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MASTER

AN EXTENSION OF APT FOR PRODUCING INPUT
DATA FOR A FOUR-AXIS FILAMENT
WINDER POSTPROCESSOR

(Union Carbide APT Filament-Winding Pre-Postprocessor - UCAFIP)

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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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ABSTRACT

Fortran computer routines, which compute a geodesic path on an arbitrary surface of revolution and determine the machine feed-eye positions, have been incorporated into the APT system. The output of these routines is a cutter location tape which is processed by an APT postprocessor to produce a punched tape for a four-axis numerically controlled filament winding machine.

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SUMMARY

Computer routines,^(1,2) which compute a geodesic path on an arbitrary surface of revolution and determine the machine feed-eye positions, have been incorporated into the APT system as a pre-postprocessor. By the term "pre-postprocessor" is meant that they function like a postprocessor, but the output, instead of being a control tape for a machine, is another cutter-location (CL) tape. This second CL tape, containing the machine-eye locations, is then processed by a machine postprocessor to produce a control tape for a four-axis numerically controlled filament-winding machine.

To use the system, the contour of the surface of revolution is first described in an APT part program and a zero radius cutter traced around this contour. The geodesic paths to be wrapped are then specified in the part programming instruction, GEODES. The pre-postprocessor, like any other postprocessor, is called by a MACHIN statement.

The geodesic paths on the defined surface are computed in the pre-postprocessor. The machine feed-eye positions necessary to lay a filament along the geodesic paths are then calculated. These eye positions are such that the eye will maintain a specified clearance from the mandrel. The desired clearance is established by the part programming instruction, CLEAR. The eye geometry is defined by using OPTION instructions.

INTRODUCTION

By combining high-strength filaments with resin in a composite structure, structural elements and parts have been produced which have exceedingly high strength-to-weight ratios. New materials which lend themselves to filament winding are being rapidly developed and new applications of composite structures are appearing. Products currently made by filament-winding techniques range from light-weight fishing rods to large railway tank cars.

Manufacturing techniques for filament winding have advanced from machines mechanically controlled by cams and chains to highly versatile numerically controlled machines. However, in order to utilize the capabilities of a numerically controlled machine, algorithms must be developed for computing those machine motions which are necessary to lay filaments along the desired paths. This capability is not currently available in APT or any of the other powerful numerical-control computer systems.

One large class of filament-winding applications involves shapes which are surfaces of revolution. Since a geodesic path on any surface is a stable path, geodesics are often chosen as the desired filament paths. Algorithms and computer routines have been developed⁽¹⁾ for determining a geodesic path on an arbitrary surface of revolution. These routines are useful in designing filament-wound structures and analyzing their properties. The routines were extended⁽²⁾ to compute the machine feed-eye positions for laying a filament along the desired surface paths. These computer routines have now been incorporated into the APT system by Union Carbide at Oak Ridge to produce input data for a four-axis filament-winder postprocessor.

DISCUSSION

A revised version of the filament-winding computer routines, described by Bookhart and Fowler,⁽²⁾ has been incorporated into the APT system by Union Carbide at Oak Ridge. The revision primarily deals with input and output statements and a reduced amount of dimension and common data. The algorithms are identical to those described by Bookhart and Fowler. These routines function as a pre-postprocessor; that is, the routines are called by a MACHIN statement and have as input a cutter-location (CL) tape. However, unlike other postprocessors whose output is a machine-control tape, the output of this program is another CL tape. This second CL tape is used by a filament-winding machine postprocessor to obtain the punched tape for controlling the machine. The flow of a part program through the APT system with the pre-postprocessor is indicated in Figure 1.

For the convenience of the user, several new words were created and added to the APT vocabulary. A typical part program is contained in Figure 2 and a description of the new words is given in Table 1.

The pre-postprocessor words are passed along to the pre-postprocessor on an APT CL tape. Figure 3 shows a typical CL tape. The statement "MACHIN/FLMWDR, PREPRO, 1" calls in the pre-postprocessor. The other MACHIN statement calls the filament-winding machine postprocessor.

If the motions for an entire wrap were included in the machine control tape, the length of tape would be about the same length as the filament laid down. This, of course, would be impractical. However, filament winding involves repeating a wrap circuit many, many times. Hence, one circuit of a pattern can be programmed and the circuit repeated until the wrap is complete. To accomplish this procedure of repeating the motions, two tape readers with identical tapes are used. One tape is read until a circuit of the path is completed, then control is switched to the other reader on which an identical tape is located at the beginning of the circuit. While the second reader has control, the first tape is rewound to the beginning of the circuit. This switching back and forth between readers continues until all of the circuits in a pattern have been completed. The number of times the readers switch (one less than the number of circuits) is conveyed to the control system by the REPEAT instruction. The number specified is put in the punched tape in a r word. After the appropriate number of circuits of a pattern have been executed, the tape readers, instead of rewinding, will proceed to the next pattern. The tape rewind is high speed to insure that the tape has been fully rewound before control is switched to that reader. This high-speed rewind, however, results in considerable tape overshoot. Therefore, tape leader is required prior to each circuit.

A numerically controlled machine lends itself very nicely to transitioning from one wrap pattern to another. This provision allows many patterns to be wrapped from a single setup. To accomplish this transition from one pattern to another, the

Figure 1. FLOW OF A PART PROGRAM THROUGH THE APT SYSTEM.

transition motion appears in the control tape as a wrap pattern. However, since the control tapes are identical, each reader must read this transition motion. Therefore, only one half of the transition appears in the machine control tape.

Setup is considered to be a transition from a known point to the beginning of a pattern and is treated in a similar manner to other transitions. The procedure used is to begin the winding operation with the feed eye at a known point on the surface. The initial transition then moves the feed eye from this known surface point to the feed-eye position of the beginning of the first wrap pattern. Again, only one half of this motion is included in the tape. The known surface point is programmed to be at the maximum diameter of the mandrel. If the mandrel is cylindrical at the maximum diameter, the beginning (lower end) of the cylinder is chosen.

PART NO
CHARGE

MACHIN / FLMWDR, PREPRO, 1
MACHIN / BLKCLW, FLMWDR, 1
OPTION / n, k
FEDRAT / f, IPM, RANGE, LOW
HIGH

(Surface contour description here.
Trace zero radius cutter around surface.)

CLEAR / c
LINTOL / t
SHAFT / Y SMALL, s_1 , Y LARGE, s_2

GEODES / INTLPT, x_1 , y_1 , AT ANGL, α_1 , CIRCTS, n, \$
INCR, a, CIRPAT, p, REVPAT, r, ADJUST, i

GEODES / INTLPT, x_k , y_k , AT ANGL, α_k , CIRCTS, n, \$
INCR, a, CIRPAT, p, REVPAT, r, ADJUST, i

STOP
FINI

Figure 2. TYPICAL APT PART PROGRAM.

Table 1
DESCRIPTION OF PRE-POSTPROCESSOR WORDS

WORD	DESCRIPTION
CLEAR	The desired clearance from eye to mandrel.
LINTOL	The wrap tolerance - deviation allowed between the spiral and geodesic on the surface.
SHAFT	The lower and upper radii of the mandrel shafts.
GEODES	
INTLPT	Coordinates of the initial point of the geodesic.
AT ANGL	The initial helix angle.
CIRCTS	The number of circuits to be wrapped.
INCR	The advance (revolution per circuit).
CIRPAT	The number of circuits per pattern.
REVPAT	The number of revolutions per pattern.
ADJUST	Flag indicating whether to adjust helix angle (flag = 0) or distort rotation of the geodesic (flag = 1)

Feed rate has been interpreted for a filament-winding machine to mean the rate of filament fed from the eye. Since the machine postprocessor has no information concerning the length of the filament being fed, this quantity must be passed along by the pre-postprocessor. Thus, the data on the second CL tape include, besides the the motion information, the incremental length of filament fed from the eye..

```

PARTNO
MACHIN / FLMWDR, PREPRO, 1
MACHIN / BLKCLW, FLMWDR, 1
OPTION / n, k
FEDRAT / f, IPM, RANGE, LOW
HIGH

r1, z1
r2, z2
.
.
.
rm, zm

```

Points along contour of surface (where Z is the axis of revolution of the surface). The points (r_i, z_i) are in the x, y data locations on the CL tape.

```

CLEAR / c
LINTOL / t
SHAFT / Y SMALL, s1, Y LARGE, s2
GEODES / INTLPT, x1, y1, AT ANGL, α1, CIRCTS, n, $
INCR, a, CIRPAT, p, REVPAT, r, ADJUST, i
.
.
.
GEODES / INTLPT, xk, yk, AT ANGL, α1, CIRCTS, n, $
INCR, a, CIRPAT, p, REVPAT, r, ADJUST, i

STOP
FINI

```

Figure 3. TYPICAL CUTTER-LOCATION TAPE 1.

Figure 4 shows a typical CL tape produced by the pre-postprocessor. An explanation of the data appears in Table 2. Since there are four motions (two linear and two rotary, see Figure 5) and a filament length to be passed on, the multiaxis format is

Table 2
DESCRIPTION OF CUTTER-LOCATION TAPE 2 DATA

DATA	DESCRIPTION
SEQNO/START	Command to put a rewind stop code in the punched tape.
SEQNO/k	Command to insert the sequence number, k, in the punched tape.
REPEAT/n	Command to insert the number of circuits, n, in the punched tape. A reference rewind stop (O code) and tape leader are also inserted.
SWITCH	Command to put m32 code in the tape (switches to other tape reader and signifies end of the geodesic circuit).
STOP	Command to put m00 code in tape. (When all circuits have been completed, stop machine. Otherwise functions as SWITCH command.)
X _i	The X coordinate (R in cylindrical coordinates) of the eye, inches absolute.
Y _i	The Y coordinate (Z in cylindrical coordinates) of the eye, inches absolute.
a _i	The rotation angle of the eye in revolutions.
b _i	The rotary position of the table (θ coordinate) in revolutions absolute.
l _i	The incremental length of filament fed from the eye.

```

MULTAX
OPTION / n, k
FEDRAT / f, IPM, RANGE, LOW
HIGH
SEQNO / START
SEQNO / 5
REPEAT / 2
FROM /  $x_1, y_1, 0, a_1, b_1, 0$ 
GOTO /  $x_2, y_2, 0, a_2, b_2, 0$ 
SWITCH
} Transition from
  Setup Point

SEQNO / 10
REPEAT /  $n_1$ 
FROM /  $x_3, y_3, 0, a_3, b_3, 0$ 
GOTO /  $x_4, y_4, 0, a_4, b_4, l_4$ 
GOTO /  $x_5, y_5, 0, a_5, b_5, l_5$ 
} A Circuit
  of the
  First Geodesic
:
GOTO /  $x_i, y_i, 0, a_i, b_i, l_i$ 
SWITCH

SEQNO / 15
REPEAT / 2
FROM /  $x_i, y_i, 0, a_i, 0, 0$ 
GOTO /  $x_i + 1, y_i + 1, 0, a_i + 1, b_i + 1, 0$ 
SWITCH
} Transition from First
  Geodesic to Second

SEQNO / 20
REPEAT /  $n_2$ 
FROM /  $x_i + 2, y_i + 2, 0, a_i + 2, b_i + 2, 0$ 
GOTO /  $x_i + 3, y_i + 3, 0, a_i + 3, b_i + 3, l_i + 3$ 
} A Circuit
  of the
  Second Geodesic
:
GOTO /  $x_k, y_k, 0, a_k, b_k, l_k$ 
SWITCH
:
GOTO /  $x, y, 0, a, b, l$ 
STOP
FINI
} Last
  GOTO Point of
  Final Geodesic

```

Figure 4. TYPICAL CUTTER-LOCATION TAPE 2.

Figure 5. FILAMENT WINDER MOTIONS.

utilized. The x and y positions of the record are taken up by the x and y machine coordinates. The z position of the record is not used. The head angle (a axis) appears in the position normally reserved for i, the table angle (b axis) in the position of j, and the filament length appears in the k position.

EXAMPLE

An illustrative example is shown on the following pages. The example is for the same part used in the report by Bookhart and Fowler⁽²⁾, see Figure 6. The APT part program is given as Figure 7. Note that a DNTCUT command was used so that all of the points passed along on the CL tape will lie on the surface itself. The pre-postprocessor listing showing the points along the geodesic on the surface and the corresponding feed-eye coordinates follows as outlined in Table 3. Figure 8 shows the part as it was wound on the numerically controlled filament winder. (a) The first geodesic defined in the part program (a helix angle of 18.03 degrees on the cylindrical section) is the one seen in the figure.

(a) The machine was manufactured by the Black-Clawson Company, Hamilton, Ohio; the control system by the General Electric Company.

Figure 6. CONTOUR OF THE SURFACE USED IN THE EXAMPLE.

