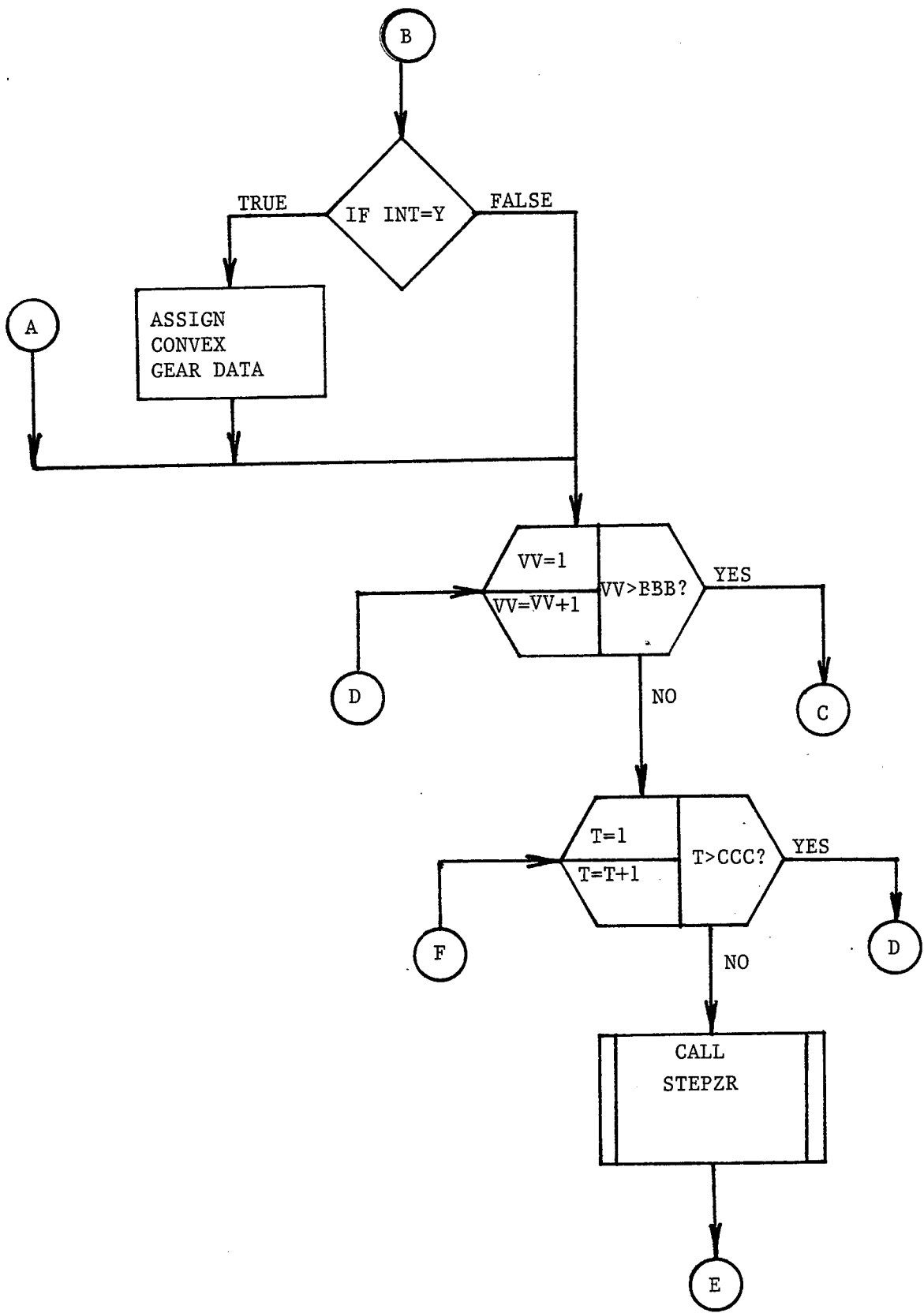
```

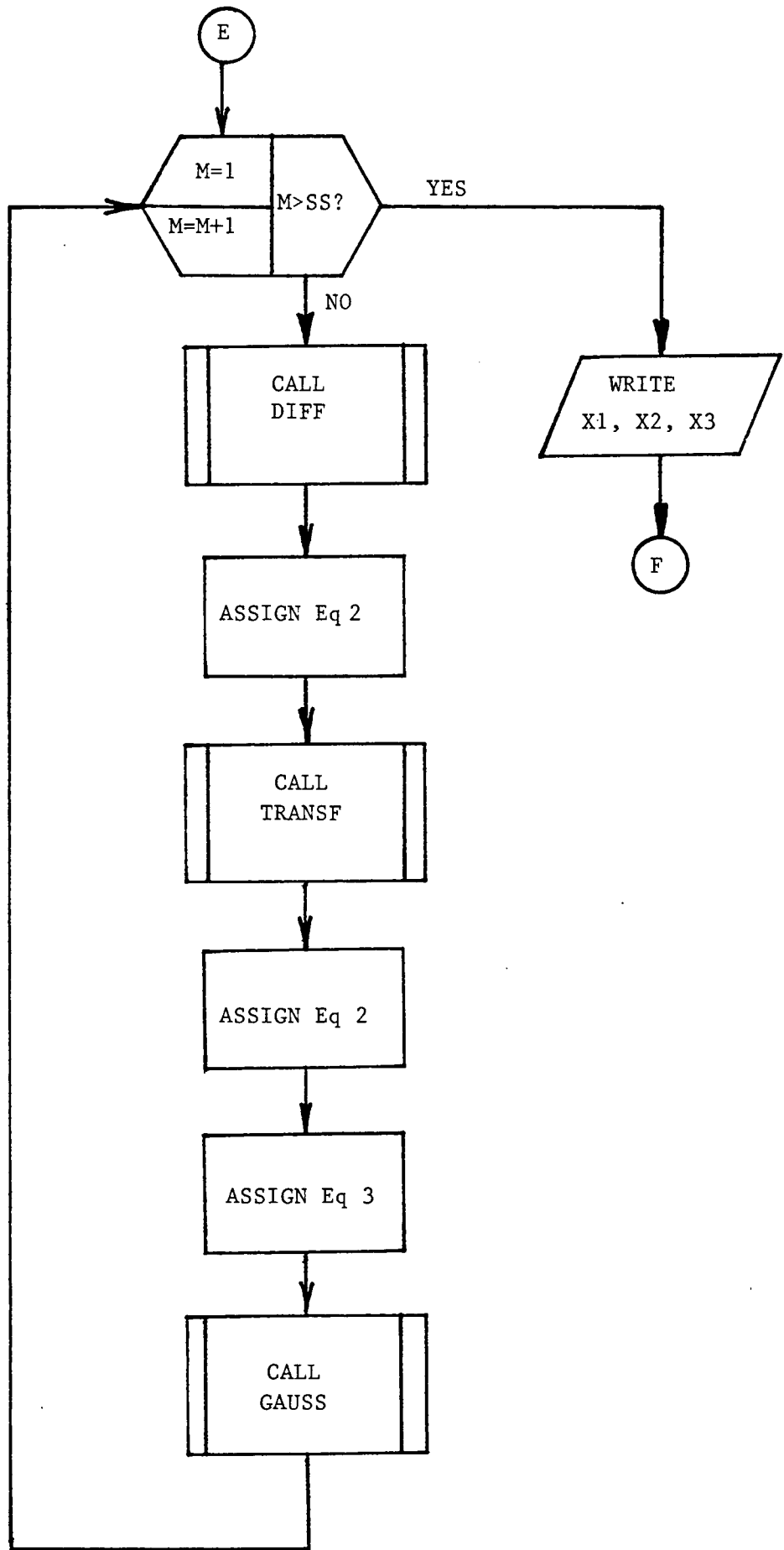
RETURN
END

```

FLOWCHART: POINTS.: F







FLOWCHART: POINTS.F (DISCUSSION)

There are 4 loops in the main program.