PAGE 1	4/19/68	
PARTNO	WINDER TEST MANDREL	B GOKHART T.W. 9704-2
CHARGE#5575		101
MACHIN/FLMWDR,PREPRO,1		0102
MACHIN/BLKCLW,FLMWDR,1		0103
OPTION/12,6	6 INCHES OF LEADER	0104
OPTION/20,2	2 PUNCHED TAPES	0105
FEDRAT/1800,IPM,RANGE,LOW		0107
CLPRNT		0109
OR#POINT/0,0		0110
XAX#LINE/OR,ATANGL,0		0111
YAX#LINE/OR,ATANGL,90		0112
P1#POINT/4,10		0113
P2#POINT/6,10		0115
P3#POINT/18,14		0117
P4#POINT/18,24		0119
P5#POINT/6,50		0121
P6#POINT/0,50		0123
L1#LINE/P1,P2		0125
L2#LINE/P2,P3		0201
L3#LINE/P3,P4		0203
L4#LINE/P4,P5		0205
L5#LINE/P5,P6		0207
C1#CIRCLE/YLARGE,L1,XSMALL,L2,RADIUS,.5		0209
C2#CIRCLE/YLARGE,L2,XSMALL,L3,RADIUS,.5		0211
C3#CIRCLE/XSMALL,L3,XSMALL,L4,RADIUS,.5		0213
C4#CIRCLE/XSMALL,L4,XSMALL,L5,RADIUS,.5		0215
OUTTOL/.001		0217
INTOL/0		0219
DNTCUT		0221
FROM/OR		0223
INDIRP/P1		0225
GO/TO,L1		0301
CUT		0303
GORG/L1,TANTO,C1		0305
GOFWD/C1,TANTO,L2		0307
GOFWD/L2,TANTO,C2		0309
GOFWD/C2,TANTO,L3		0311
GOFWD/L3,TANTO,C3		0313
GOFWD/C3,TANTO,L4		0314
GOFWD/L4,TANTO,C4		0315
GOFWD/C4,TANTO,L5		0316
GOFWD/L5,TO,YAX		0317
CLEAR/1		0319
L INTOL/.05C		0321
SHAFT/YSMALL,4,YLARGE,4		0323
GEODES/INTLPT,18,20,ATANGL,18,CIRCTS,897,\$		0325
INCR,.000017,CIRPAT,65,REVPAT,95,ADJUST,0		0403
GEODES/INTLPT,18,20,ATANGL,56,CIRCTS,510,\$		0404
INCR,.00197,CIRPAT,1,REVPAT,1,ADJUST,0		0406
STOP		0407
FINI		0409
		0411

Figure 7. PART PROGRAM USED IN THE EXAMPLE.

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Figure 8. PART USED IN THE EXAMPLE AS WOUND ON THE NUMERICALLY CONTROLLED WINDER.

Table 3
PRE-POSTPROCESSOR LISTING

GEODESIC	HELIX ANGLE	AT POINT R Z	TOTAL ROTATION	DISTORT FACTOR	FILMT LENGTH	NO. OF CIRCUITS	CIRC PER PATTERN	REV PER PATTERN	ADVANCE PER CIR	WRAP TOLERANCE	CLEAR- ANCE
1	18.03	18.0000 20.0000	495.66	1.0000	145.46	897	69	95	0.00002	0.050	1.000
**	WRAP POINT ON MANDREL R Z	THE TA	**	EYE LOCATION IN SPACE R Z THETA	A ANGLE	**	VECTOR LENGTH	FILMT FED	FILMT DOWN	B ANGLE (REV)	A ANGLE (REV)
18.0000	14.3604	0.	18.0000	14.3604	0.	180.00				0.	0.50000
18.0000	14.3604	0.	18.6014	25.5785	11.32	162.51	11.80	11.800	0.	0.03145	0.45143
18.0000	15.3153	0.59	18.3485	26.2506	12.17	162.29	11.50	0.704	1.004	0.03382	0.45081
18.0000	16.2702	1.98	18.2987	26.3877	12.35	162.25	10.64	0.144	1.004	0.03429	0.45069
18.0000	17.2251	2.97	18.2517	26.5058	12.49	162.20	9.76	0.124	1.004	0.03471	0.45057
18.0000	18.1800	3.96	18.2086	26.6239	12.64	162.16	8.88	0.124	1.004	0.03511	0.45046
18.0000	19.1349	4.95	18.1686	26.7230	12.76	162.13	7.98	0.104	1.004	0.03544	0.45036
18.0000	20.0897	5.94	18.1329	26.8221	12.88	162.09	7.08	0.104	1.004	0.03577	0.45026
18.0000	21.0446	6.92	18.1007	26.9022	12.97	162.07	6.16	0.084	1.004	0.03603	0.45018
18.0000	21.9995	7.91	18.0729	26.9822	13.06	162.04	5.24	0.084	1.004	0.03628	0.45011
18.0000	22.9544	8.90	18.0491	27.0433	13.13	162.02	4.30	0.064	1.004	0.03648	0.45005
18.0000	23.9093	9.89	18.0278	27.1043	13.20	162.00	3.36	0.064	1.004	0.03667	0.44999
18.0000	23.9411	9.93	17.8311	27.6246	13.79	161.78	3.88	0.554	0.034	0.03830	0.44940
17.9945	23.9901	9.98	17.2283	29.2269	15.73	160.99	5.58	1.752	0.052	0.04370	0.44719
17.9842	24.0383	10.03	15.7463	33.1799	21.35	158.88	9.98	4.452	0.052	0.05931	0.44134
17.9682	24.0849	10.08	13.7083	38.6161	31.63	155.57	16.24	6.312	0.052	0.08786	0.43215
16.0155	29.2920	16.61	12.2270	42.5652	42.09	152.57	15.12	4.768	5.888	0.11691	0.42381
14.2911	33.8904	23.98	11.2958	45.0480	50.50	150.23	12.94	3.102	5.282	0.14029	0.41731
12.7709	37.9444	32.30	10.4529	47.2966	59.89	147.68	11.10	2.913	4.753	0.16637	0.41024
11.4338	41.5099	41.68	9.6947	49.3268	70.40	144.90	9.56	2.752	4.292	0.19555	0.40250
10.2616	44.6356	52.28	9.0196	51.1307	82.09	141.85	8.26	2.593	3.893	0.22804	0.39403
9.2391	47.3625	64.25	8.4239	52.7107	95.08	138.48	7.16	2.452	3.552	0.26412	0.38467
8.3533	49.7246	77.77	7.9074	54.0921	109.64	134.72	6.26	2.364	3.264	0.30455	0.37423
7.5944	51.7483	93.02	7.4698	55.2610	125.85	130.47	5.52	2.287	3.027	0.34958	0.36243
6.9555	53.4519	110.21	7.1125	56.2102	143.85	125.59	4.92	2.239	2.839	0.39959	0.34887
6.4746	54.7344	127.71	6.7264	56.6716	159.00	119.95	4.06	1.605	2.465	0.44166	0.33318
6.1217	55.6756	145.21	6.4092	57.0094	174.82	113.80	3.48	1.589	2.169	0.48561	0.31610
6.0958	55.7332	146.53	6.3601	57.0543	178.45	112.29	3.68	0.354	0.154	0.49569	0.31191
6.0645	55.7847	147.83	6.3354	57.0818	183.28	110.24	4.00	0.470	0.150	0.50910	0.30623
6.0273	55.8321	149.18	6.3502	57.0669	188.36	107.97	4.34	0.495	0.155	0.52321	0.29991
5.9846	55.8747	150.61	6.4075	57.0015	193.44	105.48	4.68	0.501	0.161	0.53735	0.29300
5.9371	55.9118	152.13	6.5160	56.8887	198.42	102.82	5.02	0.509	0.169	0.55118	0.28562

Table 3 (Continued)

5.8855	55.9429	153.78	6.6607	56.7285	202.89	100.01	5.32	C.48C	C.180	0.56359	0.27781
5.8305	55.9676	155.59	6.8400	56.5356	206.80	97.12	5.58	C.455	C.195	0.57446	0.26979
5.7729	55.9855	157.65	7.0401	56.3258	210.04	94.25	5.78	C.416	C.216	0.58345	0.26182
5.7137	55.9964	160.05	7.1461	56.1117	211.60	91.48	5.74	C.209	C.249	0.58779	0.25410
5.6535	56.0000	163.09	7.1972	56.0000	212.18	90.00	5.52	C.087	C.307	0.58938	0.25000
5.5709	56.0000	172.89	7.1991	56.0000	212.20	90.00	4.56	C.003	C.963	0.58943	0.25000
5.6535	56.0000	182.70	7.2010	56.0000	212.21	90.00	3.60	C.003	C.963	0.58948	0.25000
5.7137	55.9964	185.74	7.2150	55.9297	212.39	88.51	3.32	C.027	C.307	0.58998	0.24586
5.7729	55.9855	188.14	7.2654	55.7983	213.13	85.61	3.18	C.109	C.249	0.59202	0.23780
5.8305	55.9676	190.19	7.3283	55.6500	214.20	82.37	3.12	C.156	C.216	0.59499	0.22881
5.8855	55.9429	192.01	7.3826	55.4852	215.43	78.93	3.10	C.175	C.195	0.59841	0.21924
5.9371	55.9118	193.66	7.4552	55.2969	217.09	75.40	3.16	C.240	C.180	0.60303	0.20945
5.9846	55.8747	195.18	7.5323	55.0850	219.09	71.97	3.28	C.289	C.169	0.60859	0.19991
6.0273	55.8321	196.61	7.6244	54.8421	221.56	68.72	3.48	C.361	C.161	0.61544	0.19090
6.0645	55.7847	197.96	7.7285	54.5655	224.51	65.78	3.76	C.435	C.155	0.62363	0.18272
6.0958	55.7332	199.26	7.8521	54.2471	228.07	63.16	4.14	C.530	C.150	0.63352	0.17545
6.1217	55.6756	200.58	7.9534	53.9585	231.42	61.31	4.48	C.494	C.154	0.64282	0.17031
6.5447	54.5474	220.99	8.6876	52.0117	251.36	52.53	5.16	3.235	2.555	0.69822	0.14593
7.0708	53.1446	239.09	9.5308	49.7657	268.06	45.39	5.86	3.319	2.619	0.74462	0.12608
7.6960	51.4774	255.07	10.5165	47.1363	282.62	39.35	6.72	3.581	2.721	0.78507	0.10931
8.4210	49.5440	269.19	11.6556	44.0953	295.32	34.24	7.76	3.903	2.863	0.82034	0.09512
9.2498	47.3338	281.68	12.9604	40.6066	306.40	29.90	9.00	4.285	3.045	0.85112	0.08306
10.1892	44.8289	292.75	14.4641	36.5971	316.14	26.16	10.50	4.767	3.267	0.87816	0.07268
11.2478	42.0058	302.60	16.1896	32.0009	324.70	22.93	12.30	5.331	3.531	0.90194	0.06369
12.4366	38.8357	311.36	18.1515	26.7643	332.20	20.13	14.42	5.958	3.838	0.92279	0.05593
13.7682	35.2849	319.17	19.0025	23.5371	336.16	18.90	13.72	3.491	4.191	0.93378	0.05250
15.2571	31.3144	326.16	19.0077	22.3188	337.59	18.58	10.32	1.193	4.593	0.93775	0.05162
16.4950	28.0135	330.93	19.0008	21.7386	338.20	18.40	7.12	C.565	3.765	0.93945	0.05111
17.9682	24.0849	335.71	19.0020	21.2754	338.65	18.14	3.14	C.454	4.434	0.94068	0.05039
17.9842	24.0383	335.76	19.0004	20.5210	339.35	17.75	3.84	C.752	C.052	0.94264	0.04930
17.9945	23.9901	335.81	19.0026	18.3592	341.42	17.35	6.00	2.212	C.052	0.94839	0.04819
18.0000	23.9411	335.86	18.8983	13.5361	346.20	17.25	10.96	5.012	C.052	0.96167	0.04792
18.0000	23.9093	335.90	18.3571	12.9551	347.10	17.70	11.52	C.594	C.034	0.96415	0.04917
18.0000	22.9544	336.89	18.2954	12.8941	347.20	17.76	10.58	C.064	1.004	0.96443	0.04932
18.0000	21.9995	337.87	18.2456	12.8330	347.29	17.80	9.64	C.064	1.004	0.96468	0.04945
18.0000	21.0446	338.86	18.1994	12.7910	347.35	17.84	8.68	C.044	1.004	0.96487	0.04957
18.0000	20.0898	339.85	18.1579	12.7490	347.41	17.88	7.72	C.044	1.004	0.96504	0.04967
18.0000	19.1349	340.84	18.1212	12.7069	347.47	17.92	6.76	C.044	1.004	0.96520	0.04977
18.0000	18.1800	341.83	18.0893	12.6649	347.53	17.95	5.80	C.044	1.004	0.96535	0.04985
18.0000	17.2251	342.82	18.0617	12.6419	347.56	17.97	4.82	C.024	1.004	0.96544	0.04992
18.0000	16.2702	343.81	18.0392	12.6189	347.59	17.99	3.84	C.024	1.004	0.96552	0.04998
18.0000	15.3152	344.80	18.0217	12.5959	347.61	18.01	2.86	C.024	1.004	0.96560	0.05002
18.0000	14.3604	345.79	17.9711	12.5543	347.66	18.06	1.90	C.044	1.004	0.96573	0.05017
17.9975	14.3011	345.85	17.7925	12.3545	347.90	18.33	2.06	C.222	C.062	0.96640	0.05092
17.9870	14.2427	345.91	17.4566	11.9882	348.39	19.05	2.44	C.442	C.062	0.96776	0.05292

Table 3 (Continued)

17.9696	14.1859	345.97	16.9924	11.4958	349.13	20.20	3.02	C.642	C.062	C.96981	C.05612
17.9457	14.1316	346.04	16.1937	10.6337	350.59	22.15	4.14	1.182	C.062	C.97385	C.06154
17.9155	14.0805	346.10	14.5063	8.8231	354.33	26.01	6.68	2.602	C.062	C.98425	C.07225
17.8795	14.0333	346.16	11.5931	6.1932	363.23	33.79	10.92	4.302	C.062	1.00896	C.09387
17.8382	13.9908	346.22	9.4265	5.4721	372.45	42.78	13.34	2.482	C.062	1.03458	C.11884
17.7921	13.9534	346.28	7.0990	4.6921	394.25	54.98	16.84	3.562	C.062	1.09514	C.15271
17.7419	13.9217	346.35	6.5373	4.5051	432.79	62.00	20.78	4.003	C.063	1.20220	C.17221
17.6883	13.8961	346.41	8.8924	5.2877	464.88	61.03	24.82	4.103	C.063	1.29134	C.16953
17.6581	13.8860	346.45	10.5964	5.8571	473.68	60.27	26.74	1.954	C.034	1.31579	C.16741
14.5254	12.8418	350.83	10.9112	5.9613	474.93	60.23	22.56	C.342	3.522	1.31924	C.16731
12.0024	12.0008	356.21	11.3124	6.1019	476.43	60.37	21.06	C.434	2.934	1.32343	C.16769
9.9864	11.3288	362.00	11.8759	6.2898	478.40	60.77	19.20	C.610	2.470	1.32888	C.16882
8.3984	10.7995	370.06	12.4582	6.6110	480.40	62.11	17.70	C.612	2.112	1.33446	C.17253
7.1818	10.3939	380.68	12.9388	7.1330	482.28	65.13	16.34	C.487	1.847	1.33966	C.18092
6.5226	10.1742	388.89	13.3931	7.6051	483.97	68.43	15.62	C.482	1.202	1.34436	C.19007
6.0770	10.0257	397.11	13.9006	8.1697	485.82	73.01	15.16	C.557	1.017	1.34951	C.20281
6.0358	10.0128	398.06	14.3260	8.6197	487.15	77.00	15.52	C.470	C.110	1.35320	C.21389
5.9935	10.0046	399.07	14.8537	9.1979	488.48	82.33	15.98	C.574	C.114	1.35688	C.22870
5.9506	10.0000	400.14	15.6156	10.0000	489.82	90.00	16.68	C.820	C.120	1.36062	C.25000
5.9189	10.0000	400.58	15.6268	10.0000	489.84	90.00	16.60	C.012	C.092	1.36066	C.25000
5.6546	10.0000	410.05	15.6362	10.0000	489.85	90.00	15.58	C.010	1.030	1.36070	C.25000
5.5709	10.0000	420.72	15.6451	10.0000	489.86	90.00	14.62	C.009	C.969	1.36073	C.25000
5.6546	10.0000	430.60	15.6540	10.0000	489.88	90.00	13.66	C.009	C.969	1.36077	C.25000
5.9189	10.0000	440.47	15.6634	10.0000	489.89	90.00	12.64	C.010	1.030	1.36080	C.25000
5.9506	10.0000	441.30	15.6746	10.0000	489.91	90.00	12.56	C.012	C.092	1.36085	C.25000
5.9935	10.0046	442.37	16.2246	10.6639	490.81	98.36	13.06	C.620	C.120	1.36335	C.27323
6.0358	10.0128	443.38	16.7542	11.2319	491.81	105.11	13.58	C.634	C.114	1.36614	C.29197
6.0770	10.0257	444.34	17.2229	11.7469	492.79	110.73	14.06	C.590	C.110	1.36886	C.30759
6.7990	10.2663	456.39	18.1585	12.7535	494.64	120.58	13.72	1.209	1.549	1.37399	C.33494
7.7824	10.5941	466.20	18.8136	13.4558	495.75	126.71	12.96	C.860	1.620	1.37707	C.35198
9.0222	11.0074	474.19	19.0002	13.8729	496.18	130.31	11.52	C.313	1.753	1.37827	C.36197
10.5381	11.5127	480.75	19.0154	14.1056	496.32	132.50	9.66	C.088	1.948	1.37868	C.36805
12.3659	12.1220	486.16	19.0019	14.2336	496.38	133.92	7.48	C.028	2.208	1.37882	C.37200
14.5066	12.8355	490.58	19.0015	14.3012	496.40	134.88	5.02	C.022	2.482	1.37890	C.37467
17.6581	13.8860	495.00	19.0139	14.3363	496.43	135.70	1.50	C.024	3.544	1.37896	C.37695
17.6883	13.8961	495.04	19.0012	14.4093	496.44	139.79	1.48	C.014	C.034	1.37900	C.38831
17.7419	13.9217	495.10	19.0157	14.6103	496.54	147.12	1.52	C.103	C.063	1.37927	C.40866
17.7921	13.9534	495.16	19.0059	14.8111	496.63	151.94	1.56	C.103	C.063	1.37954	C.42207
17.8382	13.9908	495.22	19.0125	15.0506	496.79	155.35	1.66	C.162	C.062	1.37996	C.43153
17.8795	14.0333	495.29	19.0079	15.3254	496.98	157.79	1.80	C.202	C.062	1.38049	C.43832
17.9155	14.0805	495.35	19.0019	15.6701	497.24	159.57	2.02	C.282	C.062	1.38123	C.44325
17.9457	14.1316	495.41	19.0054	16.1592	497.66	160.87	2.40	C.442	C.062	1.38238	C.44686
17.9696	14.1859	495.47	19.0027	16.8937	498.32	161.78	3.04	C.702	C.062	1.38421	C.44940
17.9870	14.2427	495.54	19.0021	18.2342	499.57	162.40	4.32	1.342	C.062	1.38770	C.45110

Table 3 (Continued)

17.9975	14.3011	495.60	19.0000	21.8613	503.09	162.76	8.00	3.742	0.062	1.39746	0.45212
18.0000	14.3604	495.66	18.6014	25.5785	506.98	162.51	11.80	3.863	0.062	1.40828	0.45143

TOTAL FILAMENT LENGTH A 3624.29 YARDS

GEODESIC	HELIX ANGLE	AT R	POINT Z	TOTAL ROTATION	DISTORT FACTOR	FILMNT LENGTH	NO. OF CIRCUITS	CIRC PER PATTERN	REV PER PATTERN	ADVANCE PER CIR	WRAP TOLERANCE	CLEAR- ANCE
2	55.57	18.0000	20.0000	360.71	1.0000	114.40	510	1	1	0.00197	0.050	1.000

**	WRAP POINT ON MANDREL R	Z	THETA	**	EYE LOCATION IN SPACE R	Z	THETA	A ANGLE	**	VECTOR LENGTH	FILMT FED	FILMT DOWN	B ANGLE (REV)	A ANGLE (REV)
18.0000	14.3604	0.	18.6014	25.5785	0.	162.51							0.	0.45143
18.0000	14.3604	0.	19.0048	18.3627	17.89	125.89	7.08	-4.720	0.	0.04971	0.34970			
18.0000	15.3153	4.43	19.0013	19.4882	23.12	125.89	7.38	1.989	1.689	0.06422	0.34970			
18.0000	16.2702	8.87	19.0013	20.4431	27.55	125.89	7.38	1.689	1.689	0.07653	0.34970			
18.0000	17.2251	13.30	19.0013	21.3979	31.98	125.89	7.38	1.689	1.689	0.08885	0.34970			
18.0000	18.1800	17.73	19.0013	22.3528	36.42	125.89	7.38	1.689	1.689	0.10116	0.34970			
18.0000	19.1349	22.17	19.0013	23.3077	40.85	125.89	7.38	1.689	1.689	0.11348	0.34970			
18.0000	20.0897	26.60	19.0013	24.2626	45.29	125.89	7.38	1.689	1.689	0.12579	0.34970			
18.0000	21.0446	31.04	18.8585	24.9009	48.39	125.69	6.82	1.129	1.689	0.13442	0.34913			
18.0000	21.9995	35.47	18.6679	25.3921	50.84	125.41	6.00	0.869	1.689	0.14123	0.34837			
18.0000	22.9544	39.90	18.4925	25.8607	53.16	125.16	5.14	0.829	1.689	0.14766	0.34766			
18.0000	23.9093	44.34	18.3318	26.2954	55.28	124.92	4.22	0.769	1.689	0.15356	0.34701			
18.0000	23.9411	44.48	18.2455	26.5152	56.38	124.75	4.56	0.396	0.056	0.15661	0.34653			
17.9945	23.9901	44.71	18.0620	27.0017	58.99	124.16	5.40	0.927	0.087	0.16387	0.34488			
17.9842	24.0383	44.94	17.8357	27.6159	62.67	123.15	6.58	1.267	0.087	0.17410	0.34209			
17.9682	24.0849	45.17	17.6654	28.0716	65.77	122.24	7.52	1.027	0.087	0.18269	0.33957			
17.1568	26.2484	57.15	17.0737	29.6461	78.67	118.36	7.24	4.055	4.335	0.21854	0.32877			
16.4600	28.1067	69.95	16.6111	30.8722	91.76	114.34	6.84	3.848	4.248	0.25488	0.31761			
15.8809	29.6509	83.59	16.2589	31.8250	105.68	110.00	6.54	3.885	4.185	0.29355	0.30557			
15.4244	30.8684	98.00	16.0167	32.4682	120.25	105.32	6.30	3.904	4.144	0.33402	0.29256			
15.0962	31.7434	113.08	15.8970	32.7852	135.40	100.30	6.14	3.962	4.122	0.37612	0.27860			
14.9081	32.2450	127.95	15.9040	32.7613	150.25	95.21	6.06	3.848	3.928	0.41735	0.26448			
14.8463	32.4099	142.81	16.0354	32.4099	165.02	90.00	6.06	3.863	3.863	0.45839	0.25000			
14.9163	32.2232	158.63	16.3129	31.6668	180.63	84.31	6.14	4.191	4.111	0.50176	0.23421			
15.1244	31.6682	174.16	16.7400	30.5386	195.91	78.61	6.32	4.291	4.111	0.54419	0.21835			
15.4653	30.7591	189.14	17.3064	29.0335	210.55	73.00	6.58	4.374	4.114	0.58485	0.20278			
15.9317	29.5155	203.40	17.9983	27.1717	224.33	67.62	6.90	4.444	4.124	0.62313	0.18783			
16.5158	27.9578	216.82	18.8382	24.9467	237.32	62.50	7.34	4.587	4.147	0.65922	0.17361			
17.1663	26.2232	228.64	19.0055	23.3370	244.86	58.96	6.14	2.736	3.936	0.68017	0.16378			
17.9682	24.0849	240.46	19.0058	21.9855	250.37	55.84	3.96	2.102	4.282	0.69547	0.15510			
17.9842	24.0383	240.69	19.0004	21.6460	251.71	55.17	4.40	0.527	0.087	0.69918	0.15325			

Table 3 (Continued)

17.9945	23.9901	240.92	19.0031	21.0007	254.37	54.48	5.36	1.047	0.087	0.70659	0.15133
18.0000	23.9411	241.14	19.0026	20.2265	257.74	54.15	6.58	1.307	0.087	0.71594	0.15042
18.0000	23.9093	241.29	19.0041	19.7365	259.97	54.10	7.38	0.856	0.056	0.72215	0.15029
18.0000	22.9544	245.73	19.0013	18.7816	264.41	54.11	7.38	1.689	1.689	0.73447	0.15030
18.0000	21.9995	250.16	19.0013	17.8267	268.84	54.11	7.38	1.689	1.689	0.74679	0.15030
18.0000	21.0446	254.59	19.0013	16.8718	273.28	54.11	7.38	1.689	1.689	0.75910	0.15030
18.0000	20.0898	259.03	19.0013	15.9169	277.71	54.11	7.38	1.689	1.689	0.77142	0.15030
18.0000	19.1349	263.46	19.0013	14.9620	282.14	54.11	7.38	1.689	1.689	0.78373	0.15030
18.0000	18.1800	267.89	19.0013	14.0071	286.58	54.11	7.38	1.689	1.689	0.79605	0.15030
18.0000	17.2251	272.33	18.8195	13.4593	289.30	54.37	6.66	0.969	1.689	0.80361	0.15102
18.0000	16.2702	276.76	18.5548	13.1829	290.81	54.75	5.46	0.489	1.689	0.80780	0.15209
18.0000	15.3153	281.20	18.3303	12.9405	292.09	55.08	4.20	0.429	1.689	0.81136	0.15300
18.0000	14.3604	285.63	18.1255	12.7097	293.26	55.39	2.92	0.409	1.689	0.81462	0.15385
17.9975	14.3011	285.90	17.9866	12.5596	294.08	55.76	3.10	0.285	0.105	0.81688	0.15489
17.9870	14.2427	286.18	17.7579	12.3224	295.54	56.72	3.50	0.505	0.105	0.82095	0.15757
17.9696	14.1859	286.46	17.4944	12.0322	297.57	58.12	4.08	0.685	0.105	0.82657	0.16143
17.9457	14.1316	286.74	17.1699	11.6849	300.39	59.99	4.90	0.925	0.106	0.83442	0.16665
17.9155	14.0805	287.02	16.7831	11.2716	304.43	62.35	6.06	1.266	0.106	0.84563	0.17318
17.8795	14.0333	287.30	16.3703	10.8250	310.04	65.10	7.62	1.666	0.106	0.86121	0.18082
17.8382	13.9908	287.58	16.0244	10.4581	317.08	68.09	9.48	1.967	0.107	0.88078	0.18914
17.7921	13.9534	287.87	15.8609	10.2769	325.18	71.17	11.52	2.147	0.107	0.90327	0.19770
17.7419	13.9217	288.16	15.9555	10.3780	333.49	74.31	13.56	2.148	0.108	0.92636	0.20642
17.6883	13.8961	288.46	16.3440	10.8010	341.60	77.66	15.58	2.129	0.109	0.94888	0.21573
17.6581	13.8660	288.62	16.6038	11.0731	344.86	79.15	16.42	0.899	0.059	0.95796	0.21987
16.4478	13.4826	296.30	16.9604	11.4600	348.56	81.16	14.86	1.055	2.615	0.96822	0.22545
15.5622	13.1874	304.78	17.3841	11.9131	352.30	83.67	13.44	1.124	2.544	0.97862	0.23240
15.0210	13.0070	313.95	17.8565	12.4260	355.91	86.69	12.08	1.150	2.510	0.98864	0.24080
14.8463	12.9488	323.17	18.3472	12.9488	359.15	90.00	10.78	1.108	2.408	0.99765	0.25000
15.0345	13.0115	332.74	18.8313	13.4764	361.99	93.62	9.32	1.040	2.500	1.00553	0.26006
15.5858	13.1953	341.85	19.0111	13.8979	363.30	97.03	7.30	0.481	2.501	1.00918	0.26952
16.4146	13.4715	349.79	19.0088	14.1514	363.66	99.80	5.04	0.120	2.380	1.01017	0.27722
17.6581	13.8860	357.72	19.0101	14.3006	363.87	102.37	2.42	0.077	2.697	1.01074	0.28437
17.6883	13.8961	357.88	19.0098	14.3729	363.96	104.27	2.40	0.039	0.059	1.01101	0.28964
17.7419	13.9217	358.18	19.0030	14.5488	364.24	108.50	2.40	0.109	0.109	1.01178	0.30138
17.7921	13.9534	358.47	19.0085	14.7384	364.67	112.23	2.46	0.168	0.108	1.01296	0.31174
17.8382	13.9908	358.76	19.0086	14.9447	365.19	115.51	2.56	0.207	0.107	1.01442	0.32085
17.8795	14.0333	359.04	19.0070	15.1785	365.86	118.33	2.72	0.267	0.107	1.01629	0.32868
17.9155	14.0805	359.32	19.0032	15.4525	366.74	120.68	2.96	0.346	0.106	1.01872	0.33522
17.9457	14.1316	359.60	19.0073	15.7994	367.96	122.59	3.34	0.486	0.106	1.02211	0.34053
17.9696	14.1859	359.88	19.0056	16.2341	369.59	124.05	3.88	0.645	0.106	1.02664	0.34458
17.9870	14.2427	360.16	19.0003	16.7994	371.84	125.08	4.66	0.885	0.105	1.03288	0.34743
17.9975	14.3011	360.43	19.0093	17.6269	375.32	125.72	5.92	1.365	0.105	1.04256	0.34923
18.0000	14.3604	360.71	19.0048	18.3627	378.60	125.89	7.08	1.265	0.105	1.05168	0.34970

TOTAL FILAMENT LENGTH # 5244.91 YARDS

APPENDIX A

COMPUTATION OF A GEODESIC ON A SURFACE OF REVOLUTION

Computer routines were previously developed⁽¹⁾ for computing a geodesic path on an arbitrary surface of revolution. This step is accomplished by approximating the surface of revolution with a series of conical and cylindrical sections (approximating the contour of the surface by straight-line segments) and determining the geodesic path on each section. It was shown by S. P. Gold⁽³⁾ that the geodesic on the approximated surface converges to the geodesic on the actual surface as the surface approximation converges.