Loop 1: loops one through four to read data for the four surfaces.

Loop 2: loops one through BBB, where BBB is the number of points across the face of the tooth surface.

Loop 3: loops one through CCC, where CCC is the number of points along the length of the tooth height.

Loop 4: The final loop iterates to solve the three equations used to identify a point on the surface.

Subroutines:

1. STEPZR. This subroutine steps Z and R as the solution "marches" across the tooth face.
2. DIFF. This subroutine performs the numerical differentiation of the three equations (to form the Jacobian).
3. TRANSF. Subroutine that performs the matrix multiplication for the five coordinate transformations.
4. GAUSS. Uses gauss elimination to solve the Jacobian matrix.

```

C                                     PAT.F
C-----
C      THIS PROGRAM GIVES THE N * M GRID PATRAN INPUT FILE FOR      C
C      THE GENERATION OF SPIRAL BEVEL GEAR TOOTH SURFACE WITH FILLET  C
C-----
C      READS POINTS.OUT AND GIVES T1.OUT
C      T1.OUT => INPUT FILE FOR PATRAN
C
C      (MAIN PROGRAM)
C
C      COMMON/UNITS/NF1,NF2
C      DIMENSION X1(45,45),X2(45,45),X3(45,45)
C      DIMENSION X1R(45,45),X2R(45,45),XX(8000),ZZ(8000),YY(8000)
C      DOUBLE PRECISION ri,cl,r1,r2,mu,deden,rogear
C      DOUBLE PRECISION X1,X2,X3,X1R,X2R,XX,YY,ZZ,rotcon,rotint
C      INTEGER UU,T,INT,NF1,NF2,NF3,JI,BB,CC
C      INTEGER NUMBER,FILL,NTPIN,NTGE
C
C      PI      = 4.0*ATAN(1.0)
C
C      NF1 = 900
C      NF2 = 1000
C      NF3 = 1001
C
C      OPEN(UNIT=NF1,FILE='t1.out',STATUS='UNKNOWN')
C      OPEN(UNIT=NF2,FILE='t2.out',STATUS='UNKNOWN')
C      OPEN(UNIT=NF3,FILE='POINTS.OUT',STATUS='OLD')
C
C      WRITE(*,('PLEASE ENTER THE REQUIRED GRID PATTERN.''/
C      *'FOR EXAMPLE : FOR A 8X7 PATTERN ENTER 8 AND THEN 7 >''))
C      READ(*,*)BB
C      READ(*,*)cc
C      write(*,*)'ENTER NUMBER OF ELEMENTS THROUGH THE THICKNESS'
C      READ(*,*) number
C      WRITE(*,*)'ENTER THE NUMBER OF ELEMENTS IN THE FILLET'
C      READ(*,*)FILL
C      DO 5 INT = 1,4
C      IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
C
C-----
C      DESCRIPTION OF INPUT DATA FOR PINION
C-----
C
C      1. DEDENDUM, DEGREES          (DEDEN)
C      2. PITCH ANGLE, DEGREES      (MU)
C      3. ROTATION OF CONVEX SURFACE TO
C      CREATE TOP LAND              (ROTCON)
C      4. ROTATION OF PINION TO ELIMINATE
C      INTERFERENCE                 (ROTINT)
C      5. PINION ID, INCHES         (RI)
C      6. CLEARANCE, INCHES         (CL)
C      7. NUMBER OF PINION TEETH    (NTPIN)
C-----
C-----
C      INPUT THE PINION DATA BELOW
C-----
C      DEDEN = 1.56666666 * PI/180.0
C      MU    = 18.4333333 * PI/180.0
C      ROTCON = 2.275
C      ROTINT = -3.56
C      RI    = 0.609375
C      CL    = 0.03
C      NTPIN = 12
C-----

```

```

C
C
C
      ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
C
C
C-----
C      DESCRIPTION OF INPUT DATA FOR THE GEAR
C-----
C
C      1. DEDENDUM, DEGREES                (DEDEN)
C      2. PITCH ANGEL, DEGREES            (MU)
C      3. ROTATION OF CONVEX SURFACE TO
C          CREATE TOP LAND                (ROTCON)
C      4. ROTATION OF GEAR TO PUT IN MESH (ROGEAR)
C      5. CLEARANCE, INCHES                (CL)
C      6. ID OF GEAR BASE                  (R1)
C      7. OD OF GEAR BASE                  (R2)
C      8. NUMBER OF GEAR TEETH             (NTGE)
C-----
C
C-----
C      INPUT THE GEAR DATA BELOW
C-----
C      DEDEN = 3.883333333 * PI/180.0
C      MU    = 71.56666666 * PI/180.0
C      ROTCON = -8.49
C      ROGEAR = 190.0
C      CL    = 0.0366
C      R1    = 2.375
C      R2    = 3.250
C      NTGE  = 36
C-----
C
C
C
C
C
C
C      ENDIF
C
C      IF (int.EQ.1) THEN
C          WRITE(NF1,*) 'SET,LABEL,OFF'
C          WRITE(NF1,*) 'VI'
C          WRITE(NF1,*) '1'
C          WRITE(NF1,*) '120,0,120'
C      ENDIF
C
C      JI = 1
C
C      DO 10 UU = 1,BB
C      DO 20 T = 1,cc
C
C          READ(NF3,*)X1(UU,T),X2(UU,T),X3(UU,T)
C
C          IF ((INT .EQ. 2).OR.(INT .EQ. 4)) THEN
C              CALL ROTATE(X1(UU,T),X2(UU,T),X1R(UU,T),X2R(UU,T),INT,
C * rotcon)
C          ENDIF
C
C          CALL ALLIGN(X1(UU,T),X2(UU,T),X1R(UU,T),X2R(UU,T),INT,
C * rotint,rogear)
C
C          CALL GRID(UU,T,INT,X1,X2,X3,X1R,X2R,XX,YY,ZZ,bb,cc)
C
C          JI = JI + 1

```

```

C
20 CONTINUE
10 CONTINUE
5 CONTINUE
C
DO 6 int = 1,4
C
IF ((INT .EQ. 2).OR.(INT .EQ. 4)) THEN
CALL LINE(INT,bb,cc)
SS = INT
CALL PATCH(SS,bb,cc)
CALL HPAT(INT,bb,cc)
CALL FILLET(XX,YY,ZZ,INT,bb,cc,ri,cl,r1,r2,mu,deden,
* ntpin,ntge)
ENDIF
C
6 CONTINUE
C
CALL MODEL(bb,cc,number,fill)
CLOSE(NF3,STATUS='KEEP')
CLOSE(NF2,STATUS='KEEP')
CLOSE(NF1,STATUS='KEEP')
C
STOP
END
C
C
SUBROUTINE ROTATE(X1,X2,X1R,X2R,INT,rotcon)
C
COMMON/UNITS/NF1,NF2
DOUBLE PRECISION PI,Q,A,X1,X2,X1R,X2R,rotcon
DIMENSION A(2,2)
C
ROTATION OF PINION AND GEAR CONVEX SIDES BY Q DEG. TO CREATE TOP LAND
C
PI = 4.0 * ATAN(1.0)
IF ((INT .EQ. 1).OR.(INT .EQ. 2)) THEN
Q = rotcon*PI/180.0
ELSEIF ((INT .EQ. 3).OR.(INT .EQ. 4)) THEN
Q = rotcon*PI/180.0
ENDIF
A(1,1) = COS(Q)
A(2,1) = -SIN(Q)
A(1,2) = SIN(Q)
A(2,2) = COS(Q)
C
X1R = X1*A(1,1)+X2*A(2,1)
X2R = X1*A(1,2)+X2*A(2,2)
C
RETURN
END
C
C
SUBROUTINE ALLIGN(X1,X2,X1R,X2R,INT,rotint,rogear)
C
TO ALLIGN THE PINION ABOVE THE GEAR AND CALCULATE GAPS
C
COMMON/UNITS/NF1,NF2
DOUBLE PRECISION X1,X2,X1R,X2R,X11,X22,X11R,X22R
DOUBLE PRECISION Q,PI,X18,Y18,X18R,Y18R,rotint,rogear
C
PI = 4.0 * ATAN(1.0)
C
ROTATION OF THE PINION BY -3.56 DEG. ABOUT Z-AXIS
C
Q =rotint*PI/180.0

```

```

IF (INT.EQ.1) THEN
  X11 = X1 * COS(Q) - X2 * SIN(Q)
  X22 = X1 * SIN(Q) + X2 * COS(Q)
  X1 = X11
  X2 = X22
ELSEIF (INT.EQ.2) THEN
  X11R = X1R * COS(Q) - X2R * SIN(Q)
  X22R = X1R * SIN(Q) + X2R * COS(Q)
  X1R = X11R
  X2R = X22R
ENDIF

```

C

```

Q = -30.0 * PI / 180.0
IF (INT.EQ.1) THEN
  X30 = X1 * COS(Q) - X2 * SIN(Q)
  Y30 = X1 * SIN(Q) + X2 * COS(Q)
ELSEIF (INT.EQ.2) THEN
  X30R = X1R * COS(Q) - X2R * SIN(Q)
  Y30R = X1R * SIN(Q) + X2R * COS(Q)
ENDIF

```

C

C

C

ROTATION OF THE GEAR BY 190 DEG. ABOUT Z-AXIS

```

Q = rogear * PI / 180.0
IF (INT.EQ.3) THEN
  X18 = X1 * COS(Q) - X2 * SIN(Q)
  Y18 = X1 * SIN(Q) + X2 * COS(Q)
  X1 = X18
  X2 = Y18
ELSEIF (INT.EQ.4) THEN
  X18R = X1R * COS(Q) - X2R * SIN(Q)
  Y18R = X1R * SIN(Q) + X2R * COS(Q)
  X1R = X18R
  X2R = Y18R
ENDIF

```

C

C

```

RETURN
END

```

C

C

C

SUBROUTINE GRID(UU,T,INT,X1,X2,X3,X1R,X2R,XX,YY,ZZ,BB,cc)

C

```

COMMON/UNITS/NF1,NF2
INTEGER NN,UU,T,BB,cc
DOUBLE PRECISION X1(45,45),X2(45,45),X3(45,45)
DOUBLE PRECISION X1R(45,45),X2R(45,45)
DOUBLE PRECISION XX(8000),YY(8000),ZZ(8000)
IF (INT .EQ. 1) THEN
  NN = (UU - 1) * cc + T
ELSEIF (INT .EQ. 2) THEN
  NN = (UU - 1) * cc + T + (BB*cc)
ELSEIF (INT .EQ. 3) THEN
  NN = (UU - 1) * cc + T + 2*(BB*cc)
ELSEIF (INT .EQ. 4) THEN
  NN = (UU - 1) * cc + T + 3*(BB*cc)
ENDIF

```

C

```

IF ((INT .EQ. 1).OR.(INT .EQ. 3)) THEN
  XX(NN) = X1(UU,T)
  YY(NN) = X2(UU,T)
  ZZ(NN) = X3(UU,T)
ELSEIF ((INT .EQ. 2).OR.(INT .EQ. 4)) THEN
  XX(NN) = X1R(UU,T)
  YY(NN) = X2R(UU,T)
  ZZ(NN) = X3(UU,T)