In cylindrical coordinates, $r = r(z) = kz + b$ on each of the sections and a geodesic path can be written in terms of θ as a function of z . If the contour of the surface is approximated by straight lines joining the points (r_n, z_n) and the initial conditions for specifying a geodesic are that it passes through the point (r_0, z_0, θ_0) at the helix angle α_0 , then the theta (mandrel) rotation, R_c , for one circuit was found to be:

$$R_c = 2 \sum_{n=J}^L \Delta\theta_n,$$

where J and L are the sections in which the geodesic turns around and $\Delta\theta_n$ the theta rotation across section n in one-half circuit. The value of $\Delta\theta_n$ was found to be:

$$\Delta\theta_n = \theta(z_{n+1}) - \theta(z_n)$$

$$\Delta\theta_n = \begin{cases} \left(\sqrt{1+k_n^2}/k_n \right) \left[\sec^{-1}(r_{n+1}/c) - \sec^{-1}(r_n/c) \right] & \text{on conical sections} \\ & (k_n \neq 0), n \neq J, L, \\ (z_{n+1} - z_n) c / \left(r_n \sqrt{r_n^2 - c^2} \right) & \text{on cylindrical section } (k_n = 0), \\ \left(\sqrt{1+k_n^2}/k_n \right) \left[\sec^{-1}(r_{n+1}/c) \right] & \text{on section } J, \\ \left(\sqrt{1+k_n^2}/k_n \right) \left[-\sec^{-1}(r_n/c) \right] & \text{on section } L, \end{cases}$$

where:

$$k_n = (r_{n+1} - r_n) / (z_{n+1} - z_n), \text{ the section slope, and}$$

$$c = r_0 \sin \alpha_0.$$

The geodesic turns around at the point where the part radius equals c . That is,

$$r_{\min} = c = r_0 \sin \alpha_0.$$

The value R_c (in radians) when divided by 2π is the number of revolutions per circuit of the specified geodesic. If R_c is written as a fraction, A/B , where A and B are integers having no common factors, then A is the number of revolutions per pattern and B is the number of circuits per pattern.

Computation of the Feed-Eye Position

For a given point (r_1, z_1, θ_1) of the geodesic on the surface, the corresponding feed-eye position (r_2, z_2, θ_2) was found⁽²⁾ to be (see Figure A-1).

Figure A-1. POINT ON A SURFACE AND THE CORRESPONDING FEED-EYE POSITION.

$$r_2 = \sqrt{\left[r_1 \pm \left(k_n \rho \cos \alpha / \sqrt{1 + k_n^2} \right) \right]^2 + (\rho \sin \alpha)^2},$$

$$z_2 = z_1 \pm \rho \cos \alpha / \sqrt{1 + k_n^2}, \text{ and}$$

$$\theta_2 = \theta_1 + \tan^{-1} \left\{ \rho \sin \alpha / \left[r_1 \pm \left(k_n \rho \cos \alpha / \sqrt{1 + k_n^2} \right) \right] \right\},$$

where:

k_n is the slope (dr/dz) of the surface at (r_1, z_1, θ_1) ,

ρ is the length of the vector from surface to eye,

α is the helix angle at (r_1, z_1, θ_1) , and

+ is when z is increasing (going up part),

- is for decreasing z (going down part).

The other dimension of interest, the A angle (rotation of the eye about the r axis) is

$$A = \tan^{-1} \left[r_1 \sin (\theta_2 - \theta_1) / (z_2 - z_1) \right] .$$

APPENDIX B

THE COMPUTER PROGRAM

The routines for computing a geodesic path on an arbitrary surface of revolution have been incorporated into the APT system by Union Carbide at Oak Ridge. They have been placed in the system as a unique chain that is called in by subroutine DISPAT of Section 4 upon encountering the appropriate APT "MACHIN" statement. A control program has been provided to process the CL tape generated by the APT system. A flow chart of this control program is given in Figure B-1. This program after appropriate initialization reads the CL tape and branches depending upon the type of record read. Subroutine PARMET is called to store the coordinate data from motion records. Each of the special pre-postprocessor commands has a subroutine provided for it that is called when the command is encountered on the CL tape. The numbers assigned to the nonstandard pre-postprocessor words are given in Table B-1. An "END" or "FINI" record will trigger the end of the processing by causing subroutine HALT to be called. Subroutine HALT establishes the new CL tape as the one to be processed by the machine postprocessor and returns to DISPAT. All other records encountered are copied by subroutine PASSIT onto a tape that is to be the CL tape for the machine postprocessor.

The command "GEODES" with its parameters defines the geodesic path desired. When this command is encountered, the geodesic path and the machine eye positions are calculated for the contour described by the accumulated coordinate data. Each "GEODES" command will produce the new CL tape records necessary for the transition and for the geodesic.

Several special options were created for use by the pre-postprocessor and postprocessor. A list of these options appears in Table B-2. Options 500 and greater are pre-postprocessor options and must not be mixed with option statements for the postprocessor.

Figure B-1. PRE-POSTPROCESSOR CONTROL PROGRAM FLOW SHEET.

Table B-1
ASSIGNED NUMBERS FOR PRE-
POSTPROCESSOR WORDS

COMMAND	NUMBER
CLEAR	1085
GEODES	1084
LINTOL	1067
OPTION	1051
REPEAT	1083
SHAFT	1086
PARAMETERS	
CIRCTS	245
CIRPAT	243
FLMWDR	248
INTLPT	244
PREPRO	247
REVPAT	242

Table B-2
FILAMENT WINDER PROGRAM OPTIONS

OPTION	STANDARD VALUE	DESCRIPTION
12	2	Inches of leader to be inserted in the tape prior to the circuit rewind stop code.
20	1	Number of identical punched tapes desired.
70	3	The maximum allowable change in the rotary table rpm from one block to next.
500	0	Option to initialize the counter for storing surface coordinates (r_n, z_n). This option is used when it is desired to redefine the surface (considering surface changes due to filament buildup) and then continue the wrap.
501	0.5"	Dimension a of the feed eye (see Figure B-2).
502	6.5"	Dimension b of the feed eye (see Figure B-2).
503	7.0"	Dimension c of the feed eye (see Figure B-2).
504	45.0°	DTMAX, the maximum allowable incremental motion of the rotary table (Δb in degrees). If the computed feed-eye positions result in a single motion greater than DTMAX, subroutine BLKADD is called to interject additional feed-eye points. ⁽²⁾
505	18.0°	DBA, the incremental Δb at which additional feed-eye points are to be interjected when BLKADD is called. ⁽²⁾
506	5.0	Parameter DELMIN used in eliminating feed-eye points which are too closely spaced. ⁽²⁾ The computed feed-eye positions are examined and points eliminated until the resulting motion is such that: $5(\Delta x + \Delta y + 1) + \Delta b/3 + \Delta a/5 < \text{DELMIN}$
507	0.5"	The minimum allowable vector length from mandrel to eye.
508	0.020"	Length of the vector from surface to feed eye is incremented by $\Delta \rho$, until proper clearance is obtained. ⁽²⁾
509	0.0	The initial value for computing filament laid on the surface.

Figure B-2. GEOMETRY OF THE FEED EYE.

REFERENCES

- (1) Bookhart, T. W. and Fowler, A. H.; Geodesic Paths on Surfaces of Revolution - A Computer-Aided Filament Winding Design Program, Y-1660, Union Carbide Corporation - Nuclear Division, Y-12 Plant, Oak Ridge, Tennessee; November 1968.
- (2) Bookhart, T. W. and Fowler, A. H.; Computer Programs for Determining Payout Eye Positions for Laying Filaments along Geodesic Paths on Surfaces of Revolution, Y-1620, Union Carbide Corporation - Nuclear Division, Y-12 Plant, Oak Ridge, Tennessee; November 1968.
- (3) Gold, S. P.; Filament Winding a Surface of Revolution, SCL-DR-65-102; Sandia Corporation - Livermore Laboratory, Livermore, California; February 1966.

PROGRAM LISTING

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*LABEL
CADJUST  ADJUST STARTING HELIX ANGLE
          SUBROUTINE ADJUST ( NA , NB , FRACT , EPS , LL )
          EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
          EQUIVALENCE (TAPETB(18),PRCTAP(18),CANTAP(17),CLTAPE(16),
1  PCCTAP(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
          DIMENSION INTAP(20),TAPSTO(250)
          COMMON TAPSTO,NWPR,NOREC,MULFLG
          EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
          DIMENSION R(500),Z(500),AK(500),F(500),CTHETA(500),FLNGTH(500),
1  X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
          COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1  TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2  DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3  , NCPERP,NREVPT,LA,III,FLTCTL,ADUM,ICUM
          CONV # 180.0 / PI
          ITER # 0
          AZERO # ALPHA0
          RZERO # RO
          ZZERO # ZO
          C # CONS
          IF ( ALPHA0 - 89.0 ) 30 , 30 , 20
20  RO # RMAX
          ALPHA0 # ATANF( CONS / SQRTF( RO **2 - CONS **2 ) ) * CONV
          DO 22 N # 2 , M
          IF ( RO - R(N) ) 24 , 24 , 22
22  CONTINUE
24  ZO # Z(N)
30  FRC# FRACT
          RV # FLOATF( NA ) / FLOATF ( NB ) + ADVNCE
          AAZERO # ALPHA0
40  CONTINUE
          DELA# RV - FRC
          IF ( ABSF( DELA) - EPS ) 110 , 110 , 50
50  DTDA # 0.0
          CSQ # CONS **2
          RCOS # RO * COSF ( ALPHA0 / CONV )
          NLI # NLOW + 1
          NHI # NHIGH - 1
          SQ2 # 1.0 / SQRTF ( R(NLI)**2 - CSQ )
          DTDA # DTDA - F(NLOW) * RCOS * SQ2 / AK(NLOW)
          IF ( NHI - NLI ) 85 , 55 , 55
55  DO 80 N # NLI , NHI
          IF ( AK(N) ) 60 , 70 , 60
60  SQ1 # SQ2
          SQ2 # 1.0 / SQRTF ( R(N+1)**2 - CSQ )
          DTDA # DTDA + F(N) * RCOS * ( - SQ2 + SQ1 ) / AK(N)
          GO TO 80
70  DTDA # DTDA + RCOS * R(N) * ( Z(N+1) - Z(N) ) * ( SQ2 **3 )
80  CONTINUE
85  DTDA # DTDA + F(NHIGH) * RCOS * SQ2 / AK(NHIGH)
          DTDA # 2.0 * DTDA
          IF ( ABSF( DTDA ) - .01 ) 140 , 140 , 90
90  DALPHA # DELA* 360.0 / DTDA
          ALPHA0 # ALPHA0 + DALPHA

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      IF ( ITER - 10 ) 100 , 150 , 150
100  ITER # ITER + 1
      CONS # RO * SINF ( ALPHA0 / CONV )
      CALL DELTA
      NLOW # NLOW
      NHIGH # NHIGH
      FRC # TSUM / 360.0
      GO TO 40
110  DALPHA # ALPHA0 - AAZERO
      IF ( ABSF ( DALPHA ) - 5.0 ) 120 , 130 , 130
120  LL # 0
      GO TO 170
130  WRITE OUTPUT TAPE 6 , 1000 , DALPHA
1000 FORMAT ( 2HD CHANGE IN ALPHA , , F10.6 , 43H , TOO GREAT - GEOD
      ESIC DISTORTED INSTEAD )
      GO TO 160
140  WRITE OUTPUT TAPE 6 , 1010 , DTCA
1010 FORMAT ( 2HD D THETA / D ALPHA # , F9.6 , 71H , LARGE CHANGE IN
      ALPHA WOULD BE REQUIRED - GEODESIC DISTORTED INSTEAD )
      GO TO 160
150  WRITE OUTPUT TAPE 6 , 1020
1020 FORMAT ( 71HD ALPHA DID NOT CONVERGE IN 10 ITERATIONS - GEODESIC
      DISTORTED INSTEAD )
160  LL # 1
      CONS # C
      RO # RZERO
      ZO # ZZERO
      ALPHA0 # AZERO
      CALL DELTA
170  CONTINUE
      RETURN
      END