```

```
C      ENDIF
111 C      WRITE(NF1,111)'GRID',',',',,NN',',',',,XX(NN),',/',',,YY(NN),',/',',,ZZ(NN)
      FORMAT(A4,A1,I4,A2,F10.6,A1,F10.6,A1,F10.6)
C      RETURN
      END
C      SUBROUTINE LINE(INT,bb,cc)
C      COMMON/UNITS/NF1,NF2
C      INTEGER L,M,N,K,bb,cc
      DO 600 L = 1,BB
          K = L
          IF (INT .EQ. 2) THEN
              M = (L-1) * cc + 1
              n = m+bb*cc
          ELSEIF (INT .EQ. 4) THEN
              K = L + BB*16
              m = (L - 1) *cc + (2*bb*cc + 1)
              n = M + bb*cc
          ENDIF
              N = M + BB*cc
          WRITE(NF1,610)'LINE',',',',,K',',',',,ST',',',',,M',',',',,N
          WRITE(nf1,611)'LINE',',',k+bb+L-1,',/',',,k+bb+L',',',',,BR,.5,',',,k
610 C      FORMAT(a4,a1,i4,a1,2a2,i4,a1,i4)
611 C      FORMAT(a5,i3,a1,i3,a1,a6,i4)
600 C      CONTINUE
C      RETURN
      END
C      SUBROUTINE PATCH(SS,bb,cc)
C      COMMON/UNITS/NF1,NF2
C      INTEGER I,II,J,JJ,K,L,M,bb,cc
      JJ = (cc-1)*BB
      DO 700 I = 1,JJ
C      IF (SS .EQ. 2) THEN
          J = INT((I-1)/(cc-1)) + I
          II = I
      ELSEIF (SS .EQ. 4) THEN
          j = int((I-1)/(cc-1)) + I + 2*(bb*cc)
          II = jj + I + 3*bb
      ENDIF
          K = J + 1
          L = K + BB*cc
          M = L - 1
          WRITE(NF1,710)'PATCH',',',',,II',',',',,QUAD',',',',,J',',/',',,K',',/',',,L',',/',',,M
710 C      FORMAT(A5,A1,I4,A1,A5,A2,I4,A1,I4,A1,I4,A1,I4)
700 C      CONTINUE
C      RETURN
      END
C      SUBROUTINE HPAT (int,bb,cc)
C      COMMON/units/nf1,nf2
C      INTEGER i,j,bb,cc
      jj = (bb-1)*(cc-1)
      Do 800 I = 1,jj
          If(int .eq. 2) then
              k = i
```

```

      j = k + (cc-1)
WRITE(nf1,810)'HPAT',',',',',K',',',',',2P',',',',',K',',',',J
ELSEIF (INT.EQ. 4) THEN
      K = I + (BB-1)*(cc-1) +3*(bb-1)
      L = (cc-1)*bb + i + 3*bb
      J = L + (cc-1)
WRITE(NF1,810)'HPAT',',',',',K',',',',',2P',',',',',L',',',',J
ENDIF
810  FORMAT(A4,A1,I4,A1,A2,A2,I4,A1,I4)
800  CONTINUE
C
      RETURN
      END
C
C
C
      SUBROUTINE FILLET(XX,YY,ZZ,INT,bb,cc,ri,cl,r1,r2,mu,deden,
* ntpin,ntge)
C
      FINDING INNER GEAR BLANK RADIUS GRIDS & ARC LOCATIONS
C
      COMMON/UNITS/NF1,NF2
      INTEGER I,J,K,II,JJ,KK,AR,HP,LI,GR,LS1,LF,PS,PF,PAT
      INTEGER PA,G,NN,HPA,IP,bb,cc,SS
      INTEGER PA1,PA2,PA3,PA4
      INTEGER pa5,pa6,pa7,pa8,pa9,pa10,pa11,pa12
      INTEGER hh1,hh2,hh3,hp1,hp2,hp3,hp4,hp5,hp6,ggb1,ggb2,pppa
      DOUBLE PRECISION PI,RI,MM(100),XX(8000),YY(8000),ZZ(8000)
      DOUBLE PRECISION DELA,DELR,RBAR,R1,R2,ANG,MU,DEDEN,ETA,ROT
      DOUBLE PRECISION PP(100),DELTA(100),X(8000),Y(8000),Z(8000)
      DOUBLE PRECISION XR,YR,ZR,XRHO,YRHO,VEC,ROTAT,cl
      DOUBLE PRECISION RX(100),RY(100),RZ(100)
      INTEGER Li1,Li2,Li3,Li4,Li5,Li6,Li7,Li8,Li9
      INTEGER Li10,Li11,Li12,Li13,Li14,Li15,Li16,Li17,Li18,Li19
      INTEGER W1,w2,w3,w4,w5,w6,w7,w8,w9,w10,w11,w12,w13,w14
      INTEGER w15,w16,w17,w18,w19
      INTEGER ntp,ntpin,ntge
C
      LL = 4*(BB*cc)
      DO 125 NN = 1,LL
          X(NN) = XX(NN)
          Y(NN) = YY(NN)
          Z(NN) = ZZ(NN)
125  CONTINUE
C
      DO 130 nn = LL +bb, 4*bb*cc +bb
          x(nn-bb) = xx(nn)
          Y(nn-bb) = yy(nn)
          z(nn) = zz(nn)
C130 CONTINUE
C
      FOR INSIDE RADIUS COORDINATES UNDER THE GEAR TOOTH
C
          PI = 3.141592654
          IF(INT.EQ.2)THEN
              GR = LL
              PI = 3.141592654
          ENDIF
C
          IF(INT.EQ.4) THEN
              GR = LL + 6*BB
              PI = 3.141592654
          ENDIF
C
      DO 155 I = 1,BB
          IF(INT.EQ.2)THEN

```

```

JJ = (I-1)*cc + 1
KK = (I-1)*cc + BB*cc + 1
J = I + BB
IF (ABS(Y(JJ)).LE.1.0E-5)GOTO 141
MM(I) = ATAN(Y(JJ)/X(JJ))
IF (X(JJ).LT.0.0.AND.Y(JJ).LT.0.0)MM(I) = MM(I) + PI
IF (X(JJ).LT.0.0.AND.Y(JJ).GT.0.0)MM(I) = MM(I) + PI
GOTO 142
141 CONTINUE
MM(I) = 0.0
IF (Z(JJ).LT.0.0)MM(I) = PI
142 CONTINUE
IF (ABS(Y(KK)).LT.1.E-5)GOTO 143
PP(J) = ATAN(Y(KK)/X(KK))
IF (X(KK).LT.0.0.AND.Y(KK).LT.0.0)PP(J) = PP(J) + PI
IF (X(KK).LT.0.0.AND.Y(KK).GT.0.0)PP(J) = PP(J) + PI
GOTO 140
143 CONTINUE
PP(J) = 0.0
IF (X(KK).LT.0.0)PP(J) = PI
140 GOTO 155
C
ELSEIF(INT.EQ.4)THEN
JJ = (I-1)*cc + 2*(BB*cc)+1
KK = (I-1)*cc + 3*(BB*cc)+1
J = I + 2*(BB*cc) + BB
IF (ABS(Y(JJ)).LE.1.0E-5)GOTO 151
MM(I) = ATAN(Y(JJ)/X(JJ))
IF (X(JJ).LT.0.0.AND.Y(JJ).LT.0.0)MM(I) = MM(I) + PI
IF (X(JJ).LT.0.0.AND.Y(JJ).GT.0.0)MM(I) = MM(I) + PI
GOTO 152
151 CONTINUE
MM(I) = 0.0
IF (X(JJ).LT.0.0)MM(I) = PI
152 CONTINUE
IF (ABS(Y(KK)).LT.1.E-5)GOTO 153
PP(J) = ATAN(Y(KK)/X(KK))
IF (X(KK).LT.0.0.AND.Y(KK).LT.0.0)PP(J) = PP(J) + PI
IF (X(KK).LT.0.0.AND.Y(KK).GT.0.0)PP(J) = PP(J) + PI
GOTO 150
153 CONTINUE
PP(J) = 0.0
IF (X(KK).LT.0.0)PP(J) = PI
150 GOTO 155
ENDIF
155 CONTINUE
C
C FOR INNER GEAR BLANK RADIUS GRIDS & ARC LOCATIONS
C
IF(INT.EQ.4)THEN
DELTA = (R2-R1)/(BB-1)
REAR = R1
ENDIF
C
DO 910 I = 1, BB
J = I + BB
G = GR + 1 + (I-1)*2
C
IF(INT.EQ.2)THEN
JJ = (I-1)*cc + 1
K = I + 2*BB
XR = RI*COS(MM(I))
YR = RI*SIN(MM(I))
ZR = Z(JJ)
DELTA(I) = ((PP(J)-MM(I))*180./PI)
WRITE(nf1,915)'GRID,',G+bb,',',XR,'/',YR,'/',ZR

```



```

911 WRITE(nf1,911)'LINE,' ,k+bb,' ,ARC,5(0)/1/' ,delta(i),' ,',g+bb
FORMAT(a5,i3,a12,f10.5,a1,i4)

```

C

```

ELSEIF(INT.EQ.4)THEN
JJ = (I-1)*cc + 2*(BB*cc)+1
J = I + 2*(BB*cc)+BB
K = I + (cc-1)*BB
RBAR = R1 + (I-1)*DELR
RX(I) = RBAR*COS(MM(I))
RY(I) = RBAR*SIN(MM(I))
RICC = SQRT(X(JJ)*X(JJ)+Y(JJ)*Y(JJ))
RZ(I) = Z(JJ) + (RICC-RBAR)/TAN(PI/2.-(MU-DEDEN))
DELTA(I) = (PP(J)-MM(I))*180./PI
WRITE(nf1,915)'GRID,' ,G+2*bb,' ,',RX(i),'/',Ry(i),'/',Rz(i)
WRITE(nf1,920)'LINE,' ,19*bb+i,' ,ARC,5(0)/1.0/' ,delta(i),' ,',g+2*bb
ENDIF
915 FORMAT(A5,I4,A2,F10.6,A1,F10.6,A1,F10.6)
920 FORMAT(A5,I4,A20,F10.4,A2,I4)
910 CONTINUE
925 CONTINUE

```

C

C

C

TO MAKE HYPAT FROM GEAR BLANK INSIDE RADIUS TO TOOTH BOTTOM

```

IF(INT.EQ.2)THEN
GR = 4*BB*cc
PA = 2*BB*cc - BB
LI = 3*BB
HP = 2*(cc-1)*(bb-1) + (BB-1)
ntp = ntpin
ELSEIF(INT.EQ.4)THEN
GR = 4*BB*cc + 6*BB
PA = 2*BB*cc + BB
LI = BB*cc
HP = 2*(cc-1)*(bb-1) +3*(BB-1)
ntp = ntge
ENDIF
NT = FLOAT(NTP)

```

C

C

```

DO 930 I = 1,BB
LI = LI + i
IF(INT.EQ.2)THEN
Li1 = 4*bb + 2*i
Li2 = 4*bb*cc +bb + (2*i-1)
Li3 = 10*bb+(2*i-1)
Li4 = 10*bb+2*i
Li5 = Li1
Li6 = 12*bb+i
Li7 = 4*bb*cc + 3*bb +(4*i-2)
Li8 = 4*bb*cc +3*bb +4*i
Li9 = 13*bb+i
Li10 = bb*cc+cc*i-(cc-1)
Li11 = 4*bb*cc+bb+(2*i)
Li12 = 14*bb+i
Li13 = 4*bb*cc +3*bb +(4*i-3)
Li14 = 4*bb*cc +3*bb +(4*i-1)
Li15 = 15*bb+i
Li16 = 3*bb+i
Li17 = 10*bb+(2*i-1)
II = (I-1)*cc + 1
DELA = ABS(DELTA(I)*PI/180.)
ROT = (2.* PI / NT - DELA)/2.
VEC = SQRT(X(II)*X(II)+Y(II)*Y(II))
ETA = ACOS(1.-(CL/VEC)**2.)
XRHO = VEC*COS(MM(I)-ROT)

```

```

        YRHO = VEC*SIN(MM(I)-ROT)
        ANG = ((PI-2.*ROT)*180.)/ PI
        W4 = 8*bb + i
        W5 = 4*bb*cc + i
        W6 = 4*bb*cc + 3*bb + 4*i
WRITE(nf1,929)'LINE,',4*bb+(2*i-1),',ARC,',xrho,'/',yrho,'/0/',
*   xrho,'/',yrho,'/1.0/',ang,'',i
WRITE(nf1,933)'LINE,',6*bb+(2*i-1),',/',6*bb+2*i,',BR,.5,',
*   4*bb+(2*i-1)

933  FORMAT (a5,i4,a1,i4,a7,i4)

929  FORMAT(a5,i4,a5,f8.5,a1,f8.5,a3,f8.5,a1,f8.5,a5,f11.5,a1,i4)
934  FORMAT(a5,i4,a3,a2,i4,a1,i4)
      ELSE
        Li1 = 25*bb+(2*i-1)
        Li2 = 4*cc*bb + 8*bb + (2*i - 1)
        Li3 = 27*bb + 2*i
        Li4 = 27*bb + 2*i + 1
        Li5 = 25*bb+(2*i-1)
        Li6 = 29*bb + 1 + i
        Li7 = 4*bb*cc + 10*bb + (4*i -2)
        Li8 = 4*bb*cc +10*bb + 4*i
        Li9 = 30*bb + 1 + i
        Li10 = 3*cc*bb + (cc*i - cc+1)
        Li11 = 4*bb*cc + 8*bb + 2*i
        Li12 = 31*bb + 1 + i
        Li13 = 4*bb*cc + 10*bb + (4*i - 3)
        Li14 = 4*bb*cc + 10*bb + (4*i - 1)
        Li15 = 32*bb + 1 + i
        li16 = 19*bb + i
        Li17 = 27*bb + 2*i
        II = (I-1)*cc + 2*(BB*cc)+1
        DELA = ABS(DELTA(I)*PI/180.)
        ROT = (2.* PI / NT - DELA)/2.
        VEC = SQRT(X(II)*X(II)+Y(II)*Y(II))
        XRHO = VEC*COS(MM(I)+ROT)
        YRHO = VEC*SIN(MM(I)+ROT)
        ANG = -((PI-2.*ROT)*180.)/ PI
WRITE(NF1,931)'LINE,',20*bb+i,',ARC,',',0/0/0/',XRHO,'/',
*   YRHO,'/',Z(II),',',ANG,'',II
        w1 = 22*bb + (2*i-1)
        w2 = w1 +1
        w3 = 20*bb+i
        w4 = 24*bb + i
        w5 = 4*bb*cc + 7*bb + i
        w6 = 4*bb*cc + 10*bb + 4*i
WRITE(nf1,933)'LINE,',w1,'/',w2,',BR,.5,',w3
931  FORMAT(A5,I4,A5,A6,F7.4,A1,F7.4,A1,F10.6,A1,F8.3,A1,I4)
      ENDIF
        IF(INT.EQ.2)ROTAT = -(2 * ROT * 180./PI)
        IF(INT.EQ.4)ROTAT = (2 * ROT * 180./PI)
        IF(I.EQ.1)GR = GR + 1
        IF(I.GT.1)GR = GR + 2
        Write(nf1,932)'LINE,',LI1, ',ARC,0/0/0/0/0/1/',ROTAT,'',LI2
write(nf1,936)'LINE,',LI3, ',',LI4, ',BR,.5,',LI5
write(nf1,934)'LINE,',w4,',ST',',',w5,',',w6
write(nf1,937)'LINE,',LI6,',ST',',',LI7,',',LI8
write(nf1,937)'LINE,',LI9,',ST',',',LI10,',',LI11
write(nf1,937)'LINE,',LI12,',ST',',',LI13,',',LI14
write(nf1,938)'LI,',Li15,',MER,',',Li16,'/',Li17
938  format(a3,i4,a6,i4,a1,i4)
937  format(a5,i4,a3,a2,i4,a1,i4)
936  format(a5,i4,a1,i4,a7,i4)
932  FORMAT(A5,I4,A18,F8.3,A1,I4)
930  CONTINUE