*LABEL
CBLKADD ADD BLOCKS WHEN CARGE MANDREL ROTATION OCCURS
      SUBROUTINE BLKADD ( RRI,ZZI,TTI,AKI,TPRI,RR2,ZZ2,TT2,AK2,
1  TPR2,FILFED,FILCWN,UPDOWN )
      EQUIVALENCE (SYSTEM(1700),KGM (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
      DIMENSION INTAP(20),TAPSTO(250)
      COMMON TAPSTO,NWPR,NOREC,MULFLG
      EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
      DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1  X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
      COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1  TSUM,FLSUM,NHIGH,NLOW,DISTRT,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2  DELRH0,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3  , NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
      BANGLE # TPRI
      DENGM # TPR2 - TPRI
      DR # RR2 - RRI
      DZ # ZZ2 - ZZI
      DK # AK2 - AKI
      DCD # 0.0
      DWN # 0.0

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DDDSUM # 0.0
DWN SUM # 0.0
DTT # TT2 - TT1
100 CONTINUE
BANGLE # BANGLE + DBA
110 CONTINUE
FACTOR # ( BANGLE - TPR1 ) / DENOM
RRS # RRI + FACTOR * DR
ZZS # ZZ1 + FACTOR * DZ
TTS # TT1 + FACTOR * DTT
AKK # AK1 + FACTOR * DK
IF ( ABSF ( AKK ) - 1.0 E 10 ) 120, 130, 130
120 FI # SQRTF ( 1.0 + AKK **2 )
GO TO 140
130 FI # ABSF ( AKK )
140 CONTINUE
DDDSUM # DDDSUM + DDD
DWN SUM # DWN SUM + DWN
DDD # FACTOR * FILFED - DDDSUM
DWN # FACTOR * FILDWN - DWN SUM
SINA # CONS / RRS
COSA # SQRTF ( 1.0 - SINA ** 2 )
BA# ( BANGLE - TTS ) * PI / 180.0
CB # COSF(BA)
IF ( ABSF ( CB ) - .001 ) 150, 150, 160
150 RHO # RRS / ( - UPDOWN * AKK * COSA / FI )
GO TO 170
160 TANB # SINF(BA)/ CB
RHO # ( RRS * TANB ) / ( SINA - UPDOWN * AKK * COSA * TANB / FI )
170 CONTINUE
XXX # RRS + UPDOWN * AKK * RHO * COSA / FI
YYY # RHO * SINA
RHOCOS # RHO * COSA * UPDOWN / FI
XX # SQRTF ( XXX ** 2 + YYY ** 2 )
YY # ZZS + RHOCOS
IF ( ABSF ( RHOCOS ) - .00001 ) 180, 180, 190
180 AANGL # 90.0
GO TO 220
190 AANGL # ATANF ( (RRS * SINF(BA)) / ( - RHOCOS ) ) * 180.0 / PI
IF ( AANGL ) 200, 220, 220
200 AANGL # AANGL + 180.0
220 CONTINUE
CALL RMANDL ( YY, RMI )
IF ( XX - RMI - DEL ) 230, 240, 240
230 XX # RMI + DEL
240 CONTINUE
BREV # BANGLE / 360.0
AREV # AANGL / 360.0
WRITE OUTPLT TAPE 6,4000, RRS,ZZS,TTS,XX,YY,BANGLE,AANGL,RHO,DDD,
1 DWN,BREV,AREV
4000 FORMAT ( 3F **, F8.4,F10.4,F10.2,2F10.4,3F10.2,1F10.3,F9.3,
12F10.5)
LLL # LLL + 1
X(LLL) # XX
Y(LLL) # YY
B(LLL) # BANGLE
A(LLL) # AANGL
F(LLL) # DDD
IF ( BANGLE - TPR2 + DBA ) 250, 300, 300
250 IF ( BANGLE - TPR2 + 2.0 * DBA ) 100, 100, 260

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260 DB # ( TPR2 - BANGLE ) / 2.0
    BANGLE # BANGLE + DB
    GO TO 110
300 CONTINUE
    FILFED # CCD
    FILCWN # DWN
    RETURN
    END

*LABEL
CBLKDLT DELETE BLOCKS THAT ARE TOO SMALL
    SUBROUTINE BLKDLT ( NOPTS )
    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
    DIMENSION INTAP(20),TAPSTO(250)
    COMMON TAPSTO,NWPR,NOREC,MULFLG
    EQUIVALENCE (SYSTEM(1739),KID),(TAPSTO(1),INTAP(1))
    DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1    X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
    COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1    TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2    DELRHO,NSTART,LLL,RHOMIN,CTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3    , NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
    EQUIVALENCE(NNTAP(1),SAPSTO(1))
    DIMENSION NNTAP(30), SAPSTO(250)
B    SAPSTO(4)#272425624763
    NNTAP( 5) #C
    NNTAP( 8) #0
    N # 1
    XOLD # X(N)
    YOLD # Y(N)
    BOLD # B(N)
    AOLD # A(N)
100 CONTINUE
    DSUM # 0.0
150 CONTINUE
    N # N + 1
    XNEW # X(N)
    YNEW # Y(N)
    BNEW # B(N)
    ANEW # A(N)
    DNEW # FFL(N)
    DX # XNEW - XOLD
    DY # YNEW - YOLD
    DB # BNEW - BOLD
    DA # ANEW - AOLD
    DSUM # DSUM + DNEW
    FACTOR # 5.0 * ( ABSF(DX) + ABSF(DY) + DSUM ) + DB / 3.0
1    + ABSF(DA) / 5.0
    IF ( FACTOR - DELMIN ) 200 , 200 , 170
170 BREV # BNEW / 360.0
    AREV # ANEW / 360.0
    CALL INCRMT(5,NNTAP,SAPSTO)
    GO TO
    NNTAP(3) #5
C

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      SAPSTO(6)#XNEW
      SAPSTO(7)#YNEW
      SAPSTO(9)#AREV
      SAPSTO(10)#BREV
      SAPSTO(11)#DSUM
      NWD#11
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
      IF ( N - NOPTS + 1 ) 180 , 190 , 220
180  XOLD # XNEW
      YOLD # YNEW
      BOLD # BNEW
      AOLD # ANEW
      GO TO 100
190  CONTINUE
      XNEW # X(N+1)
      YNEW # Y(N+1)
      BNEW # B(N+1)
      ANEW # A(N+1)
      DSUM # FFL(N+1)
      GO TO 210
200  CONTINUE
      IF ( N - NOPTS ) 150 , 210 , 210
210  BREV # BNEW / 360.0
      AREV # ANEW / 360.0
      CALL INCRMT(5,NNTAP,SAPSTO)
      GO TO
      NNTAP(3)#5
      SAPSTO(6)#XNEW
      SAPSTO(7)#YNEW
      SAPSTO(9)#AREV
      SAPSTO(10)#BREV
      SAPSTO(11)#DSUM
      NWD#11
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
220  CONTINUE
      RETURN
      END
*LABEL
*CCLEAR
*LIST
*FORTRAN
      SUBROUTINE CLEAR
      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),ICUTAP( 2),PUNTAP( 1))
      DIMENSION SYSTEM(1739)
      COMMON SYSTEM
      DIMENSION INTAP(20),TAPSTO(250)
      COMMON TAPSTO,NWPR,NOREC,MULFLG
      EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
      DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1  X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
      COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1  TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2  DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL

```



```

      GO TO 1
12 CALL GEODES
      GO TO 1
C   GEODES
19 IF (INTAP(3)-1084) 10,12,27
20 CALL CLEAR
      GO TO 1
C   SHAFT
27 IF (INTAP(3)-1086) 20,28,10
28 CALL SHAFT
      GO TO 1
C   LINTOL
21 CALL WRAPIT
      GO TO 1
10 CALL PASSIT
      GO TO 1
C   MULTAX
22 IF (INTAP(3)-2) 10,23,10
23 MULFLG#3
      GO TO 10
24 IF (INTAP(3)-1) 10,25,10
25 INTAP(2)#14000
      NWPR#2
26 CALL HALT
      RETURN
      END

```

*LABEL

CDELTHA COMPUTE DELTA THETAS FOR GEODESIC I

```

      SUBROUTINE DELTHA
      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
      DIMENSION INTAP(20),TAPSTO(250)
      COMMON TAPSTO,NWPR,NOREC,MULFLG
      EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
      DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
      COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSUM,NHIGH,NLOW,DISTR,ACVNCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2 DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3 ,NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
      CONV # 180.0 / PI
      CONS # RO * SIN ( ALPHA0 / CONV )
      DO 20 N # 2 , M
      IF ( ZO - Z(N) ) 40 , 30 , 20
20 CONTINUE
30 IF ( ALPHA0 - 90.0 ) 38 , 33 , 38
33 IF ( AK(N) ) 40 , 40 , 38
38 N # N + 1
40 NSTART # N - 1
      IF ( CONS - R(1) ) 150 , 45 , 45
45 J # NSTART + 1
50 J # J - 1
      IF ( R(J) - CONS ) 60 , 60 , 50
60 NLOW # J

```

```

      IF ( CONS - R(M) ) 150 , 70 , 70
70 J # NSTART
80 J # J + 1
      IF ( R(J) - CONS ) 90 , 90 , 80
90 NHIGH # J - 1
      FOK # F(NLOW) / AK(NLOW)
      NLI # NLOW + 1
      TERM # ( R(NLI) / CONS )**2 - 1.0
      IF ( TERM ) 92 , 92 , 95
92 ASEC2 # 0.0
      GO TO 98
95 ASEC2 # ATANF ( SQRTF ( TERM ) )
98 DBETA # ASEC2
      DTHETA(NLOW) # FOK * DBETA * CONV
      FLNGTH(NLOW) # R(NLI) * FOK * SIN( DBETA )
      NHI # NHIGH - 1
      IF ( NHI - NLI ) 135 , 100 , 100
100 DO 130 N # NLI , NHI
      IF ( AK(N) ) 120 , 110 , 120
110 DBETA#CONS * (Z(N+1)-Z(N)) / (R(N)*SQRTF(R(N)**2 - CONS **2))
      DTHETA(N) # DBETA * CONV
      FLNGTH(N) # SQRTF(( Z(N+1)-Z(N))**2 + (R(N)*DBETA)**2 )
      GO TO 130
120 FOK # ABSF( F(N) / AK(N) )
      ASEC1 # ASEC2
      TERM # ( R(N+1) / CONS )**2 - 1.0
      IF ( TERM ) 122 , 122 , 125
122 ASEC2 # 0.0
      GO TO 126
125 ASEC2 # ATANF ( SQRTF ( TERM ) )
126 DBETA # ABSF ( ASEC2 - ASEC1 )
      DTHETA(N) # FOK * DBETA * CONV
      RN2 # R(N) * FOK
      RN3 # R(N+1) * FOK
      TERM # RN2**2 + RN3**2 - 2.0 * RN2 * RN3 * COS( DBETA )
      IF ( TERM ) 127 , 127 , 129
127 FLNGTH(N) # 0.0
      GO TO 130
129 FLNGTH(N) # SQRTF ( TERM )
130 CONTINUE
135 CONTINUE
      FOK # ABSF ( F(NHIGH) / AK(NHIGH) )
      DBETA # ABSF ( ASEC2 )
      DTHETA(NHIGH) # FOK * DBETA * CONV
      FLNGTH(NHIGH) # FOK * R(NHIGH) * SIN( DBETA )
      TSUM # 0.0
      FLSUM # 0.0
      DO 140 N # NLOW , NHIGH
      TSUM # TSUM + DTHETA(N)
140 FLSUM # FLSUM + FLNGTH(N)
      TSUM # 2.0 * TSUM
      FLSUM # 2.0 * FLSUM
      GO TO 160
150 CONS # MAX( R(1) , R(M) )
      ALPHA0 # ATANF( CONS / SQRTF( RO **2 - CONS **2 ) ) * CONV
      WRITE OUTPUT TAPE 6 , 8000 , ALPHA0
8000 FORMAT ( 3H0 TURN-AROUND RADIUS FOR GEODESIC , 56H IS LESS T
      HAN R(1) OR R(M) - STARTING ANGLE CHANGED TO , F10.6 )
      GO TO 45
160 CONTINUE

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      RETURN
      END

*LABEL
CERROR
*LIST
*FORTRAN
      SUBROUTINE ERROR( IER )
      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
      DIMENSION INTAP(20),TAPSTO(250)
      COMMON TAPSTO,NWPR,NOREC,MULFLG
      EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
      DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ACUM(25),IDUM(25)
      COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVANCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2 DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3 , NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
      DIMENSION FORMAT(7)
      B FORMAT(1)#740307306031
      B FORMAT(2)#456521433124
      B FORMAT(3)#604446243126
      B FORMAT(4)#312551603145
      B FORMAT(6)#606062632163
      B FORMAT(7)#254425456334
      GO TO(1,2,3,11,11,11,11,11,11,11),IER
      B 1 FORMAT(5)#602725462425
      B FORMAT(6)#626062632163
      GO TO 10
      B 2 FORMAT(5)#606022214524
      GO TO 10
      B 3 FORMAT(5)#606030252124
      10 WRITE OUTPUT TAPE IOUTAP,FORMAT
      11 RETURN
      END

*LABEL
CEYELOC DETERMINE WINDER EYE LOCATION WHICH CLEARS MANDREL
      SUBROUTINE EYELOC (RR,ZZ,THETA,RHO,UPDOWN,AKN,FN,TPI,
1 RPRIME,ZPRIME,TP2,AANGL,FL)
      EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
      EQUIVALENCE (TAPETB(18),PRCTAP(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
      DIMENSION INTAP(20),TAPSTO(250)
      COMMON TAPSTO,NWPR,NOREC,MULFLG
      EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
      DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
      COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVANCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,

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2 CELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,CELMIN,X,Y,B,A,FFL,TOL
3 ,NCPERP,NREVPT,LA,III,FLTCTL,ADUM,IDUM
  CONV # 180.0 / PI
  RHO1 # RHO
  SINA # CCNS / RR
  COSA # SQRTF ( RR**2 - CONS **2 ) / RR
  K # 0
  L # 0
100 CONTINUE
  XX # RR + UPDOWN * AKN * RHO * COSA / FN
  YY # RHO * SINA
  RPRIME # SQRTF ( XX**2 + YY**2 )
  ZPRIME # ZZ + RHO * COSA * UPDOWN / FN
  IF ( XX ) 110, 120, 130
110 DELTAT # ATANF ( YY / XX ) * CONV + 180.0
  GO TO 140
120 DELTAT # 90.0
  GO TO 140
130 DELTAT # ATANF ( YY / XX ) * CONV
140 CONTINUE
  R1 # RPRIME
  R2 # RPRIME + BB
  IF ( ZPRIME - Z(NSTART) ) 150, 150, 160
150 Z1 # ZPRIME + AA
  Z2 # ZPRIME + AA + CC
  DRDZ # BB / CC
  DO 156 N # 1, NSTART
  IF ( Z(N) - Z1 ) 156, 156, 152
152 IF ( Z(N) - Z2 ) 154, 158, 158
154 REYE # DRDZ * ( Z(N) - Z1 ) + R1
  IF ( REYE - R(N) - DEL ) 210, 156, 156
156 CONTINUE
158 CONTINUE
  GO TO 170
160 Z1 # ZPRIME - AA
  Z2 # ZPRIME - AA - CC
  DRDZ # - BB / CC
  DO 166 N # NSTART, M
  IF ( Z(N) - Z2 ) 166, 166, 162
162 IF ( Z(N) - Z1 ) 164, 168, 168
164 REYE # DRDZ * ( Z(N) - Z1 ) + R1
  IF ( REYE - R(N) - DEL ) 210, 166, 166
166 CONTINUE
168 CONTINUE
170 CALL RMANCL ( Z1, RM1 )
  CALL RMANCL ( Z2, RM2 )
  CALL RMANCL ( ZPRIME, RM3 )
  IF ( RPRIME - RM3 - DEL ) 210, 175, 175
175 IF ( R1 - RM1 - DEL ) 210, 180, 180
180 IF ( R2 - RM2 - DEL ) 210, 185, 185
185 IF ( RHO - RHOMIN ) 240, 240, 190
190 IF ( K - 1 ) 200, 240, 240
200 L # 1
  RHOTMP # RHO
  RPTMP # RPRIME
  ZPTMP # ZPRIME
  DELTMP # DELTAT
  RHO # RHO - DELRHO
  GO TO 100
210 IF ( L - 1 ) 220, 230, 230

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220 K # 1
    IF ( RHO - 60.0 ) 225 , 222 , 222
222 TP2 # THETA + DELTAT
    GO TO 260
225 RHO # RHO + DELRHO
    GO TO 100
230 RHO # RHOTMP
    RPRIME # RPTMP
    ZPRIME # ZPTMP
    DELTAT # DELTMP
240 CONTINUE
    TP2 # THETA + DELTAT
    DTP # TP2 - TP1
    IF ( DTP ) 250 , 242 , 242
242 IF ( RHO-RHO1+FL ) 244 , 244 , 260
244 IF ( THETA ) 260 , 260 , 250
250 K # 1
    IF ( RHO - 60.0 ) 255 , 260 , 260
255 RHO # RHO + DELRHO
    GO TO 100
260 CONTINUE
    RHOCOS # RHO * COSA * UPDCWN / FN
    IF ( ABSF(RHOCOS) - .000001 ) 270 , 280 , 280
270 AANGL # 90.0
    GO TO 300
280 AANGL # ATANF( ( RR*SINF(DELTAT/CCNV) ) / ( - RHOCOS ) ) * CONV
    IF ( AANGL ) 290 , 300 , 300
290 AANGL # AANGL + 180.0
300 CONTINUE
    RETURN
    END

```

*LABEL

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CFLWNR    FILAMENT WINDER SUBROUTINE
SUBROUTINE FLWNR (RPI,ZPI,TPI,AANGL1,RHO1)
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 SYSEM
DIMENSION INTAP(20),TAPSTO(250)
COMMON TAPSTO,NWPR,NOREC,MULFLG
EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
COMMON M,R,Z,AK,F,RO,ZO,ALPHAO,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSUM,NHIGH,NLOW,DISTR,ACVNCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2 DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,CELMIN,X,Y,B,A,FFL,TOL
3 , NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
DIMENSION NNTAP(30),SAPSTC(250)
EQUIVALENCE(NNTAP(1),SAPSTO(1))
CONV # 180.0 / PI
DO 100 N # 1 , M
    IF ( RMAX - R(N) ) 110 , 110 , 100
100 CONTINUE
110 NSTART # N
    RHO # RHOMIN
    UPDCWN # 1.0

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      AKN # ( AK(N) + AK(N-1) ) / 2.0
      IF ( ABSF ( AKN ) - 1.0 E 10 ) 114 , 114 , 112
112  FN # ABSF ( AKN )
      GC TO 116
114  FN # SQRTF ( 1.0 + AKN**2 )
116  THETA # 0.0
      FL # 0.0
      TPI # 0.0
      IF(III - 1 ) 120 ,120 ,125
120  RPI # R(NSTART)
      ZPI # Z(NSTART)
      TPI # 0.C
      AANGLI #180.0
      RHOI # 0.G
      RHO # RHOMIN
      RHO # 2.0 * DEL
      CALL INCRMT(2,NNTAP,SAPSTO)
C   SEQNO
      NNTAP(3) #1019
      NNTAP(4) #57
      NWD#4
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
      GO TO 130
125  RHO # RHOI
      CALL INCRMT(2,NNTAP,SAPSTO)
C   SWITCH
      NNTAP(3) #6
      NWD#3
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
130  CONTINUE
      NOSEQ # ( III-1 ) * 10 + 5
      CALL INCRMT(2,NNTAP,SAPSTO)
C   SEQNO
      NNTAP(3) #1019
      SAPSTO(4) #NCSEQ
      NWD#4
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
      NREPET # 2
      CALL INCRMT(2,NNTAP,SAPSTO)
C   REPEAT
      NNTAP(3) #1083
      SAPSTO(4) #NREPET
      NWD#4
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
      WRITE OUTPUT TAPE 6 , 1000
1000 FORMAT ( 12I10** WRAP POINT ON MANDREL ** EYE LOCATION I
IN SPACE ** VECTOR FILMT FILMT B ANGLE A ANGLE
2 / 12IH R Z THETA R Z TH
3ETA A ANGLE LENGTH FEC DOWN ( REV ) ( REV ) )
      RR # R(N)
      ZZ # Z(N)
      AREV # AANGLI / 360.0
      TREV # TPI / 360.0
      WRITE OUTPUT TAPE 6 , 1010 , RR, ZZ, THETA, RPI, ZPI, TPI, AANGLI,
1 TREV, AREV
1010 FORMAT ( 1H0 , 2F10.4,F10.2,2F10.4,2F10.2,29X,2F10.5 )

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C      CALL INCRMT(5,NNTAP,SAPSTO)
B      FROM
      SAPSTO(4)#272425624763
      NNTAP( 5)#C
      NNTAP( 8)#C
      NNTAP(11)#0
      NNTAP(3)#3
      SAPSTO(6)#RPI
      SAPSTO(7)#ZPI
      SAPSTO(9)#AREV
      SAPSTO(10)#TREV
      NWD#11
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
      CALL EYELOC (  RR,ZZ,THETA,RHO,UPCCWN,AKN,FN,TPI,RPRIME,ZPRIME,
I      TP2 , AANGL , FL )
      DELR # RPRIME - RPI
      DELZ # ZPRIME - ZPI
      DELT # TP2 - TPI
      DAA # AANGL - AANGL1
      RDEL # RPI + DELR / 2.0
      ZDEL # ZPI + DELZ / 2.0
      TDEL # TREV + DELT / 720.0
      ADEL # AREV + DAA / 720.0
      CALL INCRMT(5,NNTAP,SAPSTO)
C      GO TO
      NNTAP(3)#5
B      SAPSTO(4)#272425624763
      NNTAP( 5)#C
      NNTAP( 8)#C
      SAPSTO(6)#RDEL
      SAPSTO(7)#ZDEL
      SAPSTO(9)#ADEL
      SAPSTO(10)#TDEL
      SAPSTO(11)#FL
      NWD#11
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
      CALL INCRMT(2,NNTAP,SAPSTO)
C      SWITCH
      NNTAP(3)#6
      NWD#3
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
      NOSEQ # 10 *III
      CALL INCRMT(2,NNTAP,SAPSTO)
C      SEQNO
      NNTAP(3)#1019
      SAPSTO(4)#NOSEQ
      NWD#4
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
      CALL INCRMT(2,NNTAP,SAPSTO)
C      REPEAT
      NNTAP(3)#1083
      SAPSTO(4)#NC
      NWD#4
      NIN#1
      CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
      DIST # FL + RHO - RHO1

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TREV # TP2 / 360.0
AREV # AANGL / 360.0
WRITE OUTPUT TAPE 6 , 1020, RR, ZZ, THETA, RPRIME, ZPRIME, TP2,
1 AANGL, RHO, DIST, FL, TREV, AREV
1020 FORMAT ( 1H , 2F10.4,F10.2,2F10.4,3F10.2,F10.3,F9.3,2F10.5)
LLL # 1
X(LLL) # RPRIME
Y(LLL) # ZPRIME
B(LLL) # TP2
A(LLL) # AANGL
FFL(LLL) # DIST
CALL INCRMT(5,NNTAP,SAPSTO)
FROM
C
B
SAPSTO(4)#272425624763
NNTAP( 5 )#C
NNTAP( 8 )#0
NNTAP(11)#C
NNTAP(3)#3
SAPSTO(6) #RPRIME
SAPSTO(7)# ZPRIME
SAPSTO(9)#AREV
SAPSTO(10)#TREV
NWD#11
NIN#1
CALL WRITE(TAPES2,IRETN, NIN,SAPSTO,NWD)
RPT # RPRIME
ZPT # ZPRIME
TPT # TP2
AAT # AANGL
RHO # RHO
RPI # RPRIME
ZPI # ZPRIME
TPI # TP2
RRI # RR
ZZI # ZZ
TTI # THETA
AKI # AKN
TPRI # TP2
AANGLI # AANGL
RB # R(N)
140 CONTINUE
IF ( AK(N) ) 150 , 380 , 150
150 IF ( UPDOWN) 160 , 160 , 180
160 IF ( N - NLOW ) 200 , 200 , 170
170 RE # R(N)
ZE # Z(N)
AKE # ( AK(N) + AK(N-1) ) / 2.0
GO TO 210
180 IF ( N - NHIGH ) 190 , 200 , 200
190 RE # R(N+1)
ZE # Z(N+1)
AKE # ( AK(N) + AK(N+1) ) / 2.0
GO TO 210
200 RE # CONS
ZE # ( RE - R(N) ) / AK(N) + Z(N)
AKE # AK(N)
210 CONTINUE
AZERO # ATANF ( CONS / SQRTF ( RB**2 - CONS **2 ) )
218 ACF # ABSF ( AK(N) / F(N) )
FOK # ABSF ( F(N) / AK(N) )

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      BETA # AOF * DTHETA(N) / ( CONV * DISTRT )
      AKN # AK(N)
      FN # F(N)
      IF ( RB - RE ) 220 , 220 , 230
220  AR # -1.0
      GO TO 240
230  AR # 1.0
240  CONTINUE
      RA # RB
      RC # FOK * ( RA**4 / ( CONS * ( 2.0*(RA**2) - CONS **2) ) )
      DD# 2.0 * SQRTF ( TOL * ( 2.0 * RC - TOL ) )
      DPHI # ATANF ( DD*CONS / ( FOK*(RB**2) - AR * DD * SQRTF ( RB**2
      - CONS **2 ) ) )
      IF ( DPHI ) 242 , 242 , 246
242  DPHI # DPHI + PI
246  CONTINUE
      IF ( DPHI - BETA ) 250 , 330 , 330
250  IF ( 2.0 * DPHI - BETA ) 270 , 260 , 260
260  DPHI # .5 * BETA
      K # 1
      FL # FOK * RB * SINF ( DPHI ) / SINF ( AZERO + AR * DPHI )
      GO TO 275
270  K # 0
      FL # DD
275  DALPHA # AR * DPHI
      ACNE # AZERO + DALPHA
      RR # CONS / SINF ( AONE )
      ZZ # ( RR - R(N) ) / AK(N) + Z(N)
      THETA # THETA + FOK * DPHI * CONV * DISTRT
300  CONTINUE
      RHOI # RFO
      CALL EYELCC (RR,ZZ,THETA,RHO,UPDOWN,AKN,FN,TPI,RPRIME,ZPRIME,
      I TP2 , AANGL , FL )
      DELT # TP2 - TPI
      IF ( DELT - DTMAX ) 308 , 308 , 302
302  FILFED # FL + RHO - RHOI
      CALL BLKADC (RRI,ZZI,TTI,AKI,TPRI,RR,ZZ,THETA,AKN,TP2,
      I FILFED,FL,UPDOWN )
      DIST # FILFED
      GO TO 309
308  CONTINUE
      DIST # FI + RHO - RHOI
309  TREV # TP2 / 360.0
      AREV # AANGL / 360.0
      WRITE OUTPUT TAPE 6 , 1020, RR, ZZ, THETA, RPRIME, ZPRIME, TP2,
      I AANGL, RHO, DIST, FL, TREV, AREV
      LLL # LLL + 1
      X(LLL) # RPRIME
      Y(LLL) # ZPRIME
      B(LLL) # TP2
      A(LLL) # AANGL
      FFL(LLL) # CIST
      RPI # RPRIME
      ZPI # ZPRIME
      TPI # TP2
      AANGLI # AANGL
      RRI # RR
      ZZI # ZZ
      TTI # THETA
      AKI # AKN

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      TPI # TP2
      RB # RR
      IF ( K - 1 ) 310 , 320 , 310
310  BETA # BETA - DPHI
      AZERO # AONE
      GO TO 240
320  BETA # DPHI
      AZERO # AONE
330  CONTINUE
      DTA # BETA * FOK * CONV * DISTRT
      FL # FOK * RB * SIN( BETA ) / SIN( AZERO + AR * BETA )
360  CONTINUE
      THETA # THETA + DTA
370  CONTINUE
      GO TO 420
380  IF ( UPDOWN ) 390 , 390 , 400
390  RE # R(N)
      ZE # Z(N)
      AKE # ( AK(N) + AK(N-1) ) / 2.0
      GO TO 410
400  RE # R(N+1)
      ZE # Z(N+1)
      AKE # ( AK(N) + AK(N+1) ) / 2.0
410  CONTINUE
      DZ # Z(N+1) - Z(N)
      NDZ # DZ
      NDZ # NDZ + 1
      IF ( NDZ - 1 ) 418 , 418 , 411
411  ANDZ # NDZ
      DCT # DTHETA(N) / ANDZ
      DCZ # DZ / ANDZ
      DFL # FLNGTH(N) / ANDZ
      IF ( UPDOWN ) 412 , 412 , 413
412  ZZ # Z(N+1)
      GO TO 414
413  ZZ # Z(N)
414  IK # 1
      RR # R(N)
415  IK # IK + 1
      ZZ # ZZ + CDZ * UPDOWN
      THETA # THETA + CDT
      FL # DFL
      AKN # 0.0
      FN # 1.0
      RHO1 # RHO
      CALL EYELOC (RR,ZZ,THETA,RHO,UPDOWN,AKN,FN,TPI,RPRIME,ZPRIME,
1  TP2 , AANGL , FL )
      DIST # FL + RHO1 - RHO1
      TREV # TP2 / 360.0
      AREV # AANGL / 360.0
      WRITE OUTPLT TAPE 6 , 1020, RR, ZZ, THETA, RPRIME, ZPRIME, TP2,
1  AANGL, RHO, DIST, FL, TREV, AREV
      LLL # LLL + 1
      X(LLL) # RPRIME
      Y(LLL) # ZPRIME
      B(LLL) # TP2
      A(LLL) # AANGL
      FFL(LLL) # DIST
      RPI # RPRIME
      ZPI # ZPRIME

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      TPI # TP2
      IF ( IK - NCZ ) 415 , 416 , 416
416 THETA # THETA + DDT
      FL # DFL
      GO TO 420
418 THETA # THETA + DTHETA(N)
      FL # FLNGTH(N)
420 CONTINUE
      AKN # AKE
      IF ( ABSF ( AKN ) - 1.0 E 10 ) 424 , 422 , 422
422 FN # ARSF ( AKN )
      GO TO 426
424 FN # SQRTF ( 1.0 + AKN**2 )
426 RR # RE
      ZZ # ZE
      IF ( N - NSTART + 1 ) 430 , 500 , 430
430 CONTINUE
      RHOI # RHO
      CALL EYELOC (RR,ZZ,THETA,RHC,UPDOWN,AKN,FN,TPI,RPRIME , ZPRIME,
1 TP2 , AANGL , FL )
      DELT # TP2 - TPI
      IF ( DELT - DTMAX ) 438 , 438 , 432
432 IF ( AK(N) ) 434 , 438 , 434
434 FILFED # FL + RHO - RHOI
      CALL BLKACC (RRI,ZZI,TTI,AKI,TPRI,RR,ZZ,THETA,AKN,TP2,
1 FILFED,FL,UPDOWN )
      DIST # FILFED
      GO TO 439
438 CONTINUE
      DIST # FL + RHO - RHOI
439 TREV # TP2 / 360.0
      AREV # AANGL / 360.0
      WRITE OUTPUT TAPE 6 , 1020, RR, ZZ, THETA, RPRIME, ZPRIME, TP2,
1 AANGL, RHO, DIST, FL, TREV, AREV
      LLL # LLL + 1
      X(LLL) # RPRIME
      Y(LLL) # ZPRIME
      B(LLL) # TP2
      A(LLL) # AANGL
      FFL(LLL) # DIST
      RPI # RPRIME
      ZPI # ZPRIME
      TPI # TP2
      AANGLI # AANGL
      RRI # RR
      ZZI # ZZ
      TTI # THETA
      AKI # AKN
      TPRI # TP2
      IF ( UPDOWN ) 440 , 440 , 470
440 IF ( N - NLOW ) 450 , 450 , 460
450 UPDOWN # 1.0
      RE # CONS
      AZERO # PI / 2.0
      RE # R(N+1)
      ZE # Z(N+1)
      AKE # ( AK(N) + AK(N+1) ) / 2.0
      GO TO 218
460 N # N - 1
      RB # R(N+1)

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```

      GO TO 140
470 IF ( N - NHIGH ) 480 , 490 , 490
480 N # N + 1
      RB # R(N)
      GO TO 140
490 UPDCWN # - 1.0
      RB # CONS
      AZERO # PI / 2.0
      RE # R(N)
      ZE # Z(N)
      AKE # ( AK(N) + AK(N-1) ) / 2.0
      GO TO 218
500 IF ( UPDOWN ) 430 , 430 , 510
510 CONTINUE
      RHO1 # RHO
      RHO # RHOT
      RPRIME # RPT
      ZPRIME # ZPT
      TP2 # THETA + TPT
      AANGL # AAT
      DELT # TP2 - TP1
      DIST # FL + RHO - RHO1
      TREV # TP2 / 360.0
      AREV # AANGL / 360.0
      WRITE OUTPUT TAPE 6 , 1020, RR, ZZ, THETA, RPRIME, ZPRIME, TP2,
1  AANGL, RHO, DIST, FL, TREV, AREV
      LLL # LLL + 1
      X(LLL) # RPRIME
      Y(LLL) # ZPRIME
      B(LLL) # TP2
      A(LLL) # AANGL
      FFL(LLL) # DIST
      RPI # RPRIME
      ZPI # ZPRIME
      TPI # TPT
      AANGL1 # AANGL
      RHO1 # RHO
      CALL BLKDLT (LLL)
540 CONTINUE
      RETURN
      END

*LABEL
CGEODES
*LIST
*FORTRAN
      SUBROUTINE GEODES
      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
      DIMENSION INTAP(20),TAPSTO(250)
      COMMON TAPSTO,NWPR,NOREC,MULFLG
      EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
      DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1  X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
      COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,

```

```

1  TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2  DELRHO,NSTART,LLL,RHOMIN,CTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3  , NCERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
   DIMENSION VAR(8),IWORD(7)
C   ATANGL
   IWORD(1) #1
C   CIRCTS
   IWORD(2) #245
C   ADJUST
   IWORD(3) #159
C   REVPAT
   IWORD(4) #242
C   INCR
   IWORD(5) #66
C   CIRPAT
   IWORD(6) #243
C   INTLPT
   IWORD(7) #244
   VAR(1) #ALPHA0
   VAR(2) #NC
   VAR(3) #LA
   VAR(4) #NREVPT
   VAR(5) #ADVNC
   VAR(6) #NCERP
   VAR(7) #RO
   VAR(8) #ZO
   DO 1 J#4,NWPR
   DO 2 I#1,7
   IF(INTAP(J)-IWORD(I))2,3,2
3  VAR(I) #TAPSTO(J+1)
   IF(I-7)1,11,1
11 VAR(I+1) #TAPSTO(J+2)
   GO TO 1
2  CONTINUE
1  CONTINUE
   ALPHA0#VAR(1)
   NC#VAR(2)+.5
   LA#VAR(3)+.5
   NREVPT#VAR(4)+.5
   ADVNC#VAR(5)
   NCERP#VAR(6)+.5
   RO#VAR(7)
   ZO#VAR(8)
   CALL WNMAIN
   RETURN
   END
*LABEL
*CHALT
*LIST
*FORTRAN
   SUBROUTINE HALT
   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),CROTAP(11),
2  CORTAP( 9),
3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
4  FORTIN( 4),INTAPE( 3),ICUTAP( 2),PUNTAP( 1))
   DIMENSION SYSTEM(1739)
   COMMON SYSTEM
   DIMENSION INTAP(20),TAPSTO(250)

```

```

COMMON TAPSTO,NWPR,NOREC,MULFLG
EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
COMMON M,R,Z,AK,F,RO,ZO,ALPHAO,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2 DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3 , NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
CALL PASSIT
CALL TAPEOP(TAPES2,2,RETURN)
CALL TAPEOP(TAPES2,3,RETURN)
CALL TAPEOP(TAPES2,3,RETURN)
CALL TAPECH(CLTAPE,TAPES2)
CALL BUFTP(TAPES2,3)
CALL BUFTP(CLTAPE,2)
CALL DESPAT
RETURN
END

```

```

*LABEL
CINCRMT
*LIST
*FORTRAN

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```

SUBROUTINE INCRMT(ISIG,NNTAP,SAPSTO)
EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
1 PCCTAP(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
DIMENSION INTAP(20),TAPSTO(250)
COMMON TAPSTO,NWPR,NOREC,MULFLG
EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
COMMON M,R,Z,AK,F,RO,ZO,ALPHAO,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2 DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3 , NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
DIMENSION NNTAP(30), SAPSTO(250)
NOREC#NOREC+1
NNTAP(1)#NOREC
NNTAP(2)#ISIG*1000
RETURN
END

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*FAP

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ENTRY INIT
SYSTEM COMMON 1739
TAPSTO COMMON 250
NWPR COMMON 1
NOREC COMMON 1
MULFLG COMMON 1
M COMMON 1
R COMMON 500
Z COMMON 500
AK COMMON 500
F COMMON 500
RO COMMON 1

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ZO      COMMON  I
ALPHAC  COMMON  I
CONS    COMMON  I
NC      COMMON  I
RMAX    COMMON  I
ZMAX    COMMON  I
PI      COMMON  I
DTHETA  COMMON  500
FLNGTH  COMMON  500
TSUM    COMMON  I
FLSUM   COMMON  I
NHIGH   COMMON  I
NLOW    COMMON  I
DISTR   COMMON  I
ADVNC   COMMON  I
SHAFT1  COMMON  I
SHAFT2  COMMON  I
AA      COMMON  I
BB      COMMON  I
CC      COMMON  I
DEL     COMMON  I
DELRHO  COMMON  I
NSTART  COMMON  I
LLL     COMMON  I
RHOMIN  COMMON  I
DTMAX   COMMON  I
DEA     COMMON  I
DELMIN  COMMON  I
X       COMMON  500
Y       COMMON  500
B       COMMON  500
A       COMMON  500
FFL     COMMON  500
TOL     COMMON  I
NCPERP  COMMON  I
NREVP   COMMON  I
LA      COMMON  I
III     COMMON  I
FLTOTL  COMMON  I
ADUM    COMMON  25
IDUM    COMMON  25
INIT    SXA     LEAVE,I
        SXA     LEAVE+1,2
        SXA     LEAVE+2,4
        AXT     0,I
        STZ     TAPSTO,I
        TXI     *+1,I,I
        TXL     *-2,I,TAPSTO-IDUM
LEAVE   AXT     0,I
        AXT     0,2
        AXT     0,4
        TRA     I,4
        END

*LABEL
CINITAL
*LIST
*FORTRAN
      SUBROUTINE INITAL
      EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
      EQUIVALENCE (TAPETB(18),PRCTAP(18),CANTAP(17),CLTAPE(16),

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1  PGCTAP(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
  DIMENSION INTAP(20),TAPSTO(250)
  COMMON TAPSTO,NWPR,NOREC,MULFLG
  EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
  DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1  X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
  COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1  TSUM,FLSUM,NHIGH,NLOW,DISTR,ACVNCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2  DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3  , NCPERP,NREVPT,LA,III,FLTCTL,ADUM,IDUM
  PI#3.14159265
  AA#.5
  BB#6.5
  CC#7.0
  DELRHO#.020
  RHOMIN#.5
  DTMAX#45.0
  DBA#18.0
  DELMIN#5.0
  DEL#.75
  TCL#.020
  SHAFT1#.75
  SHAFT2#.75
  RETURN
  END

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*LABEL
COPTION
*LIST

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*FORTRAN

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  SUBROUTINE OPTION(N)
  EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
  EQUIVALENCE (TAPETB(18),PRCTAP(18),CANTAP(17),CLTAPE(16),
1  PGCTAP(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
  DIMENSION INTAP(20),TAPSTO(250)
  COMMON TAPSTO,NWPR,NOREC,MULFLG
  EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
  DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1  X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
  COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1  TSUM,FLSUM,NHIGH,NLOW,DISTR,ACVNCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2  DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3  , NCPERP,NREVPT,LA,III,FLTCTL,ADUM,IDUM
5  DO 50 I#4,NWPR,2
  IF(TAPSTO(1)-500.)50,10,10
10 IF(TAPSTO(1)-509.)11,11,50
11 IBR#TAPSTO(1)-498.9
  GO TO (20,21,22,23,24,25,26,27,28,29),IBR
C  OPTION 500 N
20 N#0
  GO TO 50

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```

C      OPTION 501  AA
21  AA#TAPSTO(I+1)
    GO TO 50
C      OPTION 502  BB
22  BB#TAPSTO(I+1)
    GO TO 50
C      OPTION 503  CC
23  CC#TAPSTO(I+1)
    GO TO 50
C      OPTION 504  DTMAX
24  DTMAX #TAPSTO(I+1)
    GO TO 50
C      OPTION 505  DBA
25  DBA#TAPSTO(I+1)
    GO TO 50
C      OPTION 506  DELMIN
26  DELMIN#TAPSTO(I+1)
    GO TO 50
C      OPTION 507  RHOMIN
27  RHOMIN#TAPSTO(I+1)
    GO TO 50
C      OPTION 508  DELRHO
28  DELRHO#TAPSTO(I+1)
    GO TO 50
C      OPTION 509  FLTOTL
29  FLTOTL#TAPSTO(I+1)
    GO TO 50
50  CONTINUE
100 RETURN
    END

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*LABEL
CPARMET

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*LIST

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*FORTRAN

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SUBROUTINE PARMET(N)
EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
EQUIVALENCE (TAPETB(18),PRCTAP(18),CANTAP(17),CLTAPE(16),
1  PCCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
2  CORTAP( 9),
3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
4  FCRTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1))
DIMENSION SYSTEM(1739)
COMMON SYSTEM
DIMENSION INTAP(20),TAPSTO(250)
COMMON TAPSTO,NWPR,NOREC,MULFLG
EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1  X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1  TSUM,FLSUP,NHIGH,NLOW,CISTRT,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2  DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3  ,NCPERP,NREVPT,LA,III,FLTCTL,ADUM,IDUM
PI#3.14159265
NOPTS#MULFLG+3
IF( N ) 1,2,1
2  RMAX#TAPSTO(6)
DO 20 I#6,NWPR,NOPTS
N#N+1
R(N)#TAPSTO(I)
20  Z(N)#TAPSTO(I+1)

```

```

      GO TO 9
13 WRITE OUTPUT TAPE IOUTAP,14
14 FORMAT(1F0,34HNUMBER OF POINTS GREATER THAN 500)
      GO TO 9
      I DO 12 I#6,NWPR,NOPTS
      N#N+1
      IF(N-500)21,21,13
21 R(N)#TAPSTO(I)
   Z(N)#TAPSTO(I+1)
   IF(ABSF(Z(N)-Z(N-1))-.0001) 3,4,4
4 AK(N-1)#(R(N)-R(N-1))/(Z(N)-Z(N-1))
  IF(ABSF(AK(N-1))-.0001) 10,10,11
10 AK(N-1)#0.0
11 F(N-1)#SQRTF(1.0+AK(N-1)**2)
   GO TO 8
3 IF(R(N)-R(N-1)) 5,5,6
6 AK(N-1)# 1C.E 20
   GO TO 7
5 AK(N-1)#-1C.E 20
7 F(N-1)# 10.E 20
8 RMAX#MAXIF(R(N),RMAX)
  ZMAX#Z(N)
12 M#N
9 RETURN
END

*LABEL
CPASSIT
*LIST
*FORTRAN
  SUBROUTINE PASSIT
    EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
    EQUIVALENCE (TAPETB(18),PRCTAP(18),CANTAP(17),CLTAPE(16),
1    PCCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
2    CORTAP( 9),
3    TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
4    FCRTIN( 4),INTAPE( 3),IOUTAP( 2),PLNTAP( 1))
    DIMENSION SYSTEM(1739)
    COMMON SYSTEM
    DIMENSION INTAP(20),TAPSTO(250)
    COMMON TAPSTO,NWPR,NOREC,MULFLG
    EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
    DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1    X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
    COMMON M,R,Z,AK,F,RO,ZO,ALPHAO,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1    TSLM,FLSUM,NHIGH,NLOW,DISTR,ACVNCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2    CELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,CELMIN,X,Y,B,A,FFL,TOL
3    ,NCPERP,NREVPT,LA,III,FLTCTL,ADUM,IDUM
    NOREC#NOREC+1
    INTAP(1)#NOREC
    NIN#1
    CALL WRITE(TAPES2,IRETN,NIN,TAPSTO,NWPR)
    RETURN
  END

*LABEL
CPERROR
*LIST
*FORTRAN
  SUBROUTINE PERROR
    EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
    EQUIVALENCE (TAPETB(18),PRCTAP(18),CANTAP(17),CLTAPE(16),

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1  PCCTAP(15),PLOTAP(14),SRFTAP(13),LIBTAP(12),CRDTAP(11),
2      CORTAP( 9),
3  TAPES1( 8),TAPES2( 7),TAPES3( 6),TAPES4( 5),
4  FCRTIN( 4),INTAPE( 3),IOUTAP( 2),PUNTAP( 1)
  DIMENSION SYSTEM(1739)
  COMMON SYSTEM
  DIMENSION INTAP(20),TAPSTO(250)
  COMMON TAPSTO,NWPR,NOREC,MULFLG
  EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
  DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1  X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
  COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1  TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVANCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2  DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3  , NCERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
  WRITE OUTPLT TAPE 6,1
1  FORMAT(45H SYSTEM ERROR IN FILAMENT WINDER PREPROCESSOR)
  CALL TAPEOP(TAPES2,1,IER)
  CALL TAPEOP(TAPES2,2,IER)
  CALL DESPAT
  RETURN
  END

```

*FAP

	ENTRY	READER
SYSTEM	COMMON	1739
TAPSTO	COMMON	250
NWPR	COMMON	1
NOREC	COMMON	1
MULFLG	COMMON	1
M	COMMON	1
R	COMMON	500
Z	COMMON	500
AK	COMMON	500
F	COMMON	500
RO	COMMON	1
ZO	COMMON	1
ALPHA0	COMMON	1
CONS	COMMON	1
NC	COMMON	1
RMAX	COMMON	1
ZMAX	COMMON	1
PI	COMMON	1
DTHETA	COMMON	500
FLNGTH	COMMON	500
TSUM	COMMON	1
FLSUM	COMMON	1
NHIGH	COMMON	1
NLOW	COMMON	1
DISTR	COMMON	1
ADVANCE	COMMON	1
SHAFT1	COMMON	1
SHAFT2	COMMON	1
AA	COMMON	1
BB	COMMON	1
CC	COMMON	1
DEL	COMMON	1
DELRHO	COMMON	1
NSTART	COMMON	1
LLL	COMMON	1
RHOMIN	COMMON	1

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DTMAX  COMMON  1
DBA    COMMON  1
DELMIN COMMON  1
X      COMMON  500
Y      COMMON  500
B      COMMON  500
A      COMMON  500
FFL    COMMON  500
TOL    COMMON  1
NCPERP COMMON  1
NREVPT COMMON  1
LA     COMMON  1
III    COMMON  1
FLTOTL COMMON  1
ADUM   COMMON  25
IDUM   COMMON  25
READER SXA     READX,1
      SXA     READX+1,2
      SXA     READX+2,4
      CALL    TAPERD,CLTAPE,IRETN,NWPR,NBLKS,TAPSTO,WRDS
      LXA     READX+2,4
      CLA     IRETN
      TZE     EOF
      TMI     READOK
      CLS     ONE
      STC*    1,4
      TRA     READX
READOK STZ*    1,4
READX  AXT     **,1
      AXT     **,2
      AXT     **,4
      TRA     2,4
EOF     CLA     ONE
      STC*    1,4
      TRA     READX
IRETN   PZE
NBLKS   PZE     0,0,1
WRDS    PZE
ONE     DEC     1.0
CLTAPE  EQU     SYSTEM-80
      END

*LABEL
CRMANDL DETERMINE RADIUS OF MANDREL FOR A GIVEN VALUE OF Z
      SUBROUTINE RMANDL ( ZS , RM )
      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
      DIMENSION INTAP(20),TAPSTO(250)
      COMMON TAPSTO,NWPR,NOREC,MULFLG
      EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
      DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
      COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSLM,NHIGH,NLOW,DISTR,ACVNCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2 DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,CELMIN,X,Y,B,A,FFL,TOL

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      3 , NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
      IF ( ZS - Z(1) ) 10 , 10 , 20
10 RM # SHAFT1
      GO TO 6C
20 DO 30 NN # 2 , M
      IF ( Z(NN) - ZS ) 30 , 40 , 50
30 CONTINUE
      RM # SHAFT2
      GO TO 6C
40 RM # R(NN)
      GO TO 6D
50 NN # NN - 1
      RM # AK(NN) * ( ZS - Z(NN) ) + R(NN)
60 CONTINUE
      RETURN
      END

*LABEL
CSHAFT
*LIST
*FORTRAN
      SUBROUTINE SHAFT
      EQUIVALENCE (SYSTEM(1700),KCM (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
      DIMENSION INTAP(20),TAPSTO(250)
      COMMON TAPSTO,NWPR,NOREC,MULFLG
      EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
      DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
      COMMON M,R,Z,AK,F,RO,ZO,ALPHAO,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2 DELRHO,NSTART,LLL,RHOMIN,CTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3 , NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
      DIMENSION VAR(2),IWORD(2)
C YSMALL
      IWORD(1)#36
C YLARGE
      IWORD(2)#35
      VAR(1)#SHAFT1
      VAR(2)#SHAFT2
      DO 10 J#4,NWPR
      DO 5 I#1,2
      IF(INTAP(J)-IWORD(1))5,1,5
1 VAR(1)#TAPSTO(J+1)
      GO TO 10
5 CONTINUE
10 CONTINUE
      SHAFT1#VAR(1)
      SHAFT2#VAR(2)
      RETURN
      END

*LABEL
CWRAP IT
*LIST
*FORTRAN

```

*LABEL

CWNMAIN MAIN PROGRAM FOR WINDER CALCULATIONS

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SUBROUTINE WNMAIN
EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
EQUIVALENCE (TAPETB(18),PRCTAP(18),CANTAP(17),CLTAPE(16),
1 PCCTAP(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
DIMENSION INTAP(20),TAPSTO(250)
COMMON TAPSTO,NWPR,NOREC,MULFLG
EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
DIMENSION R(500),Z(500),AK(500),F(500),DTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSUM,NHIGH,NLOW,DISTR,ADVNC,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2 DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,DELMIN,X,Y,B,A,FFL,TOL
3 ,NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
III=III+1
- DISTR # 1.0
IF ( ZO ) 12 , 12 , 37
12 DO 15 N # 2 , M
IF ( RO - R(N) ) 25 , 20 , 15
15 CONTINUE
WRITE OUTPUT TAPE 6 , 2050,III,, RO
2050 FORMAT ( 44H0 COULD NOT LOCATE INITIAL POINT OF GEODESIC , 13 ,
1 25H USING INITIAL RADIUS OF , F7.3 , 18H THIS ONE SKIPPED )
GO TO 500
20 N # N + 1
25 NSTART # N - 1
IF ( AK(NSTART) ) 30 , 35 , 30
30 ZC # ( RO - R(NSTART) ) / AK(NSTART) + Z(NSTART)
GO TO 37
35 ZC # Z(NSTART)
37 CONTINUE
CALL DELTA
NLOW # NLOW
NHIGH # NHIGH
IF ( NCPERP ) 150 , 150 , 110
110 RVN # TSUM / 360.0
FRACT # RVN
NB # NCPERP
NA # NREVPT
IF ( LA ) 120 , 120 , 130
120 EPS # .000001
CALL ADJUST ( NA , NB , FRACT , EPS , LL )
NLOW # NLOW
NHIGH # NHIGH
IF ( LL ) 150 , 150 , 130
130 CONTINUE
RVN2 # FLOATF(NA) / FLOATF(NB) + ADVNC
DISTR # RVN2 / RVN
DO 140 N # NLOW , NHIGH
DTHETA(N) # DTHETA(N) * DISTR
140 CONTINUE
TSUM # TSUM * DISTR
150 CONTINUE
ZLOW # ( CCNS - R(NLOW) ) / AK(NLOW) + Z(NLOW)

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      ZHIGH # ( CONS - R(NHIGH) ) / AK(NHIGH) + Z(NHIGH)
      WRITE OUTPUT TAPE 6 , 5000
5000 FORMAT ( 120H1          HELIX          AT POINT          TOTAL  DISTR
1T FILMNT NO. OF CIRC PER REV PER ADVANCE  WRAP  CLEAR
2- / 120H GEODESIC ANGLE      R              Z      ROTATION  FACTOR  LE
3NGTH CIRCUITS PATTERN PATTERN PER CIR  TOLERNCE  ANCE  )
      WRITE OUTPUT TAPE 6 , 5010,III, ALPHA0 , RO , ZO , TSUM,
1 DISTRT, FLSUM, NC , NCPERP, NREVPT, ADVNCE, TOL, DEL
5010 FORMAT ( 1H0, I4,F10.2,2F10.4,F10.2,F8.4,F9.2,2I8,19,F12.5,2F10.3)
      CALL FLWNCR ( RPI, ZPI , TPI, AANGLI , RH01 )
      FLTCTL # FLTOTL + FLSUM * FLOATF ( NC )
500 CONTINUE
      FLTCT # FLTOTL / 36.0
      WRITE OUTPUT TAPE 6 , 5050 , FLTOT
5050 FORMAT ( 24H0TOTAL FILAMENT LENGTH # , F10.2 , 6H YARDS )
      RETURN
      END
      SUBROUTINE WRAPIT
      EQUIVALENCE (SYSTEM(1700),KOM (1700),KFLAGS(1692),TAPETB(1622))
      EQUIVALENCE (TAPETB(18),PROTAP(18),CANTAP(17),CLTAPE(16),
1 PCCTAP(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),PLNTAP( 1))
      DIMENSION SYSTEM(1739)
      COMMON SYSTEM
      DIMENSION INTAP(20),TAPSTO(250)
      COMMON TAPSTO,NWPR,NOREC,MULFLG
      EQUIVALENCE (SYSTEM(1739),NID),(TAPSTO(1),INTAP(1))
      DIMENSION R(500),Z(500),AK(500),F(500),CTHETA(500),FLNGTH(500),
1 X(500),Y(500),B(500),A(500),FFL(500),ADUM(25),IDUM(25)
      COMMON M,R,Z,AK,F,RO,ZO,ALPHA0,CONS,NC,RMAX,ZMAX,PI,DTHETA,FLNGTH,
1 TSUM,FLSUM,NHIGH,NLOW,DISTRT,ADVANCE,SHAFT1,SHAFT2,AA,BB,CC,DEL,
2 DELRHO,NSTART,LLL,RHOMIN,DTMAX,DBA,CELMIN,X,Y,B,A,FFL,TOL
3 , NCPERP,NREVPT,LA,III,FLTOTL,ADUM,IDUM
      TOL#TAPSTO(4)
      RETURN
      END
*LABEL
CWRITE
*LIST
*FORTRAN
      SUBROUTINE WRITE(TAPES2,IRETN,NIN,SAPSTO,NWD)
      CALL TAPEWT(TAPES2,IRETN,NIN,SAPSTO,NWD)
      IF(IRETN)5,10,10
5 RETURN
10 WRITE OUTPUT TAPE 6, 15
15 FORMAT(1H ,27HERROR IN WRITING NEW CLTAPE)
      CALL DESPAT
      RETURN
      END

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