```

C
C
C
C

CONNECT LINES ON TOP OF FILLET/ROOT RADIUS &
GEAR BLANK INSIDE RADIUS

```
DO 940 I = 1,bb
  IF(INT.EQ.2) then
    pppa = bb*cc-bb
    pa1 = bb+2*i
    pa2 = 13*bb+i
    pa3 = 15*bb+i
    pa4 = 8*bb+i
    pa5 = bb+(2*i-1)
    pa6 = 8*bb+i
    pa7 = 12*bb+i
    pa8 = 6*bb+(2*i-1)
    pa9 = 10*bb+(2*i)
    pa10 = 14*bb+i
    pa11 = 6*bb+2*i
    pa12 = 12*bb+i
  elseif(int.eq.4)then
    Pppa = 2*bb*(cc-1). + 3*bb
    pa1 = 30*bb + 1 + i
    pa2 = 17*bb + 2*i
    Pa3 = 24*bb + i
    Pa4 = 32*bb + 1 + i
    Pa5 = pa3
    Pa6 = pa2 - 1
    Pa7 = 22*bb + 2*i -1
    pa8 = 29*bb + 1 + i
    pa9 = pa8
    pa10 = pa7 + 1
    Pa11 = 31*bb + i + 1
    pa12 = 27*bb + 2*i + 1
  endif
  write(nf1,941)'PA,',1*PPPA+i,',EDGE,,,pa1,','','pa2,','','pa3,','','pa4
  write(nf1,941)'PA,',1*PPPA+bb+i,',EDGE,,,pa5,','','pa6,','','pa7,','','pa8
  write(nf1,941)'PA,',1*pppa+2*bb+i,',EDGE,,,pa9,','','pa10,','','pa11,
  * '','','pa12
941 format(a3,i4,a7,i4,a1,i4,a1,i4,a1,i4)
940 CONTINUE
```

C
C
C

CONNECT PATCHES IN BETWEEN TEETH TO MAKE HYPERPATCHES

```
do 945 i = 1,(bb-1)
  If (int.eq.2) then
    hp1 = bb*(cc-1) + i
    hp2 = hp1 + 1
    hp3 = hp1 + bb
    hp4 = hp3 + 1
    hp5 = hp3 + bb
    hp6 = hp5 + 1
  hh1 = (bb-1)*(cc-1)+i
  hh2 = hh1 + (bb-1)
  hh3 = hh2 + (bb-1)
  ELSEIF (INT .EQ. 4) THEN
    hp1 = 2*bb*(cc-1) + 3*bb + i
    hp2 = hp1 + 1
    hp3 = hp1 + bb
    hp4 = hp3 + 1
    hp5 = hp3 + bb
    hp6 = hp5 + 1
    hh1 = 2*(bb-1)*(cc-1) + 3*(bb-1) + i
    hh2 = hh1 + bb-1
    hh3 = hh2 + bb-1
  ENDIF
  write(nf1,913)'HPAT,',hh1,',2P,,,hp1,','','hp2
```

```

          write(nf1,913)'HPAT','hh2','2P','','hp3','','hp4
          write(nf1,913)'HPAT','hh3','2P','','hp5','','hp6
913  format(a5,i4,a6,i4,a1,i4)
945  CONTINUE
      IF(INT.EQ.2)GO TO 980
C
980  CONTINUE
      IF (INT.EQ.2) THEN
          WRITE(NF1,*)'SET,LINES,0'
          WRITE(NF1,*)'NAME,PI 1'
          WRITE(NF1,*)'SET,ACTIVE,NONE'
      ELSEIF(INT.EQ.4) THEN
          WRITE(NF1,*)'SET,LINES,0'
          WRITE(NF1,*)'NAME,GE 1'
          write(nf1,*)'SET,ACTIVE,NONE'
      ENDIF
C
      RETURN
      END
C
C
C
      SUBROUTINE MODEL(BB,cc,number,fill)
C
      COMMON/UNITS/NF1,NF2
      INTEGER I,J,K,L,numb
      INTEGER I1,I2,J1,J2,K1,K2,L1,L2,bb,cc
C
          WRITE(NF1,*)'NAME,GE 1,PLOT'
C  to generate the whole gear use this do loop
C  DO 901 I = 1,35
C      L = I + 1
C      WRITE(NF1,905)'NAME','','GE',L','','RO','','5(0)/1/10','','GE',I
C 905  FORMAT(A6,A2,I2,A1,A2,A1,A10,A2,I2)
C 901  CONTINUE
          WRITE(NF1,*)'NAME,GEAR'
          write(nf1,*)'NAME,PI 1,PL'
          WRITE(NF1,*)'PA,1T#,DEL'
C
          I1 = 1
          I2 = (BB-1)*(cc-1)
          j1 = i2 + 1
          j2 = i2 + 2*(bb-1)
          numb = number/2
C
          write(nf1,917)'MESH,H',i1,'T',i2,'HEX,N,1/' ,number
          *,'/1/' ,number, '/1'
          write(nf1,918)'MESH,H',j1,'T',j2,'HEX,N', ,numb, '/',
          * fill, '/', ,numb, '/', ,fill, '/1'
          write(nf1,919)'MESH,H',j2+1,'T',j2+bb-1,'HEX,N', ,3',
          * '/', ,numb, '/3/' ,numb, '/1'
C 919  format(a6,i4,a1,i4,a7,a1,a1,i4,a3,i4,a2)
C 917  format(a6,i4,a1,i4,a9,i4,a3,i4,a2)
C 918  format(a6,i4,a1,i4,a7,i4,a1,i4,a1,i4,a2)
          write(nf1,*)'NAME,PIN'
          WRITE(NF1,*)'SET,ACTIVE,NONE'
          WRITE(NF1,*)'NAME,GE 1,PLOT'
C
          K1 = (bb-1)*(cc-1) + 3 bb-1) + 1
          K2 = K1 + (bb-1) *(cc-), - 1
          JJ1 = K2 + 1
          jj2 = k2 + 2*(bb-1)
          numb = number/2
C
          write(nf1,917)'MESH,H',K1,'T',K2,'HEX,N,1/' ,number
          *,'/1/' ,number, '/1'

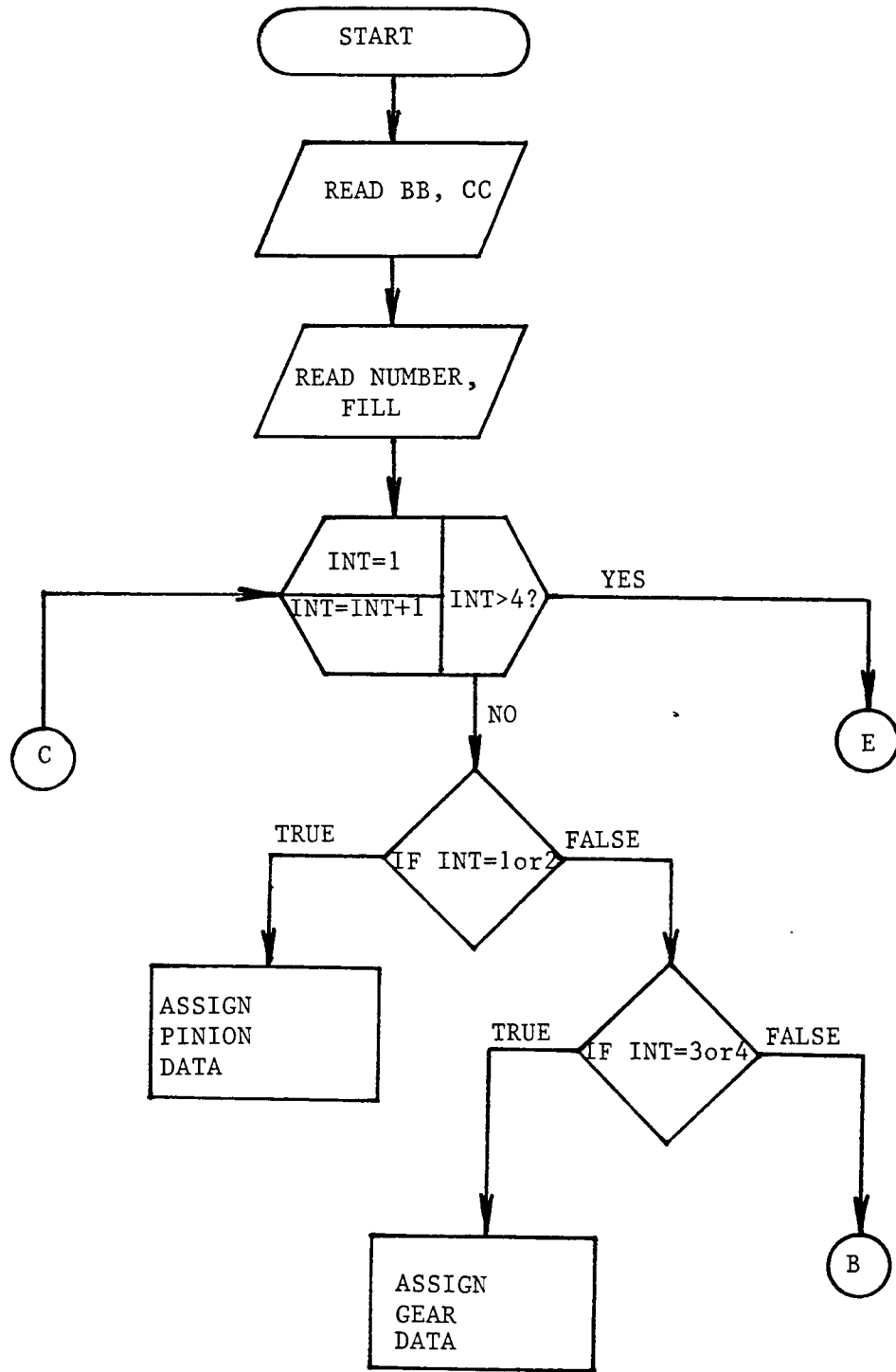
```

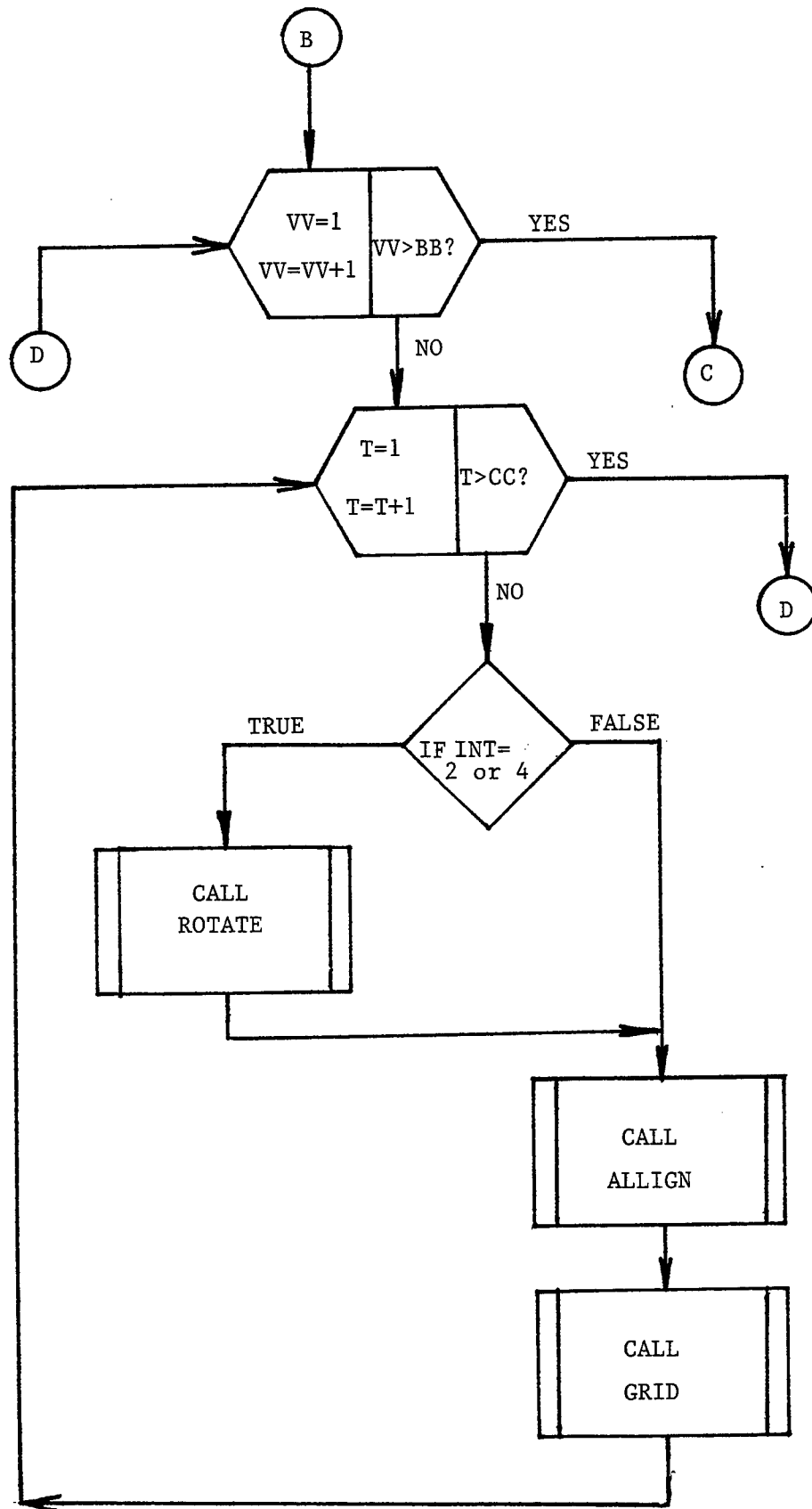
```

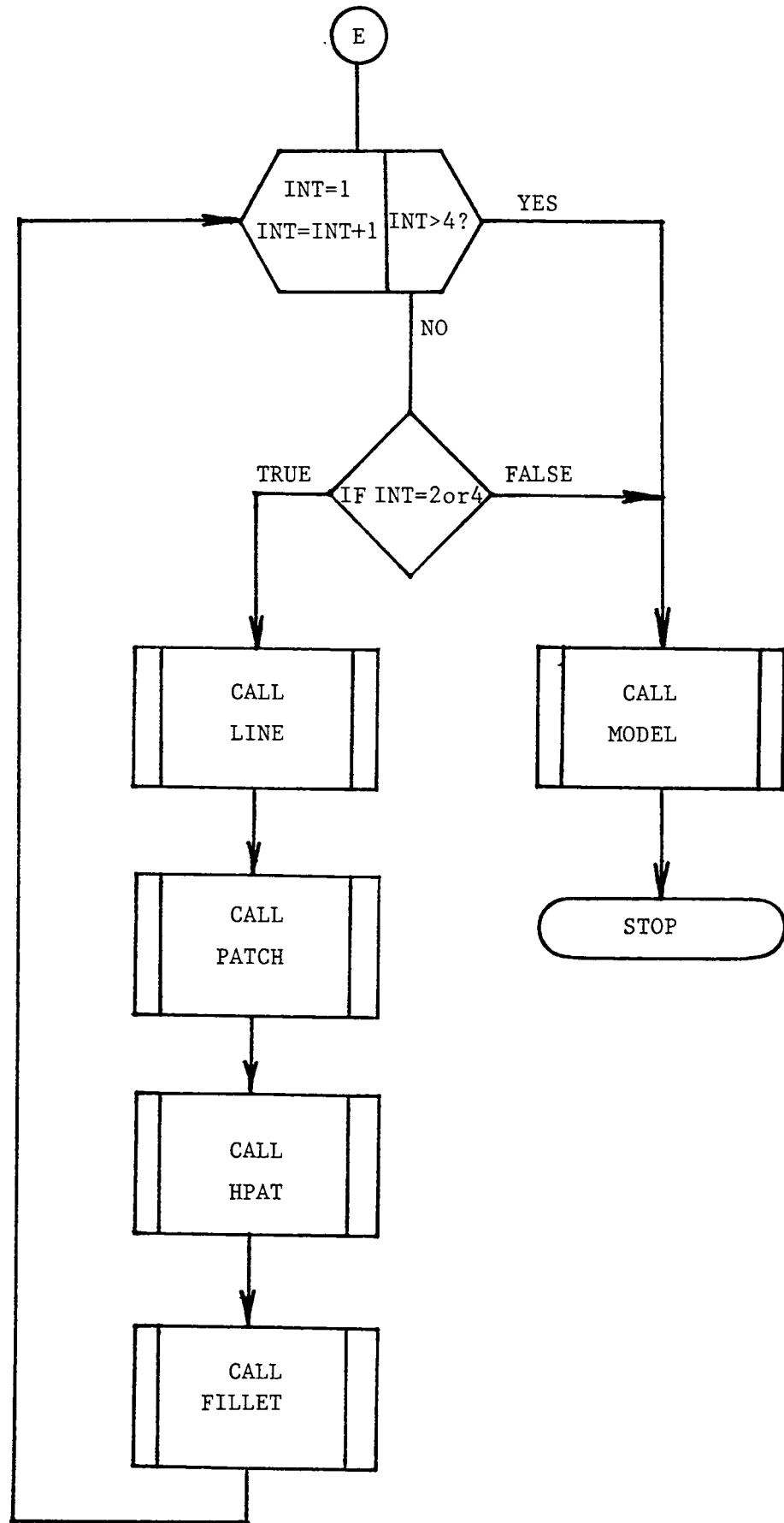
        write(nf1,918)'MESH,H',jj1,'T',jj2,',HEX,N',fill,'/',
* numb,'/',fill,'/',numb,'/1'
        write(nf1,921)'MESH,H',jj2+1,'T',jj2+bb-1,',HEX,N',
* numb,'/','3', '/',numb,'/','3', '/1'

921     FORMAT(a6,i4,a1,i4,a7,i4,a1,a1,a1,i4,a1,a1,a2)
        K1 = (BB-1)*(cc-1) + 1
        K2 = 2*(BB-1)*(cc-1)
        L1 = 2*(bb-1)*cc + 1
        L2 = 2*(BB-1)*cc + 2*(bb-1)
C      to generate the whole pinion use this do loop
C      DO 902 J = 1,11
C          K = J + 1
C          WRITE(NF1,906)'NAME,', 'PI',K,',',',',RO',',',',',3(0)/1/0/0/30,'
C      *      , 'PI',J
C 906     FORMAT(A6,A2,I2,A1,A2,A1,A14,A2,I2)
C 902     CONTINUE
C          WRITE(NF1,*)'NAME,PINION1'
C
C          WRITE(NF1,*)'NAME,GEAR'
C          WRITE(NF1,*)'GR,1T#,DEL'
C          WRITE(NF1,*)'NAME,PINION,RO,4(0)/1/0/-90,PIN'
C          write(nf1,*)'NAME,PINION,PL'
        Return
        END

```







FLOWCHART: PAT.F (DISCUSSION)

There are four loops in the main program.

Loop 1: Loops one through four to read data for the four surfaces.

Loop 2: Loops one through BB, where BB is the number of points across the face of the tooth surface.

Loop 3: Loops one through CC, where CC is the number of points along the height of the tooth.

Loop 4: The final loop creates the lines, patches, hyper-patches, fillet and meshes the model for one gear tooth and one pinion tooth.

Subroutines:

1. ROTATE: Rotates the pinion and gear convex sides by Q degrees to create top land.
2. ALIGN: Aligns the pinion in mesh with the gear.
3. GRID: Creates PATRAN commands for the grids.
4. LINE: Creates PATRAN commands for the lines.
5. PATCH: Creates PATRAN commands for the patches.
6. HPAT: Creates PATRAN commands for the hyper-patches.
7. FILLET: Creates PATRAN commands to creat the fillet.
8. MODEL: Creates PATRAN commands to mesh the model.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (<i>Leave blank</i>)	2. REPORT DATE April 1994	3. REPORT TYPE AND DATES COVERED Final Contractor Report	
4. TITLE AND SUBTITLE Manual for Automatic Generation of Finite Element Models of Spiral Bevel Gears in Mesh		5. FUNDING NUMBERS WU-505-62-36 G-NAG3-1476 1L162211A47A	
6. AUTHOR(S) G.D. Bibel, S. Reddy, and A. Kumar		8. PERFORMING ORGANIZATION REPORT NUMBER E-8671	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of North Dakota Grand Forks, North Dakota 58201		10. SPONSORING/MONITORING AGENCY REPORT NUMBER NASA CR-191009 ARL-CR-121	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Vehicle Propulsion Directorate U.S. Army Research Laboratory Cleveland, Ohio 44135-3191 and NASA Lewis Research Center Cleveland, Ohio 44135-3191		11. SUPPLEMENTARY NOTES G.D. Bibel, University of North Dakota, Grand Forks, North Dakota (work funded by NASA Grant NAG3-1476); S. Reddy and A. Kumar, University of Akron, Akron, Ohio. Project Manager, Robert F. Handschuh, Army Research Laboratory, Vehicle Propulsion Directorate, organization code 2730, NASA Lewis Research Center, (216) 433-3969.	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category 37		12b. DISTRIBUTION CODE	
13. ABSTRACT (<i>Maximum 200 words</i>) The goal of this research is to develop computer programs that generate finite element models suitable for doing 3D contact analysis of faced milled spiral bevel gears in mesh. A pinion tooth and a gear tooth are created and put in mesh. There are two programs: Points.f and Pat.f to perform the analysis. Points.f is based on the equation of meshing for spiral bevel gears. It uses machine tool settings to solve for an N x M mesh of points on the four surfaces, pinion concave and convex, and gear concave and convex. Points.f creates the file POINTS.OUT, an ASCII file containing N x M points for each surface. (N is the number of node points along the length of the tooth, and M is nodes along the height.) Pat.f reads POINTS.OUT and creates the file t1.out. T1.out is a series of PATRAN input commands. In addition to the mesh density on the tooth face, additional user specified variables are the number of finite elements through the thickness, and the number of finite elements along the tooth full fillet. A full fillet is assumed to exist for both the pinion and gear.			
14. SUBJECT TERMS Gears; Gear teeth; Finite elements		15. NUMBER OF PAGES 58	
		16. PRICE CODE A04	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT