

TABLE OF CONTENTS

I. INTRODUCTION

II. COMPUTER PROGRAM DESCRIPTIONS

1. Centrifugal Flow Pump Sizing Program
2. Axial Thrust Balancer Stability Analysis
3. Circular Section Volute Design
4. Inducer and Impeller Performance Design
5. Impeller Discharge Traverse Data Evaluation
6. Pump Air Test Data Reduction
7. Overall Performance of a Two Stage LH₂ Pump
8. Crossover Passage Design
9. Air Pump Performance Map
10. Pump Axial Thrust Program
11. LH₂ Pump Test Data Reduction Program
12. Axial Blade Design Program
13. Multistage Axial Flow Turbine Performance Analysis Program

(NASA-CR-132222) FLUID DYNAMICS COMPUTER
 PROGRAMS FOR NEVA TURBOPUMP (Aerojet
 Nuclear Systems Co., Azusa, Calif.)
 461 p HC \$25.25
 CSC 21F

G3/22

Unclas
17723

N73-24670

1. CENTRIFUGAL FLOW PUMP SIZING PROGRAM

COMPUTER PROGRAM

CENTRIFUGAL FLOW PUMP SIZING PROGRAM

I. INTRODUCTION

Preliminary sizing of a centrifugal flow pump is performed based on an assumed or initial hydraulic efficiency. Component losses are computed and a new value of efficiency is determined. Sizing and loss computations are repeated until the hydraulic efficiency approaches a constant value and the specified head is satisfied. With this program, a pump can be sized for a specified flow coefficient or the optimum flow coefficient can be determined by iterative process through selection of the appropriate program flag. Because of design model limitations, this program is generally not recommended for final detail design.

This program was used for the design point selection of the NERVA two-stage turbopump described in Reference 1.

Reference 1 - Aerojet Nuclear Systems Company Engineering Operations Report
N8300R:71-076, NERVA Turbopump Design Report, Volume 1,
September 1971

I. INTRODUCTION

During the design of the NERVA Turbopump, numerous computer programs were developed for the analyses of fluid dynamic problems within the machine. The programs developed are shown in the following list.

1. Centrifugal Flow Pump Sizing Program
2. Axial Thrust Balancer Stability Analysis
3. Circular Section Volute Design
4. Inducer and Impeller Performance Program
5. Impeller Discharge Traverse Data Evaluation
6. Pump Air Test Data Reduction
7. Overall Performance of a Two Stage LH₂ Pump
8. Crossover Passage Design
9. Air Pump Performance Map
10. Pump Axial Thrust Program
11. LH₂ Pump Test Data Reduction Program
12. Axial Blade Design Program
13. Multistage Axial Flow Turbine Performance Analysis Program

This report contains program descriptions, example cases, users instructions, and listings for the majority of these programs. In some cases only the listing is included.

II. COMPUTER PROGRAM DESCRIPTIONS

II. DESIGN MODEL

A. IMPELLER MODEL

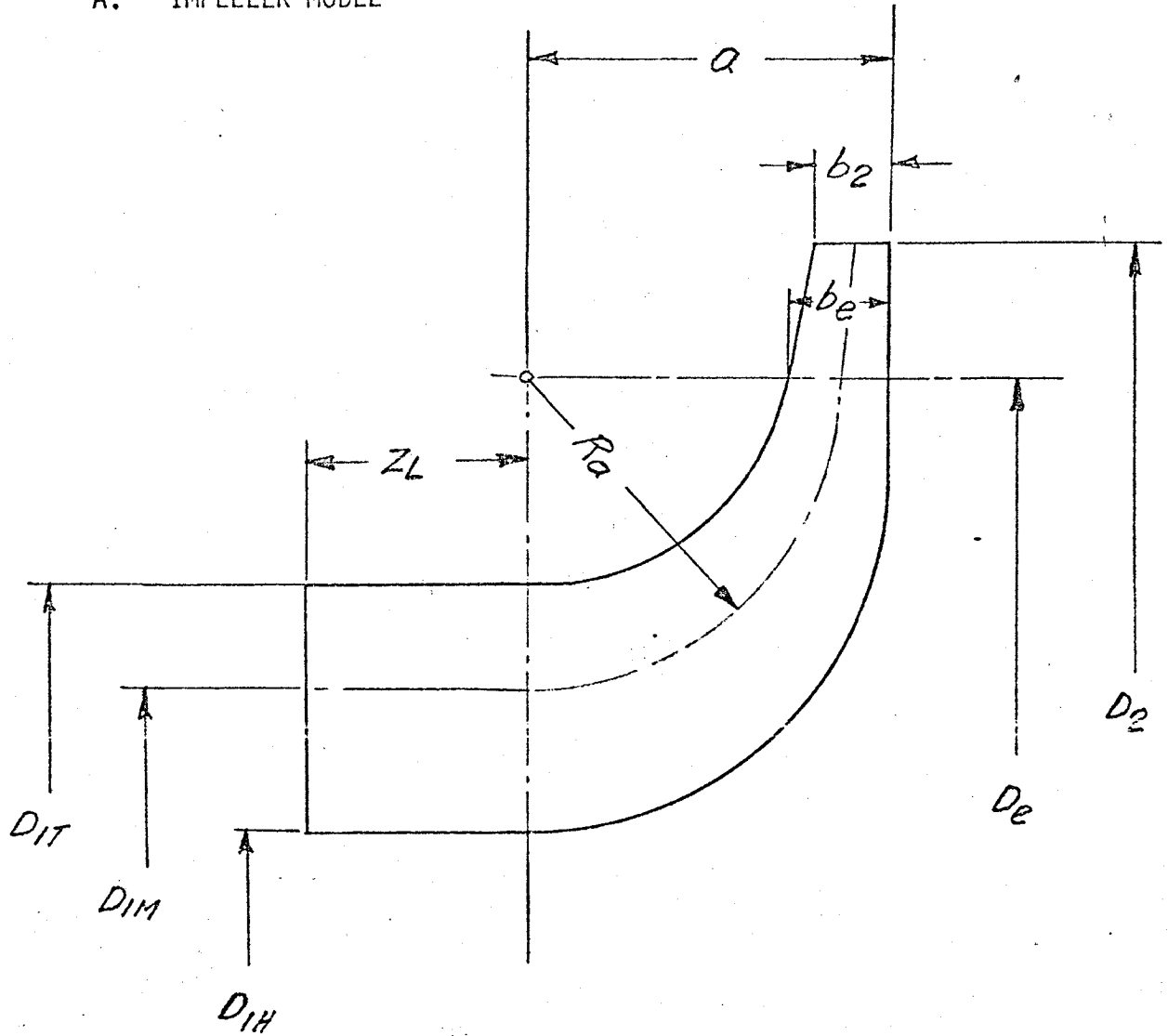


FIGURE 1

Refer to Figure 1:

$$D_{1H} = \xi D_{1T}$$

$$D_{1M} = \left(\frac{D_{1T}^2 + D_{1H}^2}{2} \right)^{1/2}$$

$$D_e = D_{M1} + 2 R_a$$

$$b_e = \frac{D_2}{D_e} b_2$$

$$Z_L = \frac{\pi}{Z_0} D_{1T} \mathcal{C}_{IND} \sin(1.1 \beta_T)$$

$$h_1 = \frac{D_{1T} - D_{1H}}{2}$$

$$R_a = 1.5 \frac{h_1 + b_2}{2}$$

$$R_{m1} = \frac{D_{m1}}{2}$$

If the inducer (axial section) is integral to the impeller the first partial blades are assumed to begin at the start of the transition section. The transition section is divided into 3 cones. The blade angle within each conical section is constant. The radial section contains logarithmic spiral blading ($\beta = \beta_2$).

Blading of impellers without integral inducers begins at the start of the transition section. For such impellers the input parameters Z_0 designating the number of inducer blades must be zero.

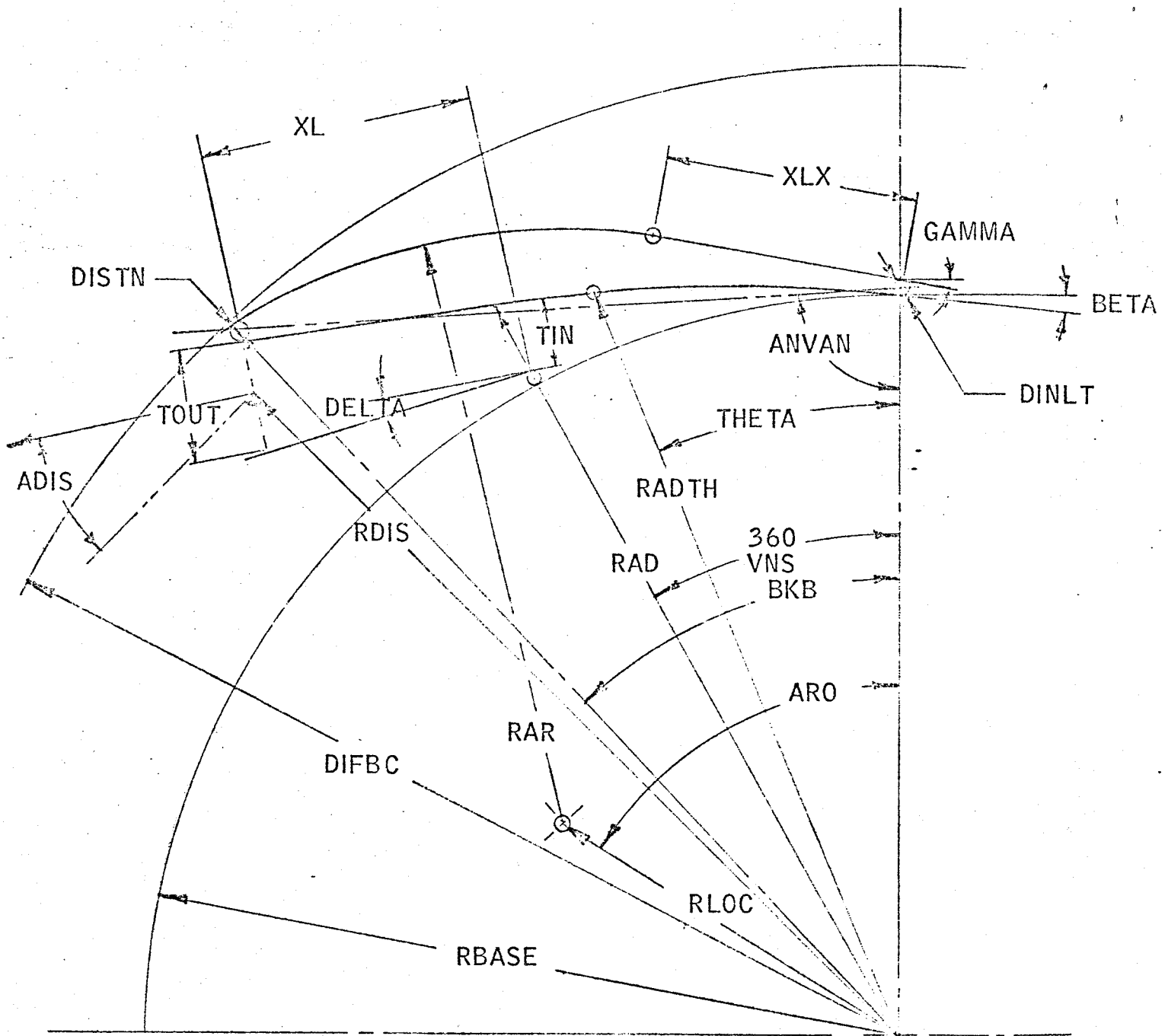
B. VANED DIFFUSER MODEL

The parallel wall vaned diffuser consists of vanes with straight line contours within the region of vane overlap. The vane shape is shown in Figure 2.

III. INSTRUCTIONS TO INPUT

1. The ratio QKI is the ratio of the impeller recirculatory flow to the net pump flow.
2. PHIMN is the limiting minimum value for the inlet tip flow coefficient.
3. The cavitation parameter VHKM is the ratio of the Net Positive Suction Head to the inlet velocity head.

DIFFUSER BLADE



CVAN = CHORD LENGTH
 VNS = NUMBER OF VANES
 RDIS = RADIUS TO POINT OF MEAN DISCHARGE THROAT
 ADIS = ANGLE OF DISCHARGE AT THROAT (MEAN ANGLE)

FIGURE 2

4. The first partial impeller blades designated by Z1 are the longest blades next to the full blades. The inducer blades Z0 which generally extend to the impeller discharge are considered as full blades & must be added to the partial blades to obtain the total number of impeller blades. Z2, Z3 and Z4 are splitter vanes or shorter partial blades. The value to be input for the blade schedule NZ is equal to the highest number of partial blades, e.g., for Z3 $NZ = 3$. The blade schedule for the 24 blade M-1 oxydizer impeller, for instance, is:

Z	=	24	total number of blades
Z0	=	3	full blades or inducer blades
Z1	=	3	first or long partial blades
Z2	=	6	second or intermediate partial blades
Z3	=	6	third or short partial blades.

5. The blade angle distribution factor KBMID is the ratio of the inducer discharge mean blade angle to the inducer inlet mean blade angle. For flat plate inducers with constant hub ratio $KBMID = 1.0$.
6. The tip clearance factor SIG is generally 1.2.
7. To improve axial thrust balance the impeller disc is sometimes extended beyond the discharge mean diameter of the impeller, as indicated in Figure below. DR is the radial extension of the impeller disc.

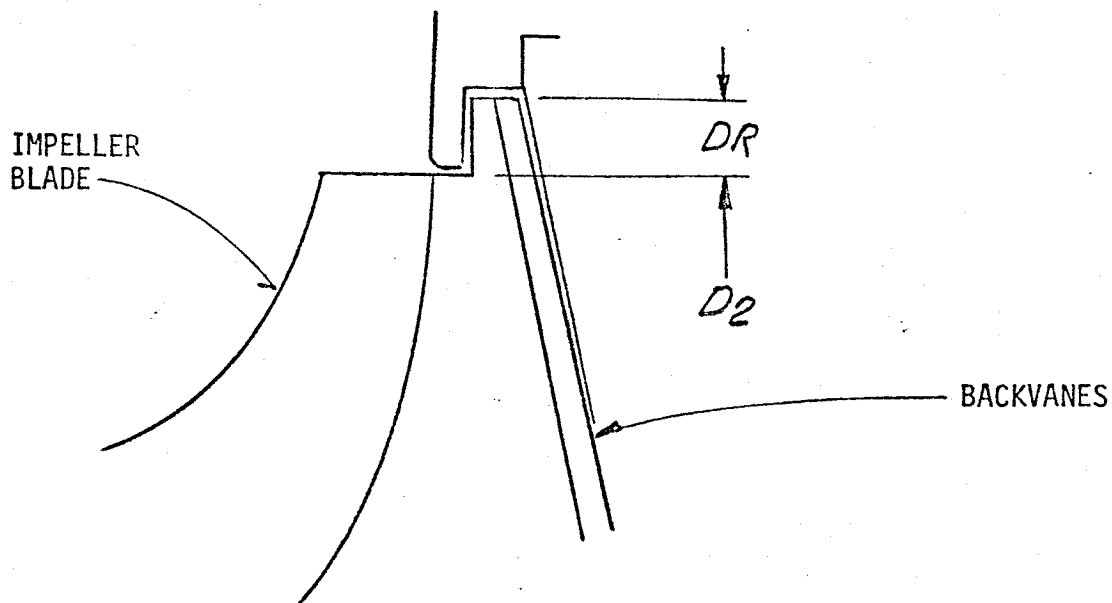


FIGURE 3

8. Impeller configuration flag FLAG
 - 0 unshrouded with backvanes
 - 1 shrouded with backvanes
 - 2 unshrouded with smooth backside
 - 3 shrouded with smooth backside
9. The labyrinth clearance factor FLACO is the ratio of the radial labyrinth clearance to the labyrinth diameter.
10. The flow coefficient factor KPHI is the ratio of the desired flow coefficient to that recommended by Stepanoff in Reference 2. For unshrouded impellers KPHI is generally less than 1.0.
11. A desired flow coefficient can be input. This will override the program recommended value. If three values are input, e.g. three pumps will be calculated in the same run.
12. The ratio XKQD is the ratio of the diffuser recirculatory flow to the net pump flow.
13. The diffuser length to throat ratio is equal to XL/TIN (see Figure 2).
14. For the parallel wall diffuser, the diffuser area ratio REX is $TOUT/TIN$.
15. The diffuser blade shape and especially the thickness to chord length ratio varies significantly with blade number and blade angle. If these parameters are not specified (see note 17) the program searches for an acceptable blade shape within a range of blade angles and blade number limited by RLBET and RLZD. RLBET is the difference between the maximum allowable blade angle and the minimum calculated value (generally approximately 2 to 3 degrees). RLZD is the maximum diffuser blade number specified. The acceptance criteria for the blade profile is incorporated into the main program.
16. Flag OPTFI = 1.0 if discharge flow coefficient optimization is desired.
17. SBETA and SZD are optional. If not input RLBET and RLZD must be specified in order that a low loss diffuser vane may be selected from a sample of vane shapes (see also Note 15).

Reference 2

Stepanoff, A. J. - Centrifugal and Axial Flow Pump, John Wiley & Sons, 1957

18. If the friction loss coefficient FRD is input it will override the program calculated friction coefficient based on the vane surface finish (see Note 21).
19. Diffuser loss adjustment factor FLACO \sim 2.25. Value can be zero if a continuous crossover channel is used.
20. Optional housing structural constraints: RPHG, FSTHG & SSTHG. All these parameters must be either zero or positive.
21. XKFVD must be input if FRD is zero.
22. FLAHG - HOUSING TYPE DEFINITION
 - 1.0 Single Discharge - Single Tongue Vol. (no vaned diffuser)
 - 2.0 Dual Discharge Volute (no vaned Diffuser)
 - 3.0 Double Volute (no vaned diffuser)
 - 4.0 Vaned Diffuser, Single Discharge - Single Tongue Volute
 - 5.0 Vaned Diffuser, Dual Discharge - Volute
 - 6.0 Vaned Diffuser, Double Volute
 - 7.0 Vaned Diffuser + Crossover Channel with vaneless
 - 8.0 Vaned Diffuser + Reversing channel with continuous vane

23. The following parameters are related to internal crossover designs defined by housing type definition flags (FLAHG) 7.0 and 8.0:

Friction Loss Coefficient for vaneless turn CLUT (FLAHG = 7.0). For cast channels CLUT \approx 0.04. This value is lower for machined channels.

The angle correction factor FINC applies to the inlet angle of the reversing vanes (FLAHG = 7.0). FINC is the ratio of vane inlet angle to fluid angle at the inlet to the vane.

A fluid angle BE10 at the reversing vane discharge of 90° indicates that the fluid exits the vaned passages in radial direction.

The number of reversing vanes ZRV is related to the number of diffuser vanes in the program. The program determined value is overridden when ZRV is input.

The reversing vane discharge diameter D9 is related to the impeller eye diameter in the model. The program determined value is ignored if D9 is input.

The vane height B9 is indicated in Figure 4 and related to B7 in subroutine REVCH.

The ratio $RBRM = r_m/B_m$ (Figure 4) is optional. If input it will override the program constant of 1.4.

The program constant for RB67 of 1.1 can be circumvented by inputting a specified value.

The inlet blade thickness THRV applies to housing configuration (FLAHG) 7. If input it will override the program value of 0.120.

The program constant for RDSV is 1.1.

IV. SUMMARY OF RUN MODES

1. With all optional parameters specified, e.g. discharge flow coefficient, diffuser blade number and angle.
2. As above with as many as 3 flow coefficients for evaluation purposes.
3. Flow coefficient in percent of Stepanoff's recommended value, with or without specified diffuser parameters.
4. Flow coefficient optimization, no options.

NOMENCLATURE INPUT

<u>SYBMOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>	<u>FORMAT</u>
WP	Flow Rate	lb/s	F
XN	Rotational Speed	RPM	F
RHO	Fluid Density	lb/ft ³	F
QKI (1)*	Ratio Recirc. Flow Impeller	-	F
HNPISH	Net Positive Suction Head	ft	F
HTOT	Tot Head Required	ft	F
EPS	Inlet Hub Ratio	-	F
PHIMN (2)*	Impeller Inlet Min Flow Coefficient	-	F
BB2	Impeller Discharge Blade Angle	Deg	F
VHKM (3)*	Min Cavitation Parameter	-	F
SOL1	Inducer Blade Solidity	-	F
Z0	Inducer Blade Number	-	F
Z1 (4)*	First Partial Impeller Blades	-	F
Z2 (4)*	Second Partial Impeller Blades	-	F
Z3 (4)*	Third Partial Impeller Blades	-	F
Z4 (4)*	Fourth Partial Impeller Blades	-	F
KBMID (5)*	Blade Angle Distribution Factor	-	F
NZ (4)*	Blade Schedule	-	I
SLC	Blade Tip Clearance	In	F
SIG (6)*	Tip Clearance Loss Factor	-	F
DR (7)*	Radial Extension of Impeller Disk	In	F
FLAG (8)*	Impeller Configuration	-	F
FLACO (9)*	Labyrinth Clearance Factor	-	F
KPH1 (10)*	Flow Coefficient Factor	-	F
PHI21 (11)*	Selected Discharge Flow Coefficient	-	F
PHI22 (11)*	Selected Discharge Flow Coefficient	-	F
PHI23 (11)*	Selected Discharge Flow Coefficient	-	F
ETAHI	Initial Hydraulic Efficiency	-	F
Z	Total Number of Impeller Blades	-	F
XKQD (12)*	Ratio Recirc. Flow Diffuser	-	F
DINLT	Diffuser Inlet Blade Thickness	In	F
RL (13)*	Diffuser Length to Throat Ratio	-	F
REX (14)*	Diffuser Area Ratio	-	F

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>	<u>FORMAT</u>
RLBET	(15)* Range Diffuser Inlet Blade Angle	-	F
RLZD	(15)* Max. Diffuser Blade Number	-	F
XKMSC	Surface Finish, Impeller	In	E
OPTFI	(16)* Flow Coefficient Optimization Flag	-	F
SBETA	(17)* Selected Diffuser Blade Inlet Angle	Deg	F
SZD	(17)* Selected Diffuser Blade Number	-	F
FRD	(18)* Friction Coefficient Diffuser	-	F
FLA	(19)* Diffuser Loss Adjustment Factor	-	F
RPHG	(20)* Max to Design Pressure Ratio	-	F
FSTHG	(20)* Housing Safety Factor	-	F
SSTHG	(20)* Housing Material Yield Strength	lb/sq in	F
VIS	Fluid Dynamic Viscosity	lb sec/sq ft	E
XKFVD	(21)* Surface Finish Diffuser Vane	In	E
XKDVD	Diffusion Loss Factor ($\sim .260$)	-	F
XKIVD	Incidence Loss Factor ($\sim .300$)	-	F
EVD	Diffusion Exponent Diffuser (~ 3.0)	-	F
FLAHG	(22)* Housing Type Definition	-	F
XKSFS	Volute Surface Finish	In	E
CLUT	(23)* Friction Loss Coeff, Vaneless Turn	-	F
FINC	(23)* Angle Correction Factor	-	F
BE10	(23)* Fluid Angle, REversing Vane Discharge	Deg	F
ZRV	(23)* Number of Reversing Vanes	-	F
D9	(23)* Reversing Vane Discharge Dia	In	F
B9	(23)* Vane Height, Revers Vane Discharge	In	F
RBRM	(23)* Ratio Mean Turning Radius to Mean Passage Height	-	F
RB67	(23)* Ratio B6/B7	-	F
THRV	(23)* Inlet Blade Thickness	In	F
RDSV	(23)* Ratio DSV/D9 (~ 1.1)	-	F

*Note number, see Instructions Section III.

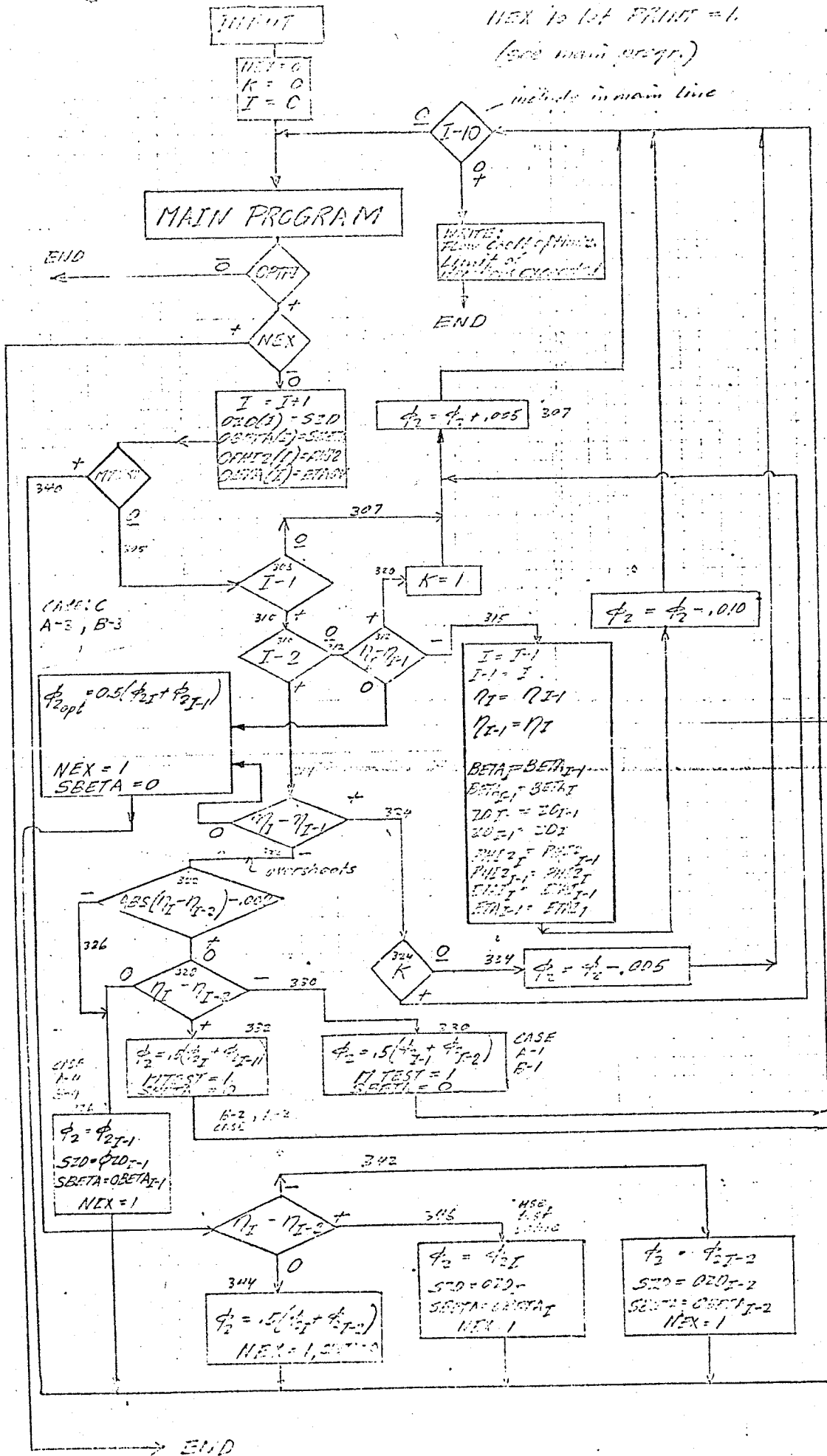
NOMENCLATURE OUTPUT

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>
RA	See Figure 1	In
RC	See Figure 1	In
ZL	Axial Length of Inducer Section	In
CLIND	Chord Length, Inducer	Deg
THIND	Blade Wrap Inducer	In.
DHIND	Hydraulic Diameter Inducer Blade Passage	In
CLTOT	Total Chord Length	In
RP2	Radius Locating 2nd Partial Blade	-
SOLTO	Total Solidity	-
CLIMP	Chord Length Impeller	In
THIMP	Blade Wrap Impeller	Deg
DHIMP	Hudraulic Diameter Impeller Blade Passage	In.
THTOT	Total Blade Wrap	Deg
SOL2	Blade Solidity 1st-2nd Partial	-
DH2	Hydraulic Dia. 1st-2nd Partial	In
BBC1	Blade Angle Cone 1	Deg
BBC2	Blade Angle Cone 2	Deg
BBC3	Blade Angle Cone 3	In
DHTOT	Hyd. Diameter Total	-
SOL3	Blade Solidity 2nd-3rd Partial	In.
DH3	Hydraulic Dia. 2nd-3rd Partial	-
CLRS	Chord Length Radial Section	In
CLC1	Chord Length Cone 1	In
CLC2	Chord Length Cone 2	In
CLC3	Chord Length Cone 3	In
CLTS	Chord Length Total	-
SOLIP	Impeller Blade Solidity	-

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>
THRS	Blade Wrap Radial Section	Deg
THC1	Blade Wrap Cone 1	Deg
THC2	Blade Wrap Cone 2	Deg
THC3	Blade Wrap Cone 3	Deg
THTS	Blade Wrap Total	Deg
SCL	Blade Tip Clearance	In
DELE	Clearance Loss Parameters	-
DELK	Clearance Loss Parameter	-
DELR	Clearance Loss Parameter	-
WZTH	Discharge Relative Velocity	ft/sec
RW	Relative Velocity Ratio	-
HTH	Theoretical Head	ft
SLPCF	Slip Coefficient	-
PSINC	Head Loss Coefficient Inducer	-
PSF	Head Loss Coefficient Friction	-
PSD	Head Loss Coefficient Diffusion	-
PSTIP	Head Loss Coefficient Tip	-
PSCL	Head Loss Coefficient Clearance	-
PSIBL	Head Loss Coefficient Blade	-
PSITH	Theoretical Head Coefficient	-

Parameters describing diffuser blade geometry are depicted in Figure 2. Other diffuser data:

STANG	Stagger Angle	Deg
TRACO	Chord Length(Transformed)	In.
SOLID	Solidity	-
BBM4	Inlet Mean Blade Angle	Deg
BBM5	Exit Mean Blade Angle	Deg
FEE	Blade Turning Angle	
ACROSS	Blade Cross-sectional Area	in ²
AEW	Passage End Wall Area	in ²
ABS1	Blade Surface Area	In ²
AR	Ratio AEW/(Z x ABS1)	
DH	Hydraulic Diameter	in ²
ATHT	Total Throat Area	in ²



NEX to last PRINT = 1.
(see main progr.)

include in main line

END

END

MAIN PROGRAM

CASE: C
A=3, B=3

CASE
A=1
B=1

END

NEX=1, SBETA=0

phi_2 = phi_2I
S2D=phi_2I-1
SBETA=OBETA I
NEX=1

phi_2 = phi_2I-2
S2D=phi_2I-2
SBETA=OBETA I-2
NEX=1

END


```

000001 SUBROUTINE ANSWR
000002 REWL KBMID
000003 COMMON XK(8),XZ(8),XFR(8),XR(8)
000004 COMMON DH1, RM1, H, RA, RC, BBM1, CLIND, THIND, ZL, DHIND, BLK1, A1, AB1, DPIND
000005 1, BBC1, BBC2, BBC3, CLC1, CLC2, CLC3, CLTS, THC1, THC2, THC3, THTS, CLRS, THRS,
000006 2CLIMP, THIMP, CLTOT, THTOT, BLK2, A2, SOL1, SOL2, SOL3, SOL4, SOL5, SOLIP, SOL
000007 3TO, DH2, DH3, DH4, DH5, DHIMP, DHTOT, RP2, RP3, RP4, SM, QI, SIG, DR, CM2, SCL
000008 COMMON DT1, EPS, D2, B2, BBT1, BBT2, Z, Z0, Z1, Z2, Z3, Z4, NZ, KBMID, XSI, DPIMP
000009 COMMON WP, XN, RHO, QKI, HNPST, HTOT, PHIMN, VHKM, ETAHI, PSITH, ESHR, RWR
000010 COMMON XKPH1, PHI21, PHI22, PHI23, CM1, UT1, PHI1T, S, XNS, PSIO, PHI2, NCASE
000011 COMMON FLAG, VIS, FLACO, WWR, U2, PSIBL, DPIP, PSIIP, PSIIN, FRD
000012 COMMON B4, RL, REX, R4, BETA, BFL4, ZD, DINLT, DISTH, TIN, TOJT, XL, VS,
000013 1RADUS(95), THETA, RADTH, ALPHA, PAC, DELTA, GAMMA, ARC, RAR, RLOC, CVAN,
000014 2ANVAN, RKB, DIFBC, RDIS, ADIS, THICK, THICO, STANG, TRACO, SOLID, BBM4,
000015 3BB45, FEE, ACROS, AEW, ABS1, DH, AR, ATHT, RI, NOGO, NSKIP, OPTFI, PRINT, FI2
000016 COMMON RIOP, RIIM, RIBL, RIH, DEL, BEL5, DEQ, RMTH, OMPR, OMEW, OMOV
000017 COMMON V4, M, XKOVD, XK1VD, XKEVD, EVD, FLA, XKOD, O, QD, QMTOT
000018 COMMON RPHG, SSTHG, FSTHG, XKSES, XKMSC, D6, D7, C7, DPSSC, DPSFS, DPSMC, C34
000019 COMMON RLRET, RLZD, SBETA, SZD, PSHSG, ETAOV, LOOP, FLAG, B9
000020 COMMON CLUT, FINC, BE10, RBRM, D9, RB67, THRV, ZRV, RDSV, TEX5, DLDM, BCMS
000021 110 FORMAT(1X, 'INLET HUB DIAMETER, DH1', 13X, F10.3, 2X, 'INCHES', 10X, 'INLE
000022 7T MEAN RADIUS, RM1', 14X, F10.3, 2X, 'INCHES')
000023 111 FORMAT(1X, 'INDUCER VANE HEIGHT, H', 14X, F10.3, 2X, 'INCHES', 10X, 'INLET
000024 8 AREA, A1', 22X, F10.3, 2X, 'SQ IN')
000025 112 FORMAT(1X, 'INLET BLOCKAGE, BLK1', 16X, F10.3, 3X, '***', 12X, 'INDUCER DI
000026 1FF PARAMETER, DPIND', 7X, F10.3, 3X, '***')
000027 113 FORMAT(1X, 'INLET AREA WITH BLOCKAGE, AB1', 7X, F10.3, 2X, 'SQ IN', 11X, '
000028 1DISCHARGE AREA, A2', 18X, F10.3, 2X, 'SQ IN')
000029 114 FORMAT(1X, 'INLET MEAN BLADE ANGLE, BBM1', 8X, F10.3, 2X, 'DEGREES')
000030 115 FORMAT(1X, 'IMPLLR DIFF PARAMETER, DPIMP', 8X, F10.3, 3X, '***', 12X, 'DIS
000031 2CHARGE BLOCKAGE, BLK2', 12X, F10.3, 3X, '***')
000032 116 FORMAT(1X, 'INLET TIP TO DISCHARGE DIA RATIO, XSI', F9.3, 3X, '***', 12X
000033 1, 'STATIC MOMENT, SM', 19X, F10.3, 2X, 'SQ IN', /)
000034 117 FORMAT(5X, 7HRA =, F10.3, 5X, 7HRC =, F10.3, 5X, 7HZL =, F10.3, 5X
000035 1, 7HCLRS =, F10.3, 5X, 7HTHRS =, F10.3)
000036 118 FORMAT(5X, 7HCLIND =, F10.3, 5X, 7HCLIMP =, F10.3, 5X, 7HBBC1 =, F10.3, 5X
000037 1, 7HCLC1 =, F10.3, 5X, 7HTHC1 =, F10.3)
000038 119 FORMAT(5X, 7HTHIND =, F10.3, 5X, 7HTHIMP =, F10.3, 5X, 7HBBC2 =, F10.3, 5X
000039 1, 7HCLC2 =, F10.3, 5X, 7HTHC2 =, F10.3)
000040 120 FORMAT(5X, 7HDHIND =, F10.3, 5X, 7HDHIMP =, F10.3, 5X, 7HBBC3 =, F10.3, 5X
000041 1, 7HCLC3 =, F10.3, 5X, 7HTHC3 =, F10.3)
000042 121 FORMAT(5X, 7HCLTOT =, F10.3, 5X, 7HTHTOT =, F10.3, 5X, 7HDHTOT =, F10.3, 5X
000043 1, 7HCLTS =, F10.3, 5X, 7HTHTS =, F10.3)
000044 WRITE(3, 114) BBM1
000045 WRITE(3, 110) DH1, RM1
000046 WRITE(3, 111) H, A1
000047 WRITE(3, 112) BLK1, DPIND
000048 WRITE(3, 113) AB1, A2
000049 WRITE(3, 115) DPIMP, BLK2
000050 WRITE(3, 116) XSI, SM
000051 WRITE(3, 117) RA, RC, ZL, CLRS, THRS
000052 WRITE(3, 118) CLIND, CLIMP, BBC1, CLC1, THC1
000053 WRITE(3, 119) THIND, THIMP, BBC2, CLC2, THC2
000054 WRITE(3, 120) DHIND, DHIMP, BBC3, CLC3, THC3
000055 WRITE(3, 121) CLTOT, THTOT, DHTOT, CLTS, THTS
000056 IF(NZ-2) 10, 11, 12

```

```

000057      6 FORMAT(5X,'SOLIP =',F10.4,5X,'SOLTO =',F10.4)
000058      10 WRITE(3,6) SOLIP,SOLTO
000059          GO TO 30
000060      22 FORMAT(5X,7HRP2 =,F10.3,5X,7HSOL2 =,F10.3,5X,7HSOL3 =,F10.3,5X
000061      1,7HSOLIP =,F10.3/5X,7HSOLTO =,F10.3,5X,7HDH2 =,F10.3,5X,7HDH3
000062          2=,F10.3)
000063      11 WRITE(3,22) RP2,SOL2,SOL3,SOLIP,SOLTO,DH2,DH3
000064          GO TO 30
000065      12 IF(NZ-3) 13,13,14
000066      24 FORMAT(5X,7HSOL2 =,F10.3,5X,7HSOL3 =,F10.3,5X,7HSOL4 =,F10.3,5X
000067      3,7HRP2 =,F10.3,5X,7HRP3 =,F10.3/5X,7HSOLIP =,F10.3,5X,7HSOLTO
000068      4=,F10.3,5X,7HDH2 =,F10.3,5X,7HDH3 =,F10.3,5X,7HDH4 =,F10.3)
000069      13 WRITE(3,24) SOL2,SOL3,SOL4,RP2,RP3,SOLIP,SOLTO,DH2,DH3,DH4
000070          GO TO 30
000071      27 FORMAT(5X,7HRP2 =,F10.3,5X,7HSOL2 =,F10.3,5X,7HSOL3 =,F10.3,5X
000072      1,7HDH2 =,F10.3,5X,7HDH3 =,F10.3/5X,7HRP3 =,F10.3,5X,7HSOL4
000073      2=,F10.3,5X,7HSOL5 =,F10.3,5X,7HDH4 =,F10.3,5X,7HDH5 =,F10.3/5
000074      3X,7HRP3 =,F10.3,5X,7HSOLIP =,F10.3,5X,7HSOLTO =,F10.3)
000075      14 WRITE(3,27) RP2,SOL2,SOL3,DH2,DH3,RP3,SOL4,SOL5,DH4,DH5,RP3,SOLIP,
000076      1SOLTO
000077      30 RETURN
000078          END

```

W ELT ASIN.1,710427, 63089

```
000001      FUNCTION ASIN(A)
000002      IF(A) 2,2
000003      1 SIGN=-1.
000004      GO TO 3
000005      2 SIGN=1.
000006      3 ASIN=ATAN(1./SQRT(1./A**2-1.))*SIGN
000007      RETURN
000008      END
```

ELT CLAB, 1, 710427, 63091

```

000001 SUBROUTINE CLAB
000002 COMMON XK(8),XZ(3),XFR(8),XR(8)
000003 COMMON DH1,RM1,H,RA,RC,BBM1,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND
000004 1,BBC1,BBC2,BBC3,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,THTS,CLRS,THRS,
000005 2CLIMP,THIMP,CLTOT,THTOT,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SOLIP,SOL
000006 3TO,DH2,DH3,DH4,DH5,DHIMP,DHTOT,RP2,RP3,RP4,SM,QI,SIG,DR,CN2,SCL
000007 COMMON DT1,EPS,D2,B2,BBT1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,KSMID,XSI,DPIMP
000008 COMMON WP,XN,RHO,QKI,HNPISH,HTOT,PHIMN,VHKM,ETAHI,PSITH,ESHR,RWR
000009 COMMON XKPH1,PHI21,PHI22,PHI23,CM1,UT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
000010 COMMON FLAG,VIS,FLACO,W,U2,PSIBL,DPIPS,PSIIP,PSIIN,FRD
000011 COMMON B4,RL,REX,R4,BETA,BFL4,ZD,INLT,DISTH,TIN,TOUT,XL,V5,
000012 1RADUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
000013 2ANVAN,BKB,DFBC,DIS,ADIS,THICK,THICO,STANG,TRACO,SOLID,BBM4,
000014 3RMS,FEE,ACROS,AEW,ABS1,DH,AR,ATHT,RI,NO70,NSKIP,OPTFI,PRINT,FI2
000015 COMMON RIOPT,RIBM,RIBL,RIBH,DEL,BFL5,DEQ,RMTH,OMPR,OMEW,OMOV
000016 COMMON V4,M,XKDVD,XK1VD,XKFVD,EVD,FLA,XKOD,R,OD,OMTOT
000017 COMMON RPHG,SSTHG,FSTHG,XKSFS,XKMSC,D6,D7,C7,DPSSC,DPSFS,DPSMC,C34
000018 COMMON RLBT,RLZD,SBETA,SDZ,PSHSG,ETAOV,LOOP,FLAG,B9
000019 COMMON CLUT,FINC,BE10,RBRM,D9,RB67,THR, ZRV,RDSV,TEX5,DLDM,RCM5
000020 R2=D2/2.
000021 RT1=DT1/2.
000022 D=2.*RWR
000023 CO=FLACO*D
000024 PI=ESHR/16.
000025 T=.030
000026 XNTH=5.
000027 DPFF=.1645E-07*.025*RHO*XN**2*(R2**2-RT1**2)
000028 P=DPIPS-DPFF
000029 VI=VIS*(32.16/RHO)
000030 COEC=.67
000031 FA=2.*RHO*32.1741*P*144.
000032 FB=SQRT(FA)
000033 S=3.1416*CO*(D+CO)/144.
000034 CF=(XNTH-1.)*(1.-8.52/((PI-T)/CO+7.23))+1.
000035 DO 40 I=1,3
000036 COE=COEC/SQRT(CF)
000037 W=COE*S*FB
000038 RE=CO*W/(6.*S*VI*RHO)
000039 ZLAB=T/CO
000040 IF (RE-60.)200,200,300
000041 200 RZ=ZLAB/RE
000042 CALL INT4(XZ,XK,RZ,FK)
000043 COEC=1./SQRT(64./RE+48.*ZLAB/RE+FK)
000044 GO TO 40
000045 300 RE=ALOG(RE)
000046 CALL INT4(XR,XFR,RE,FFR)
000047 FFR=EXP(FFR)
000048 RE=EXP(RE)
000049 COEO=.62*RE**.0085
000050 IF (ZLAB-1.15) 310,310,320
000051 310 F=0
000052 GO TO 330
000053 320 F=1.-2.7183**(-.95*(ZLAB-1.15))
000054 330 IF (RE-6000.)340,340,350
000055 340 COEC=1./SQRT(1/COEO**2-F*(2*SQRT(1/COEO**2-64./RE)-2.))+2.*FFR*ZLAB
000056 1)

```

```

000057      60 TO 40
000058      350 CCE=1./SQRT(1./COE0**2-(2./COE0-2.)*F+2.*FFR*ZLAB)
000059      40 CONTINUE
000060      IF(PRINT) 50,50,60
000061      60 WRITE(3,27)
000062      WRITE(3,29) D
000063      WRITE(3,31) CO
000064      WRITE(3,33) XNTH
000065      WRITE(3,37) PI
000066      WRITE(3,39) T
000067      WRITE(3,41) P
000068      WRITE(3,15) W
000069      27 FORMAT(/5X, '*** LABYRINTH DATA ***',/)
000070      29 FORMAT(5X, 'LABYRINTH DIAMETER, D',33X,F10.4,2X,'IN')
000071      31 FORMAT(5X, 'RADIAL CLEARANCE, CO',34X,F10.4,2X,'IN')
000072      33 FORMAT(5X, 'NUMBER OF TEETH, XNTH',33X,F10.4,2X,'***')
000073      37 FORMAT(5X, 'TOOTH SPACING, PI',37X,F10.4,2X,'IN')
000074      39 FORMAT(5X, 'TOOTH WIDTH, T',40X,F10.4,2X,'IN')
000075      41 FORMAT(5X, 'PRESSURE DROP, P',38X,F10.4,2X,'LB/SQIN')
000076      15 FORMAT(5X, 'LABYRINTH FLOW RATE, WWR',30X,F10.4,2X,'LB/SEC')
000077      50 RETURN
000078      END
    
```

000001, 000002, 000003, 000004, 000005, 000006, 000007, 000008, 000009, 000010, 000011, 000012, 000013, 000014, 000015, 000016, 000017, 000018, 000019, 000020, 000021, 000022, 000023, 000024, 000025, 000026, 000027, 000028, 000029, 000030, 000031, 000032, 000033, 000034, 000035, 000036, 000037, 000038, 000039, 000040, 000041, 000042, 000043, 000044, 000045, 000046, 000047, 000048, 000049, 000050, 000051, 000052, 000053, 000054, 000055, 000056

```

000001      SUBROUTINE CUFIT (M,NUMBR,X,Y,C)
000002      DIMENSION X(10),Y(10),A(11,11),B(11),C(11),P(20)
000003      MX2=2*MX
000004      DO 13 I=1,MX2
000005      P(I)=0.0
000006      DO 13 J=1,NUMBR
000007      13 P(I)=P(I)+X(J)**I
000008      N=M+1
000009      DO 30 I=1,N
000010      DO 30 J=1,N
000011      K=I+J-2
000012      IF (K) 29,29,28
000013      28 A(I,J)=P(K)
000014      GO TO 30
000015      29 A(I,1)=NUMBR
000016      30 CONTINUE
000017      B(1)=0.0
000018      DO 21 J=1,NUMBR
000019      21 B(1)=B(1)+Y(J)
000020      DO 22 I=2,N
000021      B(I)=0.0
000022      DO 22 J=1,NUMBR
000023      22 B(I)=B(I)+Y(J)*X(J)**(I-1)
000024      NM1=N-1
000025      DO 300 K=1,NM1
000026      KP1=K+1
000027      L=K
000028      DO 400 I=KP1,N
000029      IF (ABS(A(I,K))-ABS(A(L,K))) 400,400,401
000030      401 L=I
000031      400 CONTINUE
000032      IF (L=K) 500,500,405
000033      405 DO 410 J=K,N
000034      TEMP=A(K,J)
000035      A(K,J)=A(L,J)
000036      410 A(L,J)=TEMP
000037      TEMP=B(K)
000038      B(K)=B(L)
000039      B(L)=TEMP
000040      500 DO 300 I=KP1,N
000041      FACT=A(I,K)/A(K,K)
000042      A(I,K)=0.0
000043      DO 301 J=KP1,N
000044      301 A(I,J)=A(I,J)-FACT*A(K,J)
000045      300 B(I)=B(I)-FACT*B(K)
000046      C(N)=B(N)/A(N,N)
000047      I=NM1
000048      710 IP1=I+1
000049      SUM=0.0
000050      DO 700 J=IP1,N
000051      700 SUM=SUM+A(I,J)*C(J)
000052      C(I)=(B(I)-SUM)/A(I,I)
000053      I=I-1
000054      IF (I) 800,800,710
000055      800 RETURN
000056      END
    
```

ELT DBLPR.1.710427. 53096

000001 SUBROUTINE DBLPR
COMMON XK(8),XZ(8),XFR(8),XR(8)
COMMON DH1,RM1,H,RV,RC,BM1,CLIND,THIND,ZL,DHIND,BLK1,AT,AB1,DPIND
1,BGC1,BGC2,BGC3,CLC3,CLC2,THC1,THC2,THC3,HTS,CLRS,THRS,
2,CLIMP,THIRP,CLTOT,THTOT,RLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SOLIP,SOL
3TO,CH2,DH3,DH4,DH5,DHWP,DH1OT,RR2,RR3,RR4,SM,QT,SIG,DR,CMS,SCL
COMMON DT1,EPS,D2,B2,BBT1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,KBMID,XST,DPIMP
COMMON WP,XN,RHO,GKI,HNPSH,HTOT,PHIMN,VHKK,ETAHI,PSITH,ESHR,RWR
COMMON XKRPH1,PHI21,PHI22,PHI23,CMT,UT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
COMMON FLAG,VIS,FLVACO,WWR,U2,PSIBL,DPIPS,PSIIP,PSIIN,FRD
COMMON B4,RL,REX,RBASE,BETA,BFL4,ZD,DINLT,DISTH,TIN,TOU,XL,VS,
1,RAOVS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
2,ANVAH,BKB,DIFRC,RDS,ADIS,THICK,THICO,STANG,TRACO,SOLD,BRM4,
3,BUM5,FEE,ACROS,NEW,ABS1,DHD,AR,ATHT,RI,NOGO,NSKIP,OPFI,PRINT,FI2
COMMON RIOT1,RIW,RI2L,RI3H,DEL,NEL3,DEG,RMTH,OMPR,OMEW,OMOV
COMMON V4,M,XKVD,XK1VD,XKFV,EVD,FLA,XKGD,G,GD,OMTOT
COMMON RPHG,SSTHG,FSH6,FKKSF5,XKMSC,D6,D7,C7,DPSSC,DPFS,DPSC,C34
COMMON RLBE1,RLZD,SBE1A,SZD,PSH6,ETAOV,L0OP,FLAH6,B9
COMMON CLUT,FINC,BE10,RRM,D9,RB67,THR,V,ZRV,RDSV,TEX5,DLDM,BCMS
ALPH4=(90.-BFL4)/57.296
VTH = .321*GD/(Z0*B2*TIN)
RVD=VTH/V4
RVD=0.01037*DHD*VTH*RH0/VIS
IF (FLHG-7.) 32,32,34
32 V5= VTH*ROIS/DIFRC/REX
60 TO 9
34 V5 = VTH*TIN/TEX5
9 IF (FRD) 10,10,20
10 IF (RED-1.E+05) 12,12,13
12 FRD=0.0032+0.221/RED**0.237
60 TO 20
13 FRD=1./((0.86858*ALOG(2.*DHD/XKVD)+1.74)**2
20 BFL4=BFL4/57.296
BMM4=BMM4/57.296
IF (FLHG-7.) 22,22,21
22 BFL5=BFL5/57.296
OMFO=FRD *TRACO*RVD**2/(4.*DHD)
DVD=1.-RBASE/DIFRC*COS(BM4)/COS(RFL5)+COS(BM4)/(2.*SOLD)*(SIN(BB
1M4)/COS(BRM4)-RBASE/DIFRC*SIN(BFL5)/COS(BFL5))
OMDD=XKDVD+DVD**EVD
60 TO 23
21 BFL5=(90.-BCM5)/57.296
OMFO = FRD*(RL*TIN+LDL4+3.14159*RBASE/ZD)*RVD**2/(4.*DHD)
60 TO 23
23 G=BMM4
C=COS(G)
A=6.5797*C**2/ZD**2-19.233*C**4/ZD**3+0.6584*C**4/ZD**4*(8.*C**2-1
1.)
PSIA=EXP(-2.*G*SIN(2.*G)/ZD)*EXP(A)/(2.*C)**(4.*C**2/ZD)
000049
SAVE=ATAN(1/PSIA*(RBASE/DIFRC)**2*1/SIN(BFL5)+SIN(BM4)/COS(BM4))
BMM4=SAVE
BMM4=SAVE
000052
BMM4=VSHF
OMID=XK1VD*(COS(BFL4)**2*(SIN(BFL4)/COS(RFL4)-SIN(BM4)/COS(BM4))
1)**2
BMM4=SAVE
000055
FLVD=(2.*RBASE-D2)/(2.*SIN(ALPH4))
000056

```

000057      REVLD=.005185*B4*C34*RH0/VIS
000058      IF (REVLD-1.E+05) 15,15,16
000059      15 FRVLD=.0032+.221/REVLD**0.237
000060      GO TO 18
000061      16 FRVLD = 1./(0.86858*ALOG(B4/XKFVD) + 1.74)**2
000062      18 OMVLD=FRVLD*FLVLD*(C34/V4)**2/(2.*B4)
000063      OMTD=JMF0+OMDD+OM1D
000064      IF (FLAG-7.) 45,45,46
000065      45 OMTDA=FLA*OMTD
000066      OMTOT=OMTDA+OMVLD
000067      GO TO 47
000068      46 OMTOT = OMTD + OMVLD
000069      47 ALPHA=ALPHA*57.296
000070      BFL4=BFL4*57.296
000071      BFL5=BFL5*57.296
000072      BSM4=BSM4*57.296
000073      IF (PRINT) 50,50,40
000074      40 WRITE (3,507)
000075      WRITE (3,508) VTH,OMVLD
000076      WRITE (3,509) RVD,OMFD
000077      WRITE (3,510) V5,OMDD
000078      WRITE (3,511) ADIS,OM1D
000079      WRITE (3,512) RED,OMTD
000080      IF (FLAG-7.) 42,42,41
000081      41 WRITE (3,613) FRD,OMTOT
000082      GO TO 43
000083      42 WRITE (3,513) FRD,OMTDA
000084      WRITE (3,515) DVD,OMTOT
000085      43 CONTINUE
000086      507 FORMAT(/45X,'PERFORMANCE-CHANNEL FLOW APPROACH'//)
000087      508 FORMAT(10X,'THROAT VELOCITY',15X,F10.2,' FT/SEC',7X,'FRICTION LOSS
000088      I COEFF, VANELESS SECTION',F10.4//)
000089      509 FORMAT(10X,'THROAT TO INLET VEL. RATIO',4X,F10.4,14X,'FRICTION LOS
000090      1S COEFFICIENT, BLADE',5X,F10.4//)
000091      510 FORMAT(10X,'DIFFUSER DISCH. VELOCITY',6X,F10.1,' FT/SEC',7X,
000092      1 'DIFFUSION LOSS COEFFICIENT',11X,F10.4//)
000093      511 FORMAT(10X,'DIFF.DISCH. MEAN CHANNEL ANGLE',F10.3,' DEG',10X,
000094      1 'INCIDENCE LOSS COEFFICIENT',11X,F10.4//)
000095      512 FORMAT(10X,'REYNOLDS NUMBER,THROAT',7X,E11.4,14X,
000096      1 'TOTAL LOSS COEFFICIENT, BLADE',8X,F10.4//)
000097      513 FORMAT(10X,'FRICTION FACTOR',15X,F10.5,14X,
000098      1 'ADJUSTED OVERALL LOSS COEFF., BLADE',2X,F10.4//)
000099      515 FORMAT(10X,'DIFFUSION PARAMETER',11X,F10.4,14X,'TOTAL LOSS COEFFIC
000100      IENT',15X,F10.4//)
000101      613 FORMAT(10X,'FRICTION FACTOR',15X,F10.5,14X,
000102      1 'TOTAL LOSS COEFFICIENT',15X,F10.4//)
000103      50 RETURN
000104      END

```


SUBROUTINE DFRBV
COMMON XK(8),XR(8),XZ(8),XFR(8),XR(8)
COMMON DHT,RM1,H,RA,RC,BBMT,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND
COMMON DHT1,RC,BC2,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,HTS,CLRS,THRS,
1,BGC1,BGC2,BGC3,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,HTS,CLRS,THRS,
2CLIMP,THIMP,CLT01,THT01,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SCLIP,SCL
310,DHS,DHS,DHTMP,DHT01,RR2,RR3,RR4,SM,01,S16,DR,CMS,SCL
COMMON DT1,EPS,D2,B2,B31,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,KBMID,XS1,DPIMP
COMMON WF,XN,RHO,OKI,HNPSH,HT01,PHINN,VHKN,ETHAI,PSITH,ESHR,BWP
COMMON XKPHT,PHI21,PHI22,PHI23,CM1,UT1,PHI11,5,XNS,PSIO,PHI2,NCASE
COMMON B4,RL,ZZZ,BETA,BFL4,ZD,UMILT,DISTH,TIN,TOU1,XL,VS,
1RADUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLCC,CVAN,
ZANVAN,BK6,DIFFRC,RDIS,ADIS,THICK,THICO,STANG,TRACO,SOLID,IBM4,
3RMS,FEE,ACROS,AEV,ABS1,DH,AR,ATHI,RI,N060,NSKIP,C7FI,PRINT,FIZ
COMMON RIOP1,RI8M,RI8L,RI8H,DEL,BFL5,DEQ,EMTH,OMPR,OMEW,OMOV
COMMON W4,M,XKVD,XK1VD,XKFLVD,EVD,FLA,XKAD,OD,OMT01
COMMON RPH6,SSTH6,XKSFS,XKMSC,D6,D7,C7,DPSSC,CPSES,DPSC,C34
COMMON RLBT,SBETA,SZD,PSHS6,ETAOV,LOOP,FLAH6,B9
COMMON CLUT,FINC,BEL0,RRM,D9,RR67,THRV,ZRV,RDSV,TEXS,DLOM,BCMS
R2=D2/2.
R2=U2*R2*RH0/(306.*VIS)
IF(FLA6-1.) 10,10,20

10 RRV2=R2+DR
RV1=R2/2.
IF(SCL) 80,80,81
SCL=0.010201+0.0008095*KD2+0.00011078*KD2**2

81 SBV=SCL/.17+SCL
SBV=SCL/.17+SCL
OMIP=.1048*XN
TEMP=SBV/.8/SCL-1.
XBV=TEMP*(40./1.1+.5.*SBV/RBV2)*R2 **.2/.56*(SBV/RBV2)**.5
POMBV=XBV/(1.+XBV)
OMFL=OMIP*POMBV
T0BV=.1562E-07*RHO*40.*(RBV2)**4-(RBV1)**4*(OMIP-OMFL)**2*(T
TEMP)**2
PFBV=OMIP*10BV/550.
XKDF=3.
PFS=0.
IF(FLA6-1.) 3,20,20
3 PFS=0.
GO TO 35
20 REX=R2+DR
RDS=.3*R2
IF(R2-10.**6) 21,22,22
21 XKDF=3.8431E-06-7.869741E-07*AL06(R2)+5.706801E-08*(AL06(R2))
1**2-1.3921085E-09*(AL06(R2))**.3.
GO TO 24
22 XKDF=31.5E-08/R2 **.0*164
E1P=.3*KD2
XDF=4.61E-09*XKDF*RH0*XN**3
IF(FLA6-2.) 61,23,23
PFB=XDF*(REX**4*(2.*REX+5.*E1P)-2.*(RBS**5-REX**5+R2**5))
PFBV=0.
IF(FLA6-2.) 61,31,32
PFS=0.
000001

000002
000003
000004
000005
000006
000007
000008
000009
000010
000011
000012
000013
000014
000015
000016
000017
000018
000019
000020
000021
000022
000023
000024
000025
000026
000027
000028
000029
000030
000031
000032
000033
000034
000035
000036
000037
000038
000039
000040
000041
000042
000043
000044
000045
000046
000047
000048
000049
000050
000051
000052
000053
000054
000055
000056

```

000057      GO TO 35
000058      61 PFBS=0.
000059      32 RWR=.55*DT1
000060      RT1=DT1/2.
000061      ESHR=5.*ETIP
000062      PFFS1=XPDF*(RWR**4*(2.*RWR+5.*ESHR)-2.*RT1**5)
000063      PFFS2=XPDF*(R2**4*(2.*R2+5.*ETIP)-2.*RWR**5)
000064      PFFS=PFFS1+PFFS2
000065      35 PFTOT=PFBV+PFFS+PFBS
000066      DLPDF=17680.*PFTOT/(U2**2*WIMP)
000067      PSIIP=PSITH-PSIBL
000068      PSIIN=PSITH+DLPDF
000069      PSIPS=PSIIP-.5*(PHI2**2+PSITH**2)
000070      DPIPS=PSIPS*U2**2/32.174*RHO/144.
000071      IF(PRENT) 50,50,40
000072      40 WRITE(3,12) RE2
000073      WRITE(3,13) XKDF
000074      WRITE(3,14) PFBV
000075      WRITE(3,15) PFBS
000076      WRITE(3,16) PFFS
000077      WRITE(3,17) PFTOT
000078      WRITE(3,18) DLPDF
000079      WRITE(3,11) PSIIP
000080      WRITE(3,43) PSIIN
000081      WRITE(3,41) PSIPS
000082      WRITE(3,53) DPIPS
000083      12 FORMAT(5X,'REYNOLDS NO., IMPELLER, RE2',11X,E10.4,2X,'****')
000084      13 FORMAT(5X,'DISK FRICTION COEFF., XKDF',12X,E10.4,2X,'****')
000085      14 FORMAT(5X,'POWER, BACKVANES, PFBV',16X,F10.3,2X,'HP')
000086      15 FORMAT(5X,'POWER, BACK FACE, PFBS',16X,F10.3,2X,'HP')
000087      16 FORMAT(5X,'POWER, FRONT FACE, PFFS',15X,F10.3,2X,'HP')
000088      17 FORMAT(5X,'POWER, TOTAL, PFTOT',19X,F10.3,2X,'HP')
000089      18 FORMAT(5X,'LOSS COEFF., DLPDF',20X,F10.4,2X,'****/')
000090      11 FORMAT(5X,'IMPELLER HEAD COEFFICIENT, PSIIP',22X,F10.4,2X,'****')
000091      43 FORMAT(5X,'INPUT HEAD COEFFICIENT, PSIIN',25X,F10.4,2X,'****')
000092      41 FORMAT(5X,'IMPELLER STATIC HEAD COEFFICIENT, PSIPS',15X,F10.4,2X,'
000093      1****')
000094      53 FORMAT(5X,'IMPELLER STATIC PRESSURE RISE, DPIPS',18X,F10.4,2X,'LB/
000095      15QIN')
000096      50 RETURN
000097      END
    
```

0 ELT GEOM, 1, 710427, 63101

```

000001 SUBROUTINE GEOM(I,MESS,N)
000002 COMMON XK(8),XZ(8),XFR(8),XR(8)
000003 COMMON DBH1,RM1,H,RA,RC,BBM1,CLIND,THIND,ZL,DPIND,BLK1,A1,AB1,DPIND
000004 1,RBC1,BBC2,BBC3,CLC1,CLC2,CLC3,CLT5,THC1,THC2,THC3,THTS,CLRS,THRS,
000005 2,CLIMP,THIMP,CLTOT,THTOT,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SOLIP,SOL
000006 3TO,DH2,DH3,DH4,DH5,DHIMP,DHTOT,RP2,RP3,RP4,SM,QI,SIG,DR,CM2,SCL
000007 COMMON DT1,EPS,XX,B2,BB1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,KBMID,XSI,DPIMP
000008 COMMON WP,XN,XXX,OKI,HNSH,HTOT,PHIMN,VHK4,ETAHI,PSITH,ESHR,RWR
000009 COMMON XKPH1,PHI21,PHI22,PHI23,CM1,UT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
000010 COMMON FLAG,VIS,FLACO,WNR,U2,PSIBL,OPTPS,PSIIP,PSIIN,FRD
000011 COMMON B4,RL,REX,PBASE,BETA,BFL4,VNS,DINLT,DISTH,TIN,TOUT,XL,V5,
000012 1,RADUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
000013 2,ANVAN,BKB,DIFBC,RDIS,ADIS,THICK,THICO,STANG,TRACO,SOLID,BBM4,
000014 3,BBM5,FEE,ACROS,AEW,ABS1,DH,AR,ATHRC,PI,NOSO,NSKIP,OPTFI,PRINT,FI2
000015 COMMON RIOPT,RIBM,RIBL,RIDH,DEL,RFL5,DEO,RMTH,OMPR,OMEW,OMOV
000016 COMMON V4,M, XKQVD,XK1VD,XKFVD,EVD,FLA, XKOD,0,0D,OMTOT
000017 COMMON RPHG,SSTHG,FSTHG,XKSFS,XKMSC,D6,D7,C7,DPSSC,OPSF5,DPSMC,C34
000018 COMMON RLBET,RLZD,SBETA, SZD,PSHS6,ETAOV,L0OP,FLAG,B9
000019 COMMON CLUT,FINC,BE10,RBRM,D9,RB67,THR, ZRV,RDSV,TEX5 ,DLDM,RCM5
000020 ALPHA=360./VNS
000021 DIS=TIN+DINLT/2.
000022 RP=RBASE+DINLT/2.
000023 THETA=ALPHA/2.
000024 K=0
000025 100 K=K+1
000026 ANG1=90.-BETA-ALPHA+THETA
000027 ANG2=ALPHA+BETA-THETA
000028 FUCT=EXP(3.14159*THETA*SIN(BETA/57.296)/COS(BETA/57.296))/180.)
000029 FTH=SIN((BETA+90.)/57.296)*RBASE*FUCT-RP*COS(ANG2/57.296)-DIS
000030 FPTH=SIN(BETA/57.296)/COS(BETA/57.296)*SIN((BETA+90.)/57.296)*
000031 1RBASE/57.296*FUCT-RP*SIN(ANG2/57.296)/57.296
000032 ERROR=FTH/FPTH
000033 THETA=THETA-ERROR
000034 IF (ABS(ERROR)-0.01) 140,140,150
000035 150 IF (K-30) 100,300,300
000036 140 C=DIS/COS(ANG2/57.296)
000037 RAD=RP+C
000038 DELTA=57.296*ATAN((TOUT-TIN)/XL)
000039 GAMMA=ALPHA-THETA+BETA-DELTA
000040 ANG3=0.
000041 N=0
000042 200 N=N+5
000043 ANG3=ANG3+5.
000044 IF (ANG3-THETA) 210,220,220
000045 210 RADUS(N)=RBASE*EXP(3.14159*ANG3*SIN(BETA/57.296)/COS(BETA/57.296
000046 1)/180.)
000047 GO TO 200.
000048 220 RADTH=RBASE*EXP(3.14159*THETA*SIN(BETA/57.296)/COS(BETA/57.296)/
000049 1180.)
000050 CD=XL-DIS*SIN(ANG2/57.296)/COS(ANG2/57.296)
000051 AXG2=90.+ANG2
000052 OD=SGRT (RAD**2+CD**2-2.*RAD*CD*COS(AXG2/57.296))
000053 PHI=ASIN((CD/OD)*SIN(AXG2/57.296))*57.296
000054 BKA=PHI+ALPHA
000055 DE=DISTH/2.0
000056 ZETA=ATAN(DE/CD)*57.296
    
```

```

000057      CE=CD/COS(ZETA/57.296)
000058      VE=ZETA+AX62
000059      OE=SQRT (RAD**2+CE**2-2.*RAD*CE*COS(VE/57.296))
000060      DIFBC=OE+DE
000061      OMEGA=ASIN((CE/OE)*SIN(VE/57.296))*57.296
000062      BKB=OMEGA+ALPHA
000063      XLX=XL/COS(THETA/57.296)
000064      SG=XL*COS(GAMMA/57.296)-(DINLT/2.0)*SIN(ANG2/57.296)
000065      P0=XLX*SIN(GAMMA/57.296)
000066      RG=DIFBC*SIN(BKB/57.296)
000067      OR=DIFBC*COS(BKB/57.296)
000068      PT=(RBASE+(DINLT/2.0)+(DINLT*COS(ANG2/57.296)/2.0)+P0)-OR
000069      GT=RG-SQ
000070      GP=SQRT (PT**2+GT**2)
000071      PH=GP/2.0
000072      SI=ATAN(SQRT(1.0/(PT/GP)**2-1.0))*57.296
000073      TI=SI-GAMMA
000074      RAR=PH/COS(TI/57.296)
000075      RAY=OR+PT-RAR*COS(GAMMA/57.296)
000076      RAX=SG+RAR*SIN(GAMMA/57.296)
000077      ARO=ATAN(RAX/RAY)*57.296
000078      RLOC=SQRT(RAY**2+RAX**2)
000079      FANG=ABS(ARO-360./VNS)
000080      HEIGH=(RBASE**2+RLOC**2-2*RBASE*RLOC*COS(FANG/57.296))**.5
000081      THICK=RAR-HEIGH-DINLT-TIN
000082      IF (RAR+RLOC-DIFBC) 70,70,80
000083      80 IF (BKB-ARO) 70,70,71
000084      71 XLX=XL/COS(DELTA/57.296)
000085      XAP=COS(GAMMA/57.296)*XLX
000086      YAP=RBASE+DINLT+XLX*SIN(GAMMA/57.296)
000087      HOP=GAMMA+ATAN(XAP/YAP)*57.296
000088      SAP=SQRT(XAP**2+YAP**2)
000089      FUNX=(DIFBC/SAP-COS(HOP/57.296))/SIN(HOP/57.296)
000090      PHO=ATAN(1./FUNX)*57.296
000091      RAR=SIN((180.-2.*RHO-HOP)/57.296)*SAP/SIN(2.*RHO/57.296)
000092      ARO=ATAN(XAP/YAP)*57.296+180-(2.*RHO+HOP)
000093      RLOC=DIFBC-RAR
000094      FANG=ABS(ARO-360./VNS)
000095      HEIGH=(RBASE**2+RLOC**2-2*RBASE*RLOC*COS(FANG/57.296))**.5
000096      THICK=RAR-HEIGH-DINLT-TIN
000097      70 CVAN=SQRT(RP**2+OE**2-2.0*RP*OE*COS(BKB/57.296))
000098      X=(OE/CVAN)*SIN(BKB/57.296)
000099      XLT=TOUT/(SIN(DELTA/57.296)/COS(DELTA/57.296))
000100      D2=DELTA/2.0
000101      DHR=XLT*(SIN(D2/57.296)/COS(D2/57.296))
000102      OZ=OD*ABS(COS(BKA/57.296))
000103      ANDX=THETA-BETA
000104      OV=OZ-DHR*COS(ANDX/57.296)
000105      DV=OD*SIN(BKA/57.296)-DHR*SIN(ANDX/57.296)
000106      RDIS=SQRT(OV**2+DV**2)
000107      DISA=ATAN(DV/OV)*57.296
000108      ADIS=DISA+BETA-THETA-D2
000109      IF (X-1.0000) 33,31,32
000110      33 ANVAN=ASIN((OE/CVAN)*SIN(BKB/57.296))*57.296
000111      GO TO 11
000112      31 ANVAN=90.0
000113      GO TO 11
000114      32 ANGL=ASIN ((DIS/CVAN)*SIN(BKB/57.296))*57.296
000115      ANVAN=180.-(BKB+ANGL)
000116      11 RO=DIFBC-DISTH/2.

```

```

000117      R1=RBASE+DINLT/2.
000118      STANG=90.-ATAN( ALOG(RO/R1)/BKB*57.296)*57.296
000119      TRACO:=(RO-R1)/SIN((90.-STANG)/57.296)+(DISTH+DINLT)/2.
000120      IF (FLAG-7.) 72,72,74
000121      72 SOLID=((ALOG(RO/R1))**2+(BKB /57.296)**2)**.5/360.*VNS*57.296
000122      GO TO 75
000123      74 SOLID=2.*(RL*TIN+DLDM)/(TIN+TOUT)
000124      75 BDM4=90.-(GAMMA+BETA)/2.
000125      AIN=ASIN(SIN((BETA+90.)/57.296)*RADTH/(DIFBC-DISTH))*57.296
000126      IF (BK !=AFO) 85,90,90
000127      85 AOS=90.-ASIN(RLOC*SIN((ARO-BKB)/57.296)/RAR)
000128      BDM5=(AOS+AIN)/2.
000129      GO TO 91
000130      90 BDM5=(90.-AIN)/2.
000131      91 FEE=BDM4-BDM5
000132      THICK=THICK/TRACO
000133      AW=3.14159*(DIFBC**2-(RBASE)**2)
000134      ACROS=TRACO*(DISTH+DINLT+4.*THICK)/6.
000135      AEW=2.*(AW-VNS*ACROS)
000136      ABS1=B4*(2.*TRACO+3.14159/2.*(DINLT+DISTH+THICK)
000137      AR=AEW/VNS/ABS1
000138      DH=B4*(TIN+TOUT)/4./(B4+(TIN+TOUT)/2.)
000139      BDEX=(ASIN( RDIS/DIFBC * SIN((90.+ADIS)/57.296)))*57.296
000140      BCM5 = 90.-BDEX
000141      THEX = 90. - ADIS - BDEX
000142      DLDM = SIN( THEX/57.296)*DIFRC/SIN((90.+ADIS)/57.296)
000143      TEX5 = (XL+DLDM)/XL*(TOUT-TIN) + TIN
000144      GO TO 301
000145      300 IMESS=1
000146      301 RETURN
000147      END

```

000001	SUBROUTINE ILOSS
000002	REAL KBWID
000003	COMMON XK(8),XZ(8),XFR(8),XFR(N)
000004	COMMON DHT,RM1,RA,RC,BM1,CLIND,THIND,ZL,DHIND,BLK1,AL,AB1,DPIND
000005	1,BEC1,BBC2,BBC3,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,HTS,CLRS,THRS,
000006	ZCLMP,THIMP,CLT01,THI01,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SOLIP,SOL
000007	310,DH2,DH3,DH4,DH5,DHIMP,DH101,RP2,RP3,RP4,SM,01,SIG,DR,CM2,SCL
000008	COMMON DT,EPS,DS,BB1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,KMID,XS1,DRIMP
000009	COMMON WP,XN,RHO,OKI,HNP,SH,HT01,PHIMN,VKX,ETVAH,PSITH,ESHR,RWR
000010	COMMON XKPH1,PHI21,PHI22,PHI23,CM1,UT1,PHI11,S,XNS,PSIO,PHI2,NCASE
000011	COMMON FLAG,VIS,FLAG,WWR,U2,PSIBL,DPFS,PSIIP,PSIIN,FRD
000012	COMMON B4,RL,REX,R4,BETA,BFL4,ZD,DINLT,D1STH,TIN,TOU,XL,VS,
000013	IRADUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARAR,PLCC,CVAN,
000014	ZANVAN,BKB,DIFFC,RDIS,ADIS,THICK,THICO,STANG,SOLID,BM4,
000015	3BWS,FEE,ACROS,AEW,ABS1,DH,AR,ALHT,RT,NOGO,NSKIP,OPTI,PRINT,EI2
000016	COMMON RI0PT,RI0M,RI9L,RI9H,DEL,BFL5,D80,GMTH,OMPR,OMEW,OMOV
000017	COMMON V4,M,XKDVD,XK1VD,XKFVD,EVD,FLA,XKOD,0,0D,OMT01
000018	COMMON RPHG,SSTHG,FSTHG,XXSFS,XXMSC,D6,D7,C7,DPS5C,DPSFS,DPSMC,C34
000019	COMMON RL0ET,RLZD,BETA,SZD,PSHSG,ETI0V,L0OP,FLA6,B8
000020	COMMON CLUT,FINC,BE10,BRM,D9,RB67,THRV,ZRV,RDSV,TEXS,DLDM,BCMS
000021	EQUIVALENCE (PSITH,PSI1),(PHI2,PHI),(U2,U)
000022	DM1=2,*RM1
000023	R2=DS/2,
000024	R1=D11/2,
000025	CCL=CLIMP/2.9
000026	DELK=25.0/CCL
000027	RR2R=RR2/57.296
000028	CUZE=U2-CM2/SIN(BB2R)*COS(BB2R)
000029	IF(BB2-90.) 19,25,25
000030	PSI5L=.6*(1.+BB2/60.)
000031	PSL=PSISL*R2**2/Z/SM
000032	SLPCF=1./(1.+PSL)
000033	60 TO 26
000034	25 SLPCF=1.-1.98/Z
000035	26 CU2TH=SLPCF*CU2E
000036	PSITH=CU2TH/U2
000037	C2 = SORT(CU2TH**2 + CM2**2)
000038	ALP2 = ATAN(CM2/CU2TH)*57.296
000039	TRNSK=.5
000040	CLT01=CLIMP+CLIND
000041	BFM1=.575*DM1
000042	BBM1R=BBM1/57.296
000043	BB1TR=BB1/57.296
000044	BFM1R=BFM1/57.296
000045	WBMI=0.321*01/(AB1*SIN(BBM1R))
000046	PHIM1=D11*PHI1/DM1
000047	WU2TH=U2*(1.-SLPCF*(1.-PHI2*COS(BB2R)/SIN(BB2R)))
000048	W2TH=SOR1(CM2**2+WU2TH**2)
000049	WT1 = SORT(CM1**2 + U1**2)
000050	RW = W2TH/WT1
000051	WMR=0.5*(WMI+W2TH)
000052	PSINC=0.15*(PHIM1*(COS(BFM1R)/SIN(BFM1R))-COS(BBM1R)/SIN(BBM1R))**
000053	12
000054	REM=DHT01*RH0*WHR/(96.522*VIS)
000055	IF(CLIND) 30,30,31
000056	30 IF(REM-1.E+05) 33,33,35

000057 33 FRM=0.0032+0.221/REM**0.237
 000058 60 TO 36
 000059 35 FRM = 1./10.86858*AL06(DH10T/(2.*XXKSC))+1.74)**2
 000060 36 CLF=FRM*CL10T/(4.*DH10T)
 000061 HLF=WR**2/64.348*CLF
 000062 PSF=WR**2/(2.*U2**2)*CLF
 000063 FRMP = FRM
 000064 PSDID=0
 000065 60 TO 40
 000066 31 WIMP=0.5*(WBMT*SIN(BBMT)/SIN(KBMID*BBMT)+W2TH)
 000067 REIMP=DHIMP*RHO*WIMP/(96.522*VIS)
 000068 IF(3E+05) 37,37,38
 000069 FRV=0.0032+0.221/REIMP**0.237
 000070 60 TO 39
 000071 38 FRMP = 1./10.86858*AL06(DHIMP/(2.*XXKSC))+1.74)**2
 000072 HLFIP=WIMP**2/64.33*(FRIMP*CLIMP*0.25/DHIMP)
 000073 CLFIP=64.348*HLFIP/WWR**2
 000074 PSFIP=32.174*HLFIP/U2**2
 000075 WIND=WBMT*SIN(BBMT)/SIN(BMT)*0.5
 000076 REIND=DHIND*RHO*WIND/(96.522*VIS)
 000077 IF(REIND - 1.E+05) 41,41,42
 000078 FRIND=0.0032+0.221/REIND**0.237
 000079 60 TO 43
 000080 42 FRIND = 1./10.86858*AL06(DHIND/(2.*XXKSC))+1.74)**2
 000081 HLFID=FRIND*CLIND*WIND**2/(257.392*CHIND)
 000082 CLID=64.348*HLFID/WWR**2
 000083 PSFID=32.174*HLFID/U2**2
 000084 PSF=PSFIP+PSFID
 000085 PSDID=0.02*DFIND**0.2
 000086 40 PSTIP=TRNSK*(PHI2*BLK2)**2
 000087 PSDIP=0.08*DFIMP**3
 000088 PSD=PSDIP+PSDID
 000089 PSIF=PSINC*PSF+PSD+PSTIP
 000090 HTH=PSIF*U2**2/32.174
 000091 IF(FLV-1.) 409,440,409
 000092 IF(FLV-3.) 410,440,410
 000093 IF(SCL) 430,440,450
 000094 SCL=0.010201+0.0008095*U2+0.00011078*U2**2
 000095 60 TO 450
 000096 440 IF(PRINT) 421,421,439
 000097 439 WRITE(3,420)
 000098 420 FORMAT(5X,'IMPELLER IS SHROUDED./')
 000099 421 PSCL=0
 000100 DELE=0
 000101 DELR=0.
 000102 SCL=0.
 000103 60 TO 470
 000104 450 CONTINUE
 000105 DELR=SCL/D2
 000106 BDR=B2/D2
 000107 DT=2/12.
 000108 CLPT=CLIMP/12.
 000109 VI=32.174*VIS/RHO
 000110 A=1.5708-B92R
 000111 DSTR=1.72*SORT(VI*CLPT*COS(A)*DELK/(PHI*U))
 000112 Y=DELR*DT/(2.*DSTR)
 000113 IF(Y-2.)1,2,2
 000114 1 FI=1.-1.-.25*Y**2**2
 000115 60 TO 3
 000116 2 FI=0.

```
000117      3 G=PHI*PSIT/(SIG+COS(A))
000118      DELE=DELK*G**5*(1+(COS(A))**2/G*FI)**1.5/(BDR*COS(A))
000119      PSCL=32.174*DELE*HTH/U2**2
000120      PSIBL=PSIBL+PSCL
000121      470 CONTINUE
000122      IF(PRINT) 50,50,60
000123      60 WRITE(3,12) SCL,PSINC,CU2TH
000124      WRITE(3,14) DELE,PSF,C2
000125      WRITE(3,16) DELK,PSO,ALP2
000126      WRITE(3,18) DELR,PSTIP,FRIMP
000127      WRITE(3,20) W2TH,PSCL
000128      WRITE(3,22) RW,PSIBL
000129      WRITE(3,10) SLPCF,PSITH
000130      WRITE(3,24) HTH
000131      10 FORMAT(5X,7HSLPCF =,3X,F10.4,24X,7HPSITH =,3X,F10.4/)
000132      12 FORMAT(/5X,7HSCCL =,3X,F10.3,24X,7HPSINC =,3X,F10.4,
000133      124X,7HCU2TH =,3X,F10.3)
000134      14 FORMAT(5X,7HDELE =,3X,F10.3,24X,7HPSF =,3X,F10.4,
000135      124X,7HC2 =,3X,F10.3)
000136      16 FORMAT(5X,7HDELK =,3X,F10.3,24X,7HPSD =,3X,F10.4,
000137      124X,7HALP2 =,3X,F10.3)
000138      18 FORMAT(5X,7HDELR =,3X,F10.3,24X,7HPSTIP =,3X,F10.4,
000139      124X,7HFRIMP =,3X,F10.3)
000140      20 FORMAT(5X,7HW2TH =,3X,F10.3,24X,7HPSCL =,3X,F10.4)
000141      22 FORMAT(5X,7HRW =,3X,F10.3,24X,7HPSIBL =,3X,F10.4)
000142      24 FORMAT(5X,7HHTH =,3X,F10.3)
000143      50 RETURN
000144      END
```


Q ELT IMGEO, 1.710427, 53109

```

000001 SUBROUTINE IMGEO
000002 REAL KMID,KP1,KP2,KP3,KP4
000003 COMMON XK(8),XZ(8),XFR(8),XR(8)
000004 COMMON DH1,RM1,H,RA,RC,BBM1,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND
000005 1,BBC1,BBC2,BBC3,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,THTS,CLRS,THRS,
000006 2,CLIMP,THIMP,CLTOT,THTOT,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SOLIP,SOL
000007 3TO,DH2,DH3,DH4,DH5,DHIMP,DHTOT,RP2,RP3,RP4,SM,OI,SIG,DR,CM2,SCL
000008 COMMON DT1,EPS,D2,B2,BBT1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,KBMID,XSI,DPIMP
000009 COMMON WP,XN,RHO,OKI,HNPS4,HTOT,PHIMN,VHKM,ETAHI,PSITH,ESHR,RWR
000010 COMMON YKPH1,PHI21,PHI22,PHI23,CM1,UT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
000011 COMMON FLAG,VIS,FLACO,WWR,U2,PSIOL,DPIPS,PSIIP,PSIIN,FRD
000012 COMMON B4,RL,REX,R4,BETA,BFL4,ZD,DINLT,DISTH,TIN,TOJT,XL,V5,
000013 IRADUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
000014 2ANVAN,BKB,DIFDC,RDIS,ADIS,THICK,THICO,STANG,TRACO,SOLID,BBM4,
000015 3,BBM5,FEE,ACKOS,AEW,ABS1,DH,AR,ATHT,RI,NOGO,NSKIP,OPTFI,PRINT,FI2
000016 COMMON RIPT,RIBM,RIBL,RIBH,DEL,BFL5,DEQ,R4TH,OMPR,OMEW,OMOV
000017 COMMON V4,M, XKDVD,XK1VD,XKFVD,EVD,FLA, XKOD,O,OD,OMTOT
000018 COMMON RPHG,SSTHG,FSTHG,XKSES,XKMSC,D6,D7,C7,DPS5C,DPSFS,DPSMC,C34
000019 COMMON RLBET,RLZD,SBETA,SZD,PSH5G,ETAOV,LOOP,FLAHG,B9
000020 COMMON CLUT,FINC,BE10,RBRM,D9,RB67,THR, ZRV,RDSV,TEX5,DLDM,PCMS
000021 DH1=EPS*DT1
000022 DM1=SQRT(0.5*(DT1**2+DH1**2))
000023 RM1=0.5*DM1
000024 H=0.5*(DT1-DH1)
000025 RA=0.75*(H+B2)
000026 RC=RM1+RA
000027 XSI=DT1/D2
000028 R2=D2*0.5
000029 IF(R2-RC) 10,10,11
000030 10 RA=R2-RM1
000031 RC=R2
000032 IF(PRINT) 11,11,13
000033 13 WRITE(3,500)
000034 500 FORMAT(5X,'RC2 EQUALS R2//')
000035 11 RC2=0.134*RA+RM1
000036 PC3=0.366*RA+RC2
000037 BBT1R=BBT1/57.296
000038 BBM1=ATAN(DT1/DM1*SIN(BBT1R)/COS(BBT1R))*57.296
000039 BBM1R=BBM1/57.296
000040 TEMP=BB2/BBM1/KBMID
000041 CK1=TEMP**1.05-TEMP+1.
000042 TEMP=BB2/(KBMID*BBM1)
000043 CK2=1.+(TEMP**1.05-TEMP)/6.
000044 CK3=1.+(TEMP**1.05-TEMP)/10.
000045 TEMP=KBMID*BBM1
000046 TMP2=BB2-TEMP
000047 BBC1=TEMP+CK1/6.*TMP2
000048 BBC2=TEMP+CK2/2.*TMP2
000049 BBC3=TEMP+5.*CK3/6.*TMP2
000050 BB2R=BB2/57.296
000051 BBC1R=BBC1/57.296
000052 BBC2R=BBC2/57.296
000053 BBC3R=BBC3/57.296
000054 CLIND=3.14159/Z0*DM1*SOL1
000055 CLCB=BBM1R*0.5*(1.+KBMID)
000056 THIND=360./Z0*SOL1*COS(CLCB)
    
```

```

000057      ZI=3.14159/Z0*DM1*SOL1*SIN(CLCB)
000058      CLC1=(RC2-RM1)/(0.259*SIN(BBC1R))
000059      CLC2=(RC3-RC2)/(0.707*SIN(BBC2R))
000060      CLC3=(RC-RC3)/(0.965*SIN(BBC3R))
000061      CLTS=CLC1+CLC2+CLC3
000062      THC1=57.296*(ALOG(RC2)-ALOG(RM1))/(0.259*SIN(BBC1R)/COS(BBC1R))
000063      THC2=57.296*(ALOG(RC3)-ALOG(RC2))/(0.707*SIN(BBC2R)/COS(BBC2R))
000064      THC3=57.296*(ALOG(RC)-ALOG(RC3))/(0.965*SIN(BBC3R)/COS(BBC3R))
000065      THTS=THC1+THC2+THC3
000066      CLRS=(R2-RC)/SIN(BB2R)
000067      THRS=57.296*(ALOG(R2)-ALOG(RC))/(SIN(BB2R)/COS(BB2R))
000068      CLIMP=CLTS+CLRS
000069      THIMP=THTS+THRS
000070      CLTOT=CLIMP+CLIND
000071      THTOT=THIMP+THIND
000072      IF(Z0) 20,20,21
000073      20 ZX=Z1
000074      GO TO 22
000075      21 ZX=Z3
000076      22 BLK1=0.025*ZX/(RM1*SIN(BBM1R))
000077      A1=0.7853975*(DT1**2-DH1**2)
000078      AB1=A1*(1.-BLK1)
000079      TM1=6.28318*RM1/ZX
000080      IF(Z0) 23,23,24
000081      23 SOL1=0
000082      DPIND=0
000083      DHIND=0
000084      THIND=0
000085      CLIND=0
000086      GO TO 25
000087      24 DHIND=(1.-BLK1)*TM1*SIN(CLCB)*H/(2.*((1.-BLK1)*TM1*SIN(CLCB)+H))
000088      DIND=1.-SIN(BBM1R)/SIN(KBMID*BBM1R)+(COS(KBMID*BBM1R)/SIN(KBMID*
000089      1BBM1R)-COS(BBM1R)/SIN(BBM1R))*SIN(DBM1R)/(2.*SOL1)
000090      DPIND=DIND
000091      25 ZX=Z0
000092      A2=(1.-BLK2)*3.14159*D2*B2
000093      RBD=D2/D2
000094      IF(NZ-2) 30,31,32
000095      30 RM2=SQRT(0.5*(R2**2+RM1**2))
000096      SOLIP=CLIMP*Z/(6.28318*RM2)
000097      SOLT0=SOL1+SOLIP
000098      PMC1=SQRT(0.5*(RM1**2+RC2**2))
000099      RMC2=SQRT(0.5*(RC2**2+RC3**2))
000100      RMC3=SQRT(0.5*(RC3**2+RC**2))
000101      TMC1=6.28318*RMC1/Z*SIN(BBC1R)-0.157
000102      TMC2=6.28318*RMC2/Z*SIN(BBC2R)-0.157
000103      TMC3=6.28318*RMC3/Z*SIN(BBC3R)-0.157
000104      RMRS=SQRT(0.5*(RC**2+RC2**2))
000105      TMRS=6.28318*RMRS/Z*SIN(BB2R)-0.157
000106      HMC1=R2*B2/RC+(RC-RMC1)*(H-B2*R2/RC)/(RC-PM1)
000107      HMC2=R2*B2/RC+(RC-RMC2)*(H-B2*R2/RC)/(RC-PM1)
000108      HMC3=R2*B2/RC+(RC-RMC3)*(H-B2*R2/RC)/(RC-PM1)
000109      HMRS=R2+(R2-RMRS)*(B2*R2/RC-B2)/(P2-RC)
000110      DHIMP=0.5*(CLC1*TMC1+HMC1/(TMC1+HMC1)+CLC2*TMC2+HMC2/(TMC2+HMC2)+
000111      1CLC3*TMC3+HMC3/(TMC3+HMC3)+CLRS*TMRS+HMRS/(TMRS+HMRS))/CLIMP
000112      DHTOT=(CLIMP*DHIMP+CLIND*DHIND)/CLTOT
000113      SM=CLC1*RMC1*SIN(BBC1R)+CLC2*RMC2*SIN(BBC2R)+CLC3*RMC3*SIN(BBC3R)+
000114      1CLRS*RMRS*SIN(BB2R)
000115      GO TO 999
000116      31 KP1=0.5

```

```

000117      KP2=KP1
000118      CLP1=KP1*CLIMP
000119      CLP2=KP2*CLIMP
000120      GO TO 40
000121      32 IF(NZ=3) 33,33,34
000122      33 ZDN=2.*(Z0+Z1)+Z2+Z
000123      KP1=0.3333
000124      KP2=KP1
000125      KP3=KP1
000126      CLP1=KP1*CLIMP
000127      CLP2=CLP1
000128      CLP3=CLP1
000129      GO TO 40
000130      34 IF(NZ=4) 35,35,999
000131      35 ZDN=3.*(Z0+Z1)+2.*Z2+Z3+Z
000132      KP1=0.25
000133      KP2=KP1
000134      KP3=KP1
000135      KP4=KP1
000136      CLP1=KP1*CLIMP
000137      CLP2=CLP1
000138      CLP3=CLP1
000139      CLP4=CLP1
000140      40 IF(CLP1-CLC1) 41,41,42
000141      41 DLC11=CLC1-CLP1
000142      RP2=RC2-0.259*SIN(BBC1R)*DLC11
000143      GO TO 50
000144      42 IF(CLP1-CLC1-CLC2) 43,43,44
000145      43 DLC21=CLC1+CLC2-CLP1
000146      RP2=RC3-0.707*SIN(BBC2R)*DLC21
000147      GO TO 50
000148      44 IF(CLP1-CLTS) 45,45,46
000149      45 DLC31=CLTS-CLP1
000150      RP2=RC-0.965*SIN(BBC3R)*DLC31
000151      GO TO 50
000152      46 DLR1=CLIMP-CLP1
000153      RP2=RP2-SIN(BB2R)*DLR1
000154      50 RM2=SQRT(0.5*(RM1**2+RP2**2))
000155      SOL2=CLP1*(Z0+Z1)/(6.28318*RM2)
000156      HM2=RP2*B2/RC+(RC-RM2)*(H-B2*R2/RC)/(RC-RM1)
000157      IF(CLP1-CLC1) 60,60,61
000158      60 SNBM2=SIN(BBC1R)
000159      GO TO 70
000160      61 IF(CLP1-CLC1-CLC2) 62,62,63
000161      62 SNBM2=(CLC1*SIN(BBC1R)+(CLC2-DLC21)*SIN(BBC2R))/CLP1
000162      GO TO 70
000163      63 IF(CLP1-CLTS) 64,64,65
000164      64 SNBM2=(CLC1*SIN(BBC1R)+CLC2*SIN(BBC2R)+(CLC3-DLC31)*SIN(BBC3R))/CL
000165      P1
000166      GO TO 70
000167      65 SNBM2=(CLC1*SIN(BBC1R)+CLC2*SIN(BBC2R)+CLC3*SIN(BBC3R)+(CLRS-DLR1)
000168      1*SIN(BB2R))/CLP1
000169      70 TM2=6.28318*RM2/(Z0+Z1)*SNBM2-0.157
000170      DH2=TM2*HM2*0.5/(TM2+HM2)
000171      IF(NZ=3) 75,76,76
000172      75 RM3=SQRT(0.5*(RP2**2+R2**2))
000173      HM3=B2+(R2-RM3)*(R2+R2/RC-B2)/(R2-RC)
000174      SOL3=CLP2*Z/(6.28318*RM3)
000175      SOLT0=SOL1+SOL2+SOL3
000176      SOLIP=SOL2+SOL3

```

```

000177      IF (CLP1-CLC1) 80,80,81
000178      80 SNBM3=(DLC11*SIN(BBC1R)+CLC2*SIN(BBC2R)+CLC3*SIN(BBC3R)+CLRS*SIN(B
000179      1B2R))/CLP2
000180      GO TO 90
000181      81 IF (CLP1-CLC1-CLC2) 82,82,83
000182      82 SNBM3=(DLC21*SIN(BBC2R)+CLC3*SIN(BBC3R)+CLRS*SIN(BB2R))/CLP2
000183      GO TO 90
000184      83 IF (CLP1-CLTS) 84,84,85
000185      84 SNBM3=(DLC31*SIN(BBC3R)+CLRS*SIN(BB2R))/CLP2
000186      GO TO 90
000187      85 SNBM3=SIN(BB2R)
000188      90 TM3=6.28318*RM3/Z*SNBM3-0.157
000189      DH3=TM3*HM3*0.5/(TM3+HM3)
000190      DHIMP=(CLP1*DH2+CLP2*DH3)/CLIMP
000191      DHTOT=(CLIND*DHIND+CLIMP*DHIMP)/CLTOT
000192      SM=(CLP1*RM2*(Z0+Z1)*SNBM2+CLP2*RM3*Z*SNBM3)/Z
000193      GO TO 999
000194      76 CTRY=CLP1+CLP2
000195      IF (CTRY-CLC1) 100,100,101
000196      100 DLC12=CLC1-CTRY
000197      RP3=RC2-0.259*SIN(BBC1R)*DLC12
000198      GO TO 110
000199      101 IF (CTRY-CLC1-CLC2) 102,102,103
000200      102 DLC22=CLC1+CLC2-CTRY
000201      RP3=RC3-0.707*SIN(BBC2R)*DLC22
000202      GO TO 110
000203      103 IF (CTRY-CLTS) 104,104,105
000204      104 DLC32=CLTS-CTRY
000205      RP3=RC-0.965*SIN(BBC3R)*DLC32
000206      GO TO 110
000207      105 DLR2=CLIMP-CTRY
000208      RP3=R2-SIN(BB2R)*DLR2
000209      110 RM3=SQRT(0.5*(RP2**2+RP3**2))
000210      HM3=R2*B2/RC+(RC-RM3)*(H-B2*R2/RC)/(RC-RM1)
000211      SOL3=CLP2*(Z0+Z1+Z2)/(6.28318*RM3)
000212      IF (CTRY-CLC1) 111,111,112
000213      111 SNBM3=SIN(BBC1R)
000214      GO TO 130
000215      112 IF (CTRY-CLC1-CLC2) 113,113,114
000216      113 SNBM3=((CLC2-DLC22)*SIN(BBC2R)+(CLC1-CLP1)*SIN(BBC1R))/CLP2
000217      GO TO 130
000218      114 IF (CTRY-CLTS) 115,115,116
000219      115 IF (CLC1-CLP1) 117,117,118
000220      117 SNBM3=(DLC21*SIN(BBC2R)+(CLTS-DLC32)*SIN(BBC3R))/CLP2
000221      GO TO 130
000222      118 SNBM3=((CLC1-CLP1)*SIN(BBC1R)+CLC2*SIN(BBC2R)+(CLC3-DLC32)*SIN(BBC
000223      13R))/CLP2
000224      GO TO 130
000225      116 IF (CLC1-CLP1) 120,120,119
000226      119 SNBM3=((CLC1-CLP1)*SIN(BBC1R)+CLC2*SIN(BBC2R)+(CLC3-DLC32)*SIN(BBC
000227      13R)+(CLRS-DLR2)*SIN(BB2R))/CLP2
000228      GO TO 130
000229      120 IF (CLC1+CLC2-CLP1) 121,121,122
000230      300 FORMAT(/,10X,'LC1+LC2-LP1 IS ZERO OR NEGATIVE, NZ=3',/)
000231      121 WRITE(3,300)
000232      GO TO 999
000233      122 SNBM3=((CLC2-DLC21)*SIN(BBC2R)+CLC3*SIN(BBC3R)+(CLRS-DLR2)*SIN(BB2
000234      1R))/CLP2
000235      130 TM3=6.28318*RM3/(Z0+Z1+Z2)*SNBM3-0.157
000236      DH3=TM3*HM3*0.5/(TM3+HM3)

```

```

000237      IF(NZ=3) 135,135,135
000238      135 RM4=SQRT(0.5*(RP3**2+R2**2))
000239      HM4=R2*(R2-RM4)*(B2*R2/RC-B2)/(R2-RC)
000240      SOL4=CLP3*Z/(6.28318*RM4)
000241      SOLTO=SOL1+SOL2+SOL3+SOL4
000242      SOLIP=SOLTO-SOL1
000243      IF(CTRY-CLC1) 140,140,141
000244      140 SNB4=(DLC12*SIN(BBC1R)+CLC2*SIN(BBC2R)+CLC3*SIN(BBC3R)+CLRS*SIN(B
000245      B2R))/CLP3
000246      GO TO 150
000247      141 IF(CTRY-CLC1-CLC2) 142,142,143
000248      142 SNBM4=(DLC22*SIN(BBC2R)+CLC3*SIN(BBC3R)+CLRS*SIN(BB2R))/CLP3
000249      GO TO 150
000250      143 IF(CTRY-CLT5) 144,144,145
000251      144 SNBM4=(DLC32*SIN(BBC3R)+CLRS*SIN(BB2R))/CLP3
000252      GO TO 150
000253      145 SNBM4=SIN(BB2R)
000254      150 TM4=6.28318*PM4/Z*SNBM4
000255      DH4=TM4*HM4*0.5/(TM4+HM4)
000256      DHIMP=(CLP1*DH2+CLP2*DH3+CLP3*DH4)/CLIMP
000257      DHTOT=(CLIND*DHIND+CLIMP*DHIMP)/CLTOT
000258      SM=(CLP1*RM2*(Z0+Z1)*SNBM2+CLP2*RM3*(Z0+Z1+Z2)*SNBM3+CLP3*RM4*Z*SN
000259      BM4)/Z
000260      GO TO 999
000261      136 CLPT=CLP1+CLP2+CLP3
000262      IF(CLPT-CLC1-CLC2) 160,160,161
000263      160 DLC23=CLC1+CLC2-CLPT
000264      RP4=RC3-0.707*SIN(BBC2R)*DLC23
000265      GO TO 165
000266      161 IF(CLPT-CLT5) 162,162,163
000267      162 DLC33=CLT5-CLPT
000268      RP4=RC-0.965*SIN(BBC3R)*DLC33
000269      GO TO 165
000270      163 DLR3=CLIMP-CLPT
000271      RP4=R2-SIN(BB2R)*DLR3
000272      165 RM4=SQRT(0.5*(RP4**2+RP3**2))
000273      HM4=R2/RC*B2+(RC-RM4)*(H-B2*R2/RC)/(RC-RM4)
000274      SOL4=CLP3*(Z0+Z1+Z2+Z3)/(6.28318*RM4)
000275      IF(CLPT-CLC1-CLC2) 170,170,171
000276      170 IF(CLPT-CLP1-CLP2) 172,172,173
000277      172 SNBM4=SIN(BBC2R)
000278      GO TO 190
000279      173 SNBM4=(DLC12*SIN(BBC1R)+(CLC2-DLC23)*SIN(BBC2R))/CLP3
000280      GO TO 190
000281      171 IF(CLPT-CLT5) 174,174,175
000282      174 IF(CLPT-CLP1-CLP2) 176,176,177
000283      176 SNBM4=(DLC22*SIN(BBC2R)+(CLC3-DLC33)*SIN(BBC3R))/CLP3
000284      GO TO 190
000285      177 SNBM4=(DLC12*SIN(BBC1R)+CLC2*SIN(BBC2R)+(CLC3-DLC33)*SIN(BBC3R))/
000286      CLP3
000287      GO TO 190
000288      175 IF(CLPT-CLC2-CLP1-CLP2) 179,179,178
000289      178 SNBM4=(DLC22*SIN(BBC2R)+CLC3*SIN(BBC3R)+(CLRS-DLR3)*SIN(BB2R))/CLP
000290      13
000291      GO TO 190
000292      179 IF(CLPT-CLP1-CLP2) 180,180,181
000293      301 FORMAT(/10X,'LTS=(LP1+LP2) IS ZERO OR NEGATIVE, NZ=4',/)
000294      180 WRITE(3,301)
000295      GO TO 999
000296      181 SNBM4=(DLC32*SIN(BBC3R)+(CLRS-DLR3)*SIN(BB2R))/CLP3

```

```

000297      190  TM4=(6.28318*RM4)/(Z0+Z1+Z2+Z3)*SNBM4-0.157
000298      DH4=TM4*HM4*0.5/(TM4+HM4)
000299      RM5=SQRT(0.5*(RP4**2+R2**2))
000300      HM5=0.2*(R2-RM5)*(R2*R2/RC-B2)/(R2-RC)
000301      SOL5=CLP4*Z/(6.28318*RM5)
000302      SOLT0=SOL1+SOL2+SOL3+SOL4+SOL5
000303      SOLIP=SOLT0-SOL1
000304      IF (CLPT-CLC1-CLC2) 200,200,201
000305      200  SNBM5=(DLC23*SIN(BBC2R)+CLC3*SIN(BBC3R)+CLRS*SIN(BB2R))/CLP4
000306      GO TO 205
000307      201  IF (CLPT-CLTS) 202,202,203
000308      202  SNBM5=(DLC33*SIN(BBC3R)+CLRS*SIN(BB2R))/CLP4
000309      GO TO 205
000310      203  SNBM5=SIN(BB2R)
000311      205  TMS=6.28318*RM5*SNBM5/Z-0.157
000312      DH5=TM5*HM5*0.5/(TM5+HM5)
000313      DHIMP=(CLP1*DH2+CLP2*DH3+CLP3*DH4+CLP4*DH5)/CLIMP
000314      DHTOT=(CLIMP*DHIMP+CLIND*DHIND)/CLTOT
000315      SM=(CLP1*RM2*(Z0+Z1)*SNBM2+CLP2*RM3*(Z0+Z1+Z2)*SNBM3+CLP3*RM4*(Z-Z
000316      14)*SNBM4+CLP4*RM5*Z*SNBM5)/Z
000317      999  DIMP=1.-AB1/A2*SIN(BBM1R)/SIN(BB2R)+(AB1/A2*COS(BB2R)/SIN(BB2R)-CO
000318      1S(BBM1R)/SIN(BBM1R))/(2.*SOLIP)*SIN(BBM1R)
000319      DIMP=DIMP
000320      RETURN
000321      END
    
```

@ ELT INPUT,1,710427, 63111

```

000001
000002      SUBROUTINE INPUT
000003      REAL KRMID
000004      COMMON 1 XK(8),XZ(8),XFR(8),XR(8)
000005      COMMON DH1,RM1,H,RA,RC,BBM1,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND
000006      1,BBC1,BRC2,BBC3,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,THTS,CLRS,THRS,
000007      2CLIMP,THIMP,CLTOT,HTOT,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SOLIP,SOL
000008      3TO,DH2,DH3,DH4,DH5,DHIMP,DHTOT,RP2,RP3,RP4,SM,QI,SIG,DR,CM2,SCL
000009      COMMON DT1,EPS,D2,B2,BBT1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,KRMID,XSI,DPIMP
000010      COMMON WP,XN,RHO,OKI,HNPSH,HTOT,PHIMN,VHKM,ETAHI,PSITH,ESHR,RWR
000011      COMMON XKPH1,PHI21,PHI22,PHI23,CM1,UT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
000012      COMMON FLAG,VIS,FLACO,WWR,U2,PSIDL,OPIPS,PSIIP,PSIIN,FRD
000013      COMMON B4,RL,REX,R4,BETA,BFL4,ZD,DINLT,DISTH,TIN,TOJT,XL,V5,
000014      1RADUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
000015      2ANVAN,BKB,DIFBC,RDIS,ADIS,THICK,THIC,STANG,TRACO,SOLID,BBM4,
000016      3BBS5,FEE,ACROS,AEW,ARS1,DH,AR,ATHT,PI,NOGO,NSKIP,OPTFI,PRINT,FI2
000017      COMMON RIOPT,RIB4,RIBL,RIBH,DEL,BFL5,DEG,RMTH,OMPR,OMEV,OMOV
000018      COMMON V4,M,      XKDVD,XK1VD,XKFVD,EVD,FLA,      XKQD,0,00,OMTOT
000019      COMMON RPHG,SSTHG,FSTHG,XKSFS,XKMSC,D6,D7,C7,DPS5C,DPSFS,DPSMC,C34
000020      COMMON RLDET,RLZD,SBETA,SZD,PSHSG,ETAOV,LOOP,FLAG,B9
000021      COMMON CLUT,FINC,RE10,RBRM,D9,RB67,THR, ZRV,RDSV,TEX5,DLDM,BCM5
000022      1 FORMAT(10F8.3)
000023      READ(2,1) WP,XN,RHO,OKI,HNPSH,HTOT,EPS,PHIMN,BB2,VHKM
000024      510 FORMAT(7F6.3,16,F6.4,3F6.3,F8.5)
000025      READ(2,510) SOL1,Z0,Z1,Z2,Z3,Z4,KRMID,NZ,SCL,SIG,DR,FLAG,FLACO
000026      520 FORMAT(12F6.4,E8.4)
000027      READ(2,520)XKPH1,PHI21,PHI22,PHI23,ETAHI,Z,XKQD,DINLT,RL,REX,RLBE
000028      1T,RLZD,XKMSC
000029      530 FORMAT(4F6.3,F12.4,F6.3,F8.3,F10.4,E10.4)
000030      READ(2,530) OPTFI,SBETA,SZD,FRD,      FLA,RPHG,FSTHG,SSTHG,VIS
000031      540 FORMAT(E8.3,4F8.4,E10.4,5F6.3)
000032      READ(2,540) XKFVD,XKQVD,XK1VD,EVD,FLAG,XKSFS,CLUT,FINC,RE10,ZRV,
000033      109
000034      550 FORMAT(5F6.3)
000035      READ(2,550) B9,RBRM, R367, THR,RDSV
000036      4 FORMAT(1H1)
000037      2 FORMAT(5X,'***** INPUT *****'//)
000038      10 FORMAT(1X,'FLOW RATE, WP',23X,F10.3,2X,'LB/SEC', 8X,'DIFF BLADE IN
000039      1LET THICKNESS, DINLT',7X,F10.3,2X,'INCH')
000040      12 FORMAT(1X,'TOTAL HEAD RISE, HTOT',15X,F10.3,2X,'FT',12X,'DIFF LENG
000041      1TH TO THROAT RATIO, RL',9X,F10.3,2X,'****')
000042      14 FORMAT(1X,'ROTATIONAL SPEED, XN',16X,F10.3,2X,'RPM',11X,'DIFF EXPA
000043      NSION RATIO, REX',15X,F10.3,2X,'****')
000044      16 FORMAT(1X,'NET POSITIVE SUCTION HEAD, HNPSH',4X,F10.3,2X,'FT',12X,
000045      1'RANGE, DIFFUSER INLET BLADE ANGLE, RLDET',F10.3,2X,'****')
000046      18 FORMAT(1X,'FACTOR RECIRC FLOW, IMPELLER, OKI',3X,F10.3,2X,'****',11
000047      1X,'MAX DIFF BLADE NUMBER, RLZD',13X,F10.3,2X,'****')
000048      20 FORMAT(1X,'FACTOR RECIRC FLOW, DIFFUSER, XKQD',2X,F10.3,2X,'****',1
000049      11X,'SURFACE FINISH, IMPELLER, XKMSC', 9X,E10.4,2X,'IN')
000050      21 FORMAT(63X,'FLOW COEFFICIENT FACTOR, XKPH1',10X,F10.3,2X,'****')
000051      22 FORMAT(1X,'FLUID DENSITY, RHO',18X,F10.3,2X,'LB/FT**3')
000052      24 FORMAT(1X,'FLUID DYNAMIC VISCOSITY, VIS',8X,E10.4,2X,'LB*5/SOFT')
000053      26 FORMAT(1X,'IMPELLER INLET HUB RATIO, EPS',7X,F10.3,2X,'****',11X,'B
000054      1LADE TIP CLEARANCE, SCL',16X,F10.3,2X,'INCH')
000055      28 FORMAT(1X,'INDUCER SOLIDITY, SOL1',14X,F10.3,2X,'****',11X,'DIFF LO
000056      16 SPIRAL ANGLE, SSELECTED, SBETA',2X,F10.3,2X,'DEG')
    
```

```

000057 30 FORMAT(1X,'IMP MIN INLET TIP FLOW COEFF, PHIMN',1X,F10.3,2X,'****',
000058 11X,'DIFF BLADE NUMBER, SELECTED, SZD',5X,F10.3,2X,'****')
000059 32 FORMAT(1X,'MIN CAVITATION PARAMETER, VHKM',6X,F10.3,2X,'****')
000060 34 FORMAT(1X,'IMP DISCHARGE BLADE ANGLE, BR2',6X,F10.3,2X,'DEG',11X,'
000061 1FRITION COEFF, DIFFUSER, FRD',11X,F10.4,2X,'****')
000062 36 FORMAT(1X,'IMP.BLADE ANGLE DISTR FACTOR, KBMID',1X,F10.3,2X,'****',
000063 11X,'VOLUTE SURFACE FINISH, XKSFS',12X,F10.4,2X,'****')
000064 38 FORMAT(1X,'TOT NUMBER OF IMP BLADES, Z', 9X,F10.3,2X,'****',11X,'D1
000065 1FF LOSS ADJUSTMENT FACTOR, FLA',8X,F10.3,2X,'****')
000066 40 FORMAT(1X,'INITIAL HYDRAULIC EFFICIENCY, ETAHI',1X,F10.3,2X,'****')
000067 42 FORMAT(1X,'IMPELLER CONFIGURATION, FLAG',8X,F10.3,2X,'****',11X,'MA
000068 1X TO DESIGN PRESSURE RATIO, RPHG',6X,F10.3,2X,'****')
000069 44 FORMAT(1X,'RADIAL EXTENSION OF IMP DISK, DR',4X,F10.3,2X,'INCH',10
000070 1X,'POUSING MATERIAL YIELD STRENGTH, SSTHS',2X,F10.3)
000071 46 FORMAT(1X,'LABYRINTH CLEARANCE FACTOR, FLACO',3X,F10.5,2X,'****',11
000072 1X,'HOUSE SAFETY FACTOR, FSTHG',14X,F10.3,2X,'****')
000073 48 FORMAT(1X,'TIP CLEARANCE LOSS FACTOR, SIG',6X,F10.3,2X,'****')
000074 50 FORMAT(1X,'FLOW COEFFICIENT OPTIMIZATION, OPTFI',1X,F10.3,15X,'INLE
000075 1T BLADE THICKNESS, THRV',13X,F10.3,2X,'IN')
000076 54 FORMAT(1X,'PHI21='F8.4,5X,'PHI22='F8.4,5X,'PHI23='F8.4,10X,'REVE
000077 1RSING VANE DISCHARGE DIA, D9',8X,F10.3,2X,'IN')
000078 55 FORMAT(1X,'HOUSING CONFIGURATION, FLAGH',8X,F10.3,2X,'****',11X,'SU
000079 1RFACE FINISH, DIFFUSER, XKFVD', 9X,F10.4,2X,'****')
000080 57 FORMAT(63X,'DIFFUSION LOSS FACTOR, DIFFUSER, XKDVD',2X,F10.3,2X,'*
000081 1**')
000082 59 FORMAT(63X,'INCIDENCE LOSS FACTOR, DIFFUSER, XK1VD',2X,F10.3,2X,'*
000083 1**')
000084 61 FORMAT(63X,'DIFFUSION EXPONENT, DIFFUSER, EVD',7X,F10.3,2X,'****')
000085 69 FORMAT(63X,'RATIO B/RM U-TURN, RRRM',17X,F10.3,2X,'****')
000086 73 FORMAT(63X,'PORT WIDTH REVERS VANE DISCHARGE, B9',4X,F10.3,2X,'IN
000087 1')
000088 75 FORMAT(63X,'RATIO B6/B7, RB67',23X,F10.3,2X,'****')
000089 77 FORMAT(63X,'FRIC LOSS COEFF, VANELESS TURN, CLUT',4X,F10.5,2X,'***
000090 1')
000091 79 FORMAT(63X,'OPTIONAL INPUT - RETURN CHANNEL')
000092 81 FORMAT(63X,'NUMBER OF REVERSING VANE0, ZRV',10X,F10.3,2X,'****')
000093 85 FORMAT(63X,'DIAMETER RATIO DSV/D9',19X,F10.3,2X,'****')
000094 103 FORMAT(63X,'FLUID ANGLE REVERS VANE DISCHARGE, BE10',1X,F10.3,2X,'
000095 1DEG')
000096 105 FORMAT( 1X,'Z0='F3.1,5X,'Z1='F3.1,5X,'Z2='F4.1,5X,'Z3='F4.1,5X
000097 1,'Z4='F4.1,9X,'ANGLE CORRECTION FACTOR, FINC',11X,F10.3,2X,'****'/
000098 2)
000099 106 FORMAT( 1X,'BLADE SCHEDULE, NZ ='I2,/)
000100 200 FORMAT(1X,'ALTERNATE FLOW COEFFICIENTS')
000101 WRITE(3,4)
000102 WRITE(3,2)
000103 WRITE(3,10) WP,DINLT
000104 WRITE(3,12) HTOT,RL
000105 WRITE(3,14) XN,REX
000106 WRITE(3,16) HNPISH,RLBET
000107 WRITE(3,18) QKI,RLZD
000108 WRITE(3,20) XKQD,XKMSC
000109 WRITE(3,21) XKPH1
000110 WRITE(3,22) RHO
000111 WRITE(3,24) VIS
000112 WRITE(3,26) EPS,SCL
000113 WRITE(3,28) SOL1,SBETA
000114 WRITE(3,30) PHIMN,SZD
000115 WRITE(3,32) VHKM
000116 WRITE(3,34) BB2,FRD

```


000117	WRITE(3,36) KDMIO,XKSFS
000118	WRITE(3,30) Z,FLA
000119	WRITE(3,40) ETAHI
000120	WRITE(3,42) FLAG,RPHG
000121	WRITE(3,44) DR,SSTHG
000122	WRITE(3,46) FLAGO,FSTHG
000123	WRITE(3,48) SIG
000124	WRITE(3,55) FLAG,XKFVD
000125	WRITE(3,57) XKDVD
000126	WRITE(3,59) XK1VD
000127	WRITE(3,61) EVD
000128	WRITE(3,106) NZ
000129	WRITE(3,103) BE10
000130	WRITE(3,77) CLUT
000131	WRITE(3,105) Z0,Z1,Z2,Z3,Z4 ,FINC
000132	WRITE(3,79)
000133	WRITE(3,200)
000134	WRITE(3,85) RDSV
000135	WRITE(3,69) RBRM
000136	WRITE(3,54) PHI21,PHI22,PHI23,09
000137	WRITE(3,73) B9
000138	WRITE(3,75) RB67
000139	WRITE(3,50) OPTFI ,THR
000140	WRITE(3,81) ZRV
000141	RETURN
000142	END

Q ELT INT4,1,710427, 63113

000001		SUBROUTINE INT4(X,Y,XI,YO)	61205002
000002		DIMENSION X(9),Y(9),XC(4),YC(4)	61205005
000003		EQUIVALENCE (XC(1),X1),(XC(2),X2),(XC(3),X3),(XC(4),X4),(YC(1),Y1)	61205006
000004		1,(YC(2),Y2),(YC(3),Y3),(YC(4),Y4)	61205007
000005		NA=1	
000006		J=2	61205009
000007		B=XI	61205010
000008	21	IF(X(J))26,22,26	61205011
000009	26	GO TO(30,40),NA	
000010	22	IF(Y(J))26,23,26	61205013
000011	23	IF(J-2)24,24,25	61205014
000012	24	YE=0,0	61205015
000013		GO TO 50	61205016
000014	25	NB=1	
000015		J=J-1	61205018
000016	27	X1=X(J)	61205019
000017		X2=X(J-1)	61205020
000018		X3=X(J-2)	61205021
000019		Y1=Y(J)	61205022
000020		Y2=Y(J-1)	61205023
000021		Y3=Y(J-2)	61205024
000022		GO TO(32,42),NB	
000023	30	IF(X(J)-B)29,37,37	61205026
000024	37	IF(J-2)31,31,28	61205027
000025	28	NA=2	
000026	29	J=J+1	61205029
000027		GO TO 21	61205030
000028	31	DO 60 J=1,3	61205031
000029		XC(J)=X(J)	61205032
000030	60	YC(J)=Y(J)	61205033
000031	32	D=X2-X1	61205034
000032		A1=B-X1	61205035
000033		A2=B-X2	61205036
000034		YE=A1*A2/2.0/D*((Y3-Y2)/(X3-X2)-(Y2-Y1)/D)-A2/D*Y1+A1/D*Y2	61205037
000035		GO TO 50	61205038
000036	40	NB=2	
000037		GO TO 27	61205040
000038	42	X4=X(J-3)	61205041
000039		Y4=Y(J-3)	61205042
000040		D=X3-X2	61205043
000041		A1=B-X2	61205044
000042		A2=B-X3	61205045
000043		XM12=(Y2-Y1)/(X2-X1)	61205046
000044		XM23=(Y3-Y2)/D	61205047
000045		XM34=(Y4-Y3)/(X4-X3)	61205048
000046		YE=A1*A2**2/2.0/D**2*(XM12-XM23)+A2*A1**2/2.0/D**2*(XM34-XM23)-A2*	61205049
000047		1Y2/D+A1*Y3/D	61205050
000048	50	YC=YE	61205051
000049		RETURN	61205052
000050		END	61205053

ELT LOSS1,1,710427, 63115

```
000001 SUBROUTINE LOSS1
000002 DIMENSION X(19),Y(19)
000003 COMMON XK(8),XZ(8),XFR(8),XR(8)
000004 COMMON DH1,RM1,H,RA,RC,BBM1,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND
000005 1,BBC1,BBC2,BBC3,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,THTS,CLRS,THRS,
000006 2,CLYP,THMP,CLTOT,THTOT,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOLS,SOLIP,SOL
000007 3TO,DH2,DH3,DH4,DH5,DH1P,DHTOT,RP2,RP3,RP4,SM,OI,SIG,DR,CM2,SCL
000008 COMMON DT1,EPS,D2,B2,BBT1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,KBMID,XSI,DPIMP
000009 COMMON WP,XN,RHO,QKI,HNPST,HTOT,PHIMN,VHKH,ETAHI,PSITH,ESHR,RWR
000010 COMMON X,PH1,PHI2,PHI23,CM1,UT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
000011 COMMON FLAG,VIS,FLACO,WWR,U2,PSIBL,OPIPS,PSIIP,PSIIN,FRD
000012 COMMON B4,RL,REX,R4,BETA,BFL4,ZD,DINLT,DISTH,TIN,TOUT,XL,V5,
000013 IRADUS(9S),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
000014 2 ANVAN,BKD,DIFBC,RDIS,ADIS,THICK,THICO,STANG,TRACO,SOLID,BBM4,
000015 3BBMS,FEE,ACROS,AEW,ABS1,DH,AR,ATHT,RI,NOS0,NSKIP,OPTFI,PRINT,FI2
000016 COMMON RIOPT,RIBM,RIBL,RIBH,BEL,BFL5,DEQ,FMTH,OMPR,OMEW,OMOV
000017 COMMON VM,M, XKDVD,XK1VD,XXEVD,EVD,FLA, XKOD,Q,QD,OMTOT
000018 COMMON RPH6,SSTHG,FSTHG,XKSES,XXMSC,D6,D7,C7,DPSSC,DPSES,DPSCC,C34
000019 COMMON RLBDT,RLZD,SBETA,SZD,PSHSG,ETAOV,LOOP,FLAG,B9
000020 COMMON CLUT,FINC,BE10,RBRM,D9,RB67,THR, ZRV,RDSV,TEX5 ,DLDM,BCM5
000021 500 FORMAT( 10X,'INCIDENCE LESS THAN OPTIMUM')
000022 X(1)=1.0
000023 Y(1)=.004
000024 X(2)=1.2
000025 Y(2)=.0042
000026 X(3)=1.4
000027 Y(3)=.0055
000028 X(4)=1.6
000029 Y(4)=.0085
000030 X(5)=1.8
000031 Y(5)=.0132
000032 X(6)=2.0
000033 Y(6)=.02
000034 X(7)=2.1
000035 Y(7)=.026
000036 X(8)=2.2
000037 Y(8)=.032
000038 X(9)=2.3
000039 Y(9)=.0405
000040 X(10)=2.4
000041 Y(10)=.05
000042 X(11)=2.5
000043 Y(11)=.064
000044 X(12)=2.6
000045 Y(12)=.08
000046 X(13)=2.7
000047 Y(13)=.101
000048 X(14)=2.75
000049 Y(14)=.114
000050 X(15)=2.8
000051 Y(15)=.13
000052 X(16)=2.85
000053 Y(16)=.149
000054 X(17)=2.9
000055 Y(17)=.174
000056 X(18)=2.95
```

DUPPLR, 428, 50, 1, 100,

```

000057 Y(18)=.21
000058 X(19)=2.96
000059 Y(19)=999999.
000060 RI010=.425*(90.-BBM4)
000061 RKTH=.007636+19.612*THICO-132.6273*THICO**2+372.96*THICO**3
000062 RI0=RKTH*RI010
000063 RIOPT=RI0+(.75-.0145*BBM4)*FEE
000064 RI=BFL4-BBM4
000065 IF(RI-RIOPT)3,5,6
000066 3 IF(PRINT) 6,6,4
000067 4 WRITE(3,500)
000068 6 RIBM=RI/(90.-BBM4)
000069 GO TO 7
000070 5 BFL4=BBM4+RIOPT
000071 RIBM=RIOPT/(90.-BBM4)
000072 7 RMC=.0058*STANG-.065
000073 RIBL=(BETA-90.+BFL4)/BETA
000074 RIBH=(GAMMA-90.+BFL4)/GAMMA
000075 DEL=FEE*RMC/SOLID**.5
000076 BFL5=BBM5+DEL
000077 IF (FLANG-7.) 10,10,12
000078 12 BFL5 = 90.-BCM5
000079 DEL = 0
000080 10 IF(PRINT) 8,8,9
000081 9 WRITE(3,509) RI,BFL4
000082 WRITE(3,502) RIOPT
000083 WRITE(3,504) DEL,V4
000084 WRITE(3,505) BFL5
000085 WRITE(3,506) RIBH
000086 WRITE(3,507) RIBM
000087 WRITE(3,508) RIBL
000088 509 FORMAT(05X,'ACTUAL INCIDENCE ANGLE,MEAN',3X,F10.3,' DEG',15X,
000089 1,ACTUAL FLUID INLET ANGLE, BFL4',5X,F10.3,' DEG')
000090 502 FORMAT(05X,'OPTIMUM INCIDENCE ANGLE',7X,F10.3,' DEG')
000091 504 FORMAT(05X,'DEVIATION ANGLE',15X,F10.3,' DEG',15X,
000092 1,FLUID INLET VELOCITY V4',12X,F10.3,' FT/SEC')
000093 505 FORMAT(05X,'DISCHARGE FLUID ANGLE',9X,F10.3,' DEG')
000094 506 FORMAT(5X,'I/BETA RATIO, HI PRESS. SIDE',2X,F10.3)
000095 507 FORMAT(5X,'I/BETA RATIO, MEAN',12X,F10.3)
000096 508 FORMAT(5X,'I/BETA RATIO, LO PRESS. SIDE',2X,F10.3)
000097 8 RETURN
000098 END

```

Q ELT MAIN, 1, 710427, 63118

```

000001 DIMENSION PSIHG(12),TBETA(12),TZD(12),OZD(10),OBETA(10),OETA(10)
000002 DIMENSION OPHI2(10)
000003 COMMON XK(8),XZ(8),XFR(8),XR(8)
000004 COMMON DH1,RM1,H,RA,RC,BSM1,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND
000005 1,BBC1,BBC2,BBC3,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,THTS,CLRS,THRS,
000006 2,CLMP,THMP,CLTOT,THTOT,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SOLIP,SOL
000007 3TO,DH2,DH3,DH4,DH5,DHMP,DHTOT,RP2,RP3,RP4,SM,QI,SIG,DR,CM2,SCL
000008 COMMON DT1,EPS,D2,B2,BBT1,BD2,Z,Z0,Z1,Z2,Z3,Z4,NZ,K3MID,XSI,DPIMP
000009 COMMON WP,XN,RHO,QKI,HNPSH,HTOT,PHIWN,VHKM,ETAHI,PSITH,ESHR,PWR
000010 COMMON XKPH1,PHI21,PHI22,PHI23,CM1,DT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
000011 COMMON FLAG,VIS,FLACO,WWR,U2,PSIBL,DPIPS,PSIIP,PSIIN,FRD
000012 COMMON B4,RL,REX,R4,BETA,BFL4,ZD,DINLT,DISTH,TIN,TOJT,XL,V5,
000013 1RADIUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
000014 2 ANVAN,BKB, R5 ,RDIS,ADIS,THICK,THICO,STANG,TRACO,SOLID,BRM4,
000015 3BBW5,FEE,ACROS,AEW,ARS1,DH,AR,ATHRC,RI,NOG0,NSKIP,OPTFI,PRINT,FI2
000016 COMMON RIOPT,RIBM,RIBL,RIBH,DEL,BFL5,DEQ,RMTH,OMPR,OMEW,OMOV
000017 COMMON V4,M, XKQVD,XK1VD,XKFVD,EVD,FLA, XKOD,O,OD,OMTOT
000018 COMMON RPHG,SSTHG,FSTHG,XKSES,XKMSC,D6,D7,C7,DPSSC,DPSFS,DPSMC,C34
000019 COMMON RLBET,RLZD,SBETA,SZD,PSHS6,ETAOV,LOOP,FLAG,B9
000020 COMMON CLUT,FINC,BE10,RRBM,D9,RR67,THR,VRV,RDSV,TEX5 ,DLDM,BCMS
000021 1 FORMAT(8F10.0)
000022 READ(2,1)XK,XZ,XFR,XR
000023 400 CALL INPUT
000024 NCASE=0
000025 NEX=0
000026 MTEST=0
000027 K=0
000028 NOG0=0
000029 IF(WP)401,500,401
000030 401 CALL SIZE1
000031 IF(NOG0) 404,404,405
000032 405 WRITE(3,406)
000033 406 FORMAT('/////5X,'INPUT VALUE OF BR2 NOT ACCEPTABLE',////)
000034 GO TO 400
000035 404 I=0
000036 IF(PHI21) 280,280,279
000037 279 OPTFI=0
000038 225 IF(NCASE=1) 226,228,230
000039 226 PHI2=PHI21
000040 NCASE=1
000041 GO TO 280
000042 228 IF(PHI22) 400,400,232
000043 232 PHI2=PHI22
000044 NCASE=2
000045 GO TO 280
000046 230 IF(NCASE=2) 228,231,400
000047 231 IF(PHI23) 400,400,234
000048 234 PHI2=PHI23
000049 NCASE=3
000050 280 PRINT=0
000051 289 LOOP=0
000052 NSKIP=0
000053 IF(I-10) 300,300,295
000054 295 WRITE(3,296)
000055 296 FORMAT('/////5X,'FLOW COEFFICIENT OPTIMIZATION, LIMIT OF ITERATIONS
000056 1EXCEEDED')
    
```

```

000057      GO TO 400
000058      300 CALL SAFE
000059      CALL IMGEO
000060      IF(PRINT) 153,153,151
000061      151 CALL ANSWR
000062      153 CALL LOSS
000063      CALL DFRBV
000064      IF(FLAG-1.) 130,30,130
000065      130 IF(FLAG-3.) 35,30,35
000066      35 WWR=0.
000067      GO TO 31
000068      30 CALL CLAS
000069      31 IF(FLAG-3.) 33,33,32
000070      33 M=0
000071      GO TO 301
000072      32 DISTH=2.*DINLT
000073      CU2TH=PSITH*U2
000074      C2=SQRT(CU2TH**2+CM2**2)
000075      ALP2R=ATAN(CM2/CU2TH)
000076      CM3=CM2*(1.-BLK2)
000077      R4=.5*D2*(.000157*XNS**2+.917+1.)
000078      D4=2.*R4
000079      B4=1.10*B2
000080      ALP4=ATAN(CM3/CU2TH)*57.296
000081      BFL4=90.-ALP4
000082      VU4=D2/D4*CU2TH
000083      ALP4R=ALP4/57.296
000084      V4=VU4/COS(ALP4R)
000085      ALP2=57.296*ALP2R
000086      C3=SQRT(CU2TH**2+CM3**2)
000087      C34=0.5*(C3+V4)
000088      VTHRC=C2*EXP(0.37532-0.286*ALOG(ALP2))
000089      OD=0*(1.+XK00)
000090      ATHRC=.321*OD/VTHRC
000091      ATHRC=1.1*ATHRC
000092      IF(SBETA) 43,43,42
000093      42 BETA=SBETA
000094      ZD=SZD
000095      GO TO 44
000096      43 ZD=7.
000097      BETA=FLOAT(IFIX(ALP4-.5))
000098      SAVE=BETA
000099      44 M=0
000100      45 TINE=ATHRC/B4/ZD
000101      TOUT=REX*TIN
000102      XL=RL*TIN
000103      46 IMESS=0
000104      CALL GEOM(IMESS,N)
000105      IF(IMESS)79,4,79
000106      79 IF(SBETA) 80,80,408
000107      408 WRITE(3,410)
000108      410 FORMAT(10X'MORE THAN 30 ITERATIONS IN SUBROUTINE GEOM')
000109      GO TO 400
000110      4 CONTINUE
000111      C ACCEPTANCE CRITERIA FOR BLADE PROFILE
000112      IF(FLAG-6.) 101,101,49
000113      101 IF(ARO-BKB) 84,84,49
000114      49 IF((GAMMA-BETA)-1.5) 84,50,50
000115      50 IF((GAMMA-BETA)-5.5) 61,61,84
000116      84 IF(SBETA) 80,80,72
    
```

72 WRITE(3,10) Z0,BETA,GAMMA,ARO,BKB
510 FORMATT(//5X,7HZD =.2X,F6.3,BX,7HBETA =.2X,F6.3,9X,7HGAMMA =.2

511 FORMATT(5X,7HDIFFUSER BLADE GEOMETRY NOT ACCEPTABLE.)

61 IF(PRINT) 73,73,74

74 CALL OUTP(N)

WRITE(3,501)

501 FORMATT(1,54X,7HDIFFUSER.)

73 CALL LOSS1

CALL DBLPR

IF(FLAG-6.) 301,301,304

304 CALL REVCN

GO TO 92

301 CALL SCRL

IF(FLAG-3.) 303,303,302

303 SBETA=0

SZD=0

GO TO 205

302 IF(NOG0) 91,91,412

WRITE(3,414)

414 FORMATT(//5X,NOG0=1, HOUSING STRUCTURALLY NOT ACCEPTABLE.)

GO TO 400

91 IF(NSKIP) 92,92,90

92 TBETA(M)=BETA

TZD(M)=ZD

PSHG(M)=PSHSG

IF(SBETA) 80,80,200

80 IF(BETA-SAVE-RLBET) 85,86,86

85 BETA=SBETA+1.

GO TO 46

86 BETA=SAVE

IF(RLZD) 89,89,87

89 IF(M) 88,88,90

87 IF(ZD-RLZD) 88,90,90

88 ZD=ZD+2.

IF(ZD-25.) 45,45,90

90 IF(M-1) 94,200,190

94 WRITE(3,95)

95 FORMATT(//5X,NO SOLUTION, RELAX CONSTRAINTS.)

GO TO 400

200 LMIN=1

PSHMI=PSHIG(1)

GO TO 205

190 PSHMI=PSHIG(1)

LMIN=1

DO 105 L=2,M

IF(PSHMI-PSHIG(L)) 105,105,110

110 PSHMI=PSHIG(L)

LMIN=LMIN+1

105 CONTINUE

SBETA=TBETA(LMIN)

SZD=1ZD(LMIN)

ETAHI=(PSIIP-PSHIG(LMIN))/PSITH

IF(PRINT) 210,210,220

210 IF(LOOP-2) 212,214,214

212 LOOP=LOOP+1

GO TO 300

214 IF(ORFI) 215,215,219

219 IF(NEX) 216,216,215

```

000177      215 PRINT=1.
000178      GO TO 300
000179      216 IF(LOOP-3) 217,218,218
000180      217 LOOP=LOOP+1
000181      GO TO 300
000182      220 IF(NCASE) 400,400,225
000183      218 I=I+1
000184      OZD(I)=SZD
000185      OBETA(I)=SBETA
000186      OETA(I)=ETAOV
000187      OPHI2(I)=PHI2
000188      IF(MTEST) 305,305,340
000189      305 IF(I-1) 307,307,310
000190      307 PHI2=PHI2+0.005
000191      5 FORMAT(/5X,'ROUTE 307'/)
000192      WRITE(3,5)
000193      GO TO 290
000194      310 IF(I-2) 312,312,314
000195      312 IF(OETA(I)-OETA(I-1)) 315,318,320
000196      320 K=1
000197      GO TO 307
000198      318 PHI2=0.5*(OPHI2(I)+OPHI2(I-1))
000199      NEX=1
000200      6 FORMAT(/5X,'ROUTE 318'/)
000201      WRITE(3,6)
000202      GO TO 290
000203      315 KEEP=I
000204      LEAVE=I-1
000205      KEEP=LEAVE
000206      LEAVE=KEEP
000207      OETA(KEEP)=OETA(LEAVE)
000208      OBETA(KEEP)=OBETA(LEAVE)
000209      OETA(LEAVE)=OETA(KEEP)
000210      OBETA(LEAVE)=OBETA(KEEP)
000211      OZD(KEEP)=OZD(LEAVE)
000212      OZD(LEAVE)=OZD(KEEP)
000213      OPHI2(KEEP)=OPHI2(LEAVE)
000214      OPHI2(LEAVE)=OPHI2(KEEP)
000215      OETA(KEEP)=OETA(LEAVE)
000216      OETA(LEAVE)=OETA(KEEP)
000217      PHI2=PHI2-0.010
000218      7 FORMAT(/5X,'ROUTE 315'/)
000219      WRITE(3,7)
000220      GO TO 290
000221      314 IF(OETA(I)-OETA(I-1)) 322,318,324
000222      322 IF(ABS(OETA(I)-OETA(I-2))-0.001)326,328,328
000223      326 PHI2=OPHI2(I-1)
000224      SZD=OZD(I-1)
000225      SBETA=OBETA(I-1)
000226      NEX=1
000227      8 FORMAT(/5X,'ROUTE 326'/)
000228      WRITE(3,8)
000229      GO TO 289
000230      328 IF(OETA(I)-OETA(I-2)) 330,326,332
000231      330 PHI2=0.5*(OPHI2(I-1)+OPHI2(I-2))
000232      MTEST=1
000233      9 FORMAT(/5X,'ROUTE 330'/)
000234      WRITE(3,9)
000235      GO TO 290
000236      332 PHI2=0.5*(OPHI2(I)+OPHI2(I-1))

```



```

000237      *TEST=1
000238      10 FORMAT(1/5X,'ROUTE 332'//)
000239      WRITE(3,10)
000240      GO TO 290
000241      324 IF(N) 334,334,307
000242      334 PHI2=PHI2-0.005
000243      11 FORMAT(1/5X,'ROUTE 334'//)
000244      WRITE(3,11)
000245      GO TO 290
000246      340 IF(OBETA(I)-OBETA(I-2)) 342,344,346
000247      342 PHI2=OPHI2(I-2)
000248      S2D=OZD(I-2)
000249      SBETA=OBETA(I-2)
000250      NEX=1
000251      12 FORMAT(1/5X,'ROUTE 342'//)
000252      WRITE(3,12)
000253      GO TO 289
000254      344 PHI2=0.5*(OPHI2(I)+OPHI2(I-2))
000255      NEX=1
000256      13 FORMAT(1/5X,'ROUTE 344'//)
000257      WRITE(3,13)
000258      GO TO 290
000259      346 PHI2=OPHI2(I)
000260      S2D=OZD(I)
000261      SBETA=OBETA(I)
000262      NEX=1
000263      14 FORMAT(1/5X,'ROUTE 346'//)
000264      WRITE(3,14)
000265      GO TO 289
000266      290 SBETA=0
000267      GO TO 289
000268      500 STOP
000269      END

```

@ ELT OUTP1,1,710427, 33120

```

000001 SUBROUTINE OUTP1(N)
000002 COMMON XK(8),XZ(8),XFR(8),XR(8)
000003 COMMON DH1,RM1,H,RA,RC,BBM1,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND
000004 1,BBC1,BBC2,BBC3,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,FHTS,CLRS,THRS,
000005 2CLIMP,THIMP,CLTOT,THTOT,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SOLIP,SOL
000006 3TG,DH2,DH3,DH4,DH5,DHIMP,DHTOT,RP2,RP3,RP4,SM,QI,SIG,DR,CM2,SCL
000007 COMMON DT1,EPS,D2,B2,BBT1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,K3MID,XSI,DPIMP
000008 COMMON WP,XN,RHO,OKI,HNP5H,HTOT,PHIWN,VHKY,ETAHI,PSITH,ESHR,RWR
000009 COMMON XKPHI,PHI21,PHI22,PHI23,CM1,UT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
000010 COMMON FLAG,VIS,FLACO,RWR,U2,PSIRL,DPIPS,PSIIP,PSIIN,FRD
000011 COMMON B4,RL,REX,R4,BETA,BFL4,ZD,DINLT,DISPH,TIN,TOUT,XL,V5,
000012 1RADIUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
000013 2 ANVAN,BKB,DIFBC,RDIS,ADIS,THICK,THIC0,STANG,TRACO,SOLID,BBM4,
000014 3BBM5,FEE,ACROS,AEW,ABS1,DH,AR,ATHT,RI,NOG),NSKIP,OPTFI,PRINT,FI2
000015 COMMON RIPT,RIB1,RIBL,RIBH,DEL,BFL5,DEQ,RMTH,OMPR,OMEV,OMOV
000016 COMMON V4,M, XKQVD,XKIVD,XKFVD,EVD,FLA, XKQD,O,OD,OMTOT
000017 COMMON RPH6,SSTHG,FSTHG,XKSFS,XKMSC,D6,D7,C7,DPSSC,DPSFS,DPSMC,C34
000018 COMMON RLDET,RLZD,SBEITA,SZD,PSHS6,ETAOV,LOOP,FLAG,D9
000019 COMMON CLUT,FINC,BE10,RBRM,D9,RB67,THR,VR,RDSV,TEX5,DLDM,BCM5
000020 500 FORMAT('1',53X,'DIFFUSER GEOMETRY'////)
000021 100 FORMAT(36X,'BETA',9X,'ZD',8X,'RBASE',7X,'DINLT',7X,'DISTH',8X,'B4'
000022 1/)
000023 101 FORMAT(28X,6F12.3//)
000024 103 FORMAT(54X,'LOG SPIRAL DATA'////40X,'THETA',30X,'RADIUS'/40X,'(DEG)
000025 1',31X,'(IN)'/)
000026 501 FORMAT(39X,F6.2,30X,F6.3)
000027 502 FORMAT(///54X,'BLADE GEOMETRY'////10X,'DELTA',6X,'GAMMA',7X,'ARO',
000028 1 7X,'ANVAN',6X,'ADIS',8X,'RAR',8X,'RLOC',6X,'CVAN',8X,'BKB'/
000029 2 10X,'(DEG)',6X,'(DEG)',6X,'(DEG)',5X,'(DEG)',6X,'(DEG)',6X,
000030 3 '(IN)',9X,'(IN)',6X,'(IN)',7X,'(IN)'/)
000031 503 FORMAT(4X,5F11.2,3F11.3,F12.3//)
000032 504 FORMAT(10X,'DIFBC',6X,'RDIS',7X,'THICK',6X,'T/C',
000033 1 9X,'TIN',7X,'TOUT',8X,'XL',8X,'DLDM',6X,'BCM5',6X,'TEX5'/
000034 1 10X,'(IN)',7X,'(IN)',7X,'(IN)',7X,'(IN)',7X,'RATIO',6X,
000035 3 '(IN)',7X,'(IN)',7X,'(IN)',7X,'(IN)',6X,'(DEG)',5X,'(IN)'/)
000036 505 FORMAT(4X,3F11.3,F11.4,5F11.3,F9.3//)
000037 506 FORMAT(50X,'TRANSFORMED BLADE DATA'////)
000038 507 FORMAT(8X,'STANG',14X,'TRACO',16X,'SOLID',15X,'BBM4',16X,'BBM5',
000039 116X,'FEE',8X,'(DEG)',15X,'(IN)',36X,'(DEG)',15X,'(DEG)',14X,
000040 2 '(DEG)'/)
000041 508 FORMAT(6X,F7.3,5F20.3//)
000042 509 FORMAT(58X,'AREAS'////8X,'ACROS',16X,'AEW',16X,'ABS1',17X,'AR',
000043 1 18X,'DH',17X,'ATHT',7X,'(SQ IN)',13X,'(SQ IN)',13X,'(SQ IN)',
000044 2 34X,'(IN)',14X,'(SQ IN)'/)
000045 510 FORMAT(3X,F10.3,5F20.3)
000046 WRITE(3,500)
000047 WRITE(3,100)
000048 WRITE(3,101) BETA,ZD,R4,DINLT,DISTH,B4
000049 WRITE(3,103)
000050 L=N-1
000051 DO 10 J=5,L,5
000052 XXXX=FLOAT(J)
000053 10 WRITE(3,501)XXXX,RADIUS(J)
000054 WRITE(3,501)THETA,RADTH
000055 WRITE(3,501)ALPHA,RAD
000056 WRITE(3,502)

```

000057 WRITE(3,503)DELTA,GAMMA,ARO,ANVAN,ADIS,RAR,RLOC,CVAN,BKB
000058 WRITE(3,504)
000059 WRITE(3,505)DIFBC,RDIS,THICK,THICO,TIN,TOUT,XL,DLDM,BCMS,TEX5
000060 WRITE(3,506)
000061 WRITE(3,507)
000062 WRITE(3,508)STANG,TRACO,SOLID,BBM4,BBM5,FEE
000063 WRITE(3,509)
000064 WRITE(3,510)ACROS,AEW,ABS1,AR,DH,ATHT
000065 RETURN
000066 END

ELT REVC#1,710427, 63124

SUBROUTINE REVC#

COMMON XK(8),XR(8),XZ(8),XFR(8),XR(8)

COMMON DH1,RM1,H,RA,RC,BRM1,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND

1,BB1-BB2, BB3,CL1,CL2,CL3,CLTS,TH1,TH2,TH3,THS,CLRS,THRS

2,CLIMP,THIMP,CLT1,TH1,TH2,TH3,TH4,TH5,TH6,TH7,TH8,TH9,TH10

3,TO,DH2,DH3,DH4,DH5,DHIMP,DH10T,RR2,RR3,RR4,SM,01,S16,DR,CM2,SCL

COMMON DT1,EPS,D2,B2,BB1,BB2,Z,Z1,Z2,Z3,Z4,NZ,KAWID,XSI,DPIMP

COMMON WP,XN,RHO,OKI,HNPSH,HTOT,PHIMN,VHK,ETAHI,PSITH,ESHR,RWR

COMMON XKPH1,PHI21,PHI22,PHI23,CMT,UT1,PHI1T,S,XNS,PS10,PHI2,NCASE

COMMON FLA6,VIS,FLA9,WR,U2,PSIB,DPIS,PSIIN,FRD

COMMON B4,RL,REX,R4,BETA,BFL4,ZD,DINLT,DINTH,TIN,TOU,XL,C6,

1,RADUS(95),THETA,RADTH,ALPHA,RAO,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,

2,ANVAN,BKB,DIFFC,RDIS,ADIS,THICK,THICO,STANG,TRACO,SOLID,BBM4,

3,BMS,FEE,ACROS,AEW,ABS1,DH,AR,ATHI,RI,NOGO,NSKIP,OPFI,PRINT,FI2

COMMON RIOP1,RIBM,RIHL,RIBH,DEL,BFL5,DRG,INTH,OMPR,MEW,OMOV

COMMON V4,M,XKAVD,XK1VD,XKEVD,EVD,FLA,XKOD,QD,OMT1

COMMON RPHG,SSTHG,ESTHG,XKXFS,XKXSC,D6,D7,C7,DPSSC,DPSS,DPSC,C34

COMMON RLBE1,RLZC,SBE1A,SZD,PSHSG,ETAOV,LLOP,FLAHG,99

COMMON CLUT,FINC,BETO,BBRM,D9,RR67,THRV,ZRV,RDSV,ADXS,DLOM,RCMS

LW=3

WIMP = WP*(1.+OKI)

D6 = B4

ALP6 = 90. - BFL5

ALP6R=ALP6/57.296

IF(RB67) 10,10,12

10 RB67 = 1.1

12 B7 = 96/RB67

D8 = 2.*DIF8C

IF (FLAHG-7.) 48,48,49

48 CM6 = C6 * SIN(ALP6R)

CO TO 50

49 BCMSR = ALP6/57.296

CM6 = C6*SIN(BCMSR)

50 IF(RBRM) 16,16,17

16 RBRM = 1.4

17 NMUT = RBRM*(B6+B7)/2.

R8=L8/2.

IF(D9) 21,21,22

21 D9 = DT1

22 IF(RDSV) 23,23,24

23 ROSV = 1.1

24 DSV=D9*RDSV

IF(FLAHG-7.) 80,80,81

81 ZRV = ZD

60 TO 26

80 IF(ZRV) 25,25,26

25 ZRV = ZD-1.

26 TRV9=3.1416*D9 /ZRV

R9=D9/2.

RSV=DSV/2.

A9 = TRV9 - 0.080

IF(B9) 27,27,28

27 B9 = 1.15 * B7

28 DHRV = 2.*A9 * B9/(A9+B9)

RHRV=DHRV/2.

VE10 = 3.1416 *D9*B9

000001
000002
000003
000004
000005
000006
000007
000008
000009
000010
000011
000012
000013
000014
000015
000016
000017
000018
000019
000020
000021
000022
000023
000024
000025
000026
000027
000028
000029
000030
000031
000032
000033
000034
000035
000036
000037
000038
000039
000040
000041
000042
000043
000044
000045
000046
000047
000048
000049
000050
000051
000052
000053
000054
000055
000056

```

000057      CM10 = 0.321 * 00/AE10
000058      BE10R = BE10/57.296
000059      IF(DEL9-20.) 15,18,15
000060      18 C10 = CM10
000061      GO TO 19
000062      15 C10 = CM10/SIN(BE10R)
000063      19 IF(FLAG-7.) 200,200,202
000064      200 CU6 = C6 * COS(ALP6R)
000065      CM7 = RB67 * CM6
000066      CU7 = CM6*B6/(0.785*CLUT*RMUT+B6 *SIN(ALP6R)/COS(ALP6R))
000067      ALP7R = ATAN(CM7/CU7)
000068      ALP7 = 57.296 * ALP7R
000069      C7 = SQRT(CU7**2+CM7**2)
000070      HLUT = 0.01554*(CU6**2-CU7**2)
000071      TRVT = 3.1416 * D8/ZRV
000072      IF(THRV) 30,30,31
000073      30 THRV = 0.120
000074      31 BET8R = ATAN(FINC*TRVT/(TRVT-THRV)*SIN(ALP7R)/COS(ALP7R))
000075      BET8 = 57.296*BET8R
000076      BLA = (D8*SIN(BET8R) + DSV)/(D8*COS(BET8R))
000077      BLB = (D8*COS(BET8R))/(D8*SIN(BET8R) + DSV)
000078      XLAG = 2./(BLA-BLB)
000079      IF(XLAG) 60,61,61
000080      60 BLAGR = 3.1417 * -ATAN(ABS(XLAG))
000081      GO TO 63
000082      61 HLAGR = ATAN(XLAG)
000083      63 BLAG = 57.296 * BLAGR
000084      RBLU = (R8**2 - RSV**2)/(2.* R8*COS(BET8R))
000085      BLRV = RBLD * BLAGR + RSV - R9
000086      DMRV = SQRT((D8**2 + D9**2)/2.)
000087      TMRV = 3.1416/ZRV*DMRV
000088      SOLRV = BLRV/TMRV
000089      C710 = SQRT(0.5*(C10**2 + C7**2))
000090      GO TO 190
000091      202 DHDEX = 2.*B6*ADEX5/(B6+ADEX5)
000092      DHRV = 0.5*(DHDEX + DHRV)
000093      RHRV = 0.5*DHRV
000094      FLUTM = 3.1416*RMUT
000095      FLRCM = R8-R9
000096      FLCM = FLUTM + FLRCM
000097      BET7 = BCM5 + (90. - BCM5)*FLUTM/FLCM
000098      BE67R = 0.5*(BCM5 + BET7)/57.296
000099      FLUT = FLUTM/SIN(BE67R)
000100      BE79R = 0.5*(BET7 + BE10)/57.296
000101      FLRC = FLRCM/SIN(BE79R)
000102      FLC = FLUT + FLRC
000103      BLRV = FLC
000104      C710 = SQRT(0.5*(C6**2 + C10**2))
000105      AEC6 = ADEX5*B6
000106      AEC9 = A9*B9
000107      OMDRV = ((1. - AEC6/AEC9)**2 + 0.2*(1. - AEC6/AEC9)**2)/2.
000108      CLUT = 0.28 - 0.15*SQRT(2.*RMUT/(B6+B7) - 1.)
000109      HLUT = CM6**2/64.348*2.*CLUT
000110      190 RERV = DHRV*C710*RHO/(386.088*VIS)
000111      IF(RERV-1.E+05) 520,520,525
000112      520 FRC = 0.0032 + 0.221/RERV**0.237
000113      GO TO 530
000114      525 FRC = 1./(0.86858*ALOG(RHRV/YKFVD) + 1.74)**2
000115      530 HFRV = FRC*C710**2/64.348*BLRV/DHRV
000116      IF(FLAG-7.) 220,220,222
    
```

```

000117      222 HLDRV=OMDRV*C6**2/64.348
000118      HLRC = HLFVRV + HLDRV + HLOT
000119      PSIUT=32.174*HLOT/U2**2
000120      PSDRV= 32.174*HLDRV/U2**2
000121      PSFRV = 32.174*HLFVRV/U2**2
000122      PSIRC = PSIUT + PSDRV + PSFRV
000123      IF(PRINT) 72,72,730
000124      730 WRITE(LW,9)
000125      WRITE(LW,604)
000126      WRITE(LW,701) RMUT,B7
000127      WRITE(LW,707) FLC,B9
000128      WRITE(LW,709) DHRV,D9
000129      WRITE(LW,606)
000130      WRITE(LW,711) CM6,C10
000131      WRITE(LW,715) RERV
000132      WRITE(LW,607)
000133      WRITE(LW,717) FRC
000134      WRITE(LW,719) HLOT,PSIUT
000135      WRITE(LW,721) HLDRV,PSDRV
000136      WRITE(LW,723) HLFVRV,PSFRV
000137      WRITE(LW,727) HLRC,PSIRC
000138      9 FORMAT(45X,'REVERSING CHANNEL WITH CONTINUOUS VANE//')
000139      604 FORMAT(55X,'GEOMETRY//')
000140      606 FORMAT(45X,'FLUID ANGLES AND VELOCITIES//')
000141      607 FORMAT(53X,'PERFORMANCE//')
000142      701 FORMAT(1X,'MEAN TURNING RADIUS, U-TURN, RMUT',2X,F10.3,2X,'IN',
000143      112X,'CHANNEL HEIGHT B7',20X,F10.3,'IN')
000144      707 FORMAT(1X,'APPROX. CHANNEL LENGTH, FLC',8X,F10.3,2X,'IN',
000145      112X,'CHANNEL HEIGHT B9',20X,F10.3,'IN')
000146      709 FORMAT(1X,'HYDRAULIC DIA, CHANNEL, DHRV', 7X,F10.3,2X,'IN',
000147      112X,'MEAN EXIT DIA, D9',20X,F10.3,2X,'IN'//)
000148      711 FORMAT(1X,'MERIDIONAL VELOCITY, CM6',11X,F10.3,2X,'FT/S',10X,
000149      1'ABSOLUTE VELOCITY, VANE EXIT, C10',6X,F10.3,2X,'FT/S')
000150      715 FORMAT(1X,'REYNOLDS NO, MEAN, RERV',12X,E10.4,2X,'***//')
000151      717 FORMAT(1X,'FRICTION COEFFICIENT, FRC',10X,F10.5,2X,'***')
000152      719 FORMAT(1X,'HEAD LOSS, U-TURN, HLOT',12X,F10.3,2X,'FT',12X,
000153      1'HEAD LOSS COEFF, U-TURN, PSIUT',8X,F10.4,2X,'***')
000154      721 FORMAT(1X,'HEAD LOSS DIFFUSION, HLDRV',9X,F10.3,2X,'FT',12X,
000155      1'HEAD LOSS COEFF, DIFFUSION, PSDRV',5X,F10.4,2X,'***')
000156      723 FORMAT(1X,'HEAD LOSS FRICTION, HLFVRV',10X,F10.3,2X,'FT',12X,
000157      1'HEAD LOSS COEFF, FRICTION, PSFRV',5X,F10.4,2X,'***')
000158      727 FORMAT(1X,'HEAD LOSS, REVERSING SYSTEM,HLRC',3X,F10.3,2X,'FT',12X,
000159      1'HEAD LOSS COEFF, REVERSING SYST, PSIRC',5X,F10.4,2X,'***'//)
000160      GO TO 72
000161      220 DRV=1.-C10/C7 + D8 * CU7/(SOLRV*C7*(D8+D9))
000162      OMDRV = XKDVD * DRV**EVD
000163      HLDRV=OMDRV*C7**2/64.348
000164      HLINV=(CM7*(COS(ALP7R)/SIN(ALP7R)-COS(BET8R)/SIN(BET8R)))**2/64.34
000165      18
000166      HLRV=HLDRV + HLFVRV + HLINV
000167      HLRC = HLRV + HLOT
000168      PSINV = 32.174*HLINV/U2**2
000169      PSIUT=32.174*HLOT/U2**2
000170      PSIRV=32.174*HLRV/U2**2
000171      PSIRC=PSIUT+PSIRV
000172      PSDRV= 32.174*HLDRV/U2**2
000173      PSFRV = 32.174*HLFVRV/U2**2
000174      IF(PRINT) 72,72,330
000175      330 WRITE(LW,1)
000176      WRITE(LW,4)

```

```

000177 WRITE(LW,301) RMUT,RT
000178 WRITE(LW,303) BET8,BLAG
000179 WRITE(LW,305) DSV,RBLD
000180 WRITE(LW,307) BLRV,SOLRV
000181 WRITE(LW,309) DHRV,ZRV
000182 WRITE(LW,6)
000183 WRITE(LW,311) CM6,C7
000184 WRITE(LW,313) ALP7,C10
000185 WRITE(LW,315) RERV
000186 WRITE(LW,7)
000187 WRITE(LW,317) DRV,FRC
000188 WRITE(LW,319) HLU,PSIUT
000189 WRITE(LW,329) HLINV,PSINV
000190 WRITE(LW,321) HLD,PSDRV
000191 WRITE(LW,323) HLF,PSFRV
000192 WRITE(LW,325) HLRV,PSIRV
000193 WRITE(LW,327) HLRC,PSIRC
000194 1 FORMAT(40X,'REVERSING CHANNEL WITH VANELESS U-TURN'/)
000195 4 FORMAT(55X,'GEOMETRY'/)
000196 6 FORMAT(45X,'FLUID ANGLES AND VELOCITIES'/)
000197 7 FORMAT(53X,'PERFORMANCE'/)
000198 301 FORMAT(1X,'MEAN TURNING RADIUS, U-TURN, RMUT',2X,F10.3,2X,'IN',12X
000199 1,'INLET VANE HEIGHT, B7',17X,F10.3,2X,'IN')
000200 303 FORMAT(1X,'VANE INLET ANGLE, BET8',13X,F10.3,2X,'DEG',11X,
000201 1,'VANE TURNING ANGLE, BLAG',14X,F10.3,2X,'DEG')
000202 305 FORMAT(1X,'DIAMETER DSV',23X,F10.3,2X,'IN',12X,
000203 1,'VANE TURNING RADIUS, RBLD',13X,F10.3,2X,'IN')
000204 307 FORMAT(1X,'VANE LENGTH, BLRV',18X,F10.3,2X,'IN',12X,
000205 1,'VANE SOLIDITY, SOLRV',18X,F10.3,2X,'***')
000206 309 FORMAT(1X,'HYDRAULIC DIA, VANE PASSAGE, DHRV',2X,F10.3,2X,'IN',
000207 12X,'VANE NUMBER, ZRV',20X,F10.3,2X,'***')
000208 311 FORMAT(1X,'MERIDIONAL VELOCITY, CM6',11X,F10.3,2X,'FT/S',10X,
000209 1,'ABSOLUT VELOCITY, VANE INLET, C7',6X,F10.3,2X,'FT/S')
000210 313 FORMAT(1X,'FLUID ANGLE VANE INLET, ALP7',7X,F10.3,2X,'FT/S',10X,
000211 1,'ABSOLUT VELOCITY, VANE EXIT, C10',6X,F10.3,2X,'FT/S')
000212 315 FORMAT(1X,'REYNOLDS NO, MEAN, RERV',12X,F10.4,2X,'***')
000213 317 FORMAT(1X,'DIFFUSION PARAMETER VANE, DRV',6X,F10.4,2X,'***',11X,
000214 1,'FRICTION COEFFICIENT VANE, FRC',8X,F10.5,2X,'***')
000215 319 FORMAT(1X,'HEAD LOSS, U-TURN, HLU',12X,F10.3,2X,'FT',12X,
000216 1,'HEAD LOSS COEFF, U-TURN, PSIUT',8X,F10.4,2X,'***')
000217 321 FORMAT(1X,'HEAD LOSS DIFFUSION, HLD',9X,F10.3,2X,'FT',12X,
000218 1,'HEAD LOSS COEFF, DIFFUSION, PSDRV',5X,F10.4,2X,'***')
000219 323 FORMAT(1X,'HEAD LOSS FRICTION, HLF',10X,F10.3,2X,'FT',12X,
000220 1,'HEAD LOSS COEFF, FRICTION, PSFRV',6X,F10.4,2X,'***')
000221 325 FORMAT(1X,'HEAD LOSS, VANE, HLRV',14X,F10.3,2X,'FT',12X,
000222 1,'HEAD LOSS COEFF, VANE, PSIRV',10X,F10.4,2X,'***')
000223 327 FORMAT(1X,'HEAD LOSS, REVERSING SYSTEM, HLRC',3X,F10.3,2X,'FT',12X,
000224 1,'HEAD LOSS COEFF, REVERSING SYST, PSIRC',F10.4,2X,'***')
000225 329 FORMAT(1X,'HEAD LOSS, INCIDENCE, HLINV',8X,F10.3,2X,'FT',12X,
000226 1,'HEAD LOSS COEFF, INCIDENCE, PSINV',5X,F10.4,2X,'***')
000227 72 HLVD=OMTOT*V4**2/64.35
000228 PSIVD=HLVD*32.174/U2**2
000229 PSHSG=PSIVD+PSIRC
000230 PSIOV=PSIIP-PSHSG
000231 HTOTF=PSIOV*U2**2/32.174
000232 ETAHI=PSIOV/PSITH
000233 ETAOV=PSIOV/PSIIN*WP/WMP
000234 M = M+1
000235 IF(PRINT) 800,800,750
000236 750 WRITE(3,47) PSIVD

```

000237 WRITE(3,29) PSHSG
000238 WRITE(3,37) ETAHI
000239 WRITE(3,39) ETAOV
000240 WRITE(3,41) PSIOV
000241 WRITE(3,441) HTOTF
000242 47 FORMAT(5X,'HEAD LOSS COEFF, DIFFUSER, PSIVD',8X,F10.4,3X,'***)
000243 41 FORMAT(5X,'PUMP OVERALL HEAD COEFF, PSIOV',9X,F10.4,3X,'***)
000244 29 FORMAT(5X,'HEAD LOSS COEFF, HOUSING, PSHSG',9X,F10.4,3X,'***)
000245 39 FORMAT(5X,'EFFICIENCY, OVERALL, ETAOV',14X,F10.4,2X,'***)
000246 441 FORMAT(5X,'TOTAL HEAD RISE, HTOTF',18X,F10.3,2X,'FT')
000247 37 FORMAT(5X,'EFFICIENCY, HYDRAULIC, ETAHI',12X,F10.4,2X,'***)
000248 800 RETURN
000249 END

J ELT SAFE,1,710427, E3125

```

000001 SUBROUTINE SAFE
000002 COMMON XK(8),XZ(8),XFR(8),XR(8)
000003 COMMON DH1, RM1, H, RA, RC, BSM1, CLIND, THIND, ZL, DHIND, BLK1, A1, AB1, DPIND
000004 1, BBC1, BBC2, BBC3, CLC1, CLC2, CLC3, CLT5, THC1, THC2, THC3, THYS, CLRS, THRS,
000005 2CLIMP, THIMP, CLTOT, THTOT, BLK2, A2, SOL1, SOL2, SOL3, SOL4, SOL5, SOLIP, SOL
000006 3T0, DH2, DP3, DH4, DH5, DHIMP, DHTOT, RP2, RP3, RP4, SM, QI, SIG, DR, CM2, SCL
000007 COMMON DT1, EPS, D2, B2, BBT1, BB2, Z, Z0, Z1, Z2, Z3, Z4, NZ, KBMID, XSI, DPIMP
000008 COMMON WP, XN, RHO, QKI, HNP5H, HTOT, PHIMN, VHXY, ETAHI, PSITH, ESHR, RWR
000009 COMMON XKPH1, PHI21, PHI22, PHI23, CM1, UT1, PHI1T, S, XNS, PSIO, PHI2, NCASE
000010 COMMON FLAG, VIS, FLACO, WWR, U2, PSIBL, DPIP5, PSIIP, PSIIN, FRO
000011 COMMON B4, RL, REX, R4, BETA, BFL4, ZD, DINLT, DISTH, TIN, TOJT, XL, V5,
000012 1PAUS(95), THETA, RADTH, ALPHA, RAD, DELTA, GAMMA, ARO, PAR, RLOC, CVAN,
000013 2ANVAN, BK3, DIFBC, RDIS, ADIS, THICK, THICO, STANG, TRACO, SOLID, RBM4,
000014 3PBMS, FEE, ACROS, AEW, ABS1, DH, AR, ATHT, RI, NOD0, NSKIP, OPTFI, PRINT, FI2
000015 COMMON RIOP, RISM, RIBL, RIRH, DEL, BFL5, DEG, RMTN, OMPR, OMEW, OMOV
000016 COMMON V4, N, XKDVO, XK1VD, XKFVD, EVD, FLA, XKOD, Q, QD, OMTOT
000017 COMMON RPHG, S5THG, F5THG, XKSFS, XKMSC, D6, D7, C7, DPSSC, DPSFS, DPSMC, C34
000018 COMMON RLBT, RLZD, SBETA, SZD, PSHS6, ETAOV, LOOP, FLA6, B9
000019 COMMON CLUT, FINC, BE10, RBRM, D9, RB67, THRV, ZRV, RDSV, TEX5, DLDM, BCMS
000020 BB2R=BB2/57.296
000021 IF (LOOP) 20, 20, 25
000022 20 PSITH=PSIO-PHI2*COS(BB2R)/SIN(BB2R)
000023 25 HTHI=HTOT/ETAHI
000024 U2=SQRT(32.174*HTHI/PSITH)
000025 D2=229.3*U2/XN
000026 R2=D2*0.5
000027 BLK2=0.05*Z/(D2*SIN(BB2R))
000028 BLK2 = .1 * (1.-BLK2) + BLK2
000029 CM2=PHI2*U2
000030 AB2=0.321*QI/CM2
000031 R2=AB2/(3.14159*D2*(1.-BLK2))
000032 IF (PRINT) 50, 50, 40
000033 40 WRITE(3,1) NCASE
000034 WRITE(3,3) PSITH
000035 WRITE(3,4) HTHI
000036 WRITE(3,6) D2
000037 WRITE(3,7) BLK2
000038 WRITE(3,9) AB2
000039 WRITE(3,18) B2
000040 WRITE(3,8) CM2
000041 WRITE(3,5) U2
000042 WRITE(3,30) PHI2
000043 1 FORMAT('1',5X,'*** CASE',I2,' ***/)
000044 3 FORMAT(5X,'THEORETICAL HEAD COEFFICIENT',12X,F10.4,4X,'****)
000045 4 FORMAT(5X,'THEORETICAL HEAD',24X,F10.4,4X,'FT')
000046 5 FORMAT(5X,'IMPELLER TANGENTIAL VELOCITY',12X,F10.4,4X,'FT/SEC')
000047 6 FORMAT(5X,'IMPELLER DISCHARGE DIAMETER',13X,F10.4,4X,'INCH')
000048 7 FORMAT(5X,'IMPELLER DISCHARGE BLOCKAGE',13X,F10.4,5X,'****)
000049 8 FORMAT(5X,'IMPELLER MERIDIONAL VELOCITY',12X,F10.4,4X,'FT/SEC')
000050 9 FORMAT(5X,'IMPELLER DISCH BLOCKD AREA',15X,F10.4,4X,'SQ IN')
000051 18 FORMAT(5X,'IMPELLER DISCH VANE HEIGHT',14X,F10.4,4X,'INCH')
000052 30 FORMAT(5X,'IMPELLER DISCH FLOW COEFFICIENT',9X,F10.4,5X,'****',/)
000053 50 RETURN
000054 END

```

ELT SCRL,1.710427, 63128

```

000001 SUBROUTINE SCRL
000002 DIMENSION X(10),Y(10),W(10),A(11),B(11)
000003 COMMON XK(8),XZ(3),XFR(8),XR(8)
000004 COMMON DH1,RM1,H,RA,RC,BBM1,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND
000005 1,BGC1,BGC2,BGC3,CLC1,CLC2,CLC3,CLTS,THC1,THC2,THC3,THTS,CLRS,THRS,
000006 2,CL1P,TH1P,CLTOT,THTOT,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOLS,SOLIP,SOL
000007 3TO,DH2,DH3,DH4,DH5,DH1P,DHTOT,RP2,RP3,RP4,SM,QI,SIG,DR,CM2,SCL
000008 COMMON DT1,EPS,D2,B2,BBT1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,KBMID,XS1,DPIMP
000009 COMMON WP,XN,RHO,QKI,HNPISH,HTOT,PHINN,VHKM,ETAH,PSITH,ESHR,RWR
000010 COMMON X(PH1,PHI21,PHI22,PHI23,CM1,UT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
000011 COMMON B4,RL,REX,R4,BETA,BFL4,ZD,DINLT,DISTH,TIN,TOJT,XL,C5,
000012 1,RADIUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
000013 2,ANVAN,RKD,R5,DIS,ADIS,THICK,THICO,STANG,TRACO,SOLID,BBM4,
000014 3,BUM5,FEE,ACROS,AEW,ABS1,DH,AR,ATH,PI,NCGO,NSKIP,OPTFI,PRINT,FI2
000015 COMMON RIOPT,RIBM,R1BL,R1RH,DEL,BFL5,DEQ,RMTH,OMPR,OMEW,OMOV
000016 COMMON V4,M, XKOVD,XK1VD,XKFVD,EVD,FLA, XKQD,Q,OD,OMTOT
000017 COMMON RPHG,SSTHG,FSTHG,XKSFS,XKMSC,D6,D7,C7,DPSSC,DPSFS,DPSMC,C34
000018 COMMON RLBET,RLZD,SBETA,SZD,PSHSG,ETAOV,LOOP,FLAG,39
000019 COMMON CLUT,FINC,BE10,RBRM,D9,RB67,THR,VRV,ROSV,TEX5,DLDM,DCM5
000020 X(1)=10.
000021 DO 10 J=2,6
000022 10 X(J)=X(J-1)+5.
000023 Y(1)=1.086
000024 Y(2)=1.134
000025 Y(3)=1.18
000026 Y(4)=1.225
000027 Y(5)=1.27
000028 Y(6)=1.315
000029 W(1)=0.77
000030 W(2)=0.691
000031 W(3)=0.628
000032 W(4)=0.585
000033 W(5)=0.55
000034 W(6)=0.514
000035 CALL CUFIT(3,6,X,Y,A)
000036 CALL CUFIT(3,6,X,W,B)
000037 WIMP=WP*(1.+QKI)
000038 B5=1.1*B2
000039 IF(FLAG-3.) 2,2,3
000040 2 ALP2R=ATAN(CM2/PSITH/U2)
000041 ALP5R=ALP2R
000042 ALPH5=57.296*ALP5R
000043 D5=D2
000044 CU2TH=PSITH*U2
000045 CUS=CU2TH
000046 GO TO 4
000047 3 ALPH5=90.- BFL5
000048 DIFBC=R5
000049 D5=2*DIFBC
000050 ALP5R=ALPH5/57.296
000051 CUS=C5*COS(ALP5R)
000052 4 D6D5=SOLVE(ALPH5,A)
000053 D6=D5+D6D5
000054 R6=D6/2.
000055 CRK=CUS/D6D5

```

00057	C7C06=S0LVE(ALPH5,B)
00058	C7=C7C06*CU6
00059	C8=C7/2.5
00060	A7=1.321*0/C7
00061	PHI7=07/U2
00062	C=84530.*C06*R6/0
00063	STAY=FLAH6
00064	IF(FLAH6-3.) 61.61.62
00065	FLAH6=FLAH6-3.
00066	IF(FLAH6-2.) 63.64.64
00067	D7=2.*S0RT(A7/3.14159)
00068	DSC=S0RT((07**2-1.21*85**2)/2.)*+1.1*85
00069	RE=DSC*CU6*RHO/(386.088*VIS)
00070	IF(XE-1.E+05) 205.205.66
00071	F5FS=1./(0.86858*AL06(DSC/(2.*XKFS)))+1.74)**2
00072	DHSFS=(0.7512E-05)*F5FS*C*R6*C7 **2*AL06(1.+57./S0RT(0.1666*R6*C
00073	1)
00074	60 TO 69
00075	D7=1.+14*S0RT(A7/3.14159)
00076	DSC=S0RT((07**2-1.21*85**2)/2.)*+1.1*85
00077	RE=DSC*CU6*RHO/(386.088*VIS)
00078	IF(XE-1.E+05) 205.205.68
00079	F5FS=1./(0.86858*AL06(DSC/(2.*XKFS)))+1.74)**2
00080	DHSFS=(0.7512E-05)*F5FS*C*R6*C7 **2*AL06(1.+40.25/S0RT(0.1666*R6*
00081	1C)
00082	IF(FLAH6-2.) 69.69.112
00083	F5FS=1./(0.86858*AL06(DSC/(2.*XKFS)))+1.74)**2
00084	XLSC=1.57*(06+D7)
00085	DHSFS=DHSFS+F5FS0*C7**2/64.35*XLSC/07/1.434
00086	D7=2.*S0RT(A7/3.14159)
00087	D3=1.58*07
00088	EXDL=4.*07
00089	DPEXD=0.1*PHI7**2
00090	DHEXD=DPEXD*02**2/32.174
00091	DPSFS=32.174*DHSFS/U2**2
00092	IF(STAY -3.) 71.71.72
00093	71 PSIV=0
00094	60 TO 73
00095	72 HLVD=OMT0T*V4**2/64.35
00096	PSIV=HLVD*32.174/U2**2
00097	73 PSH56=PSIV0+DPSFS+DPEXD
00098	FLAH6=STAY
00099	PSIV=PSIIP-PHS6
00100	H10F=PSIV*02**2/32.174
00101	ETAHI=PSIV/PSITH
00102	ETAOV=PSIV/PSIIN*W/WIMP
00103	IF(SSTHS) 81.81.83
00104	81 PM=0
00105	ADVR0=0
00106	60 TO 82
00107	83 RO=S0RT(.5*((06/2.+07)**2+(06/2.)*2))
00108	RDMS0RT(0.5*(R4**2+R5**2))
00109	DP10T=RHO/144.*HT0T
00110	PM=DP10T-C7**2*RHO/9266.
00111	FDVT=1.047*PM*(R0-RDM)*(R0+2.*RDM)
00112	ADVR0=FDVT/SSTH6*RPH6*FSTH6
00113	ACRST=ZD*ACR0S
00114	IF(ACRST-ADVR0) 100.82.82
00115	100 IF(M) 201.201.207
000116	201 IF(SBETA) 205.205.207

```

000117      205 NOGO=1
000118      GO TO 200
000119      207 IF(LOOP) 209,209,211
000120      209 NSKIP=1
000121      GO TO 200
000122      211 IF(PRINT) 82,82,212
000123      212 WRITE(3,214)
000124      214 FORMAT(//5X,'HOUSING STRUCTURAL LIMIT EXCEEDED IN FINAL ITERATIONS
000125      1'//)
000126      82 MEX=1
000127      IF(PRINT) 200,200,210
000128      210 STAY=FLAG
000129      IF(FLAG-3.) 93,93,91
000130      91 FLAG=FLAG-3.
000131      93 IF(FLAG-2.) 104,105,106
000132      104 WRITE(3,94)
000133      94 FORMAT(5X,'*** SINGLE DISCHARGE - SINGLE TONGUE VOLUTE ***'//)
000134      GO TO 97
000135      105 WRITE(3,95)
000136      95 FORMAT(5X,'*** DUAL DISCHARGE VOLUTE ***'//)
000137      GO TO 97
000138      106 WRITE(3,96)
000139      96 FORMAT(5X,'*** DOUBLE VOLUTE ***'//)
000140      97 FLAG=STAY
000141      15 FORMAT(5X,'VOLUTE BASE CIRCLE DIAMETER, D6',9X,F10.3,2X,'INCH')
000142      19 FORMAT(5X,'VOLUTE THROAT DIAMETER, D7',14X,F10.3,2X,'INCH')
000143      17 FORMAT(5X,'VOLUTE THROAT ABSOLUTE VELOCITY, C7',5X,F10.3,2X,'FT/SE
000144      1C')
000145      27 FORMAT(5X,'HEAD LOSS COEFF, DIFFUSER, PSIVD',8X,F10.4,3X,'****')
000146      29 FORMAT(5X,'HEAD LOSS COEFF, HOUSING, PSHSG',9X,F10.4,3X,'****'//)
000147      31 FORMAT(5X,'PUMP OVERALL HEAD COEFF, PSIOV',9X,F10.4,3X,'****')
000148      33 FORMAT(5X,'VOLUTE PRESSURE, PM',21X,F10.4,3X,'PSI')
000149      35 FORMAT(5X,'REQ. TOT. BLADE AREA, ADVRO',13X,F10.4,3X,'SQIN'//)
000150      37 FORMAT(5X,'EFFICIENCY, HYDRAULIC, ETAHI',12X,F10.4,2X,'****')
000151      39 FORMAT(5X,'EFFICIENCY, OVERALL, ETAOV',14X,F10.4,2X,'****')
000152      41 FORMAT(5X,'HEAD LOSS COEFF, EXIT DIFF, DPEXD',7X,F10.4,3X,'****')
000153      441 FORMAT(5X,'TOTAL HEAD RISE, HTOTF',18X,F10.3,2X,'FT')
000154      43 FORMAT(5X,'MAX EXIT DIAMETER, D8',19X,F10.4,3X,'IN')
000155      45 FORMAT(5X,'MAX EXIT DIFFUSER LENGTH, EXDL',10X,F10.4,3X,'IN'//)
000156      47 FORMAT(5X,'MIN EXIT VELOCITY, C8',19X,F10.4,3X,'FT/SEC')
000157      48 FORMAT(5X,'REYNOLDS NUMBER, VOLUTE, RE',13X,F10.4,3X,'****')
000158      49 FORMAT(5X,'FRICTION COEFFICIENT VOLUTE, FSFS',7X,F10.4,3X,'****')
000159      50 FORMAT(5X,'VOLUTE HEAD LOSS, DHSFS',17X,F10.3,3X,'FT')
000160      51 FORMAT(5X,'EXIT DIFF HEAD LOSS, DHEXD',14X,F10.3,3X,'FT'//)
000161      52 FORMAT(5X,'HEAD LOSS COEFF, VOLUTE, DPSFS',10X,F10.4,3X,'****')
000162      WRITE(3,15) D6
000163      WRITE(3,19) D7
000164      WRITE(3,43) D8
000165      WRITE(3,17) C7
000166      WRITE(3,47) C8
000167      WRITE(3,45) EXDL
000168      WRITE(3,48) RE
000169      WRITE(3,49) FSFS
000170      WRITE(3,50) DHSFS
000171      WRITE(3,51) DHEXD
000172      WRITE(3,52) DPSFS
000173      WRITE(3,41) DPEXD
000174      WRITE(3,27) PSIVD
000175      WRITE(3,29) PSHSG
000176      WRITE(3,33) PM
    
```

000177 WRITE(3,25) ADVRO
000178 WRITE(3,31) PSIOV
000179 WRITE(3,37) ETAAI
000180 WRITE(3,39) ETAAV
000181 WRITE(3,44) HIOIF
200 RETURN
END

ELT SIZE1,1,710427, 63.31

```

000001 SUBROUTINE SIZE1
000002 COMMON XK(8),XZ(8),XFR(8),XR(8)
000003 COMMON DH1,RM1,H,RA,RC,BBM1,CLIND,THIND,ZL,DHIND,BLK1,A1,AB1,DPIND
000004 1,BBC1,BBC2,BBC3,CLC1,CLC2,CLC3,CLT5,THC1,THC2,THC3,THTS,CLRS,THRS,
000005 2,CLIMP,THIMP,CLTOT,THTOT,BLK2,A2,SOL1,SOL2,SOL3,SOL4,SOL5,SOLIP,SOL
000006 3,TO,DH2,DH3,DH4,DH5,DHIMP,DHTOT,RP2,RP3,RP4,SM,QI,SIG,DR,CM2,SCL
000007 COMMON DT1,EPS,D2,B2,BBT1,BB2,Z,Z0,Z1,Z2,Z3,Z4,NZ,K9MID,XSI,DPIMP
000008 COMMON WP,XN,RHO,OKI,HNPSH,HTOT,PHIMN,VHKM,ETAHI,PSITH,ESHR,RWR
000009 COMMON XKPH1,PHI21,PHI22,PHI23,CM1,UT1,PHI1T,S,XNS,PSIO,PHI2,NCASE
000010 COMMON FLAG,VIS,FLACO,WWR,U2,PSIBL,DPIPS,PSIIP,PSIIN,FRD
000011 COMMON B4,RL,REX,R4,BETA,BFL4,ZD,DIINT,DISTH,TIN,TOJT,XL,V5,
000012 1,RADIUS(95),THETA,RADTH,ALPHA,RAD,DELTA,GAMMA,ARO,RAR,RLOC,CVAN,
000013 2,ANVAN,BKB,DIFBC,ROIS,ADIS,THICK,THICO,STANG,TRACO,SOLID,BBM4,
000014 3,BBS,FEI,ACROS,AEW,ABS1,DH,AR,ATHT,RI,NOSO,NSKIP,OPTFI,PRINT,FI2
000015 COMMON RIOPT,PIBM,RIBL,RIBH,BEL,BFL5,DEQ,RMTH,OMPR,OMEW,OMOV
000016 COMMON V4,M, XKDVD,XK1VD,XKFVD,EVD,FLA, XKGD,Q,OD,OMTOT
000017 COMMON RPHG,SSTHG,FSTHG,XKSFS,XKMSC,D6,D7,C7,DPSSC,DPSFS,DPSMC,C34
000018 COMMON RLBT,RLZD,SBETA,SDZ,PSHSG,ETAOV,LOOP,FLAG,B9
000019 COMMON CLUT,FINC,BE10,RBRM,D9,RB67,THR, ZRV,RDSV,TEX5 ,DLDM,BCM5
000020 Q=449.*WP/RHO
000021 QI=Q*(1.+OKI)
000022 WIMP=WP*(1.+OKI)
000023 QI=QI
000024 S=XN*SQRT(QI)/HNPSH**0.75
000025 SPRM=S/SQRT(1.-EPS**2)
000026 PHI1T=3574./SPRM
000027 11 DT1=4.54*( QI/((1.-EPS**2)*XN*PHI1T))**0.333
000028 A1=0.785397*DT1**2*(1.-EPS**2)
000029 CM1=0.321*QI/A1
000030 VHKI=64.340*HNPSH/CM1**2
000031 IF (VHKI-VHKM) 10,15,15
000032 10 PHI1T=PHI1T-0.01
000033 GO TO 11
000034 15 IF (PHI1T-PHIMN) 20,25,25
000035 20 CM1=SQRT(2.*32.16*HNPSH/VHKM)
000036 A1=.321*QI/CM1
000037 DT1=SQRT(4.*A1/(3.1416*(1.-EPS**2)))
000038 12 UT1=XN*DT1/229.
000039 PHI1T=CM1/UT1
000040 IF (PHI1T-PHIMN) 13,25,25.
000041 13 XN=XN-1000.
000042 GO TO 12
000043 25 BBFL=ATAN(PHI1T)*57.296
000044 PBT1=1.74*BBFL
000045 UT1=CM1/PHI1T
000046 XNS=XI*SQRT(Q)/HTOT**0.75
000047 S0=XN*SQRT(Q)/HNPSH**0.75
000048 S1=XN*SQRT(QI)/HNPSH**0.75/SQRT(1.-EPS**2)
000049 IF (BB2-18.) 500,301,302
000050 301 PHI2=0.0465E-03*XNS+0.040
000051 GO TO 320
000052 302 IF (BB2-25.) 500,303,312
000053 303 PHI2=0.0535E-03*XNS+0.057
000054 GO TO 320
000055 312 IF (BB2-30.) 500,313,304
000056 313 PHI2=0.06121E-03*XNS+0.06258

```

```

000057      GO TO 320
000058      304 IF (BB2-35.) 500,305,306
000059      305 PHI2=0.0675E-03*XNS+0.067
000060      GO TO 320
000061      306 IF (BB2-45.) 500,307,308
000062      307 PHI2=0.0795E-03*XNS+0.075 /
000063      GO TO 320
000064      308 IF (BB2-60.) 500,309,310
000065      309 PHI2=0.0935E-03*XNS+0.086
000066      GO TO 320
000067      310 IF (BB2-90.) 500,319,500
000068      319 PHI2=0.12E-03*XNS+0.12
000069      320 G=(90.-BB2)/57.296
000070      C=COS(G)
000071      A=5.5797*C**2/Z**2-19.233*C**4/Z**3+8.6584*C**4/Z**4*(8.*C**2-1.)
000072      PSIO=EXP(-2.*G*SIN(2.*G)/Z)*EXP(A)/((2.*C)**(4.*C**2/Z))
000073      FI2=PHI2
000074      PHI2=XKPH1*PHI2
000075      516 FORMAT(///5X,'*** OUTPUT ***',/)
000076      WRITE(3,516)
000077      WRITE(3,30) XN
000078      WRITE(3,39) XNS
000079      WRITE(3,37) S0
000080      WRITE(3,49) S1
000081      WRITE(3,51) WIMP
000082      WRITE(3,43) OI
000083      WRITE(3,41) BBT1
000084      WRITE(3,31) DT1
000085      WRITE(3,32) A1
000086      WRITE(3,33) CM1
000087      WRITE(3,34) UT1
000088      WRITE(3,36) PHI1T
000089      WRITE(3,45) FI2
000090      WRITE(3,47) PHI2
000091      WRITE(3,2) PSIO
000092      2 FORMAT(5X,'SHUTOFF HEAD COEFFICIENT',16X,F8.3,5X,'****')
000093      31 FORMAT(5X,'IMPELLER INLET DIAMETER',17X,F8.3,4X,'INCHES')
000094      32 FORMAT(5X,'IMPELLER INLET AREA',21X,F8.3,4X,'SQ IN')
000095      33 FORMAT(5X,'IMPELLER INLET MERIDIONAL VELOCITY',F14.3,4X,'FT/SEC')
000096      34 FORMAT(5X,'IMPELLER INLET TANGNTL VELOCITY',12X,F8.3,4X,'FT/SEC')
000097      35 FORMAT(5X,'IMPELLER INLET FLOW COEFFICIENT',11X,F8.3,5X,'****')
000098      37 FORMAT(5X,'SUCTION SPECIFIC SPEED, S0',12X,F10.4,4X,'RPM*GPM**0.5/
000099      1FT**0.75')
000100      38 FORMAT(5X,'IMPELLER ROTATIONAL SPED',13X,F10.3,5X,'RPM')
000101      39 FORMAT(5X,'SPECIFIC SPEED',24X,F10.4,4X,'RPM*GPM**0.5/FT**0.75')
000102      41 FORMAT(5X,'INLET TIP BLADE ANGLE',19X,F8.3,4X,'DEGREES')
000103      43 FORMAT(5X,'IMPELLER FLOW RATE, OI',17X,F9.3,4X,'GPM')
000104      45 FORMAT(5X,'DISCH FLOW COEFF REC, SHROUDED IMP.',4X,F9.4,4X,'****')
000105      47 FORMAT(5X,'DISCH FLOW COEFF, INITIAL',14X,F9.4,4X,'****')
000106      49 FORMAT(5X,'SUCTION SPECIFIC SPEED, S1',12X,F10.4,4X,'RPM*GPM**0.5/
000107      1FT**0.75')
000108      51 FORMAT(5X,'IMPELLER WEIGHT FLOW, WIMP',12X,F9.3,4X,'LB/SEC')
000109      GO TO 600
000110      500 NOGO=1
000111      600 RETURN
000112      END

```

N8300R:72-106
May 1972

2. AXIAL THRUST BALANCER STABILITY ANALYSIS

COMPUTER PROGRAM
AXIAL THRUST BALANCER STABILITY ANALYSIS

I. INTRODUCTION

The dynamic stability of a series-flow self compensating thrust balance system operating with liquid hydrogen is analyzed. Two methods of analysis are presented: The energy method and the root locus method. In addition to stability parameters, the program also prints out balancer capacity, flow rate and orifice pressure drops for any specified balance piston position.

This program was written for the parametric evaluation of the axial thrust balancer design of the NERVA Turbopump described in Reference 1.

II. DESCRIPTION

The thrust balancer schematically shown in Figure 1 is a double acting series flow balance piston which is integral with the second stage impeller disk. Fluid is bled from the second stage impeller discharge and forced through the high pressure orifice into the balance piston cavity. From the balance piston cavity the fluid passes through the low pressure orifice and discharges into the sump. The sump is vented to the first stage impeller rear cavity through multiple internal flow passages and a common external line which permits installation of venturi flowmeter.

Maximum thrust (towards suction) is achieved with the high pressure orifice closed while minimum thrust is obtained with the low pressure orifice closed.

Reference 1 - Aerojet Nuclear Systems Company Engineering Operations Report
N8300R:71-076, NERVA Turbopump Design Report, Volume 1,
September 1971.

BALANCE PISTON SCHEMATIC

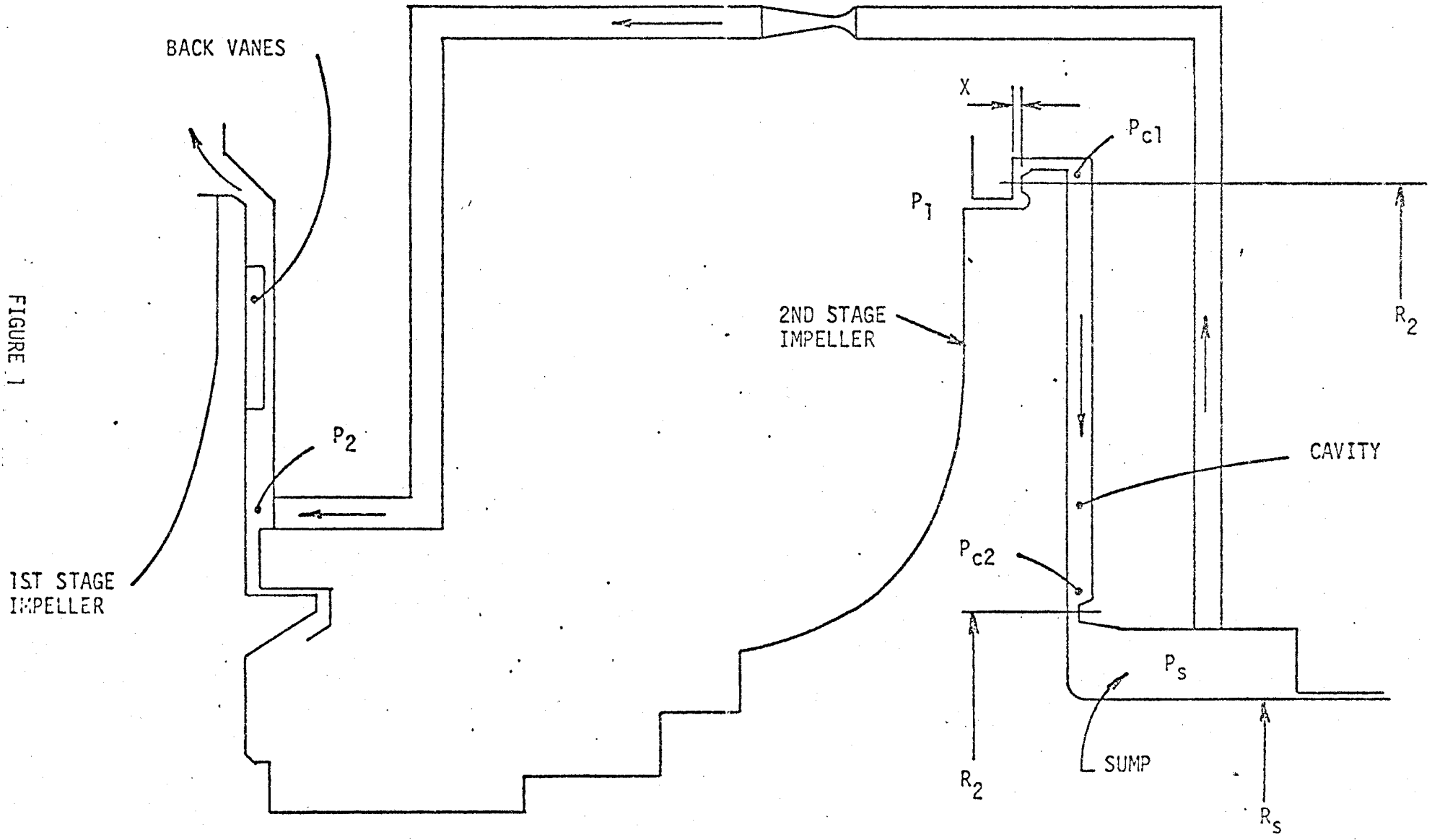


FIGURE 1

2

The balance piston operates between the second stage impeller discharge pressure, P_1 , and the first stage impeller rear cavity pressure, P_2 , (Refer to Figure 1). The effective pressure differential across the balancer face is reduced by the pressure difference, $P_{c1} - P_{c2}$, resulting from fluid rotation in the balance piston cavity. This pressure difference is calculated using the semi-empirical method presented in Reference 1. The angular velocity of the cavity fluid may exceed one half that of the rotor because of the very small axial clearance.

After assuming starting values for fluid density at each orifice the flow rate is calculated from the following equation by an iterative process.

$$\dot{W} = 2g \left[\frac{P_2 - P_1 - \Delta P_c}{\frac{1}{C_1^2 A_1^2 \rho_1} + \frac{1}{C_2^2 A_2^2 \rho_2} + \frac{1}{C_e^2 \rho_e}} \right]^{\frac{1}{2}}$$

where:

$$A_1 = 2\pi R_1 X$$

$$A_2 = 2\pi R_2 (\delta - X)$$

$$\delta = \text{total axial clearance}$$

$$X = \text{high pressure orifice gap}$$

$$C_1 = \text{high pressure orifice flow coefficient} = .85$$

$$C_2 = \text{low pressure orifice flow coefficient} = .85$$

$$C_e = \text{vent line resistance, calculated} = .5 \text{ Ft}^2$$

Using the first approximation of the flow rate the pressure drop through each orifice is calculated. The fluid frictional heating in the cavity is estimated using the friction coefficients based on Schultz-Grunows data presented in Reference 2. The frictional power is calculated as follows:

$$P_{\text{fric}} = .9223 (10^{-8}) K \rho N^3 (R_2^5 - R_1^5)$$

P_{fric} = disk friction horsepower

K = friction coefficient

ρ = fluid density (lb/ft³)

N = speed (rpm)

R_2 = outer radius, (inch)

R_1 = inner radius (inch)

The friction coefficient K is a function of Reynolds number and clearance to diameter ratio. Values of K for smooth and rough disks are published in Reference 2.

The friction loss results in an enthalpy rise

$$\Delta h = \frac{550 P_{\text{fric}}}{J \dot{W}}$$

and the resulting temperature rise is obtained by dividing Δh by the specific heat C_p .

Assuming an isenthalpic process through all orifices and considering the frictional heat input in the cavity, new values of fluid density are obtained for cavity, sump and exit. These new values are used in place of initial approximate densities and the entire flow calculation is repeated. Two to three iterations are generally required depending on the starting value to achieve consistent values of fluid density.

Reference 1 - Pratt & Whitney Aircraft, Florida Research and Development Center, Investigation of Pressure Prediction Methods for Radial Flow Impellers, PWA-FR-1276, 8 March 1965.

Reference 2 - A. J. Stepanoff, Centrifugal and Axial Flow Pumps, 2nd Edition, J. Wiley & Sons, Inc., New York

Cavity and sump thrust is calculated by numerical integration of the pressure profile, assuming a linear variation of pressure with R^2 .

The dynamic stability analysis is in essence based on the energy method and the root locus method discussed in Reference 3.

III. INSTRUCTIONS

1. The total travel DELT is divided in even increments of 0.001 inch. Present array size limits the effective travel to be analyzed to 0.019 inches, e.g. the maximum value for LIM is 19.

KSTAR permits analysis to start at a higher value of X. To avoid rubbing X will always be larger than 0.001.

2. If NFLAG is negative only the steady state operation of the balancer will be analyzed. If NFLAG is positive the entire analysis will be carried out.

3. Orifice coefficients CORF1 and CORF2 based on Rocketdyne data are 0.85.

4. The line loss coefficient between sump and exit is

$$CLINE = K \frac{\dot{W}}{\sqrt{\Delta P_{line}} \rho_{ex}}$$

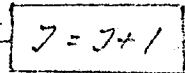
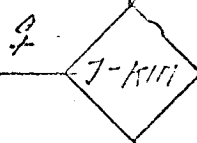
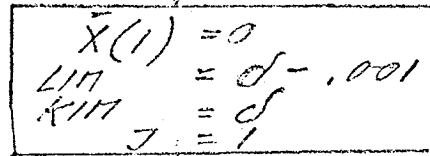
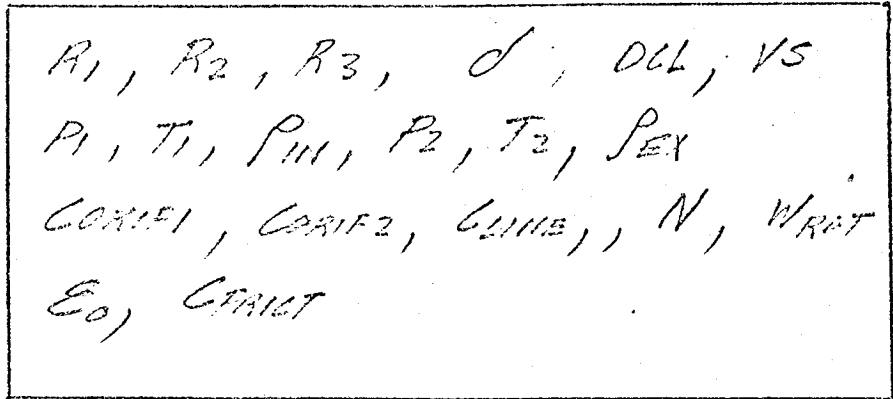
This coefficient must be estimated from ducting layout.

5. For disc friction coefficients refer to Reference 2. For most applications $CFRIC = 0.22 \times 10^{-7}$.

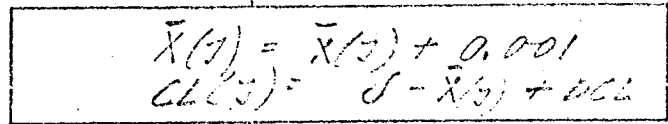
Reference 3 - Dynamic Stability Study of a Series Flow Thrust Balance Piston,
North American Aviation, Rocketdyne Division, Report R-6809P-1.

BALANCE PISTON STABILITY ANALYSIS

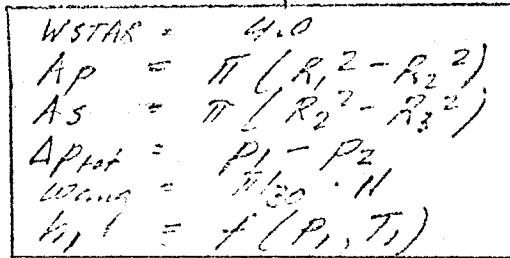
INPUT



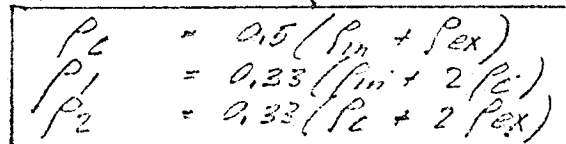
Set up arrays
for \bar{X} & CL

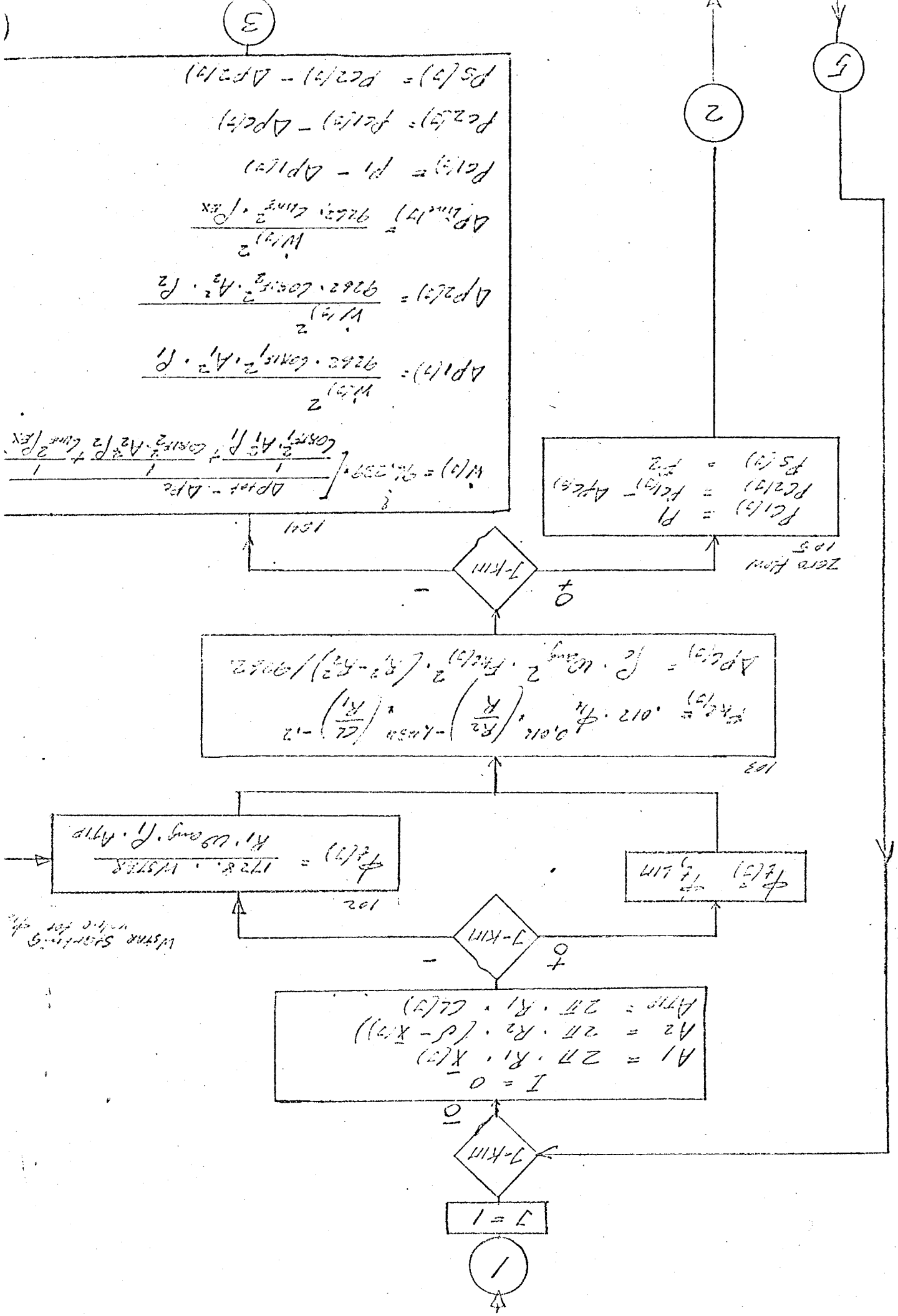


CONSTANTS

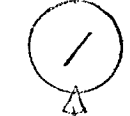


Select starting
values for
density





$$I = 1$$

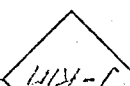


$$\begin{aligned}
 A_1 &= 2\pi \cdot R_1 \cdot X(z) \\
 A_2 &= 2\pi \cdot R_2 \cdot (\delta - X(z)) \\
 A_3 &= 2\pi \cdot R_1 \cdot C(z)
 \end{aligned}$$



$$\phi(z) = \frac{R_1 \cdot W_3788 \cdot I \cdot A_3}{1728 \cdot W_3788}$$

$$\phi = 17 \text{ LM}$$

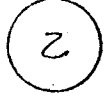


$$\Delta PC(z) = \frac{f_c \cdot W_{ang} \cdot f_h \cdot f_{ex}(z) \cdot (R_2 - R_1) / 999.2}{0.012 \cdot f_h \cdot \left(\frac{R_2}{R_1}\right) \cdot (-1.554 \cdot \left(\frac{C}{R_1}\right) \cdot -1.2)}$$



$$\begin{aligned}
 PC_1(z) &= P_1 \\
 PC_2(z) &= PC_1(z) - \Delta PC(z) \\
 PS(z) &= P_2
 \end{aligned}$$

$$\begin{aligned}
 \Delta P_1(z) &= \frac{9262 \cdot Const_1^2 \cdot A_1^2 \cdot f_1}{W(z)^2} \\
 \Delta P_2(z) &= \frac{9262 \cdot Const_2^2 \cdot A_2^2 \cdot f_2}{W(z)^2} \\
 \Delta P_{diff}(z) &= \frac{9262 \cdot Const^2 \cdot f_{ex}}{W(z)^2} \\
 PC_1(z) &= P_1 - \Delta P_1(z) \\
 PC_2(z) &= PC_1(z) - \Delta PC(z) \\
 PS(z) &= PC_2(z) - \Delta P_2(z)
 \end{aligned}$$



5

2

3

$$P_{c1}(j) = 0.5 \cdot (P_{c1}(j) + P_{c2}(j))$$

$$T_{c1}(j) = f(P_{c1}, h_1)$$

$$C_{p1}(j) = f(T_{c1}, T_{a1})$$

$$P_{c1}(j) = 9223.15 \cdot C_{p1} \cdot N^3 (R_1^5 - R_2^5) \cdot \rho_c \quad (HP)$$

$$\Delta T_{c1c} = 0.707 \cdot \frac{P_{c1}(j)}{W_{c1} \cdot C_{p1}}$$

$$T_{c2}(j) = T_{c1}(j) + \Delta T_{c1c}$$

$$h_{c2} = f(P_{c2}, T_{c2})$$

$$T_{sump}(j) = f(P_{sump}, h_{c2})$$

$$T_{c2}(j) = f(P_{c2}, h_{c2}) + 1728$$

$$P_{c1} = f(P_{c1}, h_1) + 1728$$

$$P_{c2} = f(P_{c2}, h_2) + 1728$$

$$P_s = f(P_s, h_{c2}) + 1728$$

$$P_x = f(P_x, h_{c2}) + 1728$$

$$P_c = f(P_{c1} + P_{c2}) / 2$$

J = J + 1

F

0

$$F_{12} = 1.0472 \cdot (R_1 - R_2) \cdot (3 \cdot P_{c2} (R_1 + R_2) + (P_{c1} - P_{c2}) \cdot (2R_1 + R_2)) + 7 \cdot P_s (R_2^2 - R_1^2)$$

$$P_1 = P_{c1}$$

$$P_2 = P_s$$

$$P_x = P_x$$

$$P_c = 0.5 \cdot (P_{c1} + P_{c2})$$

$$WSTAR = W$$

$$I = I + 1$$

J - K

J = 1

$$(df/dx)_j = \frac{F_{j+1} - F_j \cdot 12}{X_{j+1} - X_j}$$

$$W_{1j} = \sqrt{9 \cdot (df/dx)_j} / Wrot$$

$$V_{1j} = A_p \cdot C_{1j}$$

$$a_{c1j} = f(P_{c1j}, T_{1j})$$

$$a_{s_j} = f(P_{s_j}, T_{s_j})$$

$$F_{s_{1j}} = \frac{P_{s_{1j}} \cdot a_{c1j}^2}{4630}$$

$$T_{s_{1j}} = \frac{P_{s_{1j}} \cdot a_{s_j}}{4630}$$

(10) ↓



$$K_s = 1 - \frac{E_{SSJ}}{P_{C2} - P_{S2}}$$

$$K_c = 1 - \frac{E_{C10}}{P_1 - P_{C1}}$$

$$\mu = \frac{(p_1 - p_{c1}) / (p_{s2} - p_{c2})}{(p_1 - p_{c1}) / (p_{c2} - p_{c1})}$$

$$\lambda = \frac{(p_1 - p_{c1}) / (p_{c2} - p_{c1})}{(p_1 - p_{c1}) / (p_{s2} - p_{c2})}$$

$$\sigma_j = \frac{p - x}{x}$$

$$E_{SSJ} = \left[\frac{1}{1} + \left(\frac{E_{SSJ}}{1} - \frac{E_{SSJ}}{1} \right) \cdot \left(\frac{1 + \frac{w \cdot P_s \cdot V_3}{1728 \cdot W}}{1} \right)^2 \right]^{-1}$$

$$E_{C10} = \left[\frac{1}{1} + \left(\frac{E_{C10}}{1} - \frac{E_{C10}}{1} \right) \cdot \left(\frac{1 + \frac{w \cdot P_s \cdot V_3}{1728 \cdot W}}{1} \right)^2 \right]^{-1}$$

$$E_{SSJ} = \frac{10}{10} = 1 - V_5 \cdot V_{S4} \cdot V_5$$

$$V_5 = 1 / P_{S2}$$

$$V_{S2} = f(p_{c2}, h_{c2})$$

$$V_{S4} = f(p_{S4}, h_{c2})$$

$$P_{S2} = p_5 - \delta_1$$

$$P_{S4} = p_5 + \delta_1$$

$$E_{C10} = \frac{10}{10} = 1 - V_{c1} \cdot V_{c1H} - V_{c1L}$$

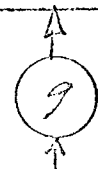
$$V_{c1} = 1 / P_{C1}$$

$$V_{c1L} = f(p_{c1L}, h_1)$$

$$V_{c1H} = f(p_{c1H}, h_1)$$

$$P_{c1L} = p_{c1} - \delta_1$$

$$P_{c1H} = p_{c1} + \delta_1$$



$$C_{11} = 1 + \Omega$$

$$C_{21} = P_{4m} \cdot A_p \cdot \bar{x} / (w \cdot 1728)$$

$$C_{31} = K_{c1} + \Lambda_1$$

$$C_{41} = \frac{P_{c1} \cdot V_c}{1728 \cdot w} \cdot \frac{2(P_1 - P_{c1})}{E E_{s1m}}$$

$$C_{51} = |\Lambda_1 \cdot K_{s1}|$$

$$C_{61} = |\Omega|$$

$$C_{71} = \frac{P_{s1} \cdot A_s \cdot \bar{x}_1}{w_1 \cdot 1728}$$

$$C_{81} = \Lambda_1 \cdot K_s + \mu_1$$

$$C_{91} = \frac{P_{s1} \cdot V_s}{1728 \cdot w_1} \cdot \frac{2(P_1 - P_{c1})}{E E_{s1}}$$

$$C_{101} = |\Lambda_1|$$

$$K_{p1} = C_{21} / C_{41}$$

$$\omega_1^2 = \frac{C_{11} \cdot C_{81} - C_{51} \cdot C_{61}}{C_{21} \cdot C_{91}}$$

$$2 \cdot S_{\omega_1} = \frac{C_{11} \cdot C_{91} + C_{21} \cdot C_{81} + C_{51} \cdot C_{61}}{C_{21} \cdot C_{91}}$$

$$\omega_2^2 = \frac{C_{31} \cdot C_{81} - C_{101} \cdot C_{51}}{C_{41} \cdot C_{91}}$$

$$2 \cdot S_{\omega_2} = \frac{C_{41} \cdot C_{81} + C_{31} \cdot C_{91}}{C_{41} \cdot C_{91}}$$

$$K_{s1} = C_{71} / C_{91}$$

$$\omega_3^2 = \frac{C_{11} \cdot C_{101} - C_{31} \cdot C_{61}}{C_{41} \cdot C_{71}}$$

$$2 \cdot S_{\omega_3} = \frac{C_{21} \cdot C_{101} + C_{31} \cdot C_{71} - C_{101} \cdot C_{61}}{C_{41} \cdot C_{71}}$$

STOP

ROOT LOCUS METHOD

$$P_2 = 2\sigma \cdot A_p (p_1 - p_{cm}) \cdot X \cdot Z_{c2} \cdot \sin \psi_{c2} \cdot \epsilon_2^2$$

$$P_3 = 2\sigma \cdot A_s (p_1 - p_{cm}) \cdot X \cdot Z_{s2} \cdot \sin \psi_{s2} \cdot \epsilon_2^2$$

$$Z_{s2} = K_s \cdot \frac{2.5 \cdot 10^3 \cdot \omega}{\omega_{s2}} \cdot \frac{1}{\omega_{s2}} \cdot \left(\frac{1 + 1/\omega_{s2}^2}{1 + \omega_{s2}^2} \right)^{0.5}$$

$$\sin \psi_{s2} = \frac{\omega_{s2} - \omega_{s2}}{\omega_{s2} \cdot \left(\frac{1 + 1/\omega_{s2}^2}{1 + \omega_{s2}^2} \right)^{0.5}}$$

$$\omega_{s2} = \omega_{c2}$$

$$\omega_{s2} = \frac{2.5 \cdot 10^3 \cdot \omega}{\omega_{s2}^2 - \omega^2}$$

$$\omega_{c2} = K_{D2} \cdot \frac{2.5 \cdot 10^3 \cdot \omega}{\omega_{c2}} \cdot \frac{1}{\omega_{c2}} \cdot \left(\frac{1 + 1/\omega_{c2}^2}{1 + \omega_{c2}^2} \right)^{0.5}$$

$$\sin \psi_{D2} = \frac{\omega_{c2} - \omega_{c2}}{\omega_{c2} \cdot \left(\frac{1 + 1/\omega_{c2}^2}{1 + \omega_{c2}^2} \right)^{0.5}}$$

$$\omega_{c2} = \frac{2.5 \cdot 10^3 \cdot \omega}{\omega_{c2}^2 - \omega^2}$$

$$\omega_{c2} = \frac{2.5 \cdot 10^3 \cdot \omega}{\omega_{c2}^2 - \omega^2}$$

NOMENCLATURE INPUT

<u>SYMBOL</u>	<u>NOTE</u>	<u>DESCRIPTION</u>	<u>UNIT</u>	<u>FORMAT</u>
R ₁		Radius High Pressure Orifice	In	F
R ₂		Radius Low Pressure Orifice	In	F
R ₃		Radius Sump	In	F
DELT		Total Travel	In	F
DCL		Cavity Clearance	In	F
VS		Sump Volume	In ³	F
VOLTP		Tip Cavity Volume	In ³	F
P1		Static Pressure, HP orifice Inlet	psia	F
T1		Temperature, HP Orifice Inlet	deg R	F
RHOIN		Initial Inlet Density	lb/ft ³	F
P2		Static Pressure, exit	psia	F
ROEX		Initial exit temperature	lb/ft ³	F
LIM	(1)*	Limit of Increments of Travel (19 max)	-	I
KSTAR	(1)*	Starting Value of X	-	I
NFLAG	(2)*	Flag Defining extent of analysis	-	I
CORF1	(3)*	Orifice Coefficient HP	-	F
CORF2	(3)*	Orifice Coefficient LP	-	F
CLINE	(4)*	Line Loss Coefficient	-	F
RPM		Rotational Speed	rpm	F
WROT		Rotor Weight	lb	F
EPS		Amplitude (~.001)	In	F
CFRIC	(5)*	Disc Friction Coefficient	-	E

*Refer to Instructions.

00101 00101 DIMENSION: XBAR(20), CL(20), PHIN(20), FKC(20), DPC(20), WDOT(20),
 1* 1011(20), PRR(20), ORGA(20), DPL(20), PCL(20), PCL(20), PCL(20), PS(20), PCW(20),
 2* 2CLAMD(20), SMD(20), SLAMS(20), CL(20), C2(20), C3(20), C4(20),
 3* 3CP(20), C7(20), C8(20), C9(20), C10(20),
 4* 4ZL101(20), OMS2(20), ZET2(20),
 5* OMS3(20), ZET3(20), XC(20)
 6* DIMENSION: YC(20), STMP1(20), ZC(20), US(20), VS(20), SIMP2(20), ZS(20),
 7* 1VC(20), CPC(20), CPB(20), F(20), COMEG(20), DFX(20), EFS(20), HCS(20),
 8* STC1(20), PPRIC(20), IC2(20), IC3(20), TX(20), RHOC1(20), RHOC2(20),
 9* DIMOS(20), RHOC(20), ESCL(20), ESS(20), FECL(20),
 10* 4EHS(20), DICI(20), XKX(20), XKXS(20), RHOCM(20), FSCM(20), EHCIM(20),
 11* BELCM(20), SBOUCM(20), CPT(20)
 12* DIMENSION: ART(20), ART(20), S1(20), S1(20), S2(20), S2(20), S3(20),
 00104 00104 1S31(20), S4(20), S4(20), RLK(20), BRK(20), OMCPO(20), GH1(20), TFS(4),
 14* ZTEAP(+), PHIM(20), XMM(20), XMP(20), ZETA(20), TSET(20)
 00105 00105 LN = 5
 16* LN = 6
 17* 10 FORMAT(7E8.3)
 20 FORMAT(5F8.3,2I5)
 30 FORMAT(3F8.3,3E8.1,2E8.4,E8.2)

0000 00454 94F 0000 00454 94F 0000 00454 94F
 0000 R 003545 AVEL 0000 R 003545 A1
 0000 R 003541 AL 0000 R 003541 CL
 0000 R 003535 CORF1 0000 R 003536 CORF2
 0000 R 002564 CPT 0000 R 002565 C1
 0000 R 002570 C5 0000 R 002571 C5
 0000 R 002564 C9 0000 R 002565 C9
 0000 R 002564 DPL 0000 R 002565 DPL
 0000 R 002564 DIFC 0000 R 002565 DIFC
 0000 R 002524 ENCI 0000 R 002524 EHS
 0000 R 002504 ESS 0000 R 002504 F
 0000 R 002504 HI 0000 R 002504 I
 0000 I 003533 KSTAR 0000 I 003533 L
 0000 I 003527 M 0000 I 003527 N
 0000 R 001130 OMS2 0000 R 001130 OMS3
 0000 R 003510 PCL 0000 R 003510 PCL
 0000 R 003500 PHDEMS 0000 R 003500 PSH
 0000 R 003500 PSH 0000 R 003500 PSH
 0000 R 003500 PTDUN 0000 R 003500 P1
 0000 R 003507 CS 0000 R 003507 RHOC
 0000 R 003521 INCEX 0000 R 003521 RHOC
 0000 R 003527 RHOC1 0000 R 003527 RHOC
 0000 R 003572 RLCL 0000 R 003572 RLK
 0000 R 003574 RL2 0000 R 003574 RHR
 0000 R 003516 R1 0000 R 003517 R2
 0000 R 003500 SLAMC 0000 R 003500 SLAMS
 0000 R 002534 S0U5 0000 R 002534 S1
 0000 R 003100 S3 0000 R 003100 S3
 0000 R 002570 TCI 0000 R 002570 TX
 0000 R 002570 TSET 0000 R 002570 VCLM
 0000 R 003523 VCM 0000 R 003524 VCL5
 0000 R 003501 VCL 0000 R 003501 VCLT
 0000 R 003510 VC 0000 R 003511 VCLT
 0000 R 002544 T5 0000 R 002544 T5
 0000 R 003513 T6 0000 R 003513 T6
 0000 R 002544 T7 0000 R 002544 T7
 0000 R 003510 VCL 0000 R 003510 VCL
 0000 R 003517 VCLH 0000 R 003517 VCLT
 0000 R 003500 VSH 0000 R 003500 VSH
 0000 R 002550 XAR 0000 R 002550 XAR
 0000 R 003520 XPR 0000 R 003520 XPR
 0000 R 001274 YC 0000 R 001274 YS
 0000 R 001274 YS 0000 R 001274 YS
 0000 R 001274 ZC 0000 R 001274 ZC
 0000 R 003544 ZETA 0000 R 003544 ZETA


```

00302 80*      FKC(J) = 0.12 * PHITR(J)**0.016*(R1/RMR)**1.434*(R1/CL(J))**0.233
00303 81*      DPC(J) = RHOC * ANVEL**2*FKC(J)**2*(R1**2 - R2**2)/1333740.
00304 82*      WDOT(J) = (.55833*SR1*(DDTOT-DPC(J))/(1./CORF1**2/A1**2/RH01 +
00304 83*      11./CORF2**2/A2 **2/RH02 + 1./CLTHE**2/RHOEX))
00305 84*      DP1(J)=WDOT(J)**2*2.239/(CORF1**2*A1**2*RHO1)
00306 85*      DP2(J)=WDOT(J)**2*2.239/( CORF2**2*A2**2*RHO2)
00307 86*      DPL(J) = WDOT(J)**2*2.239/(CLINE**2*RHOEX)
00310 87*      PC1(J) = P1 - DP1(J)
00311 88*      PC2(J) = PC1(J) - DPC(J)
00312 89*      PS(J) = PC2(J) - DP2(J)
00313 90*      PCN(J) = 0.5*(PC1(J) + PC2(J))
00314 91*      TC1(J) = PTEMP(PC1(J),H1,OC1)
00315 92*      CPC1 = PTEMP(PC1(J),TC1(J))
00316 93*      PERIC(J) = 0.9223E-08* CERIC * RPM**3*(R1**5 - R2**5) * RHOC
00317 94*      DIFRC = 4.707 * PERIC(J)/WDOT(J)/CPC1
00320 95*      TC2(J) = TC1(J) + DIFRC
00321 96*      HC2(J)= PTEMP(PC2(J),TC2(J))
00322 97*      TS(J) = PTEMP(PS(J),HC2(J),QS)
00323 98*      TX(J) = PTEMP(P2,HC2(J),QFX)
00324 99*      RHOC1(J) = PHOENS(PC1(J),H1,RLC1) * 1728.
00325 100*     RHOC2(J) = PHOENS(PC2(J),HC2(J),RLC2)*1728.
00326 101*     RHOS(J) = PHOENS(PS(J),HC2(J),RLS)*1728.
00327 102*     RHOX(J) = PHOENS(P2,HC2(J),RL2) * 1728.
00330 103*     RHOCN(J) = (RHOC1(J) + RHOC2(J))/2.
00331 104*     RHOC = RHOCN(J)
00332 105*     IF (I-1) 114,118,112
00335 106*     114 RH01 = RHOC1(J)
00336 107*     RH02 = RHOS(J)
00337 108*     RHOEX = RHOX(J)
00340 109*     WSTAR = WDOT(J)
00341 110*     I = I + 1
00342 111*     GO TO 102
00343 112*     112 F(J) = 1.5708 * (R1**2 - R2**2) * (PC1(J) + PC2(J))
00343 113*     1 + 3.1417 * PS(J) * (R2**2 - R3**2)
00344 114*     110 CONTINUE
00346 115*     50 FORMAT (/2X,'CAVITY CONDITION'/)
00347 116*     52 FORMAT (9X,'HP GAP',11X,'PC1',12X,'TC1',11X,'RHOC1',11X,'PC2',12X,
00347 117*     1,'TC2',11X,'RHOC2')
00350 118*     54 FORMAT(10X,'XBAR',11X,'PSIA',11X,'DEG R', 9X,'LB/FT**3',8X,'PSIA',
00350 119*     111X,'LEB R', 9X,'LB/FT**3'/)
00351 120*     56 FORMAT(F15.3,F15.2,2F15.3,F15.2,2F15.3/)
00352 121*     WRITE(LW,50)
00354 122*     WRITE(LW,52)
00356 123*     WRITE(LW,54)
00360 124*     WRITE(LW,56) (XBAR(J),PC1(J),TC1(J),RHOC1(J),PC2(J),TC2(J),RHOC2(J)
00360 125*     1),J,KSTAR,LIM)
00374 126*     58 FORMAT (/2X,'SUMP AND EXIT CONDITIONS'/)
00375 127*     60 FORMAT(40X,'SUMP',33X,'EXIT',18X,'FLOW RATE')
00376 128*     62 FORMAT(10X,'XBAR',12X,'PS',13X,'TS',12X,'RHOS',12X,'TX',12X,'RHOX'
00376 129*     1,12X,'WDOT')
00377 130*     64 FORMAT(11X,'IN',12X,'PSIA',10X,'DEG R', 9X,'LB/FT**3',8X,'DEG R',9
00377 131*     1X,'LB/FT**3',9X,'LB/SEC'/)
00400 132*     WRITE(LW,58)
00402 133*     WRITE(LW,60)
00404 134*     WRITE(LW,62)
00406 135*     WRITE(LW,64)
00410 136*     66 FORMAT(F15.3,F15.2,5F15.3/)
00411 137*     WRITE(LW,66) (XPAR(J),PS(J),TS(J),RHOS(J),TX(J),RHOX(J),WDOT(J),J=
00411 138*     1,KSTAR,LIM)
00411 139*     C-SPRING RATE AND FREQUENCY

```

```

00425 140* DO 128 J=KSTAR,LIM
00430 141* DFX(J) = (F(J+1)-F(J))/(XBAR(J+1)-XBAR(J))*12.
00431 142* OMEGA(J) = (32.16 * DFX(J)/XROT) **0.5
00432 143* VC(J) = AP * CL(J) + VOLTP
00434 144* 67 FORMAT(/2X,'SPRING RATE AND FREQUENCY'/)
00435 145* 68 FORMAT(10X,'XBAR',4X,'PRESS FORCE',3X,'SPRING RATE DFX',4X,'FREQUI
00435 146* IENCY',4X,'DISC FRICT',3X,'CAVITY VOL',3X,'FLOW',5X,'K-PRESS')
00436 147* 70 FORMAT( 11X,'IN',12X,'LP',12X,'LB/FT',11X,'OMEGA',12X,'HP',8X,'IN*
00436 148* 1',5',4X,'COEFF',6X,'GRADIENT'/)
00436 149* 72 FORMAT(F15.3,F15.1,F15.5,F15.1,F15.3,F10.3,F10.4,F10.3/)
00440 150* WRITE(LW,67)
00442 151* WRITE(LW,68)
00444 152* WRITE(LW,70)
00446 153* WRITE(LW,72) (XBAR(J),F(J),DFX(J),OMEGA(J),PFRICT(J),VC(J),PHIIN(J)
00446 154* 1,PFIC(J),JEXSTAR,LIM)
00463 155* IF (IFLAG) 31,31,129
00463 156* C-BULK MODULUS
00466 157* DO 159 J=KSTAR,LIM
00471 158* SOUC1(J) = PTSOUH(PC1(J),TC1(J))/12.
00472 159* SOUS(J) = PTSOUH(PS(J),TS(J))/12.
00473 160* ESC1(J) = RHOC1(J) * SOUC1(J)**2/4630.
00474 161* ESS(J) = RHOS(J)*SOUS(J)**2/4630.
00475 162* PC1H = PC1(J) + 5.
00476 163* PC1L = PC1(J) - 5.
00477 164* VC1H = (PHDENS(PC1H,H1,RLC1H) * 1728.)**(-1)
00500 165* VC1L = (PHDENS(PC1L,H1,RLC1L) * 1728.)**(-1)
00501 166* VC1 = 1./RHOC1(J)
00502 167* EHC1(J) = -VC1*10./(VC1H-VC1L)
00503 168* PSH = PS(J) + 5.
00504 169* PSL = PS(J) - 5.
00505 170* VSH=1./ (PHDENS(PSH,H2(J),RLSH) * 1728.)
00506 171* VSL=1./ (PHDENS(PSL,H2(J),RLSL) * 1728.)
00507 172* VOLS = 1./RHOS(J)
00510 173* EHS(J)=-VOLS* 10./(VSH-VSL)
00511 174* TCM = (TC1(J) + TC2(J))/2.
00512 175* HCM = PTERTH(PCM(J),TCM)
00513 176* SOUCH(J) = PTSOUH(PCM(J),TCM)/12.
00514 177* ESCM(J) = RHOCM(J) * SOUCH(J)**2/4630.
00515 178* PCMH = PCM(J) + 5.
00516 179* PCML = PCM(J) - 5.
00517 180* VCMH = 1./ (PHDENS(PCMH,HCM,RLCMH) * 1728.)
00520 181* VCML = 1./ (PHDENS(PCML,HCM,RLCML) * 1728.)
00521 182* VCM = 1./ RHOCM(J)
00522 183* EHCM(J) = -VCM * 10./(VCMH - VCML)
00523 184* ELCM(J) = (1./ESCM(J) + (1./EHC1(J) - 1./ESCM(J))*1./((1. + (OMEGA(J)
00523 185* 1J) + RHOCM(J) * VC(J)/1728./VDOT(J)**2)**(-1)
00524 186* EEC1(J) = (1./ESC1(J) + (1./EHC1(J)-1./ESC1(J))*1./((1.+(OMEGA(J)
00524 187* 1*RHOC1(J)*VC(J)/1728./VDOT(J)**2)**(-1)
00525 188* 130 EES(J) = (1./ESS(J) + (1./EHS(J) - 1./ESS(J))*1./((1.+(OMEGA(J)*
00525 189* 1RHOS(J) * VS /1728./VDOT(J)**2)**(-1)
00527 190* 80 FORMAT (/2X,'BULK MODULUS, PSI'/)
00530 191* 82 FORMAT(10X,'XBAR',3X,'SOUND VEL',11X,'CAVITY C',18X,'SOUND VEL',1
00530 192* 13X,'SUMP')
00531 193* 84 FORMAT(11X,'IN',6X,'F1/S',6X,'E(S)',6X,'E(H)',6X,'E(E)',10X,'FT/S'
00531 194* 1,7X,'L(S)',6X,'E(h)',6X,'E(e)'/)
00532 195* 86 FORMAT(F15.3,F10.1,F15.1,F10.1/)
00533 196* WRITE(LW,80)
00535 197* WRITE(LW,82)
00537 198* WRITE(LW,84)
00537 198* (XBAR(J),SOUC1(J),ESC1(J),EHC1(J),EEC1(J),SOUS(J),

```

```

00541 200*      1EES(J),EES(J),EES(J),J=KSTAR,LIM)
00547 201*      315 FORMAT(/10X,'XBAR',3X,'SOUND VEL',7X,'MEAN CAVITY')
00548 202*      312 FORMAT(11X,'1E',6X,'FT/S',6X,'E(S)',6X,'F(H)',6X,'E(E)')
00549 203*      314 FORMAT(F15.3,F10.1/)
00549 203*      WRITE(LW,310)
00549 203*      WRITE(LW,312)
00549 206*      WRITE(LW,314) (XBAR(J),SOUNCM(J),ESCM(J),EHCH(J),ECCM(J),J=KSTAR,L
00549 207*      IM)
00549 208*      C-COEFFICIENTS
00549 209*      DO 140 J=KSTAR,LIM
00549 210*      COMEG(J) = XBAR(J)/(DELTA-XBAR(J))
00549 211*      CLAMD(J) = (P1-PC1(J))/(PC2(J)-PS(J))
00549 212*      SMU(J) = (P1-PC1(J))/(PS(J)-P2)
00549 213*      SLAMC(J) = 1.- (P1-PC1(J))/ECC1(J)
00549 214*      SLAMS(J) = 1.- (PC2(J)-PS(J))/EES(J)
00549 215*      C1(J) = 1.+ COMEG(J)
00549 216*      C2(J) = RHOCM(J)*AP*XBAR(J)/WDOT(J)/1728.
00549 217*      C3(J) = SLAMC(J) + CLAMD(J)
00549 218*      C4(J) = RHOCM(J) * VC(J) /WDOT(J)/1728. *2.*(P1-PC1(J))/ECCM(J)
00549 219*      C5(J) = APS(CLAMD(J)*SLAMS(J))
00549 220*      C6(J) = APS(COMEG(J))
00549 221*      C7(J)=RHOS(J) * AS * XBAR(J)/WDOT(J)/1728.
00549 222*      C8(J) = CLAMD(J) + SLAMS(J) + SMU(J)
00549 223*      C9(J)=RHOS(J)* VS/WDOT(J)/1728. * 2.*(P1-PC1(J))/EES(J)
00549 224*      140 C10(J) = APS(CLAMD(J))
00549 225*      73 FORMAT(/2X,'COEFFICIENTS')
00549 226*      74 FORMAT(10X,'XBAR',7X,'CAP OMEGA',6X,'CAP LAMBDA',9X,'SMU',10X,'LAM
00549 227*      BDA C',7X,'LAMBDA S')
00549 228*      76 FORMAT(11X,'1E',10X,'COMEG',9X,'CLAMD')
00549 229*      78 FORMAT(F15.3,F15.4/)
00549 230*      WRITE(LW,73)
00549 231*      WRITE(LW,74)
00549 232*      WRITE(LW,76)
00549 233*      WRITE(LW,78) (XBAR(J),COMEG(J),CLAMD(J),SMU(J),SLAMC(J),SLAMS(J),J
00549 234*      =KSTAR,LIM)
00549 235*      88 FORMAT(/2X,'COEFFICIENTS')
00549 236*      90 FORMAT(10X,'XBAR',6X,'C1',8X,'C2',8X,'C3',8X,'C4',8X,'C5',8X,'C6',
00549 237*      18X,'C7',8X,'C8',8X,'C9',8X,'C10')
00549 238*      92 FORMAT(F15.3,F8.4,E12.3,F10.4,E12.3,F10.4,F8.4,E12.3,F10.4,F10.6,
00549 239*      1F8.3/)
00549 240*      WRITE(LW,88)
00549 241*      WRITE(LW,90)
00549 242*      WRITE(LW,92) (XBAR(J),C1(J),C2(J),C3(J),C4(J),C5(J),C6(J),C7(J),
00549 243*      C8(J),C9(J),C10(J),J=KSTAR,LIM)
00549 244*      DO 150 J=KSTAR,LIM
00549 245*      XKP(J) = C2(J)/C4(J)
00549 246*      COMEG1(J) = (C1(J)*C8(J) - C5(J)*C6(J))/(C2(J)+C9(J))
00549 247*      ZET01(J) = (C1(J) * C9(J) + C2(J)*C8(J)+C7(J)*C5(J))/(C2(J)*C9(J))
00549 248*      COMEG2(J) = (C3(J)*C8(J) - C10(J)*C5(J))/(C4(J)*C9(J))
00549 249*      ZET02(J) = (C4(J)*C8(J) + C3(J)*C9(J))/ (C4(J)*C9(J))
00549 250*      XKS(J) = C7(J)/C9(J)
00549 251*      COMEG3(J) = (C1(J)*C10(J) - C3(J)*C6(J))/(C4(J)*C7(J))
00549 252*      150 ZET03(J) = (C2(J)*C10(J) + C3(J)*C7(J) -C4(J)*C6(J))/(C4(J)*C7(J)
00549 253*      1)
00549 254*      93 FORMAT(/2X,'INTERMEDIATE VALUES')
00549 255*      94 FORMAT(10X,'XBAR',6X,'KP',6X,'OMEGA1**2',6X,'ZETO1',6X,'OMEGA2**
00549 256*      12',6X,'ZETO12',7X,'KS',7X,'OMEGA3**2',6X,'ZETO13')
00549 257*      96 FORMAT(F15.3,F10.4,E13.4,F13.4,E13.4/)
00549 258*      WRITE(LW,93)
00549 259*      WRITE(LW,94)

```

```

00722 260* WRITE(LW,56) (XPAR(J),XKP(J),OMSQ1(J),ZETO1(J),OMSQ2(J),ZETO2(J),
00723 261* 1AKS(J),OMSQ3(J),ZETO3(J),J=KSTAR,LIM)
00740 262* DO 160 J=1,LIM
00743 263* EPS = AP/XKP(J)
00744 264* XC(J) = ZETO1(J)*OMEGA(J)/(OMSQ1(J) - OMEGA(J)**2)
00745 265* YC(J) = ZE(O2(J)*OMEGA(J)/(OMSQ2(J)-OMEGA(J)**2)
00746 266* SINP1(J)=(XC(J)-YC(J))/SQRT((1.+XC(J)**2)*(1.+YC(J)**2))
00747 267* ZC(J) =XKP(J)+ZETO1(J)/ZETO2(J)*YC(J)/YC(J)*SQRT((1.+XC(J)**2)/(1.
00747 268* 1+YC(J)**2))
00750 269* US(J) = ZETO3(J)*OMEGA(J)/(OMSQ3(J)-OMEGA(J)**2)
00751 270* YS(J) = YC(J)
00752 271* SINP2(J)=(US(J)-YS(J))/SQRT((1.+US(J)**2)*(1.+YS(J)**2))
00753 272* ZS(J) =XKS(J)+ZETO3(J)/ZETO2(J)*YS(J)/US(J)*SQRT((1.+US(J)**2)/(1.
00753 273* 1+YS(J)**2))
00754 274* CPC(J)=6.2834*AP*(P1-PCM(J))* XBAR(J)*EPS**2 * ZC(J) * SINP1(J)
00755 275* CPS(J) = 6.2834 *AS*(P1-PCM(J))*XBAR(J)*EPS**2*ZS(J)*SINP2(J)
00756 276* 160 CPT(J) = CPC(J) + CPS(J)
00760 277* 299 FORMAT(/2X,'INTERMEDIATE VALUES'/)
00761 278* 300 FORMAT(10X,'XBAR',6X,'X',8X,'YC',7X,'SIN(PST1)',4X,'ZC1',7X,'U',8X
00761 279* 1,'YS',6X,'SIN(PST2)',4X,'ZS2'/)
00762 280* 302 FORMAT(F15.3,3F10.4/)
00763 281* WRITE(LW,299)
00765 282* WRITE(LW,300)
00767 283* WRITE(LW,302) (XBAR(J),XC(J),YC(J),SINP1(J),ZC(J),US(J),YS(J),
00767 284* 1SINP2(J),ZS(J),J=KSTAR,LIM)
01005 285* 304 FORMAT(/2X,'STABILITY PARAMETER'/)
01006 286* 320 FORMAT(/32X,'WORK PER CYCLE'/)
01007 287* 306 FORMAT(10X,'XBAR',9X,'CPC', 1NLR',6X,'CPS', 1NLR',6X,'CPT', 1NLR'/)
01010 288* 308 FORMAT(F15.3,3F15.4/)
01011 289* WRITE(LW,304)
01013 290* WRITE(LW,306)
01015 291* WRITE(LW,308)
01017 292* WRITE(LW,302) (XBAR(J),CPC(J),CPS(J),CPT(J),J=KSTAR,LIM)
01017 293* C-ROOTS
01030 294* DO 180 J=KSTAR,LIM
01033 295* RPT(J) = ZETO1(J)/2./((1.+AS*XKS(J)/AP/XKP(J))*(1.+AS*XKS(J)/AP/XKP
01033 296* 1(J)+ZETO3(J)/ZETO1(J))
01034 297* ART(J)=OMSQ1(J)/(1.+AS*XKS(J)/AP/XKP(J))*(1.+AS*XKS(J)/AP/XKP(J)*
01034 298* 1OMSQ3(J)/OMSQ1(J))
01035 299* RT12 = ART(J)**2 - ART(J)
01035 300* IF(RT12) 172,170,170
01041 301* 170 S1(J) = -ART(J) + SQRT(RT12)
01042 302* S2(J) = -ART(J) - SQRT(RT12)
01043 303* S1I(J) = 0
01044 304* S2I(J) = 0
01045 305* GO TO 174
01046 306* 172 S1(J) = -ART(J)
01047 307* S2(J) = S1(J)
01050 308* S1I(J) = SQRT(ABS(RT12))
01051 309* S2I(J) = -S1I(J)
01052 310* 174 RT34 = (ZETO2(J)/2.)**2 - OMSQ2(J)
01053 311* IF(RT34) 170,176,176
01056 312* 176 S3(J) =-ZETO2(J)/2.+SQRT(RT34)
01057 313* S4(J) =-ZETO2(J)/2.-SQRT(RT34)
01060 314* S3I(J) = 0
01061 315* S4I(J) = 0
01062 316* GO TO 179
01063 317* 178 S3(J) = -ZETO2(J)/2.
01064 318* S4(J) = S3(J)
01065 319* S3I(J) = SQRT(ABS(RT34))

```

```

01066 320*      S4I(J) = SQRT(ABS(PT34))
01067 321* 179 CONTINUE
01070 322* 180 CONTINUE
01072 323* 322 FORMAT( /2X,'ROOTS'/)
01073 324* 324 FORMAT( 10X,'XBAR',12X,'ROOT S1',10Y,'ROOT S2',19X,'ROOT S3',19X,
01073 325* 1'ROOT S4')
01074 326* 326 FORMAT( 11X,'IN', 9X,'REAL',7X,'IMAG',11X,'REAL',7X,'IMAG',11X,
01074 327* J,'REAL',7X,'IMAG',11X,'REAL',7X,'IMAG'/)
01075 328* 328 FORMAT(F15.4,E10.4,E12.4,E14.4,E12.4,E14.4,E12.4,E14.4,E12.4/)
01076 329*      WRITE(LW,329)
01100 330*      WRITE(LW,329)
01102 331*      WRITE(LW,329)
01104 332*      WRITE(LW,329) (XBAR(J),S1(J),S1I(J),S2(J),S2I(J),S3(J),S3I(J),
01104 333* 1S4(J),S4I(J),J=KSTAR,LIN)
01104 334* C-ROOT LOCUS METHOD
01122 335* 329 FORMAT(/2X,'ROOT LOCUS METHOD'/)
01123 336* 330 FORMAT(10X,'XBAR',4X,'ROOT LOCUS GAIN',2X,'BODIE PLOT GAIN',4X,'MA
01123 337* 10 OPEN',3X,'CROSSOVER FREQU',2X,'PHASE MARGIN')
01124 338* 331 FORMAT(/3X,'NUMBER OF ITERATIONS EXCEEDED'/)
01125 339* 332 FORMAT(11X,'IN',7X,'KRL', 1/S**2',7X,'K', 1/S**2',7X,'LOOP KGHI',4X,
01125 340* 1'OMCRO', RAD/SEC',4X,'PHIM DEG'/)
01126 341* 334 FORMAT(F15.3,E15.5,SF15.4/)
01127 342* DO 198 J=KSTAR,LIN
01132 343* N = 0
01133 344* TES(1) = S1(J)
01134 345* TES(2) = S2(J)
01135 346* TES(3) = S3(J)
01136 347* TES(4) = S4(J)
01137 348* RLK(J) = 772.*(P1-PC1(J))*(AP*YKP(J)+AS*YKS(J))/XPAR(J)/WROT
01140 349* BPK(J) = RLK(J)*S1(J)*S2(J)/S3(J)/S4(J)
01141 350* OMCRO(J) = SQRT(BPK(J))
01142 351* 182 GH1(J) = BPK(J)/OMCRO(J)**2*SQRT((1.-OMCRO(J)**2/S1(J)/S2(J))**2
01142 352* 1+(OMCRO(J)/S1(J)+OMCRO(J)/S2(J))**2)/SQRT((1.-OMCRO(J)**2/S3(J)/S4
01142 353* 2(J))**2 + (OMCRO(J)/S3(J)+OMCRO(J)/S4(J))**2)
01143 354* IF(ABS(GH1(J)-1.)-.01)182,182,194
01146 355* 184 M = 2
01147 356* DO 190 L=1,2
01152 357* IF(OMCRO(J)/ABS(TES(L)) -1.) 190,188,188
01155 358* 188 M = M+1
01156 359* 190 CONTINUE
01160 360* DO 195 L=3,4
01163 361* IF(OMCRO(J)/ABS(TES(L))-1.) 195,194,194
01166 362* 194 M = M+1
01167 363* 195 CONTINUE
01171 364* OMCRO(J) = OMCRO(J) * GH1(J)**(1./M)
01172 365* IF(M=10) 181,181,196
01175 366* 181 N=N+1
01176 367* GO TO 183
01177 368* 196 WRITE(LW,331)
01201 369* 182 DO 197 L=1,4
01204 370* 197 TEMP(L) = OMCRO(J)/ABS(TES(L))
01205 371* 198 PHIM(J) = (ATAN(TEMP(1))+ATAN(TEMP(2))-ATAN(TEMP(3))-ATAN(TEMP(4)))
01205 372* 1*57.296
01210 373*      WRITE(LW,329)
01212 374*      WRITE(LW,329)
01214 375*      WRITE(LW,329)
01216 376*      WRITE(LW,329) (XBAR(J),RLK(J),BPK(J),GH1(J),OMCRO(J),PHIM(J),J=KST
01216 377* 1AR,LIN)

```

```

01234 350*      IF (PHIM(J) .EQ. 201, 203, 205)
01237 361*      201 YPM(J) = 1.E+38
01240 362*      ZETA(J) = -100.
01241 363*      XMP(J) = 1.E+38
01242 364*      TSET(J) = 1.E+38
01243 365*      GO TO 225
01244 366*      203 XMP(J) = 1.E+38
01245 367*      ZETA(J) = 0.
01246 368*      XMP(J) = 2.
01247 369*      TSET(J) = 1.E+38
01250 390*      GO TO 225
01251 391*      205 IF (PHIM(J) .EQ. 211, 213, 215)
01254 392*      211 XMP(J) = 1./SIN(PHIM(J)/57.296)
01255 393*      ZETA(J) = 0.707 * SQRT(1.-SQRT(1. - (SIN(PHIM(J)/57.296))**2))
01256 394*      GO TO 217
01257 395*      213 XMP(J) = 1.
01260 396*      ZETA(J) = 0.707
01261 397*      GO TO 217
01262 398*      215 IF (PHIM(J) .EQ. 221, 221, 223)
01265 399*      221 XMP(J) = 1.
01266 400*      ZETA(J) = 0.707 * SQRT(1.+SQRT(1.-SIN(PHIM(J)/57.296))**2))
01267 401*      GO TO 217
01270 402*      223 YPM(J) = 1.
01271 403*      ZETA(J) = 100.
01272 404*      XMP(J) = 1.
01273 405*      TSET(J) = 1.E+38
01274 406*      GO TO 225
01275 407*      217 CONST = 3.1417 * ZETA(J)/SQRT(1.-ZETA(J)**2)
01276 408*      XMP(J) = 1.+1./2.718**CONST
01277 409*      TSET(J) = 4./ZETA(J)/CONST
01300 410*      225 CONTINUE
01302 411*      336 FORMAT(//2X,'RESPONSE'//)
01303 412*      338 FORMAT(10X,'XAMP',3X,'FREQU RESP AMPL',3X,'STEP RESP AMPL',3X,'DAM
01303 413*      PING',4X,'SETTLING TIME')
01304 414*      340 FORMAT(11X,'1M',6X,'XMP',18X,'XMP',10X,'ZETA',8X,'TSET',SEC//)
01305 415*      342 FORMAT(F15.3,2F15.4,2F15.3/)
01306 416*      WRITE(LP,336)
01310 417*      WRITE(LP,338)
01312 418*      WRITE(LP,340)
01314 419*      WRITE(LP,342) (YBAR(J),XMP(J),XMP(J),ZETA(J),TSET(J),J=KSTAR,LIM)
01326 420*      GO TO 31
01327 421*      999 STOP
01330 422*      END

```

END OF UNIVAC 1106 FORTRAN V COMPILATION. 0 *DIAGNOSTIC* MESSAGE(S)

GEOMETRY

R1, HP ORIF IN 5.600
 R2, LP ORIF IN 2.600
 R3, SUMP IN 1.750
 TOT TRAVEL DELTA, IN .020
 CAVITY CLEAR DCL, IN .030
 SUMP VOL VS, IN**3 4.200
 TIP CAVITY VOL VOLTIP IN**3 .534

FLUID CONDITION, INPUT

STAT PRESSURE P1, PSIA
 TEMPERATURE T1, DEG R
 DENSITY RHOIN LB/FT**3
 STAT PRESSURE P2, PSIA
 DENSITY RHOEX LB/FT**3
 LIMIT X

INPUT PARAMETERS

ORIFICE COEFFICIENTS
 CORF1 CORF2 CLINE
 SPEED RPM
 ROTOR WEIGHT LB
 AMPLITUDE DISC FRIC
 AMP, IN COEFF CFRICT
 1235.00 52.50 4.400 498.00 3.500 18
 .850 .850 .500 24700.0 68.000 .0010 .22-07

CAVITY CONDITION

HP GAP	PC1	PC1	RHOOC1	PC2	PC2	DEG R	RHOOC2
.001	611.46	57.061	3.910	511.43	68.962	2.953	LB/FT**3
.002	656.97	56.773	3.956	546.18	63.583	3.455	LB/FT**3
.003	718.69	56.381	4.018	601.30	61.541	3.665	LB/FT**3
.004	793.81	55.905	4.094	671.09	60.345	3.811	LB/FT**3
.005	874.22	55.394	4.176	746.70	59.540	3.910	LB/FT**3
.006	950.94	54.908	4.245	819.27	58.967	3.997	LB/FT**3
.007	1018.11	54.482	4.301	882.84	58.603	4.065	LB/FT**3
.008	1073.28	53.949	4.347	934.94	58.244	4.114	LB/FT**3
.009	1116.87	53.495	4.384	975.92	58.054	4.147	LB/FT**3
.010	1150.38	53.145	4.412	1007.20	58.068	4.165	LB/FT**3
.011	1175.60	52.882	4.433	1030.52	58.279	4.172	LB/FT**3
.012	1194.29	52.687	4.449	1047.63	58.699	4.167	LB/FT**3

.013	1207.92	52.545	4.459	1060.00	59.368	4.150
.014	1217.71	52.443	4.466	1068.91	60.370	4.118
.015	1224.59	52.371	4.471	1075.42	61.871	4.065
.016	1229.28	52.322	4.475	1080.57	64.226	3.976
.017	1232.31	52.290	4.477	1085.71	68.323	3.814
.018	1234.10	52.272	4.478	1094.19	77.224	3.430

SUMP AND EXIT CONDITIONS

XBAR IN	PS PSIA	SUMP	RHOS LB/FT**3	TX	EXIT	RHOX	FLOW RATE
		TS DEG R		DEG R	LB/FT**3	WDOT LB/SEC	
.001	500.89	68.759	2.934	68.716		2.929	.987
.002	507.62	63.426	3.400	63.370		3.386	1.912
.003	516.90	61.402	3.552	61.345		3.526	2.731
.004	526.75	60.422	3.628	60.387		3.590	3.398
.005	535.15	59.928	3.671	59.913		3.622	3.879
.006	540.70	59.763	3.688	59.759		3.633	4.164
.007	542.96	59.749	3.692	59.747		3.634	4.273
.008	542.25	59.742	3.691	59.740		3.634	4.240
.009	539.30	59.812	3.683	59.805		3.630	4.094
.010	534.86	59.982	3.667	59.965		3.619	3.862
.011	529.61	60.254	3.643	60.225		3.601	3.568
.012	524.05	60.648	3.610	60.606		3.576	3.228
.013	518.58	61.184	3.568	61.130		3.540	2.855
.014	513.47	61.950	3.511	61.888		3.489	2.459
.015	508.93	63.073	3.429	63.014		3.413	2.045
.016	505.08	64.584	3.303	64.529		3.292	1.619
.017	502.01	67.260	3.078	67.211		3.070	1.180
.018	499.79	72.506	2.553	72.467		2.549	.724

SPRING RATE AND FREQUENCY

XBAR	PRESS FORCE	SPRING RATE DFDX	FREQUENCY	DISC FRICT	CAVITY VOL	FLOW	K-PRESS
------	-------------	------------------	-----------	------------	------------	------	---------

IN	LB	LB/FT	OMEGA	HP	IN**3	COEFF	GRADIENT
.001	49681.2	.38762+08	4281.6	56.822	4.321	.0175	.485
.002	52911.3	.55848+08	5139.3	61.018	4.244	.0341	.492
.003	57565.3	.68872+08	5707.2	63.289	4.166	.0490	.498
.004	63304.6	.73789+08	5907.4	65.034	4.089	.0612	.502
.005	69453.7	.70234+08	5763.4	66.609	4.012	.0700	.506
.006	75306.5	.61144+08	5377.5	67.891	3.935	.0756	.509
.007	80401.9	.49821+08	4854.1	68.920	3.857	.0784	.512
.008	84553.7	.38953+08	4292.1	69.707	3.780	.0788	.515
.009	87799.8	.29545+08	3738.0	70.273	3.703	.0772	.518
.010	90261.8	.21887+08	3217.4	70.659	3.625	.0742	.520
.011	92085.8	.15914+08	2743.5	70.888	3.548	.0700	.523
.012	93412.0	.11365+08	2318.4	70.975	3.471	.0648	.525
.013	94359.0	.80101+07	1946.4	70.925	3.394	.0587	.528
.014	95026.5	.55972+07	1627.0	70.722	3.316	.0519	.530
.015	95493.0	.39945+07	1374.5	70.325	3.239	.0443	.532
.016	95825.9	.32428+07	1238.4	69.623	3.162	.0361	.534
.017	96096.1	.40749+07	1388.2	68.306	3.084	.0271	.535
.018	96435.7	.10524+08	2231.0	65.193	3.007	.0173	.535

BULK MODULUS, PSI

XBAR IN	SOUND VEL FT/S	E(S)	CAVITY C1		SOUND VEL		SUMP	
			E(H)	E(E)	FT/S	E(S)	E(H)	E(E)
.001	3317.7	9294.3	3860.8	9287.0	2334.5	3453.7	1563.9	3449.4
.002	3399.0	9870.7	3906.3	9848.7	2723.5	5446.8	2369.9	5432.6
.003	3507.0	10674.1	3968.1	10630.4	2981.2	6367.9	2635.5	6340.4
.004	3634.8	11683.3	4043.2	11606.3	2966.1	6894.4	2774.8	6851.3
.005	3749.5	12679.2	4123.6	12554.2	3014.2	7202.7	2850.2	7141.0
.006	3854.3	13619.2	5058.8	13473.7	3034.8	7335.8	2878.1	7252.6
.007	3919.5	14270.2	5126.0	14061.1	3039.9	7367.7	2882.0	7260.0
.008	3986.2	14919.5	5181.2	14626.0	3038.9	7362.3	2882.3	7227.8

.009	4039.5	15449.6	5224.7	15054.6	3029.1	7298.9	2870.0	7136.5
.010	4080.0	15862.1	5258.3	15350.1	3010.3	7176.8	2842.4	6987.0
.011	4110.3	16175.6	5283.5	15534.9	2982.6	6999.4	2800.3	6784.5
.012	4132.6	16409.4	5302.1	15633.1	2945.8	6766.8	2741.7	6531.3
.013	4148.7	16577.4	6123.4	15839.3	2899.2	6477.9	2665.5	6230.1
.014	4160.3	16696.9	6133.1	15872.6	2837.1	6103.6	2561.9	5857.3
.015	4168.5	16781.0	6139.9	15937.0	2751.1	5605.9	2419.3	5386.7
.016	4174.0	16838.3	6144.6	16140.4	2636.1	4957.9	2213.1	4804.1
.017	4177.6	16875.5	6147.7	16552.2	2439.8	3957.0	1777.0	3896.0
.018	4179.7	16897.4	6149.5	16846.4	2115.2	2467.0	1162.3	2459.4

XBAR IN	SOUND VEL FT/S	MEAN CAVITY E(S)	E(H)	E(E)
.001	2873.8	6120.1	2562.8	6113.9
.002	3125.4	7817.4	3464.3	7801.0
.003	3285.5	8956.9	3680.4	8922.9
.004	3439.6	10086.9	3814.4	10024.7
.005	3583.9	11215.9	3912.1	11109.8
.006	3695.0	12151.4	3997.8	11986.0
.007	3787.3	12959.6	4911.4	12775.2
.008	3851.4	13554.6	4969.8	13296.0
.009	3900.9	14018.1	5011.6	13670.4
.010	3935.9	14349.1	5032.8	13899.2
.011	3958.7	14562.9	5038.8	14001.6
.012	3971.2	14673.3	5030.8	13996.2
.013	3974.5	14686.7	5008.3	13901.4
.014	3968.5	14600.1	4969.0	13733.4
.015	3951.6	14395.0	4906.3	13520.8
.016	3919.1	14017.6	4807.6	13309.3
.017	3856.8	13318.2	4636.3	13001.0

.018 3706.2 11730.9 4255.4 11685.3

COEFFICIENTS

XBAR IN	CAP OMEGA COMEG	CAP LAMBDA CLAMD	SMU	LAMBDA C	LAMBDA S
.001	.0526	59.1410	215.8410	.9329	.9969
.002	.1111	14.9919	60.0628	.9413	.9929
.003	.1765	6.1176	27.3187	.9514	.9867
.004	.2500	3.0566	15.3449	.9620	.9789
.005	.3333	1.7054	9.7112	.9713	.9704
.006	.4286	1.0197	6.6524	.9789	.9616
.007	.5385	.6381	4.8241	.9846	.9532
.008	.6667	.4118	3.6546	.9889	.9457
.009	.8182	.2705	2.8602	.9922	.9388
.010	1.0000	.1792	2.2955	.9945	.9324
.011	1.2222	.1186	1.8793	.9962	.9262
.012	1.5000	.0778	1.5628	.9974	.9198
.013	1.8571	.0500	1.3160	.9983	.9131
.014	2.3333	.0311	1.1175	.9989	.9052
.015	3.0000	.0184	.9524	.9993	.8948
.016	4.0000	.0099	.8088	.9996	.8802
.017	5.6667	.0046	.6715	.9998	.8502
.018	9.0000	.0015	.5061	.9999	.7583

COEFFICIENTS

XBAR	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
.001	1.0526	.156-03	60.0738	.177-02	58.9602	.0526	.200-04	274.8012	.002613	59.141
.002	1.1111	.173-03	15.9332	.705-03	14.8855	.1111	.239-04	74.9484	.000920	14.992
.003	1.1765	.189-03	7.0690	.392-03	6.0362	.1765	.262-04	33.3549	.000515	6.118
.004	1.2500	.208-03	4.0185	.242-03	2.9922	.2500	.287-04	18.3371	.000334	3.057
.005	1.3333	.233-03	2.6767	.157-03	1.6549	.3333	.318-04	11.3662	.000232	1.705

.006	1.4286	.266-03	1.9986	.107-03	.9806	.4286	.357-04	7.6329	.000169	1.020
.007	1.5385	.306-03	1.6227	.742-04	.6063	.5385	.407-04	5.4324	.000125	.638
.008	1.6667	.357-03	1.4008	.531-04	.3894	.6667	.468-04	4.0440	.000095	.412
.009	1.8182	.419-03	1.2627	.386-04	.2540	.8182	.544-04	3.1142	.000072	.271
.010	2.0000	.497-03	1.1736	.284-04	.1670	1.0000	.638-04	2.4625	.000056	.179
.011	2.2222	.593-03	1.1148	.210-04	.1098	1.2222	.755-04	1.9891	.000043	.119
.012	2.5000	.716-03	1.0751	.156-04	.0715	1.5000	.902-04	1.6344	.000034	.078
.013	2.8571	.877-03	1.0483	.115-04	.0457	1.8571	.109-03	1.3617	.000026	.050
.014	3.3333	.109-02	1.0300	.843-05	.0222	2.3333	.134-03	1.1456	.000020	.031
.015	4.0000	.140-02	1.0177	.602-05	.0164	3.0000	.169-03	.9689	.000016	.018
.016	5.0000	.187-02	1.0096	.411-05	.0088	4.0000	.220-03	.8175	.000012	.010
.017	6.6667	.267-02	1.0045	.260-05	.0029	5.6667	.298-03	.6754	.000009	.005
.018	10.0000	.440-02	1.0015	.147-05	.0012	9.0000	.427-03	.5073	.000006	.002

INTERMEDIATE VALUES

XBAR	KP	OMEGA1**2	2ZETOM1	OMEGA2**2	2ZETOM2	KS	OMEGA3**2	2ZETOM3
.001	.0877	.7041+09	.1148+06	.2809+10	.1390+06	.0077	.1667+10	.2906+06
.002	.2458	.5117+09	.9011+05	.1496+10	.1041+06	.0260	.8825+09	.1720+06
.003	.4809	.3929+09	.7266+05	.9843+09	.8281+05	.0509	.5780+09	.1235+06
.004	.8589	.3192+09	.6211+05	.7980+09	.7147+05	.0859	.4053+09	.9933+05
.005	1.4831	.2696+09	.5560+05	.7557+09	.6594+05	.1369	.2764+09	.8607+05
.006	2.4865	.2341+09	.5143+05	.7917+09	.6398+05	.2119	.1573+09	.7770+05
.007	4.1305	.2089+09	.4896+05	.9053+09	.6517+05	.3240	.3581+08	.7347+05
.008	6.7240	.1917+09	.4792+05	.1095+10	.6909+05	.4945	-.9954+08	.7128+05
.009	10.8700	.1797+09	.4781+05	.1383+10	.7575+05	.7519	-.2577+09	.7172+05
.010	17.5071	.1714+09	.4847+05	.1804+10	.8543+05	1.1418	-.4503+09	.7485+05
.011	28.2396	.1663+09	.4984+05	.2415+10	.9884+05	1.7375	-.6928+09	.8123+05
.012	45.9337	.1639+09	.5198+05	.3315+10	.1172+06	2.6625	-.1008+10	.9191+05
.013	75.9971	.1644+09	.5505+05	.4680+10	.1425+06	4.1363	-.1432+10	1.0077+05
.014	129.6000	.1676+09	.5915+05	.6825+10	.1701+06	6.1100	-.1432+10	1.1077+05

.015	232.5178	.1736+09	.6451+05	.1040+11	.2305+06	10.7377	-.2927+10	.1765+06
.016	454.7057	.1835+09	.7193+05	.1699+11	.3149+06	18.5709	-.4422+10	.2481+06
.017	1027.6560	.1914+09	.7959+05	.2978+11	.4635+06	33.9930	-.7309+10	.3834+06
.018	2987.5216	.1827+09	.8277+05	.5478+11	.7611+06	67.6685	-.1434+11	.6702+06

INTERMEDIATE VALUES

XBAR	X	YC	SIN(PHI1)	ZC1	U	YS	SIN(PHI2)	ZS2
.001	.7169	.2133	.4003	.0259	.7550	.2133	.4228	.0055
.002	.9543	.3639	.4014	.1054	1.0328	.3639	.4373	.0205
.003	1.1507	.4966	.3843	.2486	1.2917	.4966	.4360	.0427
.004	1.2907	.5533	.3952	.4571	1.5842	.5533	.4815	.0684
.005	1.3557	.5260	.4359	.7234	2.0399	.5260	.5898	.0926
.006	1.3476	.4511	.4870	1.0234	3.2538	.4511	.7505	.1107
.007	1.2827	.3588	.5347	1.3288	29.1295	.3588	.9291	.1234
.008	1.1870	.2755	.5662	1.6196	-2.5936	.2755	-.9951	-.1452
.009	1.0787	.2068	.5805	1.8945	-.9868	.2068	-.8320	-.2053
.010	.9683	.1533	.5788	2.1630	-.5227	.1533	-.5922	-.3271
.011	.8615	.1126	.5638	2.4424	-.3182	.1126	-.4080	-.5272
.012	.7602	.0821	.5380	2.7548	-.2102	.0821	-.2851	-.8304
.013	.6669	.0593	.5046	3.1329	-.1473	.0593	-.2041	-1.2816
.014	.5833	.0425	.4668	3.6247	-.1079	.0425	-.1494	-1.9631
.015	.5166	.0305	.4317	4.3200	-.0829	.0305	-.1129	-3.0342
.016	.4895	.0230	.4189	5.4206	-.0695	.0230	-.0922	-4.8455
.017	.5832	.0216	.4850	7.5675	-.0728	.0216	-.0941	-8.3673
.018	1.0390	.0310	.6987	13.9730	-.1043	.0310	-.1345	-17.8064

STABILITY PARAMETER

WORK PER CYCLE

XBAR	CPC, INLB	CPS, INLB	CPT, INLB
.001	3.3948	.1151	3.5099

.002	6.5080	.2067	6.7147
.003	8.8931	.2606	9.1537
.004	11.0220	.3018	11.3238
.005	13.0017	.3385	13.3402
.006	14.1140	.3535	14.4675
.007	14.0248	.3402	14.3650
.008	12.8522	.3044	13.1567
.009	11.1914	.2612	11.4526
.010	9.4967	.2209	9.7175
.011	8.0205	.1883	8.2088
.012	6.8401	.1642	7.0043
.013	5.9672	.1484	6.1155
.014	5.3808	.1402	5.5210
.015	5.1311	.1417	5.2728
.016	5.5190	.1631	5.6822
.017	7.9678	.2570	8.2248
.018	18.6621	.6880	19.3500

ROOTS

XBAR IN	ROOT S1		ROOT S2		ROOT S3		ROOT S4	
	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
.0010	-.6477+04	.0000	-.1106+06	.0000	-.2454+05	.0000	-.1145+06	.0000
.0020	-.6065+04	.0000	-.8533+05	.0000	-.1723+05	.0000	-.8682+05	.0000
.0030	-.5856+04	.0000	-.6760+05	.0000	-.1439+05	.0000	-.6842+05	.0000
.0040	-.5618+04	.0000	-.5704+05	.0000	-.1385+05	.0000	-.5762+05	.0000
.0050	-.5319+04	.0000	-.5070+05	.0000	-.1477+05	.0000	-.5117+05	.0000
.0060	-.4985+04	.0000	-.4678+05	.0000	-.1677+05	.0000	-.4722+05	.0000
.0070	-.4636+04	.0000	-.4461+05	.0000	-.2008+05	.0000	-.4510+05	.0000
.0080	-.4296+04	.0000	-.4388+05	.0000	-.2462+05	.0000	-.4447+05	.0000
.0090	-.3973+04	.0000	-.4408+05	.0000	-.3073+05	.0000	-.4502+05	.0000

.0100	-.3670+04	.0000	-.4505+05	.0000	-.3817+05	.0000	-.4726+05	.0000
.0110	-.3388+04	.0000	-.4674+05	.0000	-.4417+05	.0000	-.5467+05	.0000
.0120	-.3126+04	.0000	-.4920+05	.0000	-.4773+05	.0000	-.6944+05	.0000
.0130	-.2880+04	.0000	-.5260+05	.0000	-.5138+05	.0000	-.9108+05	.0000
.0140	-.2646+04	.0000	-.5707+05	.0000	-.5585+05	.0000	-.1222+06	.0000
.0150	-.2421+04	.0000	-.6287+05	.0000	-.6150+05	.0000	-.1690+06	.0000
.0160	-.2195+04	.0000	-.7081+05	.0000	-.6915+05	.0000	-.2457+06	.0000
.0170	-.1949+04	.0000	-.7914+05	.0000	-.7704+05	.0000	-.3865+06	.0000
.0180	-.1605+04	.0000	-.8316+05	.0000	-.8048+05	.0000	-.6807+06	.0000

ROOT LOCUS METHOD

XBAR IN	ROOT LOCUS GAIN KRL, 1/S**2	BODIE PLOT GAIN K, 1/S**2	MAG OPEN LOOP KGH1	CROSSOVER FREQU OMCRO, RAD/SEC	PHASE MARGIN PHIM DEG
.001	.48604+08	.12397+08	1.0015	3761.5641	21.4957
.002	.63319+08	.21901+08	1.0054	5249.8405	23.9971
.003	.73770+08	.29668+08	1.0066	6297.1318	23.5024
.004	.84371+08	.33882+08	.9923	6972.4957	24.4881
.005	.95197+08	.33972+08	1.0087	7120.3950	27.5699
.006	.10461+09	.30813+08	.9904	7048.3027	32.0087
.007	.11362+09	.25958+08	.9944	6556.5781	36.7374
.008	.12058+09	.20762+08	.9960	5856.0737	40.4545
.009	.12648+09	.16015+08	1.0099	5023.5977	42.5077
.010	.13126+09	.12033+08	.9935	4309.3022	43.3900
.011	.13504+09	.88573+07	.9928	3604.5788	42.7428
.012	.13792+09	.63988+07	1.0029	2963.6966	40.9274
.013	.14003+09	.45326+07	1.0084	2423.1989	38.4935
.014	.14148+09	.31307+07	1.0054	1970.1771	35.7001
.015	.14252+09	.20862+07	1.0031	1575.1344	32.4859
.016	.14360+09	.13134+07	1.0016	1225.4713	28.8664
.017	.14363+09	.74407+06	1.0076	902.0369	24.6830

.018 .13220+09 .32207+06 1.0034 584.4755 19.9504

RESPONSE

XBAR IN	FREQU XMM	RESP AMPL	STEP RESP XMP	AMPL	DAMPING ZETA	SETTLING TIME TS, SEC
.001		2.7290		1.5509	.186	.006
.002		2.4589		1.5130	.208	.004
.003		2.5076		1.5203	.204	.003
.004		2.4125		1.5058	.212	.003
.005		2.1606		1.4627	.238	.002
.006		1.8866		1.4062	.276	.002
.007		1.6718		1.3524	.315	.002
.008		1.5412		1.3143	.346	.002
.009		1.4800		1.2947	.362	.002
.010		1.4557		1.2866	.370	.003
.011		1.4734		1.2926	.364	.003
.012		1.5265		1.3097	.350	.004
.013		1.6066		1.3340	.330	.005
.014		1.7137		1.3637	.306	.007
.015		1.8619		1.4005	.280	.009
.016		2.0714		1.4456	.249	.013
.017		2.3947		1.5030	.214	.021
.018		2.9308		1.5756	.173	.040

DATA CARDS IGNORED - FIRST IS LISTED BELOW

N8300R:72-106
May 1972

3. CIRCULAR CROSS SECTION VOLUTE DESIGN

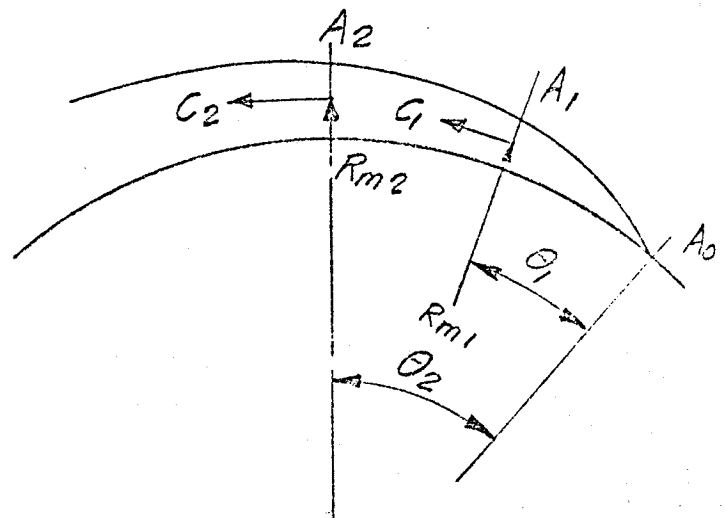
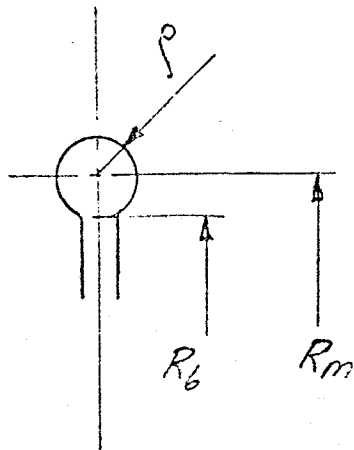
COMPUTER PROGRAM
CIRCULAR CROSS SECTION VOLUTE DESIGN

I. INTRODUCTION

This program presents an incremental method for the design of a classical pump volute with circular cross-sections which are tangent to the volute base circle. Volute area distributions as well as velocity and pressure distributions are calculated and printed out.

This program was primarily devised to determine the percentage increase in cross-sectional area required for the compensation of friction losses in the NERVA turbopump volute which is discussed in Reference 1.

II. BASIC EQUATIONS



The flow rate V in the volute is assumed to be proportional to the wrap angle θ (no back flow, zero cut water clearance flow).

The volute cross sectional area A_2 at the wrap angle θ_2 can then be calculated from the total flow at the volute throat V_{th} :

$$A_2 = \frac{\theta_2}{2\pi} \frac{V_{th}}{C_2} = \pi \rho_2^2 \quad (1)$$

Assuming constant moment of momentum:

$$R_{m1} C_1 = R_{m2} C_2 = K$$

where:

$$R_{m2} = R_6 + \rho_2$$

Thus:

$$C_2 = \frac{K}{R_{m2}} = \frac{K}{R_6 + \rho_2} \quad (2)$$

Substituting C_2 in (1)

$$A_2 = \frac{\theta_2 V_{th}}{2\pi} \frac{R_6 + \rho_2}{K} = \pi \rho_2^2$$

Solving for ρ the quadratic equation can be written as follows:

$$\rho^2 - \frac{\theta_2 V_{th}}{2\pi^2 K} \rho - \frac{\theta_2 V_{th}}{2\pi^2 K} R_6 = 0$$

Let

$$\frac{\theta_2 V_{th}}{2\pi^2 K} = Y$$

then:

$$\rho^2 - Y\rho - YR_6 = 0$$

and

$$\rho = \frac{Y \pm \sqrt{Y^2 + 4 Y R_6}}{2}$$

Friction losses are calculated for the mean cross section of a volute increment:

$$A_m = \frac{A_1 + A_2}{2}$$

$$\rho_m = \left(\frac{A_m}{\Pi}\right)^{0.5}$$

Length of volute increment:

$$L_m = \Delta\theta R_m$$

The friction coefficient is based on the relative surface finish and the empirical relationship established by Nicuradse (Reference 2).

$$\lambda = \frac{1}{(.8685 \ln \left(\frac{\rho_m}{f_s}\right) + 1.74)^2}$$

Friction loss for volute increment

$$\Delta H_{\text{fric}} = \lambda \frac{L_m}{2\rho_m} \frac{C_m^2}{2g}$$

The friction loss is recuperated by an increase in diffusion

$$\Delta H_{\text{fric}} = \Delta H_{\text{vel}}$$

which is achieved by a decrease in velocity or respectively, an increase in area.

Reference 2 - Eckert/Schnell, Axial and Radial Kompressoren, Springer-Verlag 1961

$$\Delta H_{vel} = \frac{C_2^2}{2g} - \frac{C_{2c}^2}{2g}$$

where C_{2c} is the lowered velocity corresponding to the increased or corrected area A_{2c} . From continuity:

$$C_2 A_2 = C_{2c} A_{2c}$$

$$\Delta H_{fric} = \frac{C_2^2}{2g} \left(1 - \left(\frac{C_{2c}}{C_2}\right)^2\right) = \frac{C_2^2}{2g} \left(1 - \left(\frac{A_2}{A_{2c}}\right)^2\right)$$

From this expression the corrected area A_{2c} is:

$$A_{2c} = \frac{A_2}{\left(1 - \frac{2g \Delta H_{fric}}{C_2^2}\right)^{0.5}}$$

// JOB 1

LOG DRIVE CART SPEC CART AVAIL PHY DRIVE

0000 0001 0001 0000

V2 M05 ACTUAL 16K CONFIG 16K

// FOR

*IDCSICARD,TYPEWRITER,KEYBOARD,1403 PRINTER,DISK

*LIST ALL

DIMENSION THET(90),RADN(90),ANC(90),VD(90),CN(90),A(90),RAD(90),
LC(60),HVEL(90),FRIC(90),HFR(90),PS(90),HERI(90)

LR = 2

LW = 5

1 FORMAT(1,1)

2 FORMAT(42X,'VOLUME VELOCITIES + PRESSURE DISTRIBUTION',//)

3 FORMAT(78,3,86,3,13,FR,3)

4 FORMAT(53X,**** INPUT ****//)

5 FORMAT(15X,R6,12X,ALP6,12X,OD,14X,RHD,13X,OMEG,12X,PSEX

1 //)

6 FORMAT(15X,'DLINE',10X,'SFS',13X,'NUM',13X,'BS',//)

7 FORMAT(5X,F15,3//)

8 FORMAT(5X,F15,3,E15,3,115,F15,3//)

9 RAD(LN,3) R6,ALP6,OD,RHD,OMEG,PSEX,DL,SFS,NUM,BS

11 IF (R6) 500,500,11

11 WRITE(LW,1)

WRITE(LW,2)

WRITE(LW,4)

WRITE(LW,5)

WRITE(LW,7) R6,ALP6,OD,RHD,OMEG,PSEX

WRITE(LW,6)

WRITE(LW,8) DL,SFS,NUM,BS

DHT = 360./NUM

VDI = 0.321 * OD

ALP6 = ALP6/57.296

CVOL = 360. * COS(ALPR6)/(BS * SIN(ALPR6))

DD 10 I=2,NUM

10 THET(I) = THET(I-1) + DHT

DD 20 I=1,NUM

RADN(I) = THET(I)/CVOL + SORT(2,*R6 * THET(I)/CVOL)

ANC(I) = 3.14159 * RADN(I)**2

VD(I) = THET(I)/360. * VDI

20 CN(I) = VD(I)/ANC(I)

A(I) = ANC(I)

RAD(I) = RADN(I)

C(I) = CN(I)

HVEL(I) = C(I)**2/64.348

FRIC(I) = 0

HFR(I) = 0

50 N = 0

RXC = (RAD(I-1) + R6) * C(I-1)

CONST = VD(I)/(3.14159 * RXC)

RAD(I) = (CONST + SORT(CONST**2 + 4. * CONST * R6))/2.

A(I) = 3.14159 * RAD(I)**2

STAY = A(I)

17 C(I) = VD(I)/A(I)

RAD(I) = SORT(A(I)/3.14159)

AM = 0.5*(A(I) + A(I-1))

```

RM = R6 + RADM
XLM = RM*DTHT/57.296
CM = (C(1) + C(1-1))/2.
HR(1) = FRIC(1) * XLM * CM**2/(128.696*RADM)
HVEL(1) = C(1)**2/64.348
IF(N) 30,30,32
SAFE = HVEL(1)
30 SAFE = ALL(1)
STAY = ALL(1)
35 ALL = STAY/SORT(1.-HR(1)/HVEL(1))
N = N + 1
GO TO 17
32 HR(1) = (SAFE - HVEL(1) + HR(1))/2.
IF(N-1) 35,35,36
36 IF(1-NUM) 40,42,42
40 I = I + 1
GO TO 50
42 CONTINUE
HR(1) = 0
00 80 I=2,NUM
HR(1) = HR(1-1) + HR(1)
DDEL = DDEL * HVEL(NUM)*RHU/144.
HFI = HR(1*NUM) + OMEG*HVEL(NUM)
AEX = .785*DL**2
VEX = VDI/AEX
HVEL = VEX**2/64.348
PTX = PSEX + HVGX*RHO/144.
PIN = PFX + HFI*RHO/144.
DO 70 I=1,NUM
70 PSI = PIN - (HVEL(1) + HR(1))*RHO/144.
101 FORMAT(9X,THETA,10X,RNC,11X,HCOR,10X,VEL,12X,FRIC,10X,
1 HERT,12X,PSI//)
103 FORMAT(7F15.4)
WRITE(LW,101)
WRITE(LW,102)
WRITE(LW,103) (THET(I),RADN(I),RAD(1),C(1),FRIC(1),HERT(1),PSI),1
1=1,NUM)
120 FORMAT(////20X,FRICION LOSS VOLUTE
1/)
121 FORMAT(20X,FRICION LOSS INCL EXIT DIFUSER
1/)
122 FORMAT(20X,EXIT VELOCITY
1)
123 FORMAT(20X,TOTAL DISCHARGE PRESSURE
1)
124 FORMAT(20X,PRESSURE LOSS, EXIT DIFUSER
1)
WRITE(LW,120) HERT(NUM)
WRITE(LW,121) HFI
WRITE(LW,122) VEX
WRITE(LW,123) PTX
WRITE(LW,124) DPDI
GO TO 9
500 STOP
END

```

VARIABLE ALLOCATIONS
 THETR()=0082-0000
 RADNR()=0166-0084
 ANCR()=021A-0168
 VDR()=02CE-021C
 CNR()=0382-02D0
 ATR()=0436-038A

ALPRBR()=09BF
 CVDLR()=0900
 RXCR()=0902
 CONST()=0904
 STAYR()=0906
 AMR()=0908
 POSKR()=08F2
 DLR()=08FA
 SFSR()=08FB
 O3R()=08FB
 DTHT()=08FA
 VDIR()=08FC
 HERT()=08E6-0834
 ALP6R()=08EA
 O3R()=08EC
 RHO()=08EE
 OMEGR()=08FO
 RADR()=08EA-0434
 CR()=0562-04EC
 HVELR()=0616-0564
 FRICR()=06CA-0618
 HFR()=077E-06CC
 PS1R()=0832-0780
 RADNR()=0166-0084
 ANCR()=021A-0168
 VDR()=02CE-021C
 CNR()=0382-02D0
 ATR()=0436-038A

VOLUTE VELOCITIES & PRESSURE DISTRIBUTION

*** INPUT ***

R6	ALP6	OD	RHD	OMEG	PSEX
8.000	14.300	6230.000	4.450	0.200	1580.000
DLINE	SFS	NUM	B5		
4.750	0.125E-03	J6	0.600		

*** OUTPUT ***

THETA	RNC	RCOR	VEL	FRIC	HFR1	PS
10.0000	0.2649	0.2649	251.8666	0.0000	0.0000	1565.8193
20.0000	0.3772	0.3802	244.5606	0.0135	29.4864	1566.6499
30.0000	0.4643	0.4708	239.2457	0.0128	49.9385	1567.2529
40.0000	0.5384	0.5486	234.9321	0.0124	65.9318	1567.7409
50.0000	0.6062	0.6183	231.2430	0.0121	79.1969	1568.1569
60.0000	0.6641	0.6821	227.9889	0.0118	90.5940	1568.5222
70.0000	0.7195	0.7416	225.0593	0.0116	100.6198	1568.8498
80.0000	0.7713	0.7975	222.3829	0.0115	109.5898	1569.1477
90.0000	0.8203	0.8506	219.9113	0.0113	117.7176	1569.4216
100.0000	0.8669	0.9014	217.6092	0.0112	125.1567	1569.6755
110.0000	0.9114	0.9501	215.4505	0.0111	132.0197	1569.9123
120.0000	0.9541	0.9971	213.4148	0.0110	138.3931	1570.1345
130.0000	0.9952	1.0425	211.4864	0.0109	144.3446	1570.3442
140.0000	1.0349	1.0866	209.6523	0.0108	149.9283	1570.5427
150.0000	1.0734	1.1295	207.9019	0.0107	155.1881	1570.7312
160.0000	1.1108	1.1712	206.2267	0.0106	160.1603	1570.9106
170.0000	1.1471	1.2120	204.6192	0.0106	164.8751	1571.0820
180.0000	1.1825	1.2519	203.0733	0.0105	169.3560	1571.2460
190.0000	1.2171	1.2909	201.5836	0.0105	173.6309	1571.4035
200.0000	1.2509	1.3292	200.1453	0.0104	177.7126	1571.5549
210.0000	1.2839	1.3668	198.7545	0.0104	181.6193	1571.7006
220.0000	1.3163	1.4037	197.4076	0.0103	185.3655	1571.8413
230.0000	1.3480	1.4401	196.1014	0.0103	188.9636	1571.9768
240.0000	1.3791	1.4758	194.8333	0.0102	192.4246	1572.1079
250.0000	1.4097	1.5110	193.6006	0.0102	195.7583	1572.2348
260.0000	1.4398	1.5457	192.4013	0.0101	198.9736	1572.3579
270.0000	1.4694	1.5800	191.2331	0.0101	202.0782	1572.4770
280.0000	1.4985	1.6138	190.0943	0.0100	205.0796	1572.5930
290.0000	1.5271	1.6472	188.9834	0.0100	207.9838	1572.7055
300.0000	1.5554	1.6802	187.8966	0.0100	210.7969	1572.8149
310.0000	1.5832	1.7128	186.8387	0.0099	213.5241	1572.9213
320.0000	1.6107	1.7450	185.8023	0.0099	216.1704	1573.0251
330.0000	1.6378	1.7770	184.7883	0.0099	218.7399	1573.1259

FRICTION LOSS VOLUTE = 226.028 FT
FRICTION LOSS INCL EXIT DIFFUSER = 428.834 FT
EXIT VELOCITY = 1121911 FT/S
TOTAL DISCHARGE PRESSURE = 1586.122 PSI
PRESSURE LOSS, EXIT DIFFUSER = 3.176 PSI

N8300R:72-106
May 1972

4. INDUCER AND IMPELLER PERFORMANCE PROGRAM

COMPUTER PROGRAM

INDUCER AND IMPELLER PERFORMANCE PROGRAM

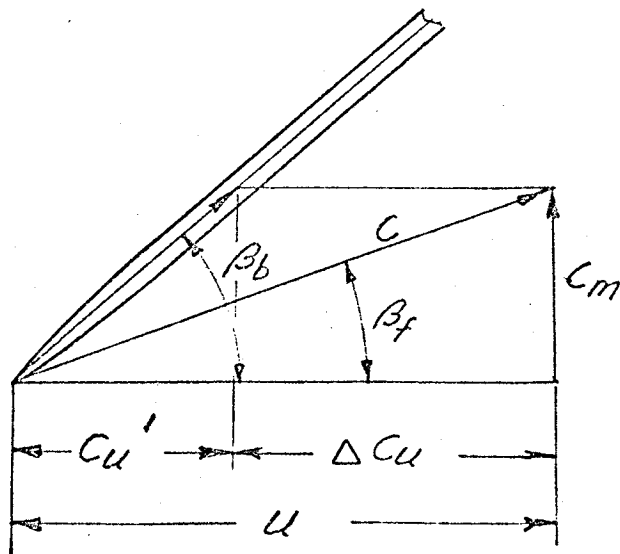
I. INTRODUCTION

A detailed loss analysis calculating incidence, friction, diffusion, discharge, blade clearance and labyrinth flow losses of inducers and impellers of arbitrary geometry is presented. Actual and ideal head coefficients, efficiency and power losses resulting from disk friction are printed out.

II. BASIC CALCULATIONS

A. Incidence Losses

It is assumed that a specified percentage of the velocity head based on the difference in tangential velocity component ΔC_{u_m} is lost.



$$\Delta C_u = C_m (\cot \beta_f - \cot \beta_b)$$

If K_i is the incidence loss factor based on the inlet mean diameter, the incidence loss is:

$$\Delta\psi_{li} = \frac{K_i \frac{C_m (\cot \beta_f - \cot \beta_b)^2}{2g}}{\frac{U^2}{g}} = \frac{K_i}{2} [\phi (\cot \beta_f - \cot \beta_b)]^2$$

where: $\phi = \frac{C_m}{\frac{K_i}{u}} (\text{inlet})^g$

The value $\frac{K_i}{2}$ used in this program is 0.15 (program constant). Program evaluations have indicated that the incidence loss so calculated is generally excessive, especially for radial impellers with diameter ratios, R_1/R_2 lower than 0.55. It would be advisable to modify above expression to include consideration of the diameter ratio (e.g. $(U_{1m}/U_{2m})^2$).

B. Friction Losses

Friction losses are based on the mean relative velocity, the hydraulic diameter of the blade passage and the blade surface finish. If not input the friction coefficient for Reynolds numbers greater than 10^5 is determined according to Reference 1:

$$\lambda = \frac{1}{(.8685 \frac{1}{n} (d_h/2 f_s) + 1.74)^2}$$

For laminar flow, $Re < 10^5$, the friction coefficient is calculated according to the following expression derived by Blasius:

$$\lambda = .0032 + \frac{0.221}{Re^{0.237}}$$

Reference 1 - Eckert/Schnell, Axial and Radial Compressors, Springer 1961

C. Diffusion Loss

The diffusion loss is related to the diffusion parameter D_I

$$D_I = 1 - \frac{W_2}{W_{1b}} + \frac{W_{u2} - W_{u1}}{2 \sigma W_{1b}}$$

where:

W_2 = relative velocity, discharge

W_{1b} = relative velocity, inlet blade passage

W_{u2}, W_{u1} = tangential components of relative velocities

σ = solidity

The diffusion loss coefficient is:

$$\Delta\psi_{\ell,d} = 0.08 D_I^3$$

D. Tip or Exit Losses

This loss is very small and generally neglected.

$$\Delta\psi_{\ell,t} = .5 \left(\frac{\phi_2}{\text{BLK2}} \right)^2$$

ϕ_2 = discharge flow coefficient

BLK2 = impeller discharge blade blockage

E. Clearance Losses

Blade tip clearance losses are related to blade loading, tip clearance and fluid viscosity. The expressions listed in subroutine ILOSS

for estimating clearance losses yield reasonable values for swept back blading operating in water as liquid nitrogen. Loss coefficients for radial blading ($\beta_2 = 90^\circ$) in liquid hydrogen calculated by the same method were found to be excessive.

F. Blade Losses

The summation of above losses constitute the blade losses.

$$\Delta\psi_{\ell,b} = \Delta\psi_{\ell,i} + \Delta\psi_{\ell,f} + \Delta\psi_{\ell,d} + \Delta\psi_{\ell,t} + \Delta\psi_{\ell,c}$$

G. Labyrinth Clearance Losses

The labyrinth clearance flow is estimated using semi-empirical equations devised by G. Vermes, Reference 2. The annular orifice flow coefficient is calculated from data presented in Reference 3. Data interpolation is performed by subroutine INT4.

H. Disc Friction Losses

The disc friction losses are computed using friction coefficients based on Schultz & Grunow's data published in Reference 4. Backvane power losses are estimated according to Reference 5.

Reference 2 - Geza Vermes, A Fluid Mechanics Approach to the Labyrinth Seal Leakage Problem, Journal of Engineering for Power, April 1961

Reference 3 - K. H. Bell & O. P. Bergelin, Flow Through Annular Orifices, TRANS. ASME, Vol. 7, 1957

Reference 4 - A. J. Stepanoff, Centrifugal and Axial Flow Pumps, J. Wiley & Sons, 1957

Reference 5 - K. T. Zanker, Experiments With Backvanes Used for Balancing Axial Thrust on Centrifugal Pump Impeller; The British Hydromechanics Research Association, RR 729, April 1962

I. Slip Factor

The slip factor μ for the determination of the theoretical head is calculated according to Reference 6 as follows:

$$\mu = \frac{1}{1 + \psi' \frac{R_2^2}{ZM_s}}$$

where:

ψ' = experience factor (see instructions)

M_s = static moment of impeller blade = $1/2 (R_2^2 - R_1^2)$ for radial blades

Z = number of impeller blades

Reference 6: G. Pfeleiderer, Die Kreiselpumpen, 5th Edition, Springer Verlag, 1961

III. GENERAL INSTRUCTIONS

A. A negative value in place of the blade tip clearance SCL will cause the program to calculate a tip clearance related to the discharge diameter of the impeller.

The program flags FLAG and IFLAG select the configuration.

FLAG

<u>Value (Real)</u>	<u>Configuration</u>
Negative	Unshrouded with backvanes
Zero	Unshrouded, smooth
Positive	Shrouded, smooth

IFLAG

<u>Value (Integer)</u>	<u>Configuration</u>
Zero	Impeller (will calculate disc friction)
Positive	Inducer (Will not calculate disc friction)

B. Values for Pfleiderer's experience factor FSLIP for slip depend on pump configuration and impeller blade discharge angle β_2 .

If the impeller discharges into a vaned diffuser:

$$FSLIP = 0.6 \left(1 + \frac{\beta_2}{60} \right)$$

If a volute housing is used only:

$$FSLIP = (0.65 \text{ to } 0.85) \left(1 + \frac{\beta_2}{60} \right)$$

If a vaneless diffuser is used in conjunction with a collector:

$$FSLIP = (0.85 \text{ to } 1.0) \left(1 + \frac{\beta_2}{60} \right)$$

C. The blade chord length CLBL must be determined from layout. The blade solidity is obtained by dividing the blade chord length by the mean blade spacing.

D. For shrouded impellers, an initial or starting value for the labyrinth flow must be input. The correct value is calculated by iterations.

NOMENCLATURE INPUT

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>	<u>FORMAT</u>
BB2	Discharge Blade Angle	Deg	F
Z	Blade Number	---	F
SM	Stat. Moment of Blade	IN ²	F
WIMP	Impeller Flow Rate	lb/sec	F
BBMI	Inlet Mean Blade Angle	Deg	F
BBTI	Inlet Tip Blade Angle	Deg	F
ETIP	Total Pinbladed Tip Width, Shroud and Disc	IN	F
AFLIM	Inlet Mean Fluid Angle	Deg	F
D2	Discharge Diameter	IN	F
B2	Discharge Blade Width	IN	F
LLBL	Blade Chord Length	IN	F
*SCL	Blade Tip Clearance	IN	F
BLKZ	Discharge Blockage	%	F
RHØ	Weight Density	lb/sec	F
SOL	Blade Solidity	--	F
DTI	Inlet Tip Diameter	IN	F
DR	Radial Extension	IN	F
DHI	Inlet Hub Diameter	IN	F
XN	Rotating Speed	RPM	F
*FLAG	Program Flag, See Instructions	--	F
VIS	Dynamic Viscosity	lb sec/ft ²	E
*IFLAG	Program Flag, See Instructions	--	I
ESHR	Axial Length of Labyrinth		F
SFFS	Surface Finish	IN	E
D	Labyrinth Diameter	IN	F
CO	Radial Clearance Labyrinth	IN	F
SNTH	Number of Labyrinth Teeth	--	F
PI	Tooth Pitch	IN	F
T	Tooth Thickness	IN	F
XKDF	Disc Friction Factor		E
FSLIP	Pfleiderers' Experience Factor for SLIP		F

*See general instructions, Page 6.

LEVEL 18 (SEPT 67)

057360 FORTRAN H

DATE 71.014/12.37.25

```

COMPILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=72,SOURCE,EBCDIC,NCLIST,NODECK,LOAD,MAP,NCEDIT,NOID,NOXREF
1SN 0002 COMMON XK(8),XZ(8),XFR(8),XR(8)
1SN 0003 COMMON RDZ,Z,SM,WIMP,RUM1,BHT1,AB1,PHI2,CM2,SOL,SFFS,AFLIM,ETIP,
1CU2TH,FSLIP,SCL,PRINT,D2,R2,CLRL,SIG,BLK2,RHO,VIS,DT1,
2 DP,DM1,PHI1F,XN,FLAG,P,D,XNTH,P1,IFLAG,CO,WR,T,MESS1,O1,U2,R2,
3 DLPDF,WWR,ESHK,DELK,PSIBL,PSITH,SLPCF,XKDF,WNET,WLABA,ILAB
1SN 0004 1 FORMAT(8F10.0)
1SN 0005 READ(5,1)XK,XZ,XFR,XR
1SN 0006 2 CALL INPI
1SN 0007 GO TO (3,4),MESS1
1SN 0008 3 R2=C2/2,
1SN 0009 RT1=DT1/2,
1SN 0010 CCL=CLRL/2.9
1SN 0011 DELK=25.0/CCL
1SN 0012 ILAB = 0
1SN 0013 IF(FLAG)60,60,61
1SN 0014 60 PRINT = 1,
1SN 0015 GO TO 10
1SN 0016 61 PRINT = 0
1SN 0017 10 CALL ILUSS
1SN 0018 PSIIP=PSITH-PSIBL
1SN 0019 PSIPS = PSIP - 0.5 * (PHI2**2 + (CU2TH/U2)**2)
1SN 0020 DP1PS=PSIPS*U2**2/32.174*RHO/144,
1SN 0021 IF(FLAG) 35,35,30
1SN 0022 30 DPFF=.1645E-07*.025*RHO*XN**2*(R2**2-RT1**2)
1SN 0023 P=DP1PS-DPFF
1SN 0024 CALL CLAB
1SN 0025 IF(PRINT)55,55,50
1SN 0026 55 IF(ABS(WLABA-WWR)-0.1) 102,102,103
1SN 0027 103 IF(WLABA - WWR) 104,102,105
1SN 0028 104 WLABA = WLABA + .1
1SN 0029 GO TO 106
1SN 0030 105 WLABA = WLABA - .1
1SN 0031 106 ILAB = ILAB + 1
1SN 0032 IF(ILAB-12) 10,10,102
1SN 0033 102 PRINT = 1,
1SN 0034 WLABA = WWR
1SN 0035 GO TO 10
1SN 0036 50 IF(IFLAG) 5,5,6
1SN 0037 6 DLPDF = 0
1SN 0038 WWR = 0
1SN 0039 GO TO 8
1SN 0040 35 WWR=0,
1SN 0041 5 CALL DFRBV
1SN 0042 8 PSIIN=PSITH+DLPDF
1SN 0043 ETAI0=PSIIP/PSIIN*WIMP/(WIMP+WWR)
1SN 0044 19 FORMAT(5X,'SLIP COEFFICIENT, SLPCF',31X,F10.4,2X,'****')
1SN 0045 7 FORMAT(5X,'THEORETICAL HEAD COEFFICIENT, PSITH',19X,F10.4,2X,'****'
1)
1SN 0046 11 FORMAT(5X,'IMPELLER HEAD COEFFICIENT, PSIIP',22X,F10.4,2X,'****')
1SN 0047 13 FORMAT(5X,'INPUT HEAD COEFFICIENT, PSIIN',25X,F10.4,2X,'****')
1SN 0048 21 FORMAT(5X,'IMPELLER STATIC HEAD COEFFICIENT, PSIPS',15X,F10.4,2X,'
1****')
1SN 0049 23 FORMAT(5X,'IMPELLER STATIC PRESSURE RISE, DP1PS',18X,F10.4,2X,'*LB/
ISOIN')
1SN 0050 17 FORMAT(5X,'OPTIMIZATION PARAMETER, ETAI0',25X,F10.4,2X,'****')
1SN 0051 WRITE(6,19) SLPCF
1SN 0052 WRITE(6,7) PSITH
1SN 0053 WRITE(6,11) PSIIP
1SN 0054 WRITE(6,13) PSIIN
1SN 0055 WRITE(6,21) PSIPS
1SN 0056 WRITE(6,23) DP1PS
1SN 0057 WRITE(6,17) ETAI0
1SN 0058 IF(FLAG) 45,45,40
1SN 0059 40 CONTINUE
1SN 0060 27 FORMAT(25X,'*** LABYRINTH DATA ***./)
1SN 0061 29 FORMAT(5X,'LABYRINTH DIAMETER, D',33X,F10.4,2X,'IN')
1SN 0062 31 FORMAT(5X,'RADIAL CLEARANCE, CD',34X,F10.4,2X,'IN')
1SN 0063 33 FORMAT(5X,'NUMBER OF TEETH, XNTH',33X,F10.4,2X,'****')
1SN 0064 37 FORMAT(5X,'TOOTH SPACING, P1',37X,F10.4,2X,'IN')
1SN 0065 39 FORMAT(5X,'TOOTH WIDTH, T',40X,F10.4,2X,'IN')

```

11

```
ISN 0066      41 FORMAT(5X,'PRESSURE DROP. P*.30X.F10.4.2X.'LD/SQIN')
ISN 0067      15 FORMAT(5X,'LABYRINTH FLOW RATE. WWR*.30X.F10.4.2X.'LB/SEC')
ISN 0068      WRITE(6,27)
ISN 0069      WRITE(6,29) O
ISN 0070      WRITE(6,31) CO
ISN 0071      WRITE(6,33) XNTH
ISN 0072      WRITE(6,37) PI
ISN 0073      WRITE(6,39) T
ISN 0074      WRITE(6,41) P
ISN 0075      WRITE(6,15) WWR
ISN 0076      45 CONTINUE
ISN 0077      GO TO 2
ISN 0078      4 STOP
ISN 0079      END
```

```

COMPILER OPTIONS = NAME= MAIN,OPT=02,LINECNT=72,SOURCE,EBCDIC,NCLIST,NODECK,LOAD,MAP,NCEDIT,NOID,NOXREF
15N 0002      SUBROUTINE ILCSS
15N 0003      COMMON XK(8),XZ(8),XFR(8),XR(8)
15N 0004      COMMON BB2,Z,SM,WIMP,BB1,BBT1,AB1,PHI2,CM2,SOL,SFFS,AFL1M,EIIP,
1CU2TH,FSLIP, SCL,PRINT,D2,B2,CLBL,SIG,BLK2,RHC,VIS, DT1,
2 DR,DH1,PHI1T,XN,FLAG,P,D,XNTH,PI,IFLAG,CC,WNR,I,MESS1,U1,U2,R2,
3 DLPDF,RWR,ESHR,DELK,PSIBL,PSITH,SLPCF, XKDF,WNET,WLAHA,ILAB
-----
15N 0005      EQUVALENCE (PSITH,PSIT),(PHI2,PHI),(U2,U)
15N 0006      TRNSK=.5
15N 0007      SIG = 1.2
15N 0008      BHM1R=BBM1/57.296
15N 0009      BBT1R=BBT1/57.296
15N 0010      BB2R=BB2/57.296
15N 0011      A1 = 0.7853975 * (DT1**2 - DH1**2)
15N 0012      DM1 = SORT(0.5 * (DH1**2 + DT1**2))
15N 0013      WIMP = ANET + WLABA
15N 0014      Q1=WIMP+448.0/RHD
15N 0015      U2=D2*XN/229.
15N 0016      A2 = 3.1417 * D2 * B2 * (1.-BLK2)
15N 0017      CM2 = .321 * Q1/A2
15N 0018      PHI2 = CM2/U2
15N 0019      CU2F=U2-CM2/SIN(BB2R)*COS(BB2R)
15N 0020      IF(BB2-90.) 20,25,25
15N 0021      20 PS1SL = FSLIP * (1. + BB2/60.)
15N 0022      PSL=PS1SL*R2**2/Z/SM
15N 0023      SLPCF=1./(1.+PSL)
15N 0024      GO TO 26
15N 0025      25 SLPCF=1.-1.98/Z
15N 0026      26 CU2TH=SLPCF*CU2F
15N 0027      CM1 = 0.321 * Q1/A1
15N 0028      UT1 = XN * DT1/229.
15N 0029      W1 = SORT(CM1**2 + UT1**2)
15N 0030      WU2TH=U2*(1.-SLPCF*(1.-PHI2*COS(BB2R)/SIN(BB2R)))
15N 0031      W2TH=SORT(CM2**2+WU2TH**2)
15N 0032      RW = W2TH/W1
15N 0033      U1M = XN * DM1/229.
15N 0034      IF(AFL1M) 30,35,40
15N 0035      30 AF1MR = ABS(AFL1M)/57.296
15N 0036      CU1M = -CM1 * SIN(AF1MR)/COS(AF1MR)
15N 0037      BF1MR = ATAN(CM1/(U1M - CU1M))
15N 0038      GO TO 42
15N 0039      35 CU1M = 0
15N 0040      BF1MR = ATAN(CM1/U1M)
15N 0041      GO TO 42
15N 0042      40 AF1MR = AFL1M/57.296
15N 0043      CU1M = CM1 * SIN(AF1MR)/COS(AF1MR)
15N 0044      BF1MR = ATAN(CM1/(U1M - CU1M))
15N 0045      42 PH1P1 = CM1/U1M
15N 0046      PSINC=0.15*(PH1M1*(COS(BF1MR)/SIN(BF1MR)-COS(BB1MR)/SIN(BB1MR)))**
-----
12
15N 0047      WU1M = U1M - CU1M
15N 0048      WM1 = SORT(CM1**2 + WU1M**2)
15N 0049      WMR = 0.5 * (WM1 + W2TH)
15N 0050      PASW = D2*SIN(BB2R) * (1.-BLK2)/Z * 3.1417
15N 0051      DHYD = 2.* B2 * PASW/(PASW + B2)
15N 0052      REIMP=DHYD *RHC*WMR / (96.522*VIS)
15N 0053      IF(REIMP-1.E+05) 37,37,38
15N 0054      37 FR1MP=0.0032+0.221/REIMP**0.237
15N 0055      GO TO 39
15N 0056      38 FR1MP = 1./((0.86858*ALOG(DHYD / (2.*SFFS ))+1.74)**2)
15N 0057      39 HLF1P=WMR **2/64.33*(FR1MP*CLBL /DHYD)
15N 0058      PSF1P=32.174*HLF1P/U2**2
15N 0059      PSTIP=TRNSK*(PHI2*BLK2)**2
15N 0060      DIFP = 1. - W2TH/W1 + (WU2TH-WU1M)/(2. * SOL * WM1 )
15N 0061      PSD = 0.08 * DIFP**3
15N 0062      PSIBL = PSINC + PSF1P + PSD + PSTIP
15N 0063      PSITH = CU2TH/U2 - U1M*CU1M/U2**2
15N 0064      HTH=PSITH*U2**2/32.174
15N 0065      IF(FLAG) 410,410,440

```



```

1SN 0066      410 IF(SCL) 430,440,450
1SN 0067      430 SCL=0.010201+0.0008095*D2+0.00011078*D2**2
1SN 0068      GO TO 450
1SN 0069      440 IF(PRINT) 101,101,102
1SN 0070      102 WRITE(6,420)
1SN 0071      420 FORMAT(/5X,'IMPELLER IS SHROUDED',/)
1SN 0072      101 PSCL=0.
1SN 0073      DELE=0.
1SN 0074      DELR=0.
1SN 0075      SCL=0.
1SN 0076      GO TO 470
1SN 0077      450 CONTINUE
1SN 0078      DELR=SCL/D2
1SN 0079      BDR=B2/U2
1SN 0080      DT=D2/12.
1SN 0081      CLPT=CLHL /12.
1SN 0082      V1=32.174*V1S/RHO.
1SN 0083      A=1.5708-BB2R
1SN 0084      USTR=1.72*SQRT(VI*CLPT*COS(A)*DELK/(PHI*U))
1SN 0085      Y=DELR*DT/(2.*DSTR)
1SN 0086      IF(Y-2.)1,2,2
1SN 0087      1 FI=1.-(Y-.25*Y**2)**2
1SN 0088      GO TO 3
1SN 0089      2 FI=0.
1SN 0090      3 G=PHI*(PSIT/(SIG*COS(A))
1SN 0091      DFLE=DELK*G**4*(1.+(COS(A))**2/G*FI)**1.5/(BDR*COS(A))
1SN 0092      PSCL=32.174*DELE*HTH/U2**2
1SN 0093      PSIBL=PSIBL+PSCL
1SN 0094      470 CONTINUE
1SN 0095      55 FORMAT(5X,'IMPELLER LOSSES',/)
1SN 0096      57 FORMAT(/,5X,'*****OUTPUT *****',/)
1SN 0097      12 FORMAT(/5X,7HSCCL =,3X,F10.3,24X,7HPSINC =,3X,F10.4,
124X,7HU2 =,3X,F10.3)
1SN 0098      14 FORMAT(5X,7HDELE =,3X,F10.3,24X,7HPSF =,3X,F10.4,
124X,7HC2TH =,3X,F10.3)
1SN 0099      16 FORMAT(5X,7HDELK =,3X,F10.3,24X,7HPSD =,3X,F10.4,
124X,7HCM2 =,3X,F10.3)
1SN 0100      18 FORMAT(5X,7HDELR =,3X,F10.3,24X,7HPSTIP =,3X,F10.4,
124X,7HPI2 =,3X,F10.3)
1SN 0101      28 FORMAT(5X,7HW2TH =,3X,F10.3,24X,7HPSCL =,3X,F10.4,
124X,7HFRIMP =,3X,F10.4)
1SN 0102      22 FORMAT(5X,7HRW =,3X,F10.3,24X,7HPSIBL =,3X,F10.4,
124X,7HDIFP =,3X,F10.3)
1SN 0103      24 FORMAT(5X,7HHTH =,3X,F10.3,68X,7HU1M =,3X,F10.3)
1SN 0104      27 FORMAT(5X,7HWIMP =,3X,F10.3,68X,7HCUIM =,3X,F10.3)
1SN 0105      29 FORMAT(9JX,7HCM1 =,3X,F10.3)
1SN 0106      IF(PRINT) 108,108,110
1SN 0107      110 WRITE(6,55)
1SN 0108      WRITE(6,57)
1SN 0109      WRITE(6,12) SCL,PSINC,U2
1SN 0110      WRITE(6,14) DELE,PSFIP,CU2TH
1SN 0111      WRITE(6,16) DELK,PSD,CM2
1SN 0112      WRITE(6,18) DELR,POSTIP,PHI2
1SN 0113      WRITE(6,28) W2TH,PSCL,FRIMP
1SN 0114      WRITE(6,22) RW,PSIBL,DIFP
1SN 0115      WRITE(6,24) HTH,U1M
1SN 0116      WRITE(6,27) WIMP,CUIM
1SN 0117      WRITE(6,29) CM1
1SN 0118      108 RETURN
1SN 0119      END

```

```

COMPILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=72,SOURCE,EBDCIC,NCLIST,NODECK,LOAD,MAP,NCEDIT,NUID,NOXREF
1SN 0002 SUBROUTINE DFRBV
1SN 0003 COMMON XK(8),XZ(8),XFR(8),XR(8)
1SN 0004 COMMON BB2,Z,SM,WIMP,BDM1,BST1,AB1,PHI2,CM2,SOL,SFFS,AFLIM,ETIP,
1CU2TH,FSLIP,SCL,PRINT,D2,B2,CLBL,SIG,BLK2,RHO,VIS, DT1,
2 DR,DH1,PHI1,XN,FLAG,P,D,XNTH,PI,IFLAG,CC,WVR,T,MESS1,Q1,U2,R2,
3 DLPDF,RWR,ESHR,DELK,PSIDL,PSITH,SLPCF, XKDF,WNET,WLABA,ILAB
1SN 0005 RE2=U2*R2/RHO/(J86.*VIS)
1SN 0006 IF (FLAG) 10,20,20
1SN 0007 10 RBV2=R2/DR
1SN 0008 RBV1=R2/2.
1SN 0009 SBV=SCL/.17+SCL
1SN 0010 CRIP=1048*XXN
1SN 0011 TEMPE=SBV/.8/SCL-1.
1SN 0012 XRV=TEMP*(40./(.1+.5.*SBV/RBV2)*RE2**2/.56*(SBV/RBV2))**.5
1SN 0013 RDMV=XUV/(1.+XUV)
1SN 0014 OMFL=OMIP/RDMV
1SN 0015 TQV=1.562E-07*RHO*40.*((RBV2)**4-(RBV1)**4)*SBV*(OMIP-OMFL)**2*(T
TEMP)**2
1SN 0016 PFBU=OMIP*TQV/550.
1SN 0017 PFS=0.
1SN 0018 PFF=0.
1SN 0019 XKDF=0.
1SN 0020 GO TO 35
1SN 0021 20 REX=R2/DR
1SN 0022 RBS=3*R2
1SN 0023 IF (XKDF) 25,25,23
1SN 0024 25 IF (RE2-10.**6) 21,22,22
1SN 0025 21 XKDF=3.68431E-06-7.869741E-07*ALOG(RE2)+5.706801E-08*(ALOG(RE2))
1**2-1.3921085E-09*(ALOG(RE2))**3
1SN 0026 GO TO 23
1SN 0027 22 XKDF=31.5E-06/RE2**0.164
1SN 0028 23 CONTINUE
1SN 0029 XPDF=4.61E-09*XKDF*RHO*XXN**3
1SN 0030 PFS=XPDF*(REX**4*(2.*REX+5.*ETIP)-2.*(RBS**5-REX**5+R2**5))
1SN 0031 PFBV=0.
1SN 0032 IF (FLAG) 31,31,32
1SN 0033 31 PFFS=0.
1SN 0034 GO TO 35
1SN 0035 32 RWR=0.5 * D
1SN 0036 RT1=D1/2.
1SN 0037 PFS1=XPDF*(RWR**4*(2.*RWR+5.*ESHR)-2.*RT1**5)
1SN 0038 PFS2=XPDF*(R2**4*(2.*R2+5.*ETIP)-2.*RWN**5)
1SN 0039 PFS=PFS1+PFS2
1SN 0040 PFCT=PFBV+PFS+PFS
1SN 0041 DLPDF=17600.*PFCT/(U2**2*WIMP)
1SN 0042 12 FORMAT(5X,'FYNULDS NO., IMPELLER, RE2',11X,E10.4,2X,'****')
1SN 0043 13 FORMAT(5X,'DISK FRICTION COEFF., XKDF',12X,E10.4,2X,'****')
1SN 0044 14 FORMAT(5X,'POWER, BACKVANES, PFBV',16X,F10.3,2X,'HP')
1SN 0045 15 FORMAT(5X,'POWER, BACK FACE, PFS',16X,F10.3,2X,'HP')
1SN 0046 16 FORMAT(5X,'POWER, FRONT FACE, PFS',15X,F10.3,2X,'HP')
1SN 0047 17 FORMAT(5X,'POWER, TOTAL, PFCT',14X,F10.3,2X,'HP')
1SN 0048 18 FORMAT(5X,'LOSS COEFF., DLPDF',20X,F10.4,2X,'****//')
1SN 0049 WRITE(6,12) RE2
1SN 0050 WRITE(6,13) XKDF
1SN 0051 WRITE(6,14) PFBV
1SN 0052 WRITE(6,15) PFS
1SN 0053 WRITE(6,16) PFS
1SN 0054 WRITE(6,17) PFCT
1SN 0055 WRITE(6,18) DLPDF
1SN 0056 RETURN
1SN 0057 END

```

```

COMPILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=72,SOURCE,EBCDIC,NCLIST,NCDECK,LOAD,MAP,NCEDIT,NO10,NOXREF
ISN 0002 SUBROUTINE INP1
ISN 0003 COMMON XK(8),XZ(8),XFR(8),XR(8)
ISN 0004 COMMON BB2,Z,SM,WIMP,BBM1,BBT1,AB1,PHI2,CN2,SOL,SFFS,AFLIM,ETIP,
1 CU2TH,FSLIP,SCL,PRINT,D2,B2,CLBL,SIG,BLK2,RHO,VIS,DT1,
2 DR,DH1,PHI1,XN,FLAG,C,D,XNTH,PI,IFLAG,CO,WWR,T,MESS1,O1,U2,R2,
3 DLPDF,RWR,ESHR,DELK,PSIBL,PSITH,SLPCF, XKDF,WNET,WLABA,ILAB
ISN 0005 MESS1=1
ISN 0006 1 FORMAT(8F10.0)
ISN 0007 2 FORMAT(4F10.0,E10.4,I10,F10.0,E10.4)
ISN 0008 3 FORMAT(4X,8E14.4)
ISN 0009 4 FORMAT(4X,5E14.4,I10,L18.5,E14.4)
ISN 0010 5 FORMAT(5F10.4,E10.4,2F10.3)
ISN 0011 READ(5,1)BB2,Z,SM,WNET,BBM1,BBT1,ETIP,AFLIM
ISN 0012 IF(WNET)51,51,50
ISN 0013 51 MESS1=2
ISN 0014 GO TO 100
ISN 0015 50 READ(5,1) D2,B2,CLBL,SCL,BLK2,RHO,SOL,DT1
ISN 0016 READ(5,2) DR,DH1,XN,FLAG,VIS,IFLAG,ESHR,SFFS
ISN 0017 READ(5,5) D,CO,XNTH,PI,T,XKDF,FSLIP,WLABA
ISN 0018 10 FORMAT('1',//5X,'INPUT'//)
ISN 0019 WRITE(6,10)
ISN 0020 6 FORMAT(11X,'BB2',11X,'Z',13X,'SM',12X,'WNET',10X,'BBM1',10X,'BBT1',
1,11X,'ETIP',8X,'AFLIM')
ISN 0021 7 FORMAT(/11X,'D2',14X,'B2',11X,'CLBL',10X,'SCL',10X,'BLK2',10X,'RHO
1',10X,'SCL',10X,'DT1')
ISN 0022 9 FORMAT(/11X,'DR',12X,'DH1',12X,'XN',10X,'FLAG',10X,'VIS',11X,'IFLA
1G',9X,'ESHR',10X,'SFFS')
ISN 0023 8 FORMAT(/11X,'D',13X,'CO',12X,'XNTH',10X,'PI',11X,'T',12X,'XKDF',11
1X,'FSLIP',9X,'WLABA')
ISN 0024 11 FORMAT(4X,8E14.4//)
ISN 0025 WRITE(6,6)
ISN 0026 WRITE(6,3)BB2,Z,SM,WNET,BBM1,BBT1,ETIP,AFLIM
ISN 0027 WRITE(6,7)
ISN 0028 WRITE(6,3) D2,B2,CLBL,SCL,BLK2,RHO,SOL,DT1
ISN 0029 WRITE(6,9)
ISN 0030 WRITE(6,4) DR,DH1,XN,FLAG,VIS,IFLAG,ESHR,SFFS
ISN 0031 WRITE(6,8)
ISN 0032 WRITE(6,11)D,CO,XNTH,PI,T,XKDF,FSLIP,WLABA
ISN 0033 100 RETURN
ISN 0034 END

```

```

COMPILER OPTIONS - NAME* MAIN,OPT=02,LINECNT=72,SOURCE,EBCDIC,NCLIST,NCDECK,LOAD,MAP,NCEDIT,NOID,NOXREF
1SN 0002 SUBROUTINE CLAB
1SN 0003 COMMON / / XK(8),XZ(8),XFR(8),XR(8)
1SN 0004 COMMON BB2,Z,SM,WIMP,BB1,BBT1,AB1,PHI2,CM2,SOL,SFFS,AFL1M,ETIP,
1CU2TH,FSLIP,SCL,PRINT,D2,B2,CLBL,SIG,BLK2,RHO,VIS, DT1,
2 DR,DM1,PH11T,XN,FLAG,P,D,XNTH,PI,IFLG,CO,W,T,MLSS1,Q1,U2,R2,
3 DLRDF,RWR,ESHK,DELK,PSIBL,PSI1H,SLPCF, / / XKDF,WNET,WLABA,ILAB
1SN 0005 VI=VIS*(32.16/RHO)
1SN 0006 COEC=.67
1SN 0007 FA=2.*RHO*32.1741*P*144.
1SN 0008 FH=SQRT(FA)
1SN 0009 S=J.1416*CO*(D+CO)/144.
1SN 0010 CF=(XNTH-1.)*(1.-8.52/((PI-T)/CO+7.23))+1.
1SN 0011 DO 40 I=1,3
1SN 0012 COF=COEC/SQRT(CF)
1SN 0013 W=CCL*5*FH
1SN 0014 RE=CO*W/(6.*S*VI*RHO)
1SN 0015 ZLAB=T/CO
1SN 0016 IF (RE-60.) 200,200,300
1SN 0017 200 KZ=ZLAB/RE
1SN 0018 CALL INT4(XZ,XK,RZ,FK)
1SN 0019 COEC=1./SQRT(64./RE+48.*ZLAB/RE+FK)
1SN 0020 GO TO 40
1SN 0021 300 RE=ALOG(RE)
1SN 0022 CALL INT4(XR,XFR,RE,FFR)
1SN 0023 FFR=EXP(FFR)
1SN 0024 RE=FFR*(RE)
1SN 0025 COED=.62*RE**-.0085
1SN 0026 IF (ZLAB-1.15) 310,310,320
1SN 0027 310 F=0
1SN 0028 GO TO 330
1SN 0029 320 F=1.-2.7183**(-.95*(ZLAB-1.15))
1SN 0030 330 IF (RE-6000.) 340,340,350
1SN 0031 340 COEC=1./SQRT(1/COEC**2-F*(2*SQRT(1/COEC**2-64./RE)-2.))+2.*FFR*ZLAB
1)
1SN 0032 GO TO 40
1SN 0033 350 COEC=1./SQRT(1./COEC**2-(2./COEC-2.)*F+2.*FFR*ZLAB)
1SN 0034 40 CONTINUE
1SN 0035 RETURN
1SN 0036 END

```

```

COMPILER OPTIONS = NAME= MAIN,OPT=02,LINECNT=72,SOURCE,EBDCIC,NCLIST,NODECK,LOAD,MAP,NCEDIT,NCID,NOXREF
1SN 0002      SUBROUTINE INT4(X,Y,X1,YC)
1SN 0003      DIMENSION X(9),Y(9),XC(4),YC(4)
1SN 0004      EQUIVALENCE (XC(1),X1),(XC(2),X2),(XC(3),X3),(XC(4),X4),(YC(1),Y1)61205006
              1,(YC(2),Y2),(YC(3),Y3),(YC(4),Y4)61205007
1SN 0005      NA=1
1SN 0006      J=2
1SN 0007      B=XI
1SN 0008      21  IF(X(J))26,22,26
1SN 0009      26  GO TO(30,40),NA
1SN 0010      22  IF(Y(J))26,23,26
1SN 0011      23  IF(J-2)24,24,25
1SN 0012      24  YK=0.0
1SN 0013      GO TO 50
1SN 0014      25  NB=1
1SN 0015      J=J-1
1SN 0016      27  X1=X(J)
1SN 0017      X2=X(J-1)
1SN 0018      X3=X(J-2)
1SN 0019      Y1=Y(J)
1SN 0020      Y2=Y(J-1)
1SN 0021      Y3=Y(J-2)
1SN 0022      GO TO(32,42),NB
1SN 0023      30  IF(X(J)-B)29,37,37
1SN 0024      37  IF(J-2)31,31,28
1SN 0025      28  NA=2
1SN 0026      29  J=J+1
1SN 0027      GO TO 21
1SN 0028      31  DO 60 J=1,3
1SN 0029      XC(J)=X(J)
1SN 0030      60  YC(J)=Y(J)
1SN 0031      32  D=X2-X1
1SN 0032      A1=B-X1
1SN 0033      A2=D-X2
1SN 0034      YE=A1*A2/2.0/D*((Y3-Y2)/(X3-X2)-(Y2-Y1)/D)-A2/D*Y1+A1/D*Y261205037
1SN 0035      GO TO 50
1SN 0036      40  NR=2
1SN 0037      GO TO 27
1SN 0038      42  X4=X(J-3)
1SN 0039      Y4=Y(J-3)
1SN 0040      D=X3-X2
1SN 0041      A1=X-X2
1SN 0042      A2=B-X3
1SN 0043      XM12=(Y2-Y1)/(X2-X1)
1SN 0044      XM23=(Y3-Y2)/D
1SN 0045      XM34=(Y4-Y3)/(X4-X3)
1SN 0046      YE=A1*A2**2/2.0/D**2*(XM12-XM23)+A2*A1**2/2.0/D**2*(XM34-XM23)-A2*612 5 49
              1Y2/D+A1*Y3/D
1SN 0047      50  YC=YE
1SN 0048      RETURN
1SN 0049      END
    
```

18

NUMBER OF TEETH, XNTH	3.0000	***
TOOTH SPACING, PI	.1830	IN
TOOTH WIDTH, T	.0195	IN
PRESSURE DROP, P	400.0932	LR/50IN
LARYNTH FLOW RATE, QMR	2.7196	LR/SEC

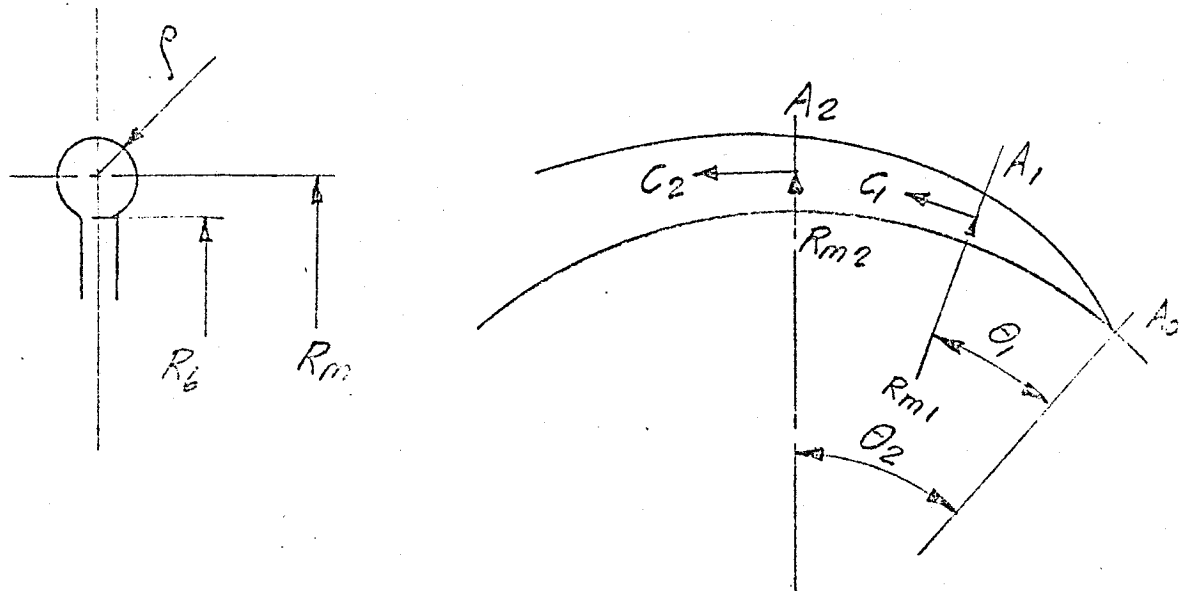
COMPUTER PROGRAM
CIRCULAR CROSS SECTION VOLUTE DESIGN

I. INTRODUCTION

This program presents an incremental method for the design of a classical pump volute with circular cross-sections which are tangent to the volute base circle. Volute area distributions as well as velocity and pressure distributions are calculated and printed out.

This program was primarily devised to determine the percentage increase in cross-sectional area required for the compensation of friction losses in the NERVA turbopump volute which is discussed in Reference 1.

II. BASIC EQUATIONS



The flow rate V in the volute is assumed to be proportional to the wrap angle θ (no back flow, zero cut water clearance flow).

The volute cross sectional area A_2 at the wrap angle θ_2 can then be calculated from the total flow at the volute throat V_{th} :

$$A_2 = \frac{\theta_2}{2\pi} \frac{V_{th}}{C_2} = \pi \rho_2^2 \quad (1)$$

Assuming constant moment of momentum:

$$R_{m1} C_1 = R_{m2} C_2 = K$$

where:

$$R_{m2} = R_6 + \rho_2$$

Thus:

$$C_2 = \frac{K}{R_{m2}} = \frac{K}{R_6 + \rho_2} \quad (2)$$

Substituting C_2 in (1)

$$A_2 = \frac{\theta_2 V_{th}}{2\pi} \frac{R_6 + \rho_2}{K} = \pi \rho_2^2$$

Solving for ρ the quadratic equation can be written as follows:

$$\rho^2 - \frac{\theta_2 V_{th}}{2\pi^2 K} \rho - \frac{\theta_2 V_{th}}{2\pi^2 K} R_6 = 0$$

Let

$$\frac{\theta_2 V_{th}}{2\pi^2 K} = Y$$

then:

$$\rho^2 - Y\rho - YR_6 = 0$$

and

$$\rho = \frac{Y \pm \sqrt{Y^2 + 4 Y R_6}}{2}$$

Friction losses are calculated for the mean cross section of a volute increment:

$$A_m = \frac{A_1 + A_2}{2}$$

$$\rho_m = \left(\frac{A_m}{\Pi}\right)^{0.5}$$

Length of volute increment:

$$L_m = \Delta\theta R_m$$

The friction coefficient is based on the relative surface finish and the empirical relationship established by Nicuradse (Reference 2).

$$\lambda = \frac{1}{(.8685 \ln \left(\frac{\rho_m}{f_s}\right) + 1.74)^2}$$

Friction loss for volute increment

$$\Delta H_{\text{fric}} = \lambda \frac{L_m}{2\rho_m} \frac{C_m^2}{2g}$$

The friction loss is recuperated by an increase in diffusion

$$\Delta H_{\text{fric}} = \Delta H_{\text{vel}}$$

which is achieved by a decrease in velocity or respectively, an increase in area.

Reference 2 - Eckert/Schnell, Axial and Radial Kompressoren, Springer-Verlag 1961

$$\Delta H_{vel} = \frac{C_2^2}{2g} - \frac{C_{2c}^2}{2g}$$

where C_{2c} is the lowered velocity corresponding to the increased or corrected area A_{2c} . From continuity:

$$C_2 A_2 = C_{2c} A_{2c}$$

$$\Delta H_{fric} = \frac{C_2^2}{2g} \left(1 - \left(\frac{C_{2c}}{C_2}\right)^2\right) = \frac{C_2^2}{2g} \left(1 - \left(\frac{A_2}{A_{2c}}\right)^2\right)$$

From this expression the corrected area A_{2c} is:

$$A_{2c} = \frac{A_2}{\left(1 - \frac{2g \Delta H_{fric}}{C_2^2}\right)^{0.5}}$$

// JDM T

LOG DRIVE CART SPEC CART AVAIL PHY DRIVE
0000 0001 0001 0000

V2 M05 ACTUAL 16K CONFIG 16K

// FOR

*IOCS(CARD,TYPEWRITER,KEYBOARD,1403 PRINTER,DISK)

*LIST ALL

DIMENSION THET(90),RADN(90),ANC(90),VD(90),CN(90),A(90),RAD(90),

IC(60),HVEL(90),FRIC(90),HFR(90),PS(90),HFRT(90)

LR = 2

LW = 5

1 FORMAT('1')

2 FORMAT(42X,'VOLUTE VELOCITIES + PRESSURE DISTRIBUTION'//)

3 FORMAT(7F8.3,E8.3,I3,F8.3)

4 FORMAT(53X,'** INPUT **'//)

5 FORMAT(15X,'R6',12X,'ALP6',12X,'OD',14X,'RHO',13X,'OMEG',12X,'PSEX'
1//)

6 FORMAT(15X,'DLIN',10X,'SFS',13X,'NUM',13X,'BS'//)

7 FORMAT(5X,F15.3//)

8 FORMAT(5X,F15.3,E15.3,I15,F15.3//)

9 READ(LR,3) R6,ALP6,OD,RHO,OMEG,PSEX,DL,SFS,NUM,BS

IF(R6) 500,500,11

11 WRITE(LW,1)

WRITE(LW,2)

WRITE(LW,4)

WRITE(LW,5)

WRITE(LW,7) R6,ALP6,OD,RHO,OMEG,PSEX

WRITE(LW,6)

WRITE(LW,8) DL,SFS,NUM,BS

DTHT = 360./NUM

VDT = 0.321 * OD

ALPR6 = ALP6/57.296

CVOL = 360. * COS(ALPR6)/(BS * SIN(ALPR6))

THET(1) = DTHT

DO 10 I=2,NUM

10 THET(I) = THET(I-1) + DTHT

DO 20 I=1,NUM

RADN(I) = THET(I)/CVOL + SQRT(2.*R6 * THET(I)/CVOL)

ANC(I) = 3.14159 * RADN(I)**2

VD(I) = THET(I)/360. * VDT

20 CN(I) = VD(I)/ANC(I)

A(I) = ANC(I)

RAD(I) = RADN(I)

C(I) = CN(I)

HVEL(I) = C(I)**2/64.348

FRIC(I) = 0

HFR(I) = 0

I = 2

50 N = 0

RXC = (RAD(I-1) + R6) * C(I-1)

CONST = VD(I)/(3.14159 * RXC)

RAD(I) = (CONST + SQRT(CONST**2 + 4. * CONST * R6))/2.

A(I) = 3.14159 * RAD(I)**2

STAY = A(I)

17 C(I) = VD(I)/A(I)

RAD(I) = SQRT(A(I)/3.14159)

AM = 0.5*(A(I) + A(I-1))

RADM = SQRT(AM/3.14159)

PAGE 2

```
RM = R6 + RADM
XLM = RM*DTHT/57.296
CM = (C(1) + C(1-1))/2.
HFR(I) = FRIC(I) * XLM * CM**2 / (128.697 * RADM)
HVEL(I) = C(1)**2 / 64.348
IF(N) 30,30,32
30 SAFE = HVEL(I)
STAY = A(I)
35 A(I) = STAY / SQRT(1. - HFR(I) / HVEL(I))
N = N + 1
GO TO 17
32 HFR(I) = (SAFE - HVEL(I) + HFR(I)) / 2.
IF(N-1) 35,35,36
36 IF(I-NUM) 40,42,42
40 I = I + 1
GO TO 50
42 CONTINUE
HFRT(I) = 0
DO 60 I=2,NUM
60 HFRT(I) = HFRT(I-1) + HFR(I)
DPDIF = OMEG * HVEL(NUM) * RHO / 144.
HFT = HFRT(NUM) + OMEG * HVEL(NUM)
AEX = .785 * DL**2
VEX = VDT / AEX
HVEX = VEX**2 / 64.348
PTEX = PSEX + HVEX * RHO / 144.
PTIN = PTEX + HFT * RHO / 144.
DO 70 I=1,NUM
70 PS(I) = PTIN - (HVEL(I) + HFRT(I)) * RHO / 144.
101 FORMAT(////5X, '*** OUTPUT ***')
102 FORMAT(9X, 'THETA', 10X, 'RNC', 11X, 'RCOR', 10X, 'VEL', 12X, 'FRIC', 10X,
1 'HFRT', 12X, 'PS')
103 FORMAT(7F15.4)
WRITE(LW,101)
WRITE(LW,102)
WRITE(LW,103) (THET(I), RADN(I), ANCR(I), C(I), FRIC(I), HFRT(I), PS(I), I
I=1,NUM)
120 FORMAT(////20X, 'FRICTION LOSS VOLUTE', 'F', 3.2X, 'FT'
1 //)
121 FORMAT(20X, 'FRICTION LOSS INCL EXIT DIFFUSER', 'F', 3.2X, 'FT')
122 FORMAT(20X, 'EXIT VELOCITY', 'F', 3.2X, 'FT/S')
1 //)
123 FORMAT(20X, 'TOTAL DISCHARGE PRESSURE', 'F', 3.2X, 'PSI')
124 FORMAT(20X, 'PRESSURE LOSS, EXIT DIFFUSER', 'F', 3.2X, 'PSI')
//)
WRITE(LW,120) HFRT(NUM)
WRITE(LW,121) HFT
WRITE(LW,122) VEX
WRITE(LW,123) PTEX
WRITE(LW,124) DPDIF
GO TO 9
500 STOP
END
```

VARIABLE ALLOCATIONS

THET(R) = 00B2-0000	RADN(R) = 0166-00B4	ANCR(R) = 021A-0168	VD(R) = 02CE-021C	CN(R) = 03B2-02D0	A(R) = 0436-0384
RAD(R) = 04EA-0438	C(R) = 0562-04EC	HVEL(R) = 0616-0564	FRIC(R) = 06CA-061B	HFR(R) = 077E-06CC	PS(R) = 0832-0780
HFRT(R) = 08E6-0834	R6(R) = 08EB	ALP6(R) = 08EA	QD(R) = 08EC	RHO(R) = 08EE	OMEG(R) = 08F0
PSEX(R) = 08F2	DL(R) = 08F4	SFS(R) = 08F6	B5(R) = 08F8	DTHT(R) = 08FA	VDT(R) = 08FC
ALP6(R) = 08FF	CVOL(R) = 0900	RXC(R) = 0902	CONS(R) = 0904	STAY(R) = 0906	AM(R) = 0908

VOLUME VELOCITIES + PRESSURE DISTRIBUTION

*** INPUT ***

R6 ALP6 OD RHO OMEG PSEX

8.000 14.300 6230.000 4.450 0.200 1580.000

DLINE

SFS NUM BS

4.750 0.125E-03 36 0.600

*** OUTPUT ***

THETA

RNC

RCOR

VEL

FRIC

HFR1

PS

10.0000	0.2649	0.2649	251.8666	0.0000	0.0000	0.0000	1565.8193
20.0000	0.3772	0.3802	244.5806	0.0135	29.4864	1566.6499	1565.8193
30.0000	0.4643	0.4708	239.2457	0.0128	49.9385	1567.2529	1567.2529
40.0000	0.5384	0.5486	234.9321	0.0124	65.9318	1567.7409	1567.7409
50.0000	0.6062	0.6183	231.2430	0.0121	79.1969	1568.1569	1568.1569
60.0000	0.6641	0.6821	227.9889	0.0118	90.5940	1568.5222	1568.5222
70.0000	0.7195	0.7416	225.0593	0.0116	100.6198	1568.8498	1568.8498
80.0000	0.7713	0.7975	222.3829	0.0115	109.5898	1569.1477	1569.1477
90.0000	0.8203	0.8506	219.9113	0.0113	117.7176	1569.4216	1569.4216
100.0000	0.8669	0.9014	217.6097	0.0112	125.1567	1569.6755	1569.6755
110.0000	0.9114	0.9501	215.4505	0.0111	132.0197	1569.9123	1569.9123
120.0000	0.9541	0.9971	213.4148	0.0110	138.3931	1570.1345	1570.1345
130.0000	0.9952	1.0425	211.4864	0.0109	144.3446	1570.3442	1570.3442
140.0000	1.0349	1.0866	209.6523	0.0108	149.9283	1570.5427	1570.5427
150.0000	1.0734	1.1295	207.9019	0.0107	155.1881	1570.7312	1570.7312
160.0000	1.1108	1.1712	206.2267	0.0106	160.1603	1570.9106	1570.9106
170.0000	1.1471	1.2120	204.6192	0.0106	164.8751	1571.0820	1571.0820
180.0000	1.1825	1.2519	203.0733	0.0105	169.3560	1571.2460	1571.2460
190.0000	1.2171	1.2909	201.5836	0.0105	173.6309	1571.4035	1571.4035
200.0000	1.2509	1.3292	200.1453	0.0104	177.7126	1571.5549	1571.5549
210.0000	1.2839	1.3668	198.7545	0.0104	181.6193	1571.7006	1571.7006
220.0000	1.3163	1.4037	197.4076	0.0103	185.3655	1571.8413	1571.8413
230.0000	1.3480	1.4401	196.1014	0.0103	188.9636	1571.9768	1571.9768
240.0000	1.3791	1.4758	194.8333	0.0102	192.4246	1572.1079	1572.1079
250.0000	1.4097	1.5110	193.6006	0.0102	195.7583	1572.2348	1572.2348
260.0000	1.4398	1.5457	192.4013	0.0101	198.9736	1572.3579	1572.3579
270.0000	1.4694	1.5800	191.2331	0.0101	202.0782	1572.4770	1572.4770
280.0000	1.4985	1.6138	190.0943	0.0100	205.0796	1572.5930	1572.5930
290.0000	1.5271	1.6472	188.9834	0.0100	207.9838	1572.7055	1572.7055
300.0000	1.5554	1.6802	187.8986	0.0100	210.7969	1572.8149	1572.8149
310.0000	1.5832	1.7128	186.8387	0.0099	213.5241	1572.9213	1572.9213
320.0000	1.6107	1.7450	185.8023	0.0099	216.1704	1573.0251	1573.0251
330.0000	1.6378	1.7770	184.7883	0.0099	218.7399	1573.1259	1573.1259

FRICTION LOSS VOLUTE	=	226.026	FT
FRICTION LOSS INCL. EXIT DIFFUSER	=	328.834	FT
EXIT VELOCITY	=	1124.911	FT/S
TOTAL DISCHARGE PRESSURE	=	1586.122	PSI
PRESSURE LOSS, EXIT DIFFUSER	=	3.176	PSI

N8300R:72-106
May 1972

5. IMPELLER DISCHARGE TRAVERSE DATA EVALUATION

COMPUTER PROGRAM
IMPELLER DISCHARGE TRAVERSE DATA EVALUATION

I. INTRODUCTION

This program serves for the reduction of total pressure and flow direction data obtained from surveys conducted with traversing probes at the discharge of a pump impeller. It calculates local, integrated and mass weighted impeller head coefficients as well as efficiency and slip.

The program was first used as a supplement to the Pump Air Test Data Reduction Program (Reference 1) for the reduction of traverse data obtained from pump air tests conducted in support of the NERVA Turbopump Program. The pump air tests and the use of this computer program are discussed in Reference 1 and 2.

II. PROGRAM DESCRIPTION

The Impeller Discharge Traverse Data Evaluation Program consists of a short main program and a subroutine TRAVD. All major calculations are performed in subroutine TRAVD which in essence was written for incorporation into the Pump Air Test Data Reduction Program, Reference 1.

Reference 1 - J. J. Brunner, Pump Air Test Data Reduction Program, Aerojet Nuclear Systems Company, Engineering Operations Report

Reference 2 - J. J. Brunner, Performance of a Two-Stage Centrifugal NERVA Pump Tested with Air as the Working Fluid, Aerojet Nuclear Systems Company, Engineering Operations Report N8300R:71-090

III. ASSUMPTIONS AND BASIC EQUATIONS

The Traverse Data Evaluation Program calculated impeller total head coefficients directly from the measured total pressures. Exit or mixing losses at the impeller discharge and flow losses in the short radial annular diffuser section extending from the impeller discharge to the location of the probe are neglected. Previous loss calculations indicate that such losses are very small. The static pressure is assumed to be constant across the width of the port and equal to the average value of the measured wall static pressures.

The absolute velocity at each traverse position is obtained from:

$$C_{(b)} = \sqrt{2g(H_{t(b)} - H_s)}$$

and the meridional velocity based on measured flow angle $\alpha_{(b)}$ is

$$C_{m(b)} = C_{(b)} \sin \alpha_{(b)}$$

Integrated and mass weighted values are determined as follows:

Integrated meridional velocity:

$$\bar{C}_m = \frac{\int_0^B C_{m(b)} db}{B}$$

wherein B = housing port width.

Tangential velocity component at each traverse position:

$$C_{u(b)} = C_{(b)} \cos \alpha_{(b)}$$

Mass weighted tangential velocity component:

$$\bar{C}_u = \frac{\int_0^B (C_{u(b)} C_{m(b)}) db}{\bar{C}_m}$$

Integrated flow angle:

$$\bar{\alpha} = \tan^{-1} \left[\frac{\bar{C}_m B}{\int_0^B C_{u(b)} db} \right]$$

Mass weighted total head:

$$\bar{H}_t = \frac{\int_0^B (H_{t(b)} C_{m(b)}) db}{\bar{C}_m}$$

A continuity check is performed by comparing the integrated flow

$$\bar{V} = \bar{C}_m A \quad (A = 2\pi R_M B)$$

with the measured flow (corrected for recirculation when applicable).

The absolute velocity components are adjusted in subsequent computations to satisfy continuity. In these calculations the meridional velocities $C_{m(b)}$ are multiplied by the ratio of measured flow to calculated flow V/\bar{V} , assuming that the distribution of these velocities is correct and that the discrepancy in flow is due to the measured fluid angle. From adjusted velocity triangles determined by $C_{(b)}$ and $C_{m(b)}$, new values of fluid angle $\alpha_{(b)}$ and tangential velocity $C_{u(b)}$ are calculated. The mass weighted total head is not affected by this adjustment because the ratio of the local value of $C_{m(b)}$ to the integrated value \bar{C}_m remains the same.

Impeller efficiency and slip coefficient deduced from measurements are based on the mass weighted, adjusted tangential velocity component \bar{C}_u .

Ideal Head Coefficient ψ_i

$$\psi_i = \frac{\frac{R_2}{R_m} \bar{C}_u}{u_2}$$

Impeller efficiency η

$$\eta = \frac{\bar{H}_t}{\psi_i \frac{u_2^2}{g}}$$

Slip coefficient μ

$$\mu = \frac{\frac{R_2}{R_M} \bar{c}_u}{u_2 - \frac{c_m^2}{\tan \beta}}$$

where:

c_{m2} = meridional velocity from one-dimensional analysis.

Nomenclature, input format, listing and sample printout are presented on the following pages.

NOMENCLATURE

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>	<u>FORMAT</u>
<u>MAIN PROGRAM CONSTANTS</u>			
AI21	1st Impeller Discharge Area, Blocked	Sq In	
AI22	2nd Impeller Discharge Area, Blocked	Sq In	
DI21	1st Impeller Discharge Diameter	In	
DI22	2nd Impeller Discharge Diameter	In	
BET21	1st Impeller Discharge Blade Angle	Deg	
BET22	2nd Impeller Discharge Blade Angle	Deg	
Z21	1st Impeller Blade Number		
Z22	2nd Impeller Blade Number		
FSLIP	Empirical Factor, Pfleiderer Slip = .65		
SM1	1st Impeller Blade Static Moment	Sq In	
SM2	2nd Impeller Blade Static Moment	Sq In	
<u>INPUT</u>			
<u>TRAVERSE EXCURSION CONSTANTS</u>			
NTRA	Number of Surveys		I2
POPS(J)	Ambient Pressure	psia	F
SN(J)	Rotational Speed	rpm	F
RVBL(J)	Percent Balancer Flow Simulated	%	F
VW(J)	Net Weight Flow	lb/s	F
RHO11(J)	Fluid Density, 1st Stage	lb/ft ³	F
RHO12(J)	Fluid Density, 2nd Stage	lb/ft ³	F
RECI1(J)	Percent Recirculation, 1st Impeller	%	F
RECI2(J)	Percent Recirculation, 2nd Impeller	%	F
PHI1(J)	Discharge Flow Coefficient, 1st Impeller		F
PHI2(J)	Discharge Flow Coefficient, 2nd Impeller		F
TOABS(J)	Ambient Temperature	Deg F	F
TI(J)	Temperature Interstage	Deg F	F
PTI(J)	Total Pressure Interstage	Deg F	F
QDN(J)	Flow Speed Ratio	gpm/rpm	F

NOMENCLATURE (Cont'd)

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>	<u>FORMAT</u>
J	Survey Number		I3
R4	Radius of Traverse Location	In	F
CAPB4	Port Width Wall to Wall	In	F
NST	Stage Number		I3
NTP	Number of Traverse Points		I3

TRAVERSE VARIABLES

B4(I)	Distance	In	F
PT4(I)	Total Pressure	In H ₂ O	F
PS4(I)	Static Pressure	In H ₂ O	F
ALP4(I)	Flow Angle	Deg	

IBM

FORTRAN Coding Form

GX28-7327-6 U/M050
Printed in U.S.A.

PROGRAM TRAVERSE DATA EVALUATION	DATE	PERIPHERALS INSTRUCTIONS	GRAPHIC					PAGE OF	
ENCODER			PUNCH					CARD ELECTRIC NUMBER	

CARD NO.

CARD NO.	FORTRAN STATEMENT																																																																							IDENTIFICATION SYMBOLS									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71		72	73	74	75	76	77	78	79	80
1	NTRA																																																																																
2	POPS(J)	SN(J)	RVBL(J)	VW(J)	RHOI1(J)	RHOI2(J)	RECI1(J)	RECI2(J)																																																																									
3	PHI1(J)	PHI2(J)	TOABS(J)	TI(J)	PIE(J)	QDN(J)	STACK AS MANY NO. 2 & 3 CARDS AS NTRA INDICATES																																																																										
4	J	P4	CAPB4	NST	NTP																																																																												
5	B4(I)	PT4(I)	PS4(I)	ALPH4(I)	← STACK AS MANY AS NTP INDICATES																																																																												

IBM is not responsible for punching statements from this form.

```

000001 COMMON POPS(12),SN(12),RVBL(12),VM(12),RH01(12),RH02(12),
000002 1REC11(12),REC12(12),A121,A122,D121,D122,FI121,BET22,TOABS(12),
000003 2TI(12),PTI(12),PHI1(12),PHI2(12),Z21,Z22,FSLIP,SML1,SML2,J,ODN(12),
000004 3PHI4(12),PHI4A(12)
000005 1 FORMAT(12)
000006 READ(5,1) NTRA
000007 A121 = 14.8
000008 A122 = 15.7
000009 D121 = 10.95
000010 D122 = 10.75
000011 BET21 = 30.
000012 BET22 = 25.
000013 Z21 = 8.
000014 Z22 = 8.
000015 FSLIP = .65
000016 SML = 12.8
000017 SML2 = 12.47
000018 3 FORMAT(6F10.4/6F10.4)
000019 READ(5,3) (POPS(J),SN(J),RVBL(J),VM(J),RH01(J),RH02(J),REC11(J),
000020 1REC12(J),PHI1(J),PHI2(J),TOABS(J),TI(J),PTI(J),ODN(J),J=1,NTRA)
000021 DO 20 J=1,NTRA
000022 TOABS(J) = TOABS(J) + 459.67
000023 DO 30 J=1,NTRA
000024 30 CALL TRAVD
000025 STOP
000026 END
000027 SUBROUTINE TRAVD
000028 DIMENSION D4(20),P14(20),H14(20),P54(20),H54(20),HTH4(20),HSH4(20)
000029 1 H1C4(20),H5C4(20),HV4(20),C4(20),CM4(20),CU4(20),DB(20),ALP4(20),
000030 2CM4B(20),CU4B(20),H14CB(20),CM4A(20),ALP4A(20),CU4A(20)
000031 COMMON POPS(12),SN(12),RVBL(12),VM(12),RH01(12),RH02(12),
000032 1REC11(12),REC12(12),A121,A122,D121,D122,BET21,BET22,TOABS(12),
000033 2TI(12),PTI(12),PHI1(12),PHI2(12),Z21,Z22,FSLIP,SML1,SML2,J,ODN(12),
000034 3PHI4(12),PHI4A(12)
000035 LR = 5
000036 LW = 6
000037 10 FORMAT(11,)
000038 1 FORMAT( 2X,IMPELLER DISCHARGE, STAGE,12.10X, Q/N = ,F7.4,8X,
000039 3 FORMAT( 2X,PARAMETERS BASED ON MEASURED VALUES,/)
000040 5 FORMAT( 5X,DISTANCE,44X,TOTAL HEAD,3X,STATIC HEAD,2X,NORM TO
000041 7 FORMAT( 5X,NORM STAT,44X,TOT HEAD,3X,STAT HEAD)
000042 9 FORMAT( 5X,H4/CAPB4,5X,HT4, FT,7X,H54, FT,5X,HEAD,8X,HEAD
000043 11,4X,NORM STAT,44X,TOT HEAD,3X,STAT HEAD)
000044 11,9X,COEFF,7X,COEFF,/)
000045 11 FORMAT(F12.4,F13.2,F14.2,BE13.4,FI10.4,FI2.4)
000046 13 FORMAT(//5X,DISTANCE,44X,ABS VELOCITY,2X,FLOW ANGLE,2X,VELO
000047 ICITY,5X,VELOCITY,5X,FLOW COEFF,/)
000048 15 FORMAT( 5X,H4/CAPB4,5X,C4,FT/S,7X,DCG,6X,CM4, FT/S,4X,CU4
000049 1, FT/S,6X,CM4/US,/)
000050 17 FORMAT(F12.4,F14.2,FI2.2,FI3.2,FI4.4)
000051 19 FORMAT(// 2X,INTEGRATED VALUES WITH MASS WEIGHTED TOTAL HEAD,/)
000052 21 FORMAT(5X,TOT HEAD,3X,NORM TOT HD,2X,TOT HEAD,6X,CM4,11X,
000053 1 ALPHA,41,8X,FLOW RATE CUFT/S,7X,FLOW ERROR)
000054 23 FORMAT( 8X,FT/RPM**2,6X,COEFF,6X,FT/S,10X,
000055 1 DEG,8X,INTGR,4X,FROM CONTINUITY,4X,PERCENT,/)
000056

```

```

00007 25 FORMAT(F12.2,F10.4,F10.4,F12.2,
          F12.3,F13.3,F14.3)
00076 27 FORMAT(//2X,ADJUSTED VALUES TO SATISFY CONTINUITY//)
00079 29 FORMAT(5X,DISTANCE,5X,CM 4,4X,ALPHA 4,4X,CU 4,5X,FLOW CO
          IEFF.)
00081 31 FORMAT(5X,IN/CAP,5X,FT/S,6X,DEG,6X,FT/S,5X,CM/U2//)
00082 33 FORMAT(F12.4,F10.2,F10.2,F12.4)
00083 35 FORMAT(// 2X,IMPELLER PERFORMANCE//)
00084 37 FORMAT(5X,ABSOLUTE FLUID ANGLE =,F6.3//)
00085 39 FORMAT(5X,SLIP
          =,F6.4//)
00086 41 FORMAT(// 2X,ADJUSTED VALUES, INTEGRATED,31X,MASS WEIGHTED TANG
          ENIAL VELOCITY COMPONENT CU//)
00088 43 FORMAT(18X,CM 4,4X,ALPHA 4,4X,CU 4,29X,CU 4,12X,CU 2)
00089 45 FORMAT(18X,FT/S,6X,DEG,6X,FT/S,12X,FT/S//)
00090 47 FORMAT(F22.2,F10.2,F16.2)
00091 71 FORMAT(13,F7.3,F10.3,213)
00092 73 FORMAT(F6.3,3E8.2)
00093 75 FORMAT(50X,THEORETICAL HEAD COEFFICIENTS//)
00094 77 FORMAT(2X,FLOW COEFF,1X,EULER,15X,ACOSTA,14X,STODOLA,13X,
          1,PFLIDENER,10X,MEASURED//)
00095 79 FORMAT(F10.4,F15.4,4E20.4//)
00097 81 FORMAT(//2X,PARAMETERS BASED//2X,ON ABOVE COEFFICIENTS///)
00098 83 FORMAT(2X,SLIP,F39.4,3E20.4//)
00099 85 FORMAT(2X,IMPELLER EFFICIENCY,F24.4,3E20.4//)
00100 87 FORMAT(//6X,102,11X,CM2)
00101 89 FORMAT(5X,FT/S,9X,FT/S//)
00102 91 FORMAT(F10.2,F13.2)
00103 READ(LR,71) J,R4,CAPR4,NST,NTP
00104 READ(LR,73) (84(I),PT4(I),PS4(I),ALP4(I),I=1,NTP)
00105 IF (NS1-1) 90,90,92
00106 90 D12 = D121
00107 A12 = A121
00108 BET2 = BET21
00109 Z = Z21
00110 SM = SM1
00111 PHID = PHID(J)
00112 V12 = VM(J) * (1.+REC11(J)/100.)/RHO11(J)
00113 V4 = VM(J) * (1.+RVH1(J)/100.)/RHO11(J)
00114 GO TO 94
00115 92 D12 = D122
00116 A12 = A122
00117 BET2 = BET22
00118 Z = Z22
00119 SM = SM2
00120 PHID = PHID(J)
00121 V12 = VM(J) * (1.+REC12(J)/100.)/RHO12(J)
00122 V4 = VM(J)/RHO12(J)
00123 94 U2 = SM(J) * D12/229.
00124 USG6 = U2**2/32.174
00125 BETR = 9E12/57.296
00126 TGR2 = SIN(BETR)/COS(BETR)
00127 PSIEU = 1. - PHID/TGR2
00128 SLP5 = 1. - 1./PSIEU * 3.1417 * SIN(BETR)/2
00129 G = (90. - BET2)/57.296
00130 C = COS(G)
00131 A6.5797C**2/Z**2-19.233C**4/Z**3+R.65R4**C**4/Z**4*(8.**C**2-1.)
00132 PS10=EXP(-2.**G*SIN(2.**G)/Z)**EXP(A)/(2.**C)**(4.**C**2/Z))
00133 PSTHS = SLP5 * PSIEU
00134 PSTHA = PS10 - PHID/TGR2
00135 SLPV = PSTHA/PSIEU
00136 PS1L = FSLIP * (1.+BET2/60.)

```

```

000117      PSL = P51GL*(D12/2.)*2/2/5M
000118      SLPP = 1./(1.+PSL)
000119      PSTHP = SLPP * PSIEU
000120      C-PARAMETERS BASED ON MEASURED VALUES
000121      DO 110 I=1,NTP
000122          B4(I) = B4(I)/CAPR4
000123          PT4(I) = PT4(I)/27.67 + POPS(J)
000124          PS4(I) = PS4(I)/27.67 + POPS(J)
000125          IF(NST=1) 96,96,97
000126      96  HT4(I)=186.768*T0ABS(J)*((PT4(I)/POPS(J))*0.283 - 1.)
000127          HS4(I)=186.768*T0ABS(J)*((PS4(I)/POPS(J))*0.283 - 1.)
000128          GO TO 98
000129      97  HT4(I) = 186.768*(TI(J)+459.67)*((PT4(I)/PTI(J))*0.283-1.)
000130          HS4(I) = 186.768*(TI(J)+459.67)*((PS4(I)/PTI(J))*0.283-1.)
000131      98  HTN4(I) = HT4(I)/SN(J)**2
000132          HSN4(I) = HS4(I)/SN(J)**2
000133          HTC4(I) = HT4(I)/USOG
000134          HSC4(I) = HS4(I)/USQG
000135          HV4(I) = HT4(I) - HS4(I)
000136          C4(I) = 8.0217 + SQRT(HV4(I))
000137          CM4(I) = C4(I) * SINH(ABS(ALP4(I)/57.296))
000138          IF(ALP4(I))95,100,100
000139      95  CM4(I) = -CM4(I)
000140      100 PHI4(I) = CM4(I)/U2
000141      110 CU4(I) = C4(I) * COS(ABS(ALP4(I)/57.296))
000142          WRITE(LW,10)
000143          WRITE(LW,1)
000144          WRITE(LW,3) NST,QDN(J),SN(J),RVBL(J)
000145          WRITE(LW,5)
000146          WRITE(LW,7)
000147          WRITE(LW,9)
000148          WRITE(LW,11) (B4(I),HT4(I),HS4(I),HTN4(I),HSN4(I),HTC4(I),HSC4(I),
000149      1I=1,NTP)
000150          WRITE(LW,13)
000151          WRITE(LW,15)
000152          WRITE(LW,17) (B4(I),C4(I),ALP4(I),CM4(I),CU4(I),PHI4(I),I=1,NTP)
000153      C-TRAVERSE INCREMENTS
000154          LIM = NTP-1
000155          DB(1) = 0.5 * (B4(2) + B4(1))
000156          DB(NTP) = 1. - 0.5 * (B4(NTP-1) + B4(NTP))
000157          DO 102 I=2,LIM
000158      102  DB(I) = (B4(I+1) - B4(I-1))*0.5
000159          SUM = 0
000160          DO 104 I=1,NTP
000161      104  SUM = SUM + DB(I)
000162      C-INTEGRATED VALUES
000163          SCM4B = 0
000164          SCU4B = 0
000165          SCUV4 = 0
000166          SHT4B = 0
000167          DO 106 I=1,NTP
000168          CM4B(I) = CM4(I) * DB(I)
000169          SCM4B = SCM4B + CM4B(I)
000170          CU4B(I) = CU4(I) * DB(I)
000171          SCU4B = SCU4B + CU4B(I)
000172          SCUV4 = SCUV4 + CM4B(I) * CU4(I)
000173          HT4CB(I) = HT4(I) * CM4B(I)
000174      106  SHT4B = SHT4B + HT4CB(I)
000175          HT4I = SHT4B/SCM4B
000176          HT4IN = HT4I/SN(J)**2

```

```

000177      HT4IC = HT4I/US06
000178      CU4I = SCU4A/SCM4B
000179      ALP4I = ATAN(SCM4B/SCU4B)*57.296
000180      VI4 = 0.043634 * R4 * CAPB4 * SCM4B
000181      ERR = (VI4-V4)/V4 * 100.
000182      FLADJ = V4/VI4
000193      WRITE(LW,19)
000194      WRITE(LW,21)
000195      WRITE(LW,23)
000196      WRITE(LW,25) HT4I,HT4IN,HT4IC,SCM4B,      ALP4I,VI4,V4,ERR
000197      C-ADJUSTED VALUES
000183      DO 114 I=1,NTP
000189          CM4A(I) = FLADJ * CM4(I)
000190          PHI4A(I) = CM4A(I)/U2
000191          ALP4A(I) = ASIN(ABS(CM4A(I)/C4(I)))*57.296
000192          IF(CM4A(I)) 112,114,114
000193          112 ALP4A(I) = -ALP4A(I)
000194          114 CU4A(I) = C4(I) * COS(ABS(ALP4A(I)/57.296))
000195          WRITE(LW,27)
000196          WRITE(LW,29)
000197          WRITE(LW,31)
000198          WRITE(LW,33) (B4(I),CM4A(I),ALP4A(I),CU4A(I),PHI4A(I),I=1,NTP)
000199      C-ADJUSTED VALUES INTEGRATED
000200      SCM4B = FLADJ * SCM4B
000201      SCU4A = 0
000202      CUV4A = 0
000203      DO 116 I=1,NTP
000204          SCU4A = SCU4A + CU4A(I) * DB(I)
000205          CM4BA = CM4B(I) * FLADJ
000206          116 CUV4A = CUV4A + CM4BA * CU4(I)
000207          CU4AI = CUV4A/SCM4B
000208          ALPIA = ATAN(SCM4B/SCU4A) * 57.296
000209          CM2 = VI2/AI2 * 144.
000210          CU2 = 2. * R4/DI2 * CU4AI
000211          ETAIA = HT4IC/PSTHA
000212          ETAIS = HT4IC/PSTHS
000213          ETAIP = HT4IC/PSTHP
000214          PSTHM = CU2/U2
000215          ETAIM = HT4IC/PSTHM
000216          CU2E = U2 - CM2/TG82
000217          SLIPM = CU2/CU2E
000218          WRITE(LW,41)
000219          WRITE(LW,43)
000220          WRITE(LW,45)
000221          WRITE(LW,47) SCM4B,ALPIA,SCU4A,CU4AI,CU2
000222          WRITE(LW,35)
000223          WRITE(LW,75)
000224          WRITE(LW,77)
000225          WRITE(LW,79) PHID,PSIEU,PSTHA,PSTHS,PSTHP,PSTHM
000226          WRITE(LW,81)
000227          WRITE(LW,83) SLPA,SLPS,SLPP,SLIPM
000228          WRITE(LW,85) ETAIA,ETAIS,ETAIP,ETAIM
000229          WRITE(LW,87)
000230          WRITE(LW,89)
000231          WRITE(LW,91) U2,CM2
000232      RETURN
000233      END

```

TRAVERSE DATA EVALUATION

IMPELLED DISCHARGE, STAGE 1 Q/N = .2185 SPEED = 7002.0 RPM BALANCER FLOW = 15.215 PERCENT

PARAMETERS BASED ON MEASURED VALUES

DISTANCE R0/CAP04	TOTAL HEAD HT4, FT	STATIC HEAD H54, FT	NORM TOT HEAD	NORM STAT HEAD	TOT HEAD COEFF	STAT HEAD COEFF
.0704	2222.89	1500.17	.4534-04	.3060-04	.6380	.4306
.1567	2216.37	1500.17	.4521-04	.3060-04	.6361	.4306
.3175	2190.32	1500.17	.4467-04	.3060-04	.6207	.4306
.4762	2183.89	1500.17	.4454-04	.3060-04	.6268	.4306
.6349	2151.29	1500.17	.4388-04	.3060-04	.6174	.4306
.7937	2066.71	1500.17	.4175-04	.3060-04	.5874	.4306
.9524	1928.82	1500.17	.3934-04	.3060-04	.5536	.4306

13

DISTANCE R0/CAP04	ARS VELOCITY C4, FT/S	FLOW ANGLE DEC	VELOCITY CM4, FT/S	VELOCITY CU4, FT/S	FLOW COEFF CM4/U2
.0704	215.65	7.80	29.27	213.66	.0874
.1567	214.60	9.00	33.58	212.03	.1003
.3175	210.74	10.00	36.59	207.53	.1093
.4762	209.74	11.30	41.10	205.67	.1227
.6349	204.69	11.20	39.76	200.79	.1187
.7937	187.53	7.50	24.48	185.93	.0731
.9524	166.09	-2.00	-5.80	165.98	-.0173

INTEGRATED VALUES WITH MASS WEIGHTED TOTAL HEAD

TOT HEAD FT	NORM TOT HD FT/RPM*2	TOT HEAD COEFF	CM4 FT/S	ALPHA 4 DEG	FLOW RATE CUFT/S INTGR FROM CONTINUITY	FLOW ERROR PERCENT
2175.38	.4437-04	.6244	29.27	8.300	4.587	12.915

ADJUSTED VALUES TO SATISFY CONTINUITY

DISTANCE R0/CAP04	CM 4 FT/S	ALPHA 4 DEG	CU 4 FT/S	FLOW COEFF CM4/U2
.0704	26.13	6.96	214.06	.0780
.1567	29.90	8.03	212.57	.0895
.3175	32.67	8.92	208.19	.0976
.4762	36.69	10.07	206.50	.1096
.6349	35.49	9.99	201.50	.1000
.7937	21.05	6.69	106.25	.0553

.9524 -5.17 -1.79 166.00 -.0155

ADJUSTED VALUES, INTEGRATED

MASS WEIGHTED TANGENTIAL VELOCITY COMPONENT CU

CM 4 FT/S	ALPHA 4 DEG	CU 4 FT/S	CU 4 FT/S	CU 2 FT/S
26.13	7.47	199.25	205.18	213.62

IMPELLER PERFORMANCE

THEORETICAL HEAD COEFFICIENTS

FLOW COEFF	EULER	ACOSTA	STODOLA	PFLEIDENER	MEASURED
.1059	.8167	.6328	.6208	.6354	.6380

PARAMETERS BASED
ON ABOVE COEFFICIENTS

SEIP	.7748	.7596	.7780	.7828
IMPELLER EFFICIENCY	.9866	1.0064	.9825	.9785

U2 FT/S	CM2 FT/S
339.81	35.76

N8300R:72-106
May 1972

6. PUMP AIR TEST DATA REDUCTION

COMPUTER PROGRAM
PUMP AIR TEST DATA REDUCTION

I. INTRODUCTION

This program computes overall as well as component performance parameters of a two-stage centrifugal flow pump from measured data including pressures, temperatures, torque and shaft speed. Calculations of isentropic head and air density account for changes in relative humidity.

The program was written for the reduction of test data obtained from pump air tests conducted in support of the NERVA Turbopump Program. The pump air test results are discussed in Reference 1.

II. BASIC EQUATIONS

I. Pressure Conversion

The following conversion factors are used in the program:

$$1 \text{ PSI} = 2.036 \text{ in. Hg}$$

$$1 \text{ PSI} = 27.67 \text{ in. H}_2\text{O}$$

Reference 1 - J. J. Brunner, Performance of a Two-Stage Centrifugal NERVA Pump Tested with Air as the Working Fluid, Engineering Operations Report N8300R:71-090, 12-9-71

2. Air Properties

Measured are barometric pressure B in in. Hg and wet and dry bulb temperature t_w and t_d from psychrometer. The vapor pressure P_w in in. Hg corresponding to the wet bulb temperature t_w is obtained from the steam tables. The actual vapor pressure P_v in in. Hg is calculated from the empirical equation presented in Reference 2:

$$P_v = P_w - \frac{B (t_d - t_w)}{2700}$$

The relative humidity r_h is the ratio of the actual vapor pressure to the pressure of saturated vapor at the prevailing dry-bulb temperature:

$$r_h = \frac{P_v}{P_d}$$

Neglecting the inert gases, the part pressures of the oxygen-nitrogen-water vapor mixture are calculated according to Dalton's Law.

The pressure of dry air p_a is:

$$p_a = B - P_v \text{ (in. Hg)}$$

and that of its constituents:

$$p_{O_2} = .21 p_a$$

$$p_{N_2} = .79 p_a$$

The density ρ of each constituent is obtained from:

$$\rho = \frac{M P}{1546 T}$$

M = molecular weight

P = pressure in lb/ft³

T = absolute temperature °R, (dry bulb)

The specific heats of the mixture are obtained by weighting the specific heat of each constituent as follows:

$$C_p = \frac{\rho_{O_2} C_{pO_2}}{\Sigma \rho} + \frac{\rho_{N_2} C_{pN_2}}{\Sigma \rho} + \frac{\rho_v C_{pv}}{\Sigma \rho}$$

The specific heat C_v is calculated analogously. Values of specific heats for each constituent used in the program are summarized below.

A_1 = pipe area, sq. in.
 A_2 = nozzle throat area, sq. in.
 ϕ = nozzle discharge coefficient

Nozzle constant $K = \phi C$

C = velocity of approach factor = $\frac{1}{\sqrt{1 - \left(\frac{A_1}{A_2}\right)^2}}$

The following equations apply for all flow nozzles employed:

3. Flow Measurement

Molecular weight: $M = \frac{1546}{R}$

gas constant: $R = 778.2 (C_p - C_v)$

$p = p_{O_2} + p_{N_2} + p_v$

tents:

The mixture density is equal to the sum of the densities of the consti-

H_2O	.445	.3345
N_2	.244	.173
O_2	.217	.155
	C_p	C_v

SPECIFIC HEATS IN BTU/(LB, °R)

The compressibility effect is considered with adiabatic expansion factor Y_a from Reference 3.

$$Y_a = \left[r_p^{\left(\frac{2}{\gamma}\right)} \left(\frac{\gamma}{\gamma-1}\right) \left(\frac{1-r_p}{1-r_p^{\left(\frac{\gamma-1}{\gamma}\right)}}\right) \left(\frac{1-\beta^4}{1-\beta^4 r_p^{\frac{2}{\gamma}}}\right) \right]^{1/2}$$

where:

r_p = pressure ratio across nozzle: P_{noz}/P_{line}

γ = ratio of specific heats C_p/C_v

β = ratio of throat to pipe diameter

4. Volumetric Flow Rate V_f

$$V_f = K (Y_a) \frac{A_2}{144} \left(\frac{2g}{\rho}\right)^{1/2} \left(\frac{144 \Delta P}{27.67}\right)^{1/2} = 0.127 K A_2 \left(\frac{\Delta P}{\rho}\right)^{1/2} \quad (\text{ft}^3/\text{sec})$$

where:

ΔP = $P_{pipe} - P_{throat}$, in H_2O

ρ = Fluid density, lb/ft^3

Reference 3 - ASME, Fluid Meters, Fifth Edition, ASME, New York, 1959

5. Isentropic Head

$$H_{is} = 778.2 C_p T_0 \left[\left(\frac{P_2}{P_0} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right] \quad (\text{ft})$$

In this calculation of the overall and stage total head rise, the velocity head

$$H_{vel} = \frac{\left(\frac{144 V_f}{\rho A} \right)^2}{2g}$$

is added to obtain the correct total head.

6. Pump Efficiency

Efficiency based on measured temperature rise Δt_{act}

$$\eta_t = \frac{\Delta t_{is}}{\Delta t_{act}}$$

where:

$$\Delta t_{is} = T_0 \left[\left(\frac{P_2}{P_0} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right]$$

Efficiency based on measured shaft torque τ (in lb)

$$\eta_\tau = \frac{12 \dot{W} \Delta H_{is}}{\omega \tau}$$

\dot{W} = net flow rate, lb/sec

ω = angular velocity = $\frac{\pi N}{30}$ rad/sec

7. Labyrinth Flow Rate, Impeller Shroud

The recirculating impeller front shroud labyrinth flow rate is estimated to determine the impeller discharge flow coefficient. Mean labyrinth through-flow area A_{1b} and orifice coefficient C_{1b} are input. The pressure gradient along the shroud is neglected.

$$\begin{aligned}\dot{W}_{1b} &= C_{1b} \frac{A_{1b}}{144} \rho \left[\frac{2g (144) \Delta P_{1b}}{\rho} \right]^{1/2} \\ &= 0.65847 C_{1b} A_{1b} (\rho \Delta P_{1b})^{1/2}\end{aligned}$$

where:

ΔP_{1b} = pressure drop in lb/sq.in. across labyrinth

C_{1b} = labyrinth flow coefficient = 0.5

8. Impeller Discharge Flow Coefficient

$$\phi_2 = 144 \frac{\dot{W} + \dot{W}_{1b}}{\rho A_2 U_2}$$

A_2 = impeller discharge area blocked, sq. in.

U_2 = $D_2 N/229$, ft/s

For the second stage the recirculating balancer flow (when simulated) must be added to the net flow.

9. Stage Head Coefficient

$$\psi = \frac{g \Delta H_{is}}{U_2^2}$$

10. Impeller Discharge Total Head Coefficient (one-dimensional)

This coefficient is based on an average static pressure determined from several wall static pressures measured around the impeller periphery between diffuser inlet and impeller discharge at radius R_M . Two methods were considered for estimating the impeller total head:

Method I (based on assumed impeller efficiency)

The static head coefficient is expressed as the difference of the total head coefficient and the velocity head in coefficient form:

$$\psi_s = \psi_t - \frac{\psi_i^2 + \phi_2^2}{2}$$

ψ_s = static head coefficient

ψ_t = total head coefficient

ψ_i = ideal head coefficient

ϕ_2 = discharge flow coefficient

Since the static head is based on measurements outside the impeller discharge the absolute velocity is reduced by the ratio of the impeller discharge radius R_2 to the radius of the pressure tap R_M . The velocity head therefore is multiplied by the radius ratio squared. Substituting the ratio of total head coefficient to impeller efficiency in place of the ideal head coefficient:

$$\psi_s = \psi_t - \left(\frac{R_2}{R_M}\right)^2 \left(\frac{\left(\frac{\psi_t}{\eta}\right)^2 + \phi_2^2}{2}\right)$$

Solving for ψ_t the quadratic equation can be written as:

$$\left(\frac{R_2}{\eta R_M}\right)^2 \psi_t^2 - \psi_t + \left(\frac{R_2}{R_M}\right)^2 \left(\frac{\phi_2^2}{2}\right) + \psi_s = 0$$

and

$$\psi_t = \frac{1 \pm \sqrt{1 - \left(\frac{R_2}{\eta R_M}\right)^2 \left[\left(\frac{R_2}{R_M}\right)^2 \phi_2^2 + 2\psi_s\right]}}{\left(\frac{R_2}{\eta R_M}\right)^2}$$

Method II (based on calculated slip)

In this method the impeller total head coefficient is calculated directly from

$$\psi_t = \psi_s + \left(\frac{R_2}{R_M}\right)^2 \left(\frac{\phi_2^2 + \psi_i^2}{2}\right)$$

with a theoretical head coefficient ψ_i based on Stodola's slip correction, defined as:

$$\psi_i = 1 - \frac{\phi_2}{\tan \beta_2} - \frac{\pi \sin \beta_2}{Z}$$

where:

β_2 = discharge blade angle

Z = number of blades

Values calculated by both methods showed excellent agreement for data points near design. For off-design points however, the slip estimate was considered more accurate and consistent than the estimate of impeller efficiency. Method II was therefore selected for incorporation into the program.

11. Housing Losses

Crossover and diffusion housing losses are expressed in head coefficient form as:

$$\Delta\psi_{\ell}(\text{Housing}) = \psi_t(\text{Impeller}) - \psi_t(\text{Stage})$$

To determine diffuser and volute losses individually, the total head at the diffuser discharge is estimated from a measured average wall static pressure and a calculated velocity head. Using Pfleiderer's criterion for slip (Reference 4) to account for flow deviation the fluid angle at the diffuser discharge is expressed as follows:

Reference 4 - C. Pfleiderer, Die Kreiselpumpen, Fifth Edition, Springer-Verlag, 1961

$$C_{tg} \alpha_5 = \frac{\beta_5 + P_\ell \frac{R_2 C_{u2}}{R_5 C_{m5}}}{1 + P_\ell}$$

with

β_5 = diffuser vane discharge angle

R_2 = impeller discharge radius

R_5 = diffuser discharge radius

C_{u2} = tangential velocity component, impeller discharge

C_{m2} = meridional velocity component, diffuser discharge

$$P_\ell = \frac{\psi^1 R_5^2}{Z S}$$

where:

Z = diffuser vane numbers

S = static moment of vane in meridional plane =
 $\frac{1}{2} (R_5^2 - R_4^2)$

ψ^1 = empirical factor = $0.75 (1 + \frac{\beta_5}{60})$

The total head at the diffuser discharge then is:

$$H_t = H_s + \frac{\left(\frac{C_{m5}}{\sin \alpha_5}\right)^2}{2g} \quad \text{and} \quad \psi_t = \frac{H_t}{u^2/g}$$

Diffuser head loss coefficient:

$$\Delta\psi_{\ell}(\text{Diffuser}) = \psi_t(\text{Impeller}) - \psi_t(\text{Diffuser})$$

Volute head loss coefficient:

$$\Delta\psi_{\ell}(\text{Volute}) = \psi_t(\text{Diffuser}) - \psi_t(\text{Stage})$$

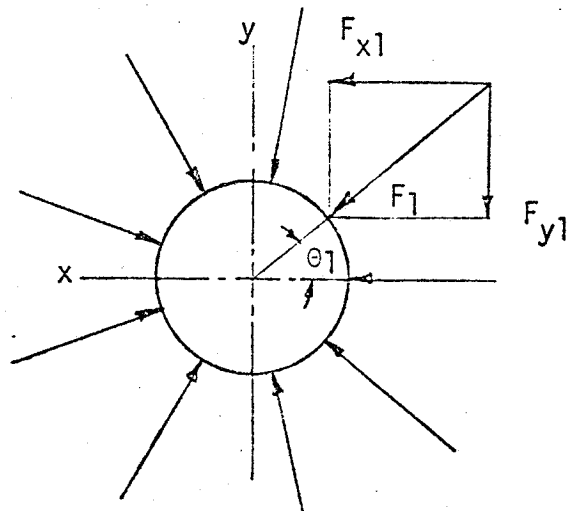
Radial Thrust

Radial thrust is determined from the wall static pressures measured around the impeller periphery. Each measured pressure multiplied by its effective area (circumferential increment \times effective width) results in a force vector F shown in Figure below. The force components of F are:

$$F_y = F \sin \theta$$

and

$$F_x = F \cos \theta$$



The radial force \bar{F} then is the resultant of the algebraic sums of the force components F_y and F_x .

$$\bar{F} = \sqrt{\Sigma F_y + \Sigma F_x}$$

The direction of the resultant force is determined by the angle

$$\theta = \tan^{-1} \left(\frac{\Sigma F_y}{-\Sigma F_x} \right)$$

θ is measured from the pressure tap nearest to the volute tongue in direction of impeller rotation.

The radial thrust parameter used in the data presentation is defined as the ratio of the resultant radial force \bar{F} (lb) to the average static pressure rise (lb/sq in) measured from the pump inlet to the second stage impeller periphery.

$$K_R = \frac{\bar{F}}{P_{2m} - P_{amb}}$$

AIR TEST DATA REDUCTION PROGRAM
 NOMENCLATURE
 INPUT DATA

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>CONSTANTS</u>	<u>UNITS</u>	<u>FORMAT</u>
IM	Month			I2
ID	Day			I2
IY	Year			I2
NOT	Test No.			I3
NODAT	Number of Data Points			I3
NOPI2	No. of Circumferential Pressures Imp, 2nd Stage			I5
NODF	No. of Circumferential Pressure Diff. Disch.			I5
CNCZ	Coeff. Disch. Flow Nozzle			F
ANOZ	Nozzle Area		Sq In	F
ADL	Area Disch. Line		Sq In	F
CORIF	Coeff. Bleed Orifice			F
ABL	Area Bleed Orifice		Sq In	F

IMPELLER 1ST STAGE

AI21	Area Imp. Disch. Blocked		Sq In	F
DI21	Diameter, Imp. Disch.		In.	F
CLAB1	Labyrinth Orifice Coeff.			F
Z21	Number of Blades			F
BET 21	Blade Disch. Angle		Deg.	F
ALB1	Flow Area, Labyrinth		Sq in	F

IMPELLER 2ND STAGE

AI22	Area Imp. Disch. Blocked		Sq In	F
DI22	Diameter, Imp. Discharge		In	F
CLAB2	Labyrinth Orifice Coeff.			F
Z22	Number of Blades			F
BET22	Disch. Blade Angle		Deg	F
ALB2	Flow Area, Labyrinth		Sq In	F

AIR TEST DATA REDUCTION PROGRAM

NOMENCLATURE

INPUT DATA

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>	<u>FORMAT</u>
<u>HOUSING</u>			
ACR01	Area Crossover Channel	Sq In	F
ACR02	Area Crossover Channel	Sq In	F
ACR03	Area Crossover Channel	Sq In	F
ACR04	Area Crossover Channel	Sq In	F
ADFD	Tang. Area Diff. Discharge	Sq In	F
BDFD	Diff. Disch. Fluid Angle	Deg	F
<u>MEASURED DATA</u>			
POHG	Pressure, Ambient	In Hg	F
TO	Temperature, Ambient	Def F	F
PSD	Static Pressure, Discharge	In H ₂ O	F
TD	Temperature, Discharge	Deg F	F
DPORI	Pressure Drop, Bleed Orifice	in H ₂ O	F
TI	Temperature, Total, Interstage	Deg F	F
PTI	Total Pressure, Interstage, RMR Dia.	In H ₂ O	F
PSI	Static Pressure, Interstage	In H ₂ O	F
SN	Rotational Speed	RPM	F
TQS	Shaft Torque, Measured	In Lb.	F
PSIM1	Mean Static Pressure, Imp Disch, 1st Stg.	In H ₂ O	F
PSIN	Mean Static Pressure, Inducer	In H ₂ O	F
PCR01	Stat Pressure, Crossover Channel	In H ₂ O	F
PCR02	Stat Pressure, Crossover Channel	In H ₂ O	F
PCR03	Stat Pressure, Crossover Channel	In H ₂ O	F
PCR04	Stat Pressure, Crossover Channel	In H ₂ O	F
DPN	Pressure Drop, Nozzle Disch. Line	In H ₂ O	F

AIR TEST DATA REDUCTION PROGRAM
 NOMENCLATURE
 INPUT DATA

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>	<u>FORMAT</u>
	IMPELLER SECOND STAGE <u>CIRCUMFERENTIAL STATIC PRESSURES</u>		
PSI2(1)-(18)	Static Pressure, Imp. Discharge	In H ₂ O	F
	DIFFUSER DISCHARGE CIRCUMFERENTIAL <u>STATIC PRESSURE</u>		
PSDF(1)-(9)	Static Pressure, Diff. Discharge	IN H ₂ O	F


```

000001 DIMENSION PONG(30),T0(30),PS0(30),TD(30),DPORI(30),TI(30),PTI(30),
000002 1PSI(30),SN(30),TOS(30), PSIN(30),PCRO1(30),PCRO2(30),PCRO3
000003 2(30),PCRO4(30),PSIMI(30)
000004 DIMENSION TOANS(30),RHO(30),RHOD(30),VDF(30),VDFG(30),
000005 1VW(30),RVOL(30),RHOI(30),VIF(30),VIG(30),PROV(30),HISOV(30),HOVN2(
000006 230), QDN(30),DTAOV(30),DTTOV(30),FFTOV(30),TOTOV(30),TOMTO(30)
000007 3, TONS(30),EFS(30),PRS1(30),HIS1(30),HNS1(30),QIN(30),DTAS1(30),
000008 4EFTS1(30),RHOI1(30),RECI1(30),PHI1(30),HC1(30),PRS2(30),HIS2(30),
000009 5HNS2(30),DTAS2(30),EFTS2(30), RHOI2(30),PHI2(30),HC2(30)
000010 DIMENSION RECI2(30),HSNW1(30),HCSI1(30),SLPC1(30),HCTI1(30),HTMI1(
000011 112),HCCRC(30),HSNW2(30),HCSI2(30),SLPC2(30),HCTI2(30),HTMI2(30),
000012 2 HSIM2(30),HS201(30),HS202(30),HS203(30),HS204(30),HS205(3
000013 50),HS206(30),HS207(30),HS208(30),HS209(30),HS210(30),HS211(30)
000014 DIMENSION HS212(30),HS213(30),HS214(30),HS215(30),HS216(30),
000015 1HS217(30),HS218(30),PSDF(30),HSDFH(30),HCDHC(30),HCDFC(30),
000016 2HCVOL(30),DPN(30),RELB2(30),HSMIN(30),RHF(30),THET2(1A),YAN07(30)
000017 COMMON J,THET(1B), PSI2(1A),B2TH,DI21,DI22,NOPI2,NST,RAFK(30),
000018 1THETR(30),DTHET(1A),EFMOT(30),PMOT(30) ,PSIM2(30),POPS(30)
000019 LR = 5
000020 LW = 6
000021 3 FORMAT('1')
000022 5 FORMAT(3A2,A4,3I5,3F8.2,F8.3)
000023 7 FORMAT('1 DATE ',A2,'-',A2,'-',A2/53X,'NERVA AIR TEST'/
000024 152X,'PERFORMANCE DATA'//)
000025 11 FORMAT(53X,'TEST NG. ',A4,/)
000026 13 FORMAT(18X,'CONSTANTS'//)
000027 17 FORMAT( 2X,'NOZZLE COEFFICIENT, CNOZ',6X,F10.4,2X,'**')
000028 19 FORMAT( 2X,'NOZZLE DIA, DNOZ',13X,F10.3,2X,'SQIN')
000029 21 FORMAT( 2X,'DISCHARGE LINE DIA, DDL',6X,F10.3,2X,'SQIN')
000030 23 FORMAT( 2X,'BLEED ORIFICE COEFF, CORIF',4X,F10.4,2X,'**')
000031 25 FORMAT( 2X,'BLEED ORIF AREA, ABL',10X,F10.3,2X,'SQIN')
000032 27 FORMAT(/18X,'IMPELLER FIRST STAGE',32X,'IMPELLER SECOND STAGE'/)
000033 29 FORMAT( 2X,'DISCHARGE AREA BLOCKED, AI21',5X,F10.3,2X,'SQIN',10X,
000034 1'DISCHARGE AREA BLOCKED, AI22',5X,F10.3,2X,'SQIN')
000035 31 FORMAT( 2X,'DISCHARGE DIAMETER, DI12',9X,F10.3,2X,'IN',12X,
000036 1'DISCHARGE DIAMETER, DI22',9X,F10.3,2X,'IN')
000037 33 FORMAT( 2X,'LABYRINTH COEFFICIENT, CLAB1',5X,F10.4,2X,' ** ',10X,
000038 1'LABYRINTH COEFFICIENT, CLAB2',5X,F10.4,2X,' **')
000039 35 FORMAT( 2X,'NUMBER OF BLADES, Z21',12X,F10.1,2X,' ** ',10X,
000040 1'NUMBER OF BLADES, Z22',12X,F10.1,2X,' **')
000041 37 FORMAT( 2X,'DISCHARGE BLADE ANGLE, DFT21',5X,F10.3,2X,'DFG',11X,
000042 1'DISCHARGE BLADE ANGLE, DFT22',5X,F10.3,2X,'DEG')
000043 38 FORMAT( 2X,'LABYRINTH FLOW AREA, ALB1',8X,F10.3,2X,'SQIN',10X,
000044 1'LABYRINTH FLOW AREA, ALB2',8X,F10.3,2X,'SQIN')
000045 39 FORMAT(/53X,'HOUSING'/)
000046 41 FORMAT( 2X,'CROSSOVER AREA, ACRO1',12X,F10.3,2X,'SQIN',10X,
000047 1'CROSSOVER AREA, ACRO2',11X,F10.3,2X,'SQIN')
000048 43 FORMAT( 2X,'CROSSOVER AREA, ACRO3',12X,F10.3,2X,'SQIN',10X,
000049 1'CROSSOVER AREA, ACRO4',11X,F10.3,2X,'SQIN')
000050 45 FORMAT( 2X,'DIFFUSER DISCHARGE AREA, ADFD',4X,F10.3,2X,'SQIN',10X,
000051 1'DIFF DISCHARGE FLOW ANGLE, RFD',1X,F10.3,2X,'DEG')
000052 51 FORMAT (5F10.3/6F10.3/8F10.3/8F10.3)
000053 53 FORMAT (8F10.3/8F10.3/2F10.4)
000054 55 FORMAT(10F8.3/8F8.3)
000055 57 FORMAT(9F8.3)
000056 59 FORMAT(61X,'WIDTH, RADIAL TRHUST, B2TH',7X,F10.3,2X,'IN')

```

Page 10

```

000057      61 FORMAT( 2X,'INDUCER INLET TIP DIA, DI11T',5X,F10.3,2X,' IN ',10X,
000058      1,'INLET TIP DIAMETER, DI21T',8X, F10.3,2X,' IN ')
000059      63 FORMAT( 2X,'INDUCER INLET HUB DIA, DI11H',5X,F10.3,2X,' IN ',10X,
000060      1,'INLET HUB DIAMETER, DI21H',8X, F10.3,2X,' IN ')
000061      65 FORMAT(///2X,'CALCULATED CONSTANTS'///)
000062      67 FORMAT( 2X,'VELOCITY OF APPROACH FACTOR, FLOW NOZZLE, VLAP',10X,
000063      1F10.4,2X,'**'//)
000064      69 FORMAT( 2X,'DRAG TORQUE, TDRG',12X,F10.3,2X,' INLB')
000065      71 FORMAT( 2X,'ABSOLUTE HUMIDITY, AHUM',34X,F10.4)
000066      73 FORMAT( 2X,'MIXTURE DENSITY, RMTX',34X,F10.4,2X,'LB/FT**3')
000067      75 FORMAT( 2X,'SPECIFIC HEAT CP',40X,F10.4,2X,'BTU/LB/DEG')
000068      77 FORMAT( 2X,'SPECIFIC HEAT CV',40X,F10.4,2X,'BTU/LB/DEG')
000069      79 FORMAT( 2X,'GAS CONSTANT, RMTX',38X,F10.4,2X,'FTLB/LB/DEG')
000070      81 FORMAT( 2X,'MOLECULAR WEIGHT, WMOL',34X,F10.4//)
000071      83 FORMAT( 2X,'TDRY =',F8.2,5X,'TWET =',F8.2,5X,'REL HUMIDITY =',
000072      1F8.2,2X,'PWET =',F8.3,2X,'INHG'//)
000073      520 READ (LR,5) IM, ID, IY, NOT, NODAT, NOPI2, NODF, TDRY, TWET, RHUM, PWET
000074      IF (NODAT) 990,990,530
000075      530 READ (LR,51) CNOZ, DNOZ, DDL, CORIF, ABL, AI21, DI21, CLAB1, Z21, BET21, ALB
000076      11, DI11T, DI11H, AI22, DI22, CLAB2, Z22, BET22, ALB2, B2TH, DI21T, ACRO1, ACRO
000077      22, ACRO3, ACRO4, ADFD, BDFD, DI21H, TDRG
000078      READ (LR,55) (THET2(I), I=1,18)
000079      READ (LR,53) (PUHG(J), TO(J), PSD(J), TD(J), DPOR1(J), TI(J), PTI(J), PSI
000080      1(J), SN(J), TQS(J), PSIM1(J), PSIN(J), PCRO1(J), PCRO2(J), PCRO3(J), PCRO4
000081      2(J), DPH(J), PMOT(J), J=1, NODAT)
000082      WRITE (LW,3)
000083      WRITE (LW,7) IM, ID, IY
000084      WRITE (LW,11) NOT
000085      WRITE (LW,13)
000086      WRITE (LW,17) CNOZ
000087      WRITE (LW,19) DNOZ
000088      WRITE (LW,21) DDL
000089      WRITE (LW,23) CORIF
000090      WRITE (LW,25) ABL
000091      WRITE (LW,69) TDRG
000092      WRITE (LW,27)
000093      WRITE (LW,29) AI21, AI22
000094      WRITE (LW,31) DI21, DI22
000095      WRITE (LW,33) CLAB1, CLAB2
000096      WRITE (LW,35) Z21, Z22
000097      WRITE (LW,37) BET21, BET22
000098      WRITE (LW,38) ALB1, ALB2
000099      WRITE (LW,61) DI11T, DI21T
000100      WRITE (LW,63) DI11H, DI21H
000101      WRITE (LW,59) B2TH
000102      WRITE (LW,39)
000103      WRITE (LW,41) ACRO1, ACRO2
000104      WRITE (LW,43) ACRO3, ACRO4
000105      WRITE (LW,45) ADFD, BDFD
000106      C-CONSTANTS
000107      BE21R = BET21/57.296
000108      TBE21 = SIN(BE21R)/COS(BE21R)
000109      SLP1 = 3.1416 * SIN(BE21R)/Z21
000110      BE22R = BET22/57.296
000111      TBE22 = SIN(BE22R)/COS(BE22R)
000112      SLP2 = 3.1416*SIN(BE22R)/Z22
000113      BDFDR = BDFD/57.296
000114      AI11 = .7854*(DI11T**2 - DI11H**2)
000115      AI21 = .7854*(DI21T**2 - DI21H**2)
000116      ANOZ = .7854 * DNOZ**2

```

```

000117      ADL = .7854 * DDL**2
000118      BENOZ = DNOZ/DDL
000119      VLAP = 1./SQRT(1.-(ANOZ/ADL)**2)
000120      RRSQ1 = (DI21/11.4)**2
000121      RRSQ2 = (DI22/11.4)**2
000122      C-PROPERTIES OF AIR-WATER VAPOR MIXTURE
000123      PVAP = PWET - PWHG(1)*(TDRY-TWET)/2700.
000124      PAIR = PWHG(1) - PVAP
000125      SHUM = PVAP/1.608/PAIR
000126      ROAIR = 1.326934 * PAIR/(TDRY + 459.67)
000127      ROVAP = SHUM* ROAIR
000128      ROMIX = ROAIR + ROVAP
000129      POXY = .21 * PAIR * .49115
000130      PNIT = .79 * PAIR * .49115
000131      ROXY = 2.98445*POXY/(459.67 + TDRY)
000132      RONIT = 2.6114 *PNIT/(459.67 + TDRY)
000133      GTOT = ROXY + RONIT + ROVAP
000134      GOXY = ROXY/GTOT
000135      GNIT = RONIT/GTOT
000136      GVAP = ROVAP/GTOT
000137      CPOXY = .217 * GOXY
000138      CVOXY = .155 * GOXY
000139      CVNIT = .173 * GNIT
000140      CPNIT = .2455* GNIT
000141      CPVAP = .44466 * GVAP
000142      CUVAP = .33442 * GVAP
000143      CVMIX = CVOXY + CVNIT + CUVAP
000144      CPMIX = CPOXY + CPNIT + CPVAP
000145      XKMIX = CPMIX/CVMIX
000146      RMIX = 778.2 * (CPMIX - CVMIX)
000147      XMMIX = 1546./RMIX
000148      XKEXP =(XKMIX-1.)/XKMIX
000149      C-INCREMENTS OF THETA
000150      DO 488 I=1,NOPI2
000151      488 THET(I) = THET2(I)
000152      DO 490 I=1,NOPI2
000153      490 THET(I) = THET(I)/57.296
000154      LIMIT = NOPI2- 1
000155      DTHET(1) = 0.5 * (THET(2)-THET(1) + 6.2834 - THET(NOPI2))
000156      DTHET(NOPI2) = 0.5 * (6.2834 - THET(LIMIT))
000157      DO 492 I=2,LIMIT
000158      492 DTHET(I) = (THET(I+1) - THET(I-1)) * 0.5
000159      J = 0
000160      500 J = J + 1
000161      IF(J-NODAT) 510,510,900
000162      C-INLET CONDITION
000163      510 POPS(J) = 0.49115 * PWHG(J)
000164      TOABS(J) = 459.67 + TO(J)
000165      RHO(J) = 144. * POPS(J)/TOABS(J)/RMIX
000166      C-PUMP DISCHARGE CONDITION
000167      PSD(J) = PSD(J)/ 27.67 + POPS(J)
000168      RHOD(J) = 144. * PSD(J)/(TD(J) + 459.67)/RMIX
000169      PNOZ = PSD(J) - DPN(J)/27.67
000170      RPNOZ = PNOZ/PSD(J)
000171      YNOZ1 = (1.-RPNOZ**2.286)/(1.-RPNOZ)
000172      YNOZ2 = (1.-BENOZ**4)/(1.-BENOZ**4 * RPNOZ**1.43)
000173      YANOZ(J) = SQRT(RPNOZ**1.43 * 3.5*YNOZ1 * YNOZ2)
000174      XKNOZ = CNOZ * YANOZ(J) * VLAP
000175      VDF(J) = 0.12708 * ANOZ *XKNOZ * SQRT(DPN(J)/RHOD(J))
000176      VDG(J) = 448.83 * VDF(J)

```

000178 W(V) = RHOD(U) * VDF(U)
 000179 HDVL = 0.0016 * (VDF(U)/ADL)**2
 000179 VWRL = 0.12708 * ARL * CORIF * SORT(DPORI(U)*RHOD(U))
 000180 RWRL(U) = 100. * VWRL/VW(U)
 000181 C-INTERSTAGE CONDITION
 000182 PSI(U) = PSI(U)/27.67 + POPS(U)
 000183 RHOI(U) = 144. * PSI(U)/(TI(U) + 459.67)/RMIX
 000184 VIF(U) = (VW(U) + VWBL)/RHOD(U)
 000185 VIG(U) = 448.83 * VIF(U)
 000186 IFF(PI(U)) 512,512,514
 000187 C121 = VIF(U)/A121 * 144./0.966
 000188 HVEL = C121**2/64.34
 000189 PTI(U) = PSI(U) + RHOD(U)*HVEL/144.
 000190 GO TO 516
 000191 514 PTI(U) = PTI(U)/27.67 + POPS(U)
 000192 C-PUMP OVERALL PERFORMANCE
 000193 516 HMOV(U) = (PSD(U) + RHOD(U) * HDVFL /144.)/POPS(U)
 000194 HISOV(U) = 778.2 * TOABS(U) * (PHOV(U)**XKEXP - 1.)*CPMIX
 000195 HMOV2(U) = HISOV(U)/SN(U)**2
 000196 CMI(U) = VDF(U)/SM(U)
 000197 DIAOV(U) = TD(U) - 10(U)
 000198 DTIOV(U) = TOABS(U) * (PROV(U)**XKEXP - 1.)
 000199 C-EFFICIENCY DERIVED FROM MEASURED SHAFT TORQUE AND MOTOR POWER
 000200 TONS(U) = 10S(U)/12. * SN(U)**2/RHOD(U)
 000201 FFS(U) = 114.587 * VW(U)*HISOV(U)/SN(U)/TOS(U)
 000202 IFF(PMOT(U)) 518,518,519
 000203 519 ENOT(U) = HISOV(U)*VW(U)/(PMOT(U))*7376 - .008727*SN(U)*TORBQ
 000204 C-INDUCER PERFORMANCE
 000205 518 IFFABS(PFIN(U)) 522,522,524
 000206 524 PFIN(U) = PFIN(U)/27.67 + POPS(U)
 000207 PFIN = PFIN(U)/POPS(U)
 000208 PFIN(U) = 778.2 * TOABS(U) * (PRIN**XKEXP - 1.)/SN(U)**2*CPMIX
 000209 C-FIRST STAGE PERFORMANCE
 000210 522 PSI(U) = PTI(U)/POPS(U)
 000211 HIS1(U) = 778.2 * TOABS(U)**2*(PRSI(U)**XKEXP - 1.)*CPMIX
 000212 HIS1(U) = HIS1(U)/SN(U)**2
 000213 QIN(U) = QDN(U) * RHOD(U)/RHOI(U)
 000214 DTASI(U) = 11(U) - 10(U)
 000215 DTISI = TOABS(U) * (PRSI(U)**XKEXP - 1.)
 000216 EFS1(U) = DTISI /DTASI(U)
 000217 U21 = SN(U)*DT21/229.
 000218 PSIM1(U) = PSIM1(U)/27.67 + POPS(U)
 000219 RHOI1(U) = 144. * PSIM1(U)/(U0.5*(T0(U)+TI(U))+459.67)/RMIX
 000220 VWLB1 = .668476
 000221 I11(U) = ALB1*CLAD1*SOR1((PSIM1(U)-PSIN(U))*RHO
 000222 RECI1(U) = (VWLB1/VW(U)) * 100.
 000223 PHII(U) = 144.0 * (VW(U)+VWLB1) / RHOI1(U)/A121/U21
 000224 HCL1(U) = 32.174 * HIS1(U)/U21**2
 000225 C-SECOND STAGE PERFORMANCE
 000226 PRS2(U) = (PSD(U) + RHOD(U) * HDVFL /144.)/PTI(U)
 000227 HIS2(U) = 778.2 * (TI(U) + 459.67) * (PRS2(U)**XKEXP - 1.)*CPMIX
 000228 HNS2(U) = HIS2(U)/SN(U)**2
 000229 DVAS2(U) = TD(U) - 11(U)
 000230 DTI2 = (TI(U) + 459.67) * ((PRS2(U)**XKEXP - 1.)
 000231 EFS2(U) = DTI2 /DVAS2(U)
 000232 EFTOV(U) = DTIOV(U)/DTASI(U)+DVAS2(U)*(1.+RWRL(U)/100.)
 000233 TOTOV(U) = 114.587 * VW(U) * HISOV(U)/SN(U)/EFTOV(U)
 000234 TOT10(U) = TOTOV(U)/12./SN(U)**2/RHOD(U)
 000235 XNO2 = FLOAT(NOP12)
 000236 READ (LR,SS) (PSI2(I),I=1,18)

```

000237      DO 100 I=1,NOP12
000238      100 PSI2(I) = PSI2(I)/27.67 + POPS(J)
000239      PSI2T = 0
000240      DO 102 I=1,NOP12
000241      102 PSI2T = PSI2T + PSI2(I)
000242      PSIM2(J) = PSI2T/XNO2
000243      RHO12(J) = 144. * PSIM2(J)/(0.5 * (TD(J) + TI(J)) + 459.67)/RMTX
000244      VWL2 = .668476 *ALB2*CLAB2*SQRT((PSIM2(J)-PST(J))*RHO1
000245      12(J))
000246      U22 = SN(J) * DI22/229.
000247      PHI2(J) = 144.0 * (VW(J)+VWLR2 +VWLR )/RHO12(J)/AI22/U22
000248      HC2(J) = 32.174 * HIS2(J)/U22**2
000249      RFLB2(J) = VWLR2/VW(J) * 100.
000250      RECI2(J) = (VWL2 + VWLR)/VW(J) * 100.
000251      RHF(J) = (HIS1(J) + HIS2(J))/HISOV(J)
000252      C-FIRST STAGE IMPELLER PERFORMANCE BASED ON STATIC WALL PRESSURES AND
000253      C-CONTINUITY
000254      PRIS1 = PSIM1(J) / POPS(J)
000255      HISW1 = 778.2 * TOABS(J) *(PRIS1**XKEXP-1.) * CPMIX
000256      HSW1(J) = HISW1/SN(J)**2
000257      HCSI1(J) = 32.174 * HISW1/U21**2
000258      SLP1(J) = 1.-1./(1.-PHI1(J)/TBE21) * SLP1
000259      HCTH1 = 1.- PHI1(J)/ TBE21 - SLP1
000260      HCTI1(J) = 0.5*RRSQ1 *(PHI1(J)**2 + HCTH1**2) + HCSI1(J)
000261      HTNI1(J) = HCTI1(J)*DI21**2/1687236.
000262      C-CROSSOVER CHANNEL
000263      IF(PCRO1(J)) 105,105,103
000264      103 PCRO1(J) = PCRO1(J)/27.67 + POPS(J)
000265      PCRO2(J) = PCRO2(J)/27.67 + POPS(J)
000266      PCRO3(J) = PCRO3(J)/27.67 + POPS(J)
000267      PCRO4(J) = PCRO4(J)/27.67 + POPS(J)
000268      PCRO1(J) = 778.2 * TOABS(J)*((PCRO1(J)/POPS(J))**XKEXP-1.)*CPMIX
000269      PCRO2(J) = 778.2 * TOABS(J)*((PCRO2(J)/POPS(J))**XKEXP-1.)*CPMIX
000270      PCRO3(J) = 778.2 * TOABS(J)*((PCRO3(J)/POPS(J))**XKEXP-1.)*CPMIX
000271      PCRO4(J) = 778.2 * TOABS(J)*((PCRO4(J)/POPS(J))**XKEXP-1.)*CPMIX
000272      RHOCR = 0.5*(RHO11(J) + RHO1(J))
000273      HVCR1 = 322.247*((VW(J) + VWLR )/RHOCR/ACRO1)**2
000274      HVCR2 = 322.247*((VW(J) + VWLR )/RHOCR/ACRO2)**2
000275      HVCR3 = 322.247*((VW(J) + VWLR )/RHOCR/ACRO3)**2
000276      HVCR4 = 322.247*((VW(J) + VWLR )/RHOCR/ACRO4)**2
000277      PCRO1(J)=1687236.*(HTNI1(J)-(PCRO1(J)+HVCR1)/SN(J)**2)/DT21**2
000278      PCRO2(J)=1687236.*(HTNI1(J)-(PCRO2(J)+HVCR2)/SN(J)**2)/DT21**2
000279      PCRO3(J)=1687236.*(HTNI1(J)-(PCRO3(J)+HVCR3)/SN(J)**2)/DT21**2
000280      PCRO4(J)=1687236.*(HTNI1(J)-(PCRO4(J)+HVCR4)/SN(J)**2)/DT21**2
000281      105 HCCR(J) = HCTI1(J) - HC1(J)
000282      C-SECOND STAGE IMPELLER PERFORMANCE BASED ON STATIC WALL PRESSURES AND
000283      C-CONTINUITY
000284      PRIS2 = PSIM2(J)/PTI(J)
000285      HISW2 = 778.2 * (TI(J) + 459.67) * (PRIS2**XKEXP - 1.)*CPMIX
000286      HSW2(J) = HISW2/SN(J)**2
000287      HCSI2(J) = 32.174 * HISW2/U22**2
000288      SLP2(J) = 1.-1./(1.-PHI2(J)/TBE22) * SLP2
000289      HCTH2 = 1.-PHI2(J)/TBE22-SLP2
000290      HCTI2(J) = 0.5*RRSQ2 *(PHI2(J)**2 + HCTH2**2) + HCSI2(J)
000291      HTNI2(J) = HCTI2(J) * DI22**2/1687236.
000292      C-SECOND STAGE IMPELLER CIRCUMFERENTIAL PRESSURE DISTRIBUTION
000293      DO 104 I=1,NOP12
000294      104 PSI2(I)=778.2 *(TI(J)+459.67)*((PSI2(I)/ PTI(J))**XKEXP - 1.)
000295      1 * CPMIX + HIS1(J)
000296      HSI2T = 0

```

```

000297      DO 106 I=1,NOP12
000298      106 HSI2T = HSI2T + PSI2(I)
000299      HSI2 = HSI2T/XNO2
000300      DO 108 I=1,NOP12
000301      108 PSI2(J) = PSI2(I)/HSI2
000302      HSI2(J) = HSI2 /SN(J)**2
000303      HS201(J) = PSI2(1)
000304      HS202(J) = PSI2(2)
000305      HS203(J) = PSI2(3)
000306      HS204(J) = PSI2(4)
000307      HS205(J) = PSI2(5)
000308      HS206(J) = PSI2(6)
000309      HS207(J) = PSI2(7)
000310      HS208(J) = PSI2(8)
000311      HS209(J) = PSI2(9)
000312      HS210(J) = PSI2(10)
000313      HS211(J) = PSI2(11)
000314      HS212(J) = PSI2(12)
000315      HS213(J) = PSI2(13)
000316      HS214(J) = PSI2(14)
000317      HS215(J) = PSI2(15)
000318      HS216(J) = PSI2(16)
000319      HS217(J) = PSI2(17)
000320      HS218(J) = PSI2(18)
000321      NST=2
000322      IF(NOP12-3) 109,109,111
000323      111 CALL RATHR
000324      C-DIFFUSION HOUSING SECOND STAGE
000325      109 READ (LR,57) (PSDF(I),I=1,9)
000326      DO 110 I=1,NODF
000327      110 PSDF(I) = PSDF(I)/27.67 + POPS(J)
000328      DO 120 I=1,NODF
000329      120 PSDF(I) = 778.2 *(TI(J)+459.67)*((PSDF(I)/PTI(J))**XKEXP-1.)*CPMI
000330      1X
000331      HSDFI = 0
000332      DO 122 I=1,NODF
000333      122 HSDFI = HSDFI + PSDF(I)
000334      XNODF = FLOAT(NODF)
000335      HSDFM(J) = HSDFI/SN(J)**2/XNODF
000336      C-DIFFUSER DISCHARGE ANGLE BASED ON PFLEIDERERS DEVIATION CRITERION
000337      CM52 = 144. * VW(J)/RHOD(J)/ADFD
000338      CUTH2 = U22*(1.-PH12(J)/TBE22) * SLPC2(J)
000339      ALS2R = ATAN(1./((2.01 + 0.245 * CUTH2/CM52)))
000340      HVDF = .975 * (CM52/SIN(ALS2R))**2/64.4
000341      HTHDF = HSDFM(J) + HVDF/SN(J)**2
000342      HCDHC(J) = HCTI2(J) - HC2(J)
000343      HCDF = 1687236./DI22**2 * HTHDF
000344      HCDFC(J) = HCTI2(J) - HCDF
000345      HCVOL(J) = HCDF - HC2(J)
000346      GO TO 500
000347      900 CONTINUE
000348      WRITE(LW,65)
000349      WRITE(LW,67) VLAP
000350      WRITE(LW,71) SHUM
000351      WRITE(LW,73) ROMIX
000352      WRITE(LW,75) CPMIX
000353      WRITE(LW,77) CVMIX
000354      WRITE(LW,79) RMIX
000355      WRITE(LW,81) XMMIX
000356      201 FORMAT(///2X,'INLET CONDITION',76X,'FLOW NOZZLE EXPANSION FACTOR'//

```

```

000357      1)
000358      203 FORMAT( 2X,'DATA',5X,'INLET TEMPERATURE',15X,'AMBIENT PRESSURE',14
000359      1X,'WEIGHT DENSITY',16X,'YANZ')
000360      205 FORMAT( 2X,'POINT',9X,'DEG F',15X,'IN HG',16X,'PSIA',13X,'LB/CUFT'
000361      1/)
000362      207 FORMAT (15,F17.3,2F20.3,F20.4,F26.5)
000363      WRITE (LW,201)
000364      WRITE (LW,83) TONY,TWET,RHUM,PNET
000365      WRITE (LW,203)
000366      WRITE (LW,205)
000367      WRITE (LW,207) (J,TD(J),POHG(J),POPS(J),RHO(J),YANZ(J),J=1,NODAT)
000368      211 FORMAT (///2X,'PUMP DISCHARGE CONDITION'//)
000369      213 FORMAT( 2X,'DATA',7X,'TEMPERATURE',3X,'STAT PRESSURE',4X,'WEIGHT D
000370      ENSITY',4X,'VOLUMETRIC FLOW RATE',5X,'WEIGHT FLOW',5X,'BLEED FLOW'
000371      2)
000372      215 FORMAT( 2X,'POINT',9X,'DEG F',10X,'PSIA',11X,'LB/CUFT',8X,'CUFT/S'
000373      1,9X,'GPM',11X,'LB/S',11X,'PERCENT'//)
000374      217 FORMAT(15,2F17.3,2F15.4,F15.3,2F15.4)
000375      WRITE (LW,211)
000376      WRITE (LW,213)
000377      WRITE (LW,215)
000378      WRITE (LW,217) (J,TD(J),PSD(J),RHOD(J),VDF(J),VDG(J),VW(J),RVRL(J),
000379      1J=1,NODAT)
000380      221 FORMAT(///2X,'INTERSTAGE CONDITION'//)
000381      223 FORMAT( 2X,'DATA',7X,'TEMPERATURE',5X,'TOT PRESSURE',4X,'STAT PRES
000382      SURE',5X,'WEIGHT DENSITY',9X,'FLOW RATE')
000383      225 FORMAT( 2X,'POINT',9X,'DEG F',6X,'PSIA (RMK DIA)',5X,'PSIA',16X,'L
000384      B/CUFT',9X,'CUFT/S',10X,'GPM'//)
000385      227 FORMAT(15,F17.3,2F15.4,F21.4,2F15.3)
000386      WRITE (LW,221)
000387      WRITE (LW,223)
000388      WRITE (LW,225)
000389      WRITE (LW,227) (J,TI(J),PTI(J),PSI(J),RHOI(J),VIF(J),VIG(J),J=1,NOD
000390      1AT)
000391      231 FORMAT(///2X,'PUMP OVERALL PERFORMANCE'//)
000392      233 FORMAT( 2X,'DATA',5X,'SPEED',4X,'PRESSURE',3X,'TEMP RISE DEG F',4X
000393      1,'HEAD RISE',4X,'HIS/N**2',7X,'Q/N',4X,'ETA TEMP',2X,'TORQUE T',3X
000394      2,'NORM TORQUE T')
000395      235 FORMAT( 2X,'POINT',5X,'RPM',7X,'RATIO',4X,'ACTUAL',4X,'ISENTR',3X,
000396      1,'ISENTR FT',4X,'FT/RPM**2',3X,'GPM/RPM',14X,'IN LB',5X,'FT**4/RPM**
000397      2*2'//)
000398      237 FORMAT(15,F12.1,3F10.3,F10.2,E15.4,2F10.4,F10.3,E15.4)
000399      WRITE (LW,231)
000400      WRITE (LW,233)
000401      WRITE (LW,235)
000402      WRITE (LW,237) (J,SN(J),PROV(J),DTAOV(J),DTIOV(J),HISOV(J),HOVN2(J),
000403      1ODN(J),EFTOV(J),TOTOV(J),TGNTO(J),J=1,NODAT)
000404      241 FORMAT(///2X,'EFFICIENCY DERIVED FROM MEASURED SHAFT TORQUE AND MO
000405      TOR POWER',37X,'REHEAT FACTOR'//)
000406      243 FORMAT( 2X,'DATA',6X,'MEASURED TORQUE',5X,'NORM TORQUE',8X,'EFFICI
000407      1ENCY',5X,'MOTOR POWER',3X,'EFFICIENCY',17X,'RHF')
000408      245 FORMAT( 2X,'POINT',8X,'IN LB',11X,'FT**4/RPM**2',10X,'EFS',11X,'WA
000409      1TT',10X,'EFMOT',13X,'(HIS1+HIS2)/HISOV'//)
000410      247 FORMAT(15,F17.4,E20.4,3F15.4,F25.5)
000411      WRITE (LW,241)
000412      WRITE (LW,243)
000413      WRITE (LW,245)
000414      WRITE (LW,247) (J,TQS(J),TQNS(J),EFS(J),PHOT(J),EFMOT(J),RHF(J),J=1
000415      1,NODAT)
000416      251 FORMAT(///2X,'FIRST STAGE PERFORMANCE'//)

```



```

000417 253 FORMAT( 2X,'DATA',5X,'PRESSURE',2X,'HEAD RISE',3X,'HIS/N**2',5X,'Q
000418 1/N NET',4X,'DELTA T',3X,'ETA TEMP',2X,'LAB FLOW',3X,'PHI(2)',6X,'P
000419 2SI')
000420 255 FORMAT( 2X,'POINT',5X,'RATIO',3X,'ISENTR FT',3X,'FT/RPM**2',4X,'GP
000421 2M/RPM',5X,'DEG F',15X,'PERCENT')
000422 257 FORMAT(I5,F12.4,F10.2,E15.4,F10.4,F10.3,F12.4,F10.3,2F10.4)
000423 WRITE(LW,251)
000424 WRITE(LW,253)
000425 WRITE(LW,255)
000426 WRITE(LW,257) (J,PRS1(J),HIS1(J),HNS1(J),QIN(J),DTAS1(J),EFTS1(J),
000427 IRCC11(J),PHI1(J),HC1(J),J=1,NODAT)
000428 261 FORMAT(///2X,'SECOND STAGE PERFORMANCE'///)
000429 263 FORMAT( 2X,'DATA',5X,'PRESSURE',2X,'HEAD RISE',3X,'HIS/N**2',5X,'Q
000430 1/N NET',4X,'DELTA T',3X,'ETA TEMP',2X,'LAB FLOW',3X,'PHI(2)',6X,'P
000431 2SI',3X,'TOT RECIRC')
000432 265 FORMAT( 2X,'POINT',5X,'RATIO',3X,'ISENTR FT',3X,'FT/RPM**2',4X,'GP
000433 1M/RPM',5X,'DEG F',15X,'PERCENT',23X,'PERCENT')
000434 267 FORMAT(I5,F12.4,F10.2,E15.4,F10.4,F10.3,F12.4,F10.3,3F10.4)
000435 WRITE(LW,261)
000436 WRITE(LW,263)
000437 WRITE(LW,265)
000438 WRITE(LW,267) (J,PRS2(J),HIS2(J),HNS2(J),QDN(J),DTAS2(J),EFTS2(J),
000439 IRELB2(J),PHI2(J),HC2(J),RECI2(J),J=1,NODAT)
000440 271 FORMAT(///2X,'INDUCER PERFORMANCE'///)
000441 273 FORMAT( 2X,'DATA',3X,'NORM STAT HEAD')
000442 275 FORMAT( 2X,'POINT',2X,'RISE FT/RPM**2')
000443 277 FORMAT(I5,E17.4)
000444 IF(AES(PSIH(1))) 532,532,534
000445 534 WRITE(LW,271)
000446 WRITE(LW,273)
000447 WRITE(LW,275)
000448 WRITE(LW,277) (J,HSNIN(J),J=1,NODAT)
000449 281 FORMAT(///2X,'FIRST STAGE IMPELLER PERFORMANCE BASED ON STATIC WAL
000450 1L PRESSURES AND CONTINUITY'///)
000451 283 FORMAT( 2X,'DATA',4X,'MEAN STATIC',6X,'NORM STAT HD',3X,'STAT HEAD
000452 1',3X,'SLIP',6X,'TOT HEAD',5X,'NORM TOT HD',4X,'PHI(2)',4X,'DENSITY
000453 2 RHO11')
000454 285 FORMAT( 2X,'POINT',3X,'PRESSURE PSIA',2X,'RISE FT/RPM**2',7X,'COEF
000455 1F',15X,'COEFF', 7X,'FT/RPM**2',18X,'LN/CFEFT')
000456 287 FORMAT(I5,F17.4,E15.4,F13.4,F10.4,F12.4,F15.4,2F12.4)
000457 532 WRITE(LW,281)
000458 WRITE(LW,283)
000459 WRITE(LW,285)
000460 WRITE(LW,287) (J,PSIM1(J),HSNW1(J),HCSI1(J),SLPC1(J),HCTI1(J),HTNI
000461 11(J),PHI1(J),RHO11(J),J=1,NODAT)
000462 291 FORMAT(///2X,'SECOND STAGE IMPELLER PERFORMANCE BASED ON STATIC WA
000463 1LL PRESSURES AND CONTINUITY'///)
000464 293 FORMAT( 2X,'DATA',4X,'MEAN STATIC',6X,'NORM STAT HD',3X,'STAT HEAD
000465 1',3X,'SLIP',6X,'TOT HEAD',5X,'NORM TOT HD',4X,'PHI(2)',4X,'DENSITY
000466 2 RHO12')
000467 295 FORMAT( 2X,'POINT',3X,'PRESSURE PSIA',2X,'RISE FT/RPM**2',7X,'COEF
000468 1F',15X,'COEFF', 7X,'FT/RPM**2',18X,'LN/CFEFT')
000469 297 FORMAT(I5,F17.4,E15.4,F13.4,F10.4,F12.4,E15.4,2F12.4)
000470 WRITE(LW,291)
000471 WRITE(LW,293)
000472 WRITE(LW,295)
000473 WRITE(LW,297) (J,PSIM2(J),HSNW2(J),HCSI2(J),SLPC2(J),HCTI2(J),HTNI
000474 12(J),PHI2(J),RHO12(J),J=1,NODAT)
000475 301 FORMAT(///2X,'CROSSOVER CHANNEL'///)
000476 303 FORMAT( 2X,'DATA',4X,'TOTAL HEAD LOSS COEFFICIENT',17X,'OVERALL')

```

```

000477      305 FORMAT( 2X,'POINT',3X,'STA 25',4X,'STA 26',4X,'STA 27',4X,'STA 28',
000478      1,8X,'ONE-DIM'/)
000479      307 FORMAT(I5,F12.4,3F10.4,F14.4)
000480      WRITE(LW,301)
000481      WRITE(LW,303)
000482      WRITE(LW,305)
000483      WRITE(LW,307) (J,PCRO1(J),PCRO2(J),PCRO3(J),PCRO4(J),HCCRC(J),J=1,
000484      1,NODAT)
000485      311 FORMAT(///2X,'CIRCUMFERENTIAL PRESSURE DISTRIBUTION - SECOND STAGE
000486      1 IMPELLER'///)
000487      313 FORMAT( 2X,'DATA',3X,'NORM AVG',5X,'RATIO OF STATIC HEAD TO AVERAG
000488      1E STATIC HEAD RISE')
000489      315 FORMAT( 2X,'POINT',2X,'STATIC HEAD',2X,'(1)',7X,'(2)',7X,'(3)',7X,
000490      1,'(4)',7X,'(5)',7X,'(6)',7X,'(7)',7X,'(8)',7X,'(9)'//)
000491      317 FORMAT(I5,F15.4,9F10.6)
000492      WRITE(LW,311)
000493      WRITE(LW,313)
000494      WRITE(LW,315)
000495      WRITE(LW,317) (J,HS1M2(J),HS201(J),HS202(J),HS203(J),HS204(J),HS20
000496      15(J),HS206(J),HS207(J),HS208(J),HS209(J),J=1,NODAT)
000497      IF(NOP12-9) 400,400,402
000498      402 CONTINUE
000499      319 FORMAT(///2X,'DATA',4X,'RATIO OF STATIC HEAD RISE TO AVERAGE STATIC
000500      1 HEAD RISE')
000501      321 FORMAT( 2X,'POINT',8X,'(10)',8X,'(11)',8X,'(12)',8X,'(13)',8X,'(14
000502      1)',8X,'(15)',8X,'(16)',8X,'(17)',8X,'(18)'//)
000503      323 FORMAT(I5,F15.6,9F11.6)
000504      WRITE(LW,319)
000505      WRITE(LW,321)
000506      WRITE(LW,323) (J,HS210(J),HS211(J),HS212(J),HS213(J),HS214(J),HS21
000507      15(J),HS216(J),HS217(J),HS218(J),J=1,NODAT)
000508      400 IF(NOP12-3) 404,404,401
000509      401 WRITE(LW,441)
000510      WRITE(LW,443)
000511      WRITE(LW,445) (J,RAFK(J),THETR(J),J=1,NODAT)
000512      441 FORMAT(///2X,'RADIAL FORCE PARAMETER RAFK AND FORCE VECTOR ANGLE T
000513      1THETA MEASURED COUNTER-CLOCKWISE WHEN LOOKING FROM SUCTION'/ 30X,
000514      2'THETA = 0' AT INSTRUMENTATION STATION 34'//)
000515      443 FORMAT( 2X,'DATA',8X,'RAFK',13X,'THETA'/2X,'POINT',7X,'IN**2',14X,
000516      1'DEG'//)
000517      445 FORMAT(I5,F15.6,F16.2)
000518      404 CONTINUE
000519      331 FORMAT(///2X,'DIFFUSION HOUSING - SECOND STAGE'///)
000520      333 FORMAT( 2X,'DATA',3X,'NORM DIFF DISCH MEAN',2X,'HEAD LOSS COEFF',3
000521      1X,'HEAD LOSS COEFF',2X,'HEAD LOSS COEFF')
000522      335 FORMAT( 2X,'POINT',3X,'STAT HD FT/RPM**2',4X,'HOUSG ONE-DIM',3X,
000523      1'DIFF ONE DIM',4X,'VOLUTE ONE-DIM'//)
000524      337 FORMAT(I5,E20.4,3F16.4)
000525      WRITE(LW,331)
000526      WRITE(LW,333)
000527      WRITE(LW,335)
000528      WRITE(LW,337) (J,HSDFM(J),HCDHC(J),HCDFC(J),HCVOL(J),J=1,NODAT)
000529      GO TO 520
000530      990 WRITE(LW,3)
000531      STOP
000532      END

```

W ELT RATHR.1.720405, 49930

```
000001 SUBROUTINE RATHR
000002 DIMENSION PSIC(10),PSIS(18)
000003 COMMON J,THET(18),PSI(18),R2TH,DI21,DI22,NOP1,NST,RAFK(30),
000004 THETR(30),DTHT(18),EFMOT(30),PMOT(30),PSIM2(30),POPS(30)
000005 IF(NST-1) 80,80,90
000006 80 DI2 = DI21
000007 GO TO 95
000008 90 DI2 = DI22
000009 95 SKY = 0
000010 SKX = 0
000011 STHET = 0
000012 DO 102 I=1,NOP1
000013 STHET = STHET + DTHT(I)
000014 PSIS(I) = PSI(I) * SIN(THET(I)) * DI2 * R2TH * SIN(DTHT(I)/2.)
000015 PSIC(I) = PSI(I) * COS(THET(I)) * DI2 * R2TH * SIN(DTHT(I)/2.)
000016 SKY = SKY + PSIS(I)
000017 102 SKX = SKX + PSIC(I)
000018 SKY = -SKY
000019 SKX = -SKX
000020 RAFK(J) = SORT(SKY**2+SKX**2)
000021 TTHET = ATAN(ABS(SKX/SKX))
000022 IF(SKX) 110,150,115
000023 115 IF(SKX) 120,155,125
000024 125 THETR(J) = 57.296 * TTHET
000025 GO TO 200
000026 155 THETR(J) = 90.
000027 GO TO 200
000028 120 THETR(J) = (3.1417 - TTHET) * 57.296
000029 GO TO 200
000030 110 IF(SKX) 130,170,135
000031 130 THETR(J) = 57.296 * (TTHET + 3.1417)
000032 GO TO 200
000033 170 THETR(J) = 270.
000034 GO TO 200
000035 135 THETR(J) = (6.2834 - TTHET) * 57.296
000036 GO TO 200
000037 150 IF(SKX) 140,160,145
000038 140 THETR(J) = 180.
000039 GO TO 200
000040 160 THETR(J) = 0
000041 GO TO 200
000042 145 THETR(J) = 0
000043 200 RETURN
000044 END
```

13:52:21

2.

END CUR

DATE 09-02-71

NERVA AIR TEST
PERFORMANCE DATA

TEST NO. 6W

CONSTANTS

NOZZLE COEFFICIENT, CNOZ	.9870	***
NOZZLE DIA, DNOZ	2.110	SGIN
DISCHARGE LINE DIA, DDL	4.725	SGIN
SPEED ORIFICE COEFF, CORIF	.6727	***
SPEED ORIF AREA, ABL	.785	SGIN
DRAW TCRUC, TCRUC	5.000	INLB

IMPELLER FIRST STAGE

DISCHARGE AREA BLOCKED, AI21	14.800	SGIN
DISCHARGE DIAMETER, DI12	18.950	IN
LABYRINTH COEFFICIENT, CLAB1	.5000	**
NUMBER OF BLADES, Z21	8.0	**
DISCHARGE BLADE ANGLE, BET21	30.000	DEG
LABYRINTH FLOW AREA, ALB1	.123	SGIN
INDUCER INLET TIP DIA, DI11T	7.000	IN
INDUCER INLET HUB DIA, DI11H	2.740	IN

IMPELLER SECOND STAGE

DISCHARGE AREA BLOCKED, AI22	15.700	SGIN
DISCHARGE DIAMETER, DI22	19.750	IN
LABYRINTH COEFFICIENT, CLAB2	.5000	**
NUMBER OF BLADES, Z22	8.0	**
DISCHARGE BLADE ANGLE, BET22	25.000	DEG
LABYRINTH FLOW AREA, ALB2	.120	SGIN
INLET TIP DIAMETER, DI21T	6.340	IN
INLET HUB DIAMETER, DI21H	4.600	IN
WIDTH, RADIAL TRUST, B2TH	1.300	IN

HOUSING

CROSSOVER AREA, ACRO1	4.000	SGIN	CROSSOVER AREA, ACRO2	5.400	SGIN
CROSSOVER AREA, ACRO3	6.900	SGIN	CROSSOVER AREA, ACRO4	8.100	SGIN
DIFFUSER DISCHARGE AREA, ADFD	20.600	SGIN	DIFF. DISCHARGE FLOW ANGLE, BDFD	14.300	DEG

CALCULATED CONSTANTS

VELOCITY OF APPROACH FACTOR, FLOW NOZZLE, VLAP	1.0205	**
ABSOLUTE HUMIDITY, AHUM	.2839	
MIXTURE DENSITY, ROMIX	.0703	LB/FT**3
SPECIFIC HEAT CP	.2400	BTU/LB/DEG
SPECIFIC HEAT CV	.1727	BTU/LB/DEG
GAS CONSTANT, RMIX	53.0587	FTLB/LB/DEG
MOLECULAR WEIGHT, WMOL	29.1420	

INLET CONDITION

TDRY	85.00	TWET	67.00	REL HUMIDITY	.37	PWET	.667	INHG
------	-------	------	-------	--------------	-----	------	------	------

FLOW NOZZLE EXPANSION FACTOR

DATA	INLET TEMPERATURE	AMBIENT PRESSURE	WEIGHT DENSITY	YAN0Z
0000	0000	0000	0000	0000

1	79.700	29.850	14.651	.0730	.97359
2	79.820	29.852	14.661	.0730	.97987
3	79.820	29.850	14.661	.0730	.98477
4	80.000	29.850	14.661	.0737	.98950
5	80.100	29.850	14.661	.0737	.99204
6	80.420	29.850	14.661	.0737	.99460
7	80.500	29.850	14.661	.0737	.99586
8	80.600	29.850	14.661	.0737	.99799
9	80.600	29.850	14.661	.0737	.99930

PUMP DISCHARGE CONDITION

DATA POINT	TEMPERATURE DEG F	STAT PRESSURE PSIA	WEIGHT DENSITY LB/CUFT	VOLUMETRIC FLOW RATE CUFT/S	WEIGHT FLOW LB/S	BLEED FLOW PERCENT
1	97.020	15.445	.0753	7.1197	3195.105	3.4318
2	97.730	15.799	.0760	6.2800	2620.710	4.3046
3	98.940	16.096	.0762	5.5271	2400.724	5.4857
4	100.500	16.370	.0793	4.6304	2001.851	7.0733
5	102.000	16.569	.0801	3.8709	1700.964	8.4106
6	103.000	16.677	.0825	3.4304	1541.206	10.1932
7	104.500	16.746	.0806	3.0610	1373.255	11.4441
8	105.000	16.862	.0810	2.2717	1020.240	15.7072
9	106.200	16.869	.0809	1.5703	705.693	22.7313

INTERSTAGE CONDITION

DATA POINT	TEMPERATURE DEG F	TOT PRESSURE PSIA (RMR DIA)	STAT PRESSURE PSIA	WEIGHT DENSITY LB/CUFT	FLOW RATE CUFT/S	GPM
1	80.350	15.1422	15.0981	.0740	7.415	3320.155
2	80.700	15.3006	15.2644	.0755	6.600	2998.350
3	80.300	15.4346	15.4053	.0762	5.907	2607.072
4	90.200	15.5644	15.5426	.0767	5.135	2304.031
5	91.000	15.6596	15.6430	.0771	4.367	1960.007
6	91.700	15.7273	15.6944	.0773	3.945	1770.819
7	92.500	15.7374	15.7270	.0773	3.555	1595.622
8	93.100	15.8019	15.7956	.0776	2.747	1233.159
9	93.400	15.8319	15.8262	.0777	2.010	902.181

PUMP OVERALL PERFORMANCE

DATA POINT	SPEED RPM	PRESSURE RATIO	TEMP RISE DEG F ACTUAL	TEMP RISE DEG F ISFNTR	HEAD RISE ISFNTR FT	HIS/N**2 FT/RPM**2	Q/N GPM/RPM	ETA TEMP	TORQUE T IN LB	NORM TORQUE T FT**4/RPM**2
1	6996.0	1.055	17.300	17.292	1554.35	.3176-04	.4567	.4712	20.966	.6549-06
2	7000.0	1.070	17.900	17.757	2203.95	.4400-04	.4030	.6427	27.146	.6000-06
3	7002.0	1.090	19.100	18.514	2739.44	.5507-04	.3543	.7445	26.029	.5656-06
4	5000.0	1.117	20.500	17.220	3220.71	.6003-04	.2974	.6116	23.072	.5141-06
5	5000.0	1.130	21.000	17.220	3220.71	.6003-04	.2974	.6116	23.072	.5141-06

6	7013.2	1.138	22.600	28,127	3773.01	.7593-04	.2284	.8474	20.154	.4257-05
7	7021.3	1.143	24.000	28,769	3893.32	.7943-04	.1962	.8155	19.200	.4051-06
8	7025.0	1.150	25.000	21,843	4024.69	.8345-04	.1457	.8101	15.228	.3194-06
9	7013.8	1.151	25.600	21,396	4104.65	.8345-04	.1006	.7688	11.110	.2325-06

EFFICIENCY DERIVED FROM MEASURED SHAFT TORQUE AND MOTOR POWER

REHEAT FACTOR

DATA POINT	MEASURED TORQUE IN LB	NORM TORQUE FT**4/RPM**2	EFFICIENCY EFS	MOTOR POWER WATT	EFFICIENCY EFMOT	RHF (HIS1+HIS2)/HISOV
1	27.8000	.6285-06	.4910	.0000	.0000	1.00273
2	27.5000	.6078-06	.5344	.0000	.0000	1.00109
3	27.2000	.5911-06	.7125	.0000	.0000	1.00133
4	26.1000	.5597-06	.7454	.0000	.0000	1.00084
5	23.6000	.5012-06	.7714	.0000	.0000	1.00053
6	22.3000	.4710-06	.7650	.0000	.0000	1.00056
7	21.3000	.4495-06	.7378	.0000	.0000	1.00091
8	19.0000	.3985-06	.6493	.0000	.0000	1.00078
9	15.6000	.3267-06	.5478	.0000	.0000	1.00077

FIRST STAGE PERFORMANCE

DATA POINT	PRESSURE RATIO	HEAD RISE ISENTR FT	HIS/N**2 FT/RPM**2	Q/N NET GPM/RPM	DELTA T DEG F	ETA TEMP	LAB FLOW PERCENT	PHI(2)	PSI
1	1.0329	928.74	.1898-04	.4599	8.650	.5728	1.731	.2072	.2670
2	1.0436	1229.73	.2510-04	.4103	8.900	.7371	1.907	.1864	.3332
3	1.0528	1482.75	.3024-04	.3638	9.500	.8326	2.110	.1665	.4256
4	1.0616	1726.76	.3525-04	.3075	10.200	.9031	2.500	.1419	.4960
5	1.0681	1934.95	.3888-04	.2503	10.900	.9323	2.974	.1200	.5471
6	1.0714	1994.87	.4068-04	.2295	11.300	.9417	3.359	.1071	.5724
7	1.0734	2051.20	.4185-04	.2045	12.000	.9119	3.768	.0959	.5859
8	1.0778	2171.19	.4425-04	.1521	12.500	.9266	5.082	.0722	.6226
9	1.0799	2226.82	.4525-04	.1046	12.800	.9277	7.386	.0588	.6369

SECOND STAGE PERFORMANCE

DATA POINT	PRESSURE RATIO	HEAD RISE ISENTR FT	HIS/N**2 FT/RPM**2	Q/N NET GPM/RPM	DELTA T DEG F	ETA TEMP	LAB FLOW PERCENT	PHI(2)	PSI	TOT RECIRC PERCENT
1	1.0219	629.86	.1287-04	.4567	8.650	.3864	1.337	.2055	.1879	4.8189
2	1.0344	978.39	.1997-04	.4030	9.000	.5799	1.656	.1848	.2915	6.0410
3	1.0440	1260.34	.2571-04	.3543	9.600	.7003	1.964	.1656	.3753	7.4407
4	1.0525	1505.65	.3074-04	.2974	10.300	.7798	2.462	.1422	.4488	9.5356
5	1.0586	1678.05	.3425-04	.2487	11.000	.8138	3.063	.1212	.5080	11.4817
6	1.0622	1760.28	.3630-04	.2204	11.300	.8404	3.519	.1097	.5300	13.7140
7	1.0644	1845.65	.3766-04	.1962	12.000	.8205	4.008	.0992	.5498	15.4523
8	1.0673	1926.70	.3926-04	.1457	12.500	.8222	5.500	.0773	.5733	24.2156
9	1.0698	1881.78	.3628-04	.1005	12.800	.7843	8.042	.0575	.5586	38.7733

INDUCER PERFORMANCE

DATA NORM STAT HD POINT RISE FT/RPM**2

1	.5785-05
2	.2065-05
3	.7194-07
4	.1871-05
5	.3737-05
6	.4739-05
7	.5458-05
8	.7596-05
9	.9265-05

FIRST STAGE IMPELLER PERFORMANCE BASED ON STATIC WALL PRESSURES AND CONTINUITY

DATA MEAN STATIC NORM STAT HD STAT HEAD SLIP TOT HEAD COEFF RISE FT/RPM**2 POINT PRESSURE PSIA LB/CUFT

1	15.1085	.2877-04	.2923	.6937	.4034	.2867-04	.2072	.6758
2	15.2499	.2314-04	.3256	.7109	.4482	.3185-04	.1864	.6761
3	15.1041	.2822-04	.3549	.7241	.4982	.3483-04	.1665	.6763
4	15.1819	.2748-04	.3867	.7397	.5306	.3835-04	.1419	.6765
5	15.4125	.2943-04	.4141	.7521	.5849	.4154-04	.1280	.6767
6	15.4451	.3067-04	.4316	.7689	.6131	.4357-04	.1271	.6768
7	15.6031	.3139-04	.4417	.7646	.6334	.4582-04	.0959	.6768
8	15.5246	.3371-04	.4743	.7756	.6892	.4898-04	.0722	.6771
9	15.5716	.3542-04	.4985	.7847	.7359	.5230-04	.0508	.6773

Page 31

SECOND STAGE IMPELLER PERFORMANCE BASED ON STATIC WALL PRESSURE AND CONTINUITY

DATA MEAN STATIC NORM STAT HD STAT HEAD SLIP TOT HEAD COEFF RISE FT/RPM**2 POINT PRESSURE PSIA LB/CUFT

1	15.5483	.1578-04	.2303	.7033	.3179	.2177-04	.2055	.0764
2	15.7792	.1837-04	.2602	.7281	.3685	.2524-04	.1848	.0775
3	15.9775	.2064-04	.3013	.7426	.4155	.2846-04	.1656	.0783
4	16.1871	.2349-04	.3430	.7612	.4765	.3263-04	.1422	.0792
5	16.3490	.2584-04	.3773	.7758	.5304	.3633-04	.1212	.0798
6	16.4301	.2708-04	.3942	.7830	.5590	.3829-04	.1097	.0801
7	16.4847	.2791-04	.4075	.7892	.5835	.3996-04	.0992	.0802
8	16.5899	.2928-04	.4270	.8010	.6287	.4306-04	.0773	.0806
9	16.6345	.2972-04	.4348	.8107	.6601	.4521-04	.0575	.0807

CROSSOVER CHANNEL

DATA TOTAL HEAD LOSS COEFFICIENT

OVERALL

1	.0000	.0000	.0000	.0000	.1364
2	.0000	.0000	.0000	.0000	.0951
3	.0000	.0000	.0000	.0000	.0647
4	.0000	.0000	.0000	.0000	.0436
5	.0000	.0000	.0000	.0000	.0375
6	.0000	.0000	.0000	.0000	.0400
7	.0000	.0000	.0000	.0000	.0446
8	.0000	.0000	.0000	.0000	.0665
9	.0000	.0000	.0000	.0000	.0991

CIRCUMFERENTIAL PRESSURE DISTRIBUTION - SECOND STAGE IMPELLER

DATA POINT	NORM AVG STATIC HEAD	RATIO OF STATIC HEAD TO AVERAGE STATIC HEAD RISE									
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
1	.3475-04	.985765	.993774	.993774	.993774	.993774	1.005783	1.009704	1.005783	1.009784	1.001780
2	.4246-04	.992284	.995441	.995441	.995441	.995441	1.011754	1.004909	1.004909	1.004909	1.001754
3	.5008-04	.991109	.996445	.996445	.996445	.999112	.999112	1.004444	1.004444	1.007111	1.001778
4	.5374-04	.990080	.996949	.996949	.996949	.999238	1.001526	1.003015	1.003015	1.006102	1.001526
5	.6472-04	.991523	.996644	.996644	.996644	.999771	1.001833	1.003894	1.003894	1.003894	1.001833
6	.6768-04	.991354	.996946	.996946	.996946	.999910	1.000873	1.004799	1.004799	1.004799	1.000873
7	.6976-04	.993020	.996828	1.000635	.996828	.996828	1.002538	1.004440	1.002538	1.002538	1.000635
8	.7343-04	.986635	.996814	1.020133	.996814	.996814	1.010341	.991426	.995018	.995018	1.003094
9	.7498-04	.994031	.985787	.985787	.977007	.977007	1.024334	1.010332	1.013934	1.013934	1.026083

RADIAL FORCE PARAMETER RAFK AND FORCE VECTOR ANGLE THETA MEASURED COUNTER-CLOCKWISE WHEN LOOKING FROM SUCTION
THETA = 0 AT INSTRUMENTATION STATION 34

DATA POINT	RAFK IN**2	THETA DEG
1	.166309	46.43
2	.097920	48.74
3	.092223	54.69
4	.067471	44.91
5	.082236	40.19
6	.080498	44.24
7	.064348	34.88
8	.075325	321.88
9	.344201	79.99

DIFFUSION HOUSING - SECOND STAGE

DATA POINT	NORM DIFF STAT HD	DISCH MEAN FT/RPM**2	HEAD LOSS COEFF		HEAD LOSS COEFF		HEAD LOSS COEFF	
			HOUSG ONE-DIM	ONE-DIM	DIFF ONE DIM	ONE DIM	VOLUTE ONE-DIM	ONE-DIM
1	.0007-05		.1301		.1277		.0024	
2	.1542-04		.0770		.0624		.0147	
3	.2141-04		.0492		.0325		.0077	
4	.2761-04		.0279		.0141		.0137	

3
4
5
6
7
8
9

.3194-24
.3487-24
.3875-24
.3772-24
.3724-24

.P384
.P280
.P337
.P554
.P814

.P133
.P155
.P192
.P429
.P699

.P171
.P135
.P145
.P125
.P115

N8300R:72-106
May 1972

7. OVERALL PERFORMANCE OF A TWO-STAGE LIQUID HYDROGEN PUMP

COMPUTER PROGRAM

OVERALL PERFORMANCE OF A TWO-STAGE LIQUID HYDROGEN PUMP

I. INTRODUCTION

This program computes overall performance parameters of a two-stage liquid hydrogen pump. Inlet conditions and stage performance parameters in normalized form are input. Print-out includes overall isentropic head, discharge pressure, reheat factor, efficiency and power. This program makes extensive use of the liquid hydrogen property deck prepared from Reference 1.

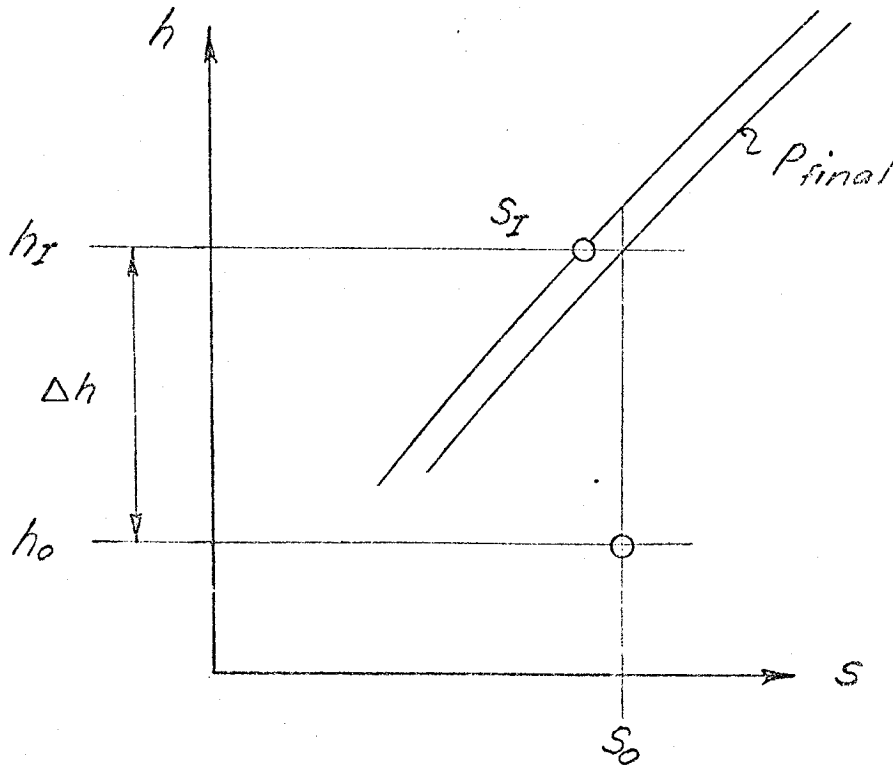
This program was used primarily for the computation of overall performance predictions for the NERVA two-stage pump. The undesired but not too severe scatter in reheat factors obtained resulted from inadequacies in the fluid property deck.

II. BASIC CALCULATIONS

The stage discharge pressure is determined from the specified isentropic head rise Δh and the inlet entropy S_0 defined by inlet temperature T_0 and inlet pressure P_0 . In this program the stage discharge pressure is computed by subroutine PRETE. In PRETE, an initial pressure is first calculated using the fluid density at the inlet. The final pressure is obtained by iteration. Increments of pressure determined from the difference in entropies $S_0 - S_1$ and the slope of the

line of constant pressure (see diagram below) are added to the initial pressure. The solution is satisfactory when:

$$s_o - s_i \leq \text{Specified Tolerance}$$



The reheat factor herein defined as the ratio of the sum of the isentropic stage heads to the overall isentropic head rise is:

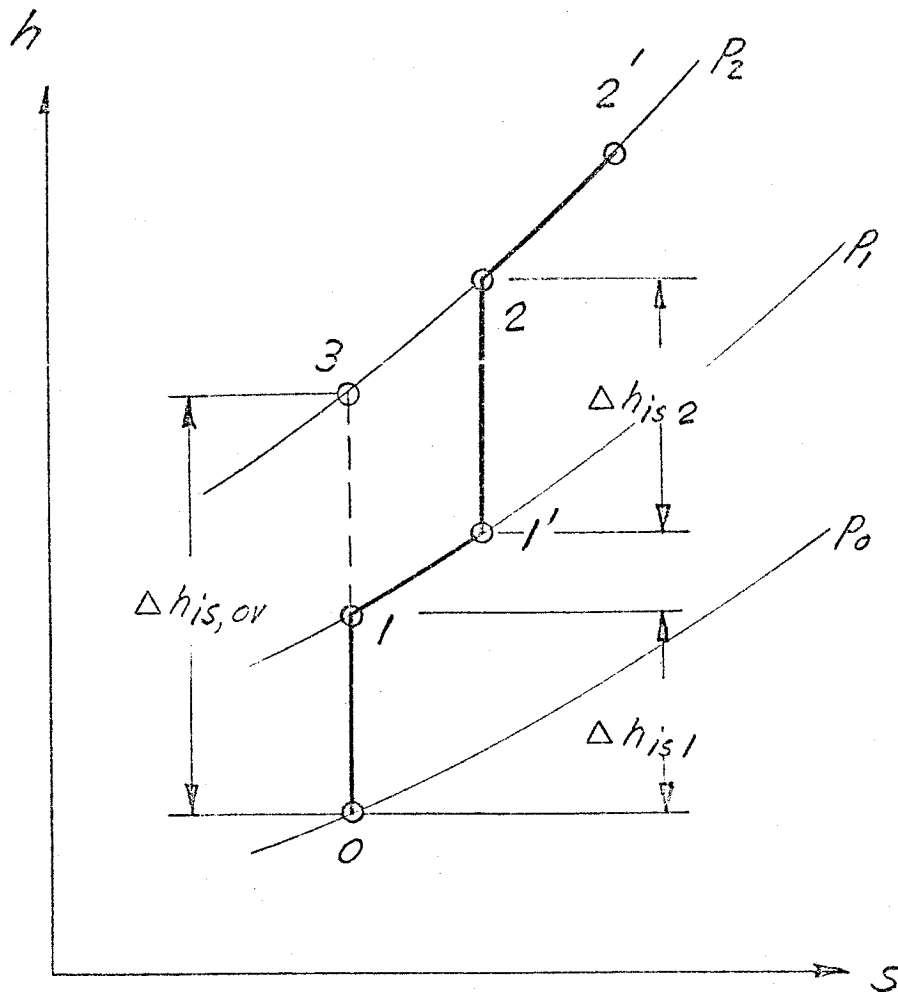
$$\mu = \frac{\sum \Delta h_{is, stage}}{\Delta h_{is, overall}} > 1.0$$

Reference 1 - NBS Report No. 9288 Cryogenic Engineering Laboratory
 National Bureau of Standards, Boulder, Colorado,
 18 August 1967

The overall efficiency of a multi-stage pump is then:

$$\eta_{ov} = \frac{1}{\mu} \eta_{stage}$$

assuming that the efficiency of all stages is the same.



After the end point 2' is determined (refer to above diagram), the overall isentropic head or the pump ideal head rise is obtained using the function HFUN. This function determines the enthalpy at point 3 from the discharge pressure at point 2 and the inlet entropy S_0 by an iterative method similar to that of subroutine PRETE.

III. FLUID PROPERTY FUNCTIONS

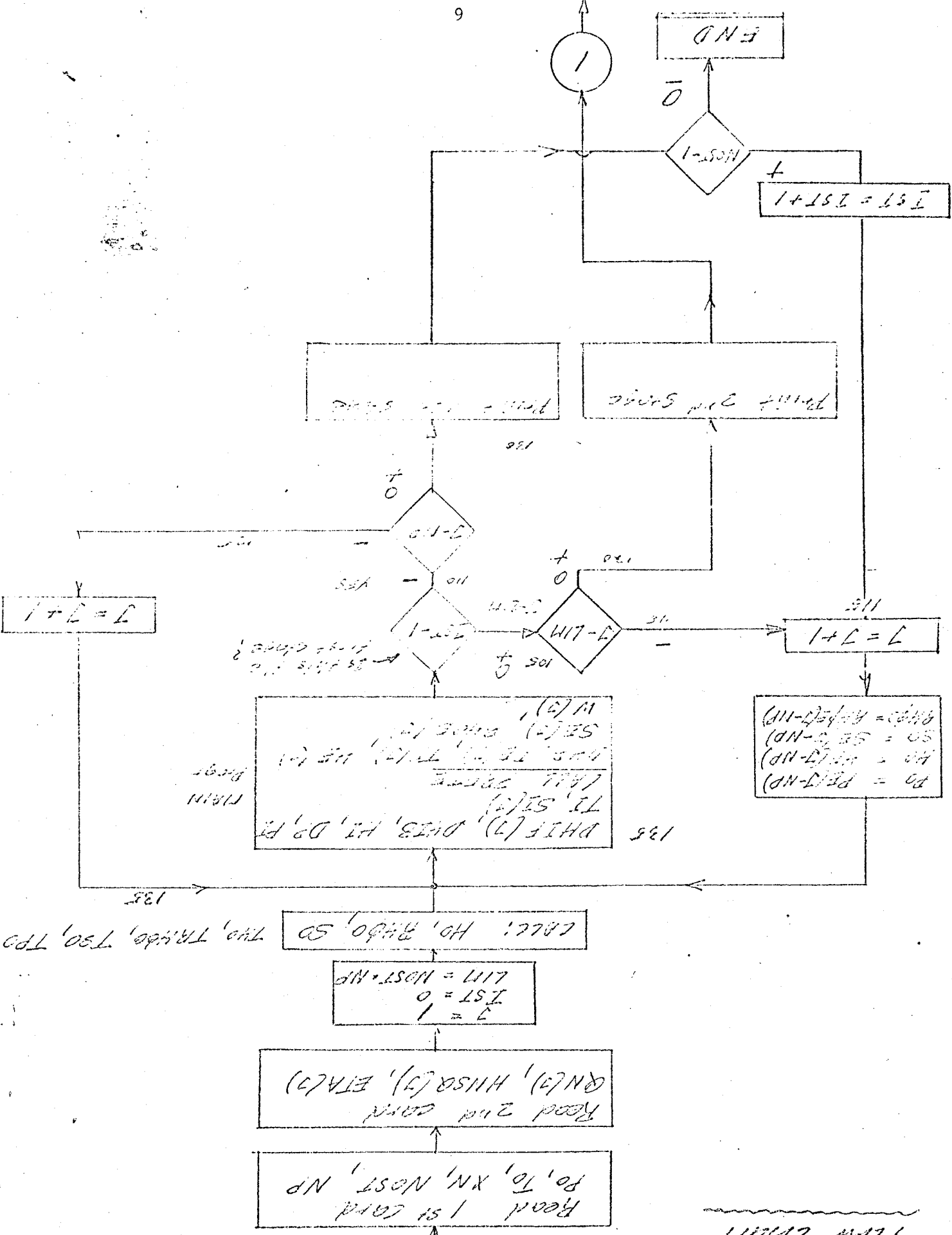
The following liquid hydrogen property functions are used in the program:

PTENTH	looks up enthalpy from pressure and temperature
PTENTR	looks up entropy from pressure and temperature
PHTEMP	looks up temperature from pressure and enthalpy
PHDENS	looks up density from pressure and enthalpy

A complete program listing and a sample print-out is presented on following pages.

NOMENCLATURE INPUT

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>	<u>FORMAT</u>
PO	Inlet Pressure	psia	F
TO	Inlet Temperature	DEGR	F ⁴
XN	Rotational Speed	RPM	F
NOST	Number of Stages	-	I4
NP	Number of Data Points (Q/N)	-	I4
First and Second Stage Parameters:			
QN	Flow Parameter Q/N	GPM/RPM	F
HNSQ	Normalized Head H/N^2	FT/(RPM) ²	E
ETA	Efficiency	-	F



UCCRN RESEARCH
 OF A TWO-STAGE PUMP
 HYDRAULIC PUMP
 Flow Chart

1

$H_0 = T_{H_0}$
 $R_{H_0} = TR_{H_0}$
 $S_0 = T_{S_0}$
 $P_0 = T_{P_0}$
 $J = 1$

$H_{IOV}(J) = H_{FUN}(PE(J+K), T_0, S_0)$
 $R_{HF}(J) = (H_I(J) + H_I(J+K)) / H_{IOV}(J)$
 $ETA_{OV}(J)$

$HP, TRQ, TRQN$
Print

END

PI FOR PRETE
 UNIVAC 1103 FORTRAN V LEVEL 2206 0018 F5018S
 THIS COMPILATION WAS DONE ON 29 SEP 71 AT 12:59:01

29 SEP 71 12:59:01.013

SUBROUTINE PRETE ENTRY POINT 000105

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000126
 0000 *DATA 000032
 0002 *BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 PHTEMP
 0004 PTENTR
 0005 NHDUS
 0006 NI02S
 0007 NSTOPS
 0010 NERR3S

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000007	10L	0000	000010	100F	0001	000072	20L	0001	000027	25L	0001	000043	30L					
0001	000050	40L	0001	000063	50L	0000	I	000000	COUNT	0000	R	000002	DP	0000	R	000006	DS		
0000	R	000001	P	0000	R	000000	PHTEMP	0004	R	000000	PTENTR	0000	R	000004	G	0000	R	000005	S
0000	R	000007	SLOPE	0000	R	000003	T												

6

```

00101 1* SUBROUTINE PRETE(HI,PI,TI,S0,SI)
00103 2* INTEGER COUNT
00104 3* 100 FORMAT(/2X,'NO SOLUTION IN PRETE')
00105 4* COUNT = 1
00106 5* P = PI + 20.
00107 6* DP = P - PI
00110 7* 10 T = PHTEMP(P,HI,0)
00111 8* S = PTENTR(P,T)
00112 9* DS = SI - S
00113 10* IF(DS) 25,20,25
00115 11* 25 SLOPE = DP/DS
00117 12* IF(ABS(SI/S0-1.)-1.E=05) 20,20,30
00122 13* 30 IF(COUNT = 15) 40,50,50
00125 14* 40 COUNT = COUNT + 1
00126 15* SI = S
00127 16* DP = SLOPE * (SI-S0)
00130 17* P = P + DP
00131 18* GO TO 10
00132 19* 50 WRITE(6,100)
00134 20* STOP
00135 21* 20 PI = P
00136 22* TI = T
00137 23* RETURN
  
```

C: FOR HFUN
 UNIVAC 1100 FORTRAN V LEVEL 1 2206 0018 F50183
 THIS COMPILATION WAS DONE ON 29 SEP 71 AT 12:59:00

29 SEP 71 12:59:00.038

FUNCTION HFUN ENTRY POINT 000106

STORAGE USED (BLOCK, NAME, LENGTH)

0001 +CODE 000123
 0002 +DATA 000033
 0002 +BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 PTENTR
 0004 PTENTH
 0005 NWDUS
 0006 NID05
 0007 NSTOP3
 0010 NERR3S

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	000010	0001	000042	100L	0001	000047	150L	0001	000062	160L	0001	000071	200L						
0001	000014	0001	000026	60L	0000	I	000001	COUNT	0000	R	000006	05	0000	R	000004	05			
0000	R	000000	HFUN	0004	R	000000	PTENTH	0003	R	000000	PTENTR	0000	R	000007	SLOPE	0000	R	000002	S21
0000	R	000005	S22	0000	R	000003	T												

10

```

00101 1* FUNCTION HFUN(P2,T1,S1)
00103 2* INTEGER COUNT
00104 3* 10 FORMAT(/2X,1NO SOLUTION OR S2 = S1 IN HFUN!)
00105 4* COUNT = 1
00106 5* S21 = PTENTR(P2,T1)
00107 6* T = T1 + 0.5
00110 7* DT = T-T1
00111 8* 50 S22 = PTENTR(P2,T)
00112 9* DS = S22 - S21
00113 10* IF(DS) 60,200,60
00116 11* 60 SLOPE = DT/DS
00117 12* IF(ABS(1.-S22/S1)=1.E-05) 200,200,100
00122 13* 100 IF (COUNT-30) 150,160,160
00123 14* 150 COUNT = COUNT + 1
00126 15* S21 = S22
00127 16* DT = SLOPE*(S1-S22)
00130 17* T = T+DT
00131 18* GO TO 50
00132 19* 160 WRITE( 6,10)
00134 22* STOP
00135 21* 200 HFUN = PTENTH(P2,T)
00136 22* RETURN
00137 23* END
  
```

#1 FOR MAIN
 UNIVAC 1105 FORTRAN V LEVEL 2206 0018 F50185
 THIS COMPILATION WAS DONE ON 29 SEP 71 AT 12:59:02

29 SEP 71 12:59:02.053

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000773
 0000 *DATA 001760
 0002 *BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 PTENTH
 0004 PTENTR
 0005 PHDENS
 0006 PHTEMP
 0007 PRETE
 0010 HFUN
 0011 NR0US
 0012 NI02S
 0013 NI01S
 0014 NR0US
 0015 NSTOP\$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	001265	1F	0000	001261	10F	0000	001263	100F	0001	000302	105L	0000	001361	11F
0001	000307	11L	0001	000472	115L	0001	000510	120L	0001	000314	125L	0000	001366	13F
0001	000320	130L	0001	000161	135L	0000	001410	14F	0001	000427	140L	0001	000373	145L
0001	000464	147L	0000	001430	15F	0001	000036	157G	0000	001453	16F	0000	001473	17F
0001	001020	19F	0000	001307	2F	0001	000004	200L	0000	001546	21F	0001	000026	220L
0000	001570	23F	0000	001577	25F	0000	001605	27F	0001	000347	270G	0000	001312	3F
0000	001613	31F	0001	000415	315G	0001	000451	335G	0000	001620	35F	0000	001626	37F
0001	000552	370G	0000	001656	39F	0000	001677	41F	0001	000812	412G	0000	001710	43F
0001	000636	430G	0000	001712	45F	0001	000752	456G	0000	001725	47F	0000	001737	49F
0000	001316	5F	0000	001323	6F	0000	001344	7F	0000	001355	8F	0001	000786	990L
0001	000767	999L	0000 R	001072	DHB	0000 R	001034	DHIB	0000 R	002000	DHIF	0000 R	001260	DHIQB
0000 R	000644	DHIOF	0000 R	001247	DP	0000 R	000132	ETA	0000 R	000512	ETAOV	0000 R	000264	HE
0010 R	000000	HFUN	0000 R	001246	HI	0000 R	001165	HION	0000 R	000416	HIOV	0000 R	000036	HNSQ
0000 R	000702	HP	0000 R	001235	HO	0000 I	001245	IST	0000 I	001234	J	0000 I	001255	KS
0000 I	001233	LIM	0000 I	001224	LR	0000 I	001225	LW	0000 I	001231	NOST	0000 I	001232	NP
0000 R	001241	OMEG	0000 R	000170	PE	0005 R	000000	PHDENS	0006 R	000000	PHTEMP	0000 R	001250	PI
0000 R	000000	PTENTH	0004 R	000000	PTENTR	0000 R	001226	PO	0000 R	001253	QE	0000 R	001252	QI
0000 R	001257	QII	0000 R	000776	QN	0000 R	000454	RHF	0000 R	000360	RHOE	0000 R	001237	RH00
0000 R	001254	RLE	0000 R	001240	RL0	0000 R	000322	SE	0000 R	000074	SI	0000 R	001236	S0
0000 R	001130	S00	0000 R	000226	TE	0000 R	001244	TH0	0000 R	001251	TI	0000 R	000550	TORQ
0000 R	000606	TORQN	0000 R	001243	T00	0000 R	001242	TT0	0000 R	001227	T0	0000 R	001256	T00
0000 R	000740	WDOT	0000 R	001230	XN									


```

00213 62*      J = 1
00214 63*      IST = 0
00215 64*      WRITE(LW,45)
00217 65*      WRITE(LW,47)
00221 66*      WRITE(LW,43) H0,S0,RH00
00226 67*      135 DHIF(J) = HNSQ(J) + XN**2
00227 68*      DHIB(J) = DHIF(J)/778.26
00230 69*      HI = H0 + DHIB(J)
00231 70*      DP = RH00/144. + DHIF(J)
00232 71*      PI = P0 + DP
00233 72*      TI = PHTEMP(PI,HI,01)
00234 73*      SI(J) = PTENTR(PI,TI)
00235 74*      CALL PRETE(HI,PI,TI,S0,SI(J))
00236 75*      DHB(J) = DHIB(J)/ETA(J)
00237 76*      HE(J) = H0 + DHB(J)
00240 77*      PE(J) = PI
00241 78*      TE(J) = PHTEMP(PE(J),HE(J),0E)
00242 79*      SE(J) = PTENTR(PE(J),TE(J))
00245 80*      RHOE(J) = PHDENS(PE(J),HE(J),RLE)*1728.
00244 81*      WDOT(J) = RH0E(J)/448.8*XN*QN(J)
00245 82*      IF(IST-1) 110,105,105
00250 83*      105 IF(J=LIM) 115,120,120
00253 84*      110 IF(J=NP) 125,130,130
00256 85*      125 J=J+1
00257 86*      GO TO 135
00263 87*      130 WRITE(LW,11)
00262 88*      WRITE(LW,13)
00264 89*      WRITE(LW,14)
00265 90*      WRITE(LW,23) (QN(J),HNSQ(J),ETA(J),DHIF(J),SI(J),PE(J),TE(J),
00266 91*      1J=1, NP)
00302 92*      WRITE(LW,16)
00304 93*      IF(NOST-1) 140,140,145
00307 94*      145 WRITE(LW,15)
00311 95*      WRITE(LW,21)
00313 96*      WRITE(LW,25) (QN(J),DHIB(J),DHB(J),HE(J),SE(J),RHOE(J),J=1, NP)
00326 97*      GO TO 147
00327 98*      140 WRITE(LW,19)
00331 99*      WRITE(LW,17)
00333 100*     WRITE(LW,27) (QN(J),DHIB(J),DHB(J),HE(J),SE(J),RHOE(J),WDOT(J),J=1
00333 101*     1, NP)
00347 102*     GO TO 990
00350 103*     147 IST = IST + 1
00351 104*     KS = IST * NP + 1
00352 105*     115 J=J+1
00353 106*     P0 = PE(J-NP)
00354 107*     H0 = HE(J-NP)
00355 108*     S0 = SE(J-NP)
00356 109*     RH00 = RH0E(J-NP)
00357 110*     GO TO 135
00358 111*     120 WRITE(LW,31)
00362 112*     WRITE(LW,13)
00364 113*     WRITE(LW,14)
00366 114*     WRITE(LW,23) (QN(J),HNSQ(J),ETA(J),DHIF(J),SI(J),PE(J),TE(J),
00366 115*     1J=KS,LIM)
00402 116*     WRITE(LW,16)
00404 117*     WRITE(LW,19)
00406 118*     WRITE(LW,17)
00410 119*     WRITE(LW,27) (QN(J),DHIB(J),DHB(J),HE(J),SE(J),RHOE(J),WDOT(J),J=K
00410 120*     1S,LIM)
00424 121*     S0 = TS0

```

```

00425 122*      TR = TT2
00426 123*      HQ = TH2
00427 124*      DO 153 J=1,NP
00432 125*      HIOV(J) = HFUN(PE(J+NP),T0,S0)
00433 126*      T00 = PHTEMP(PE(J+NP),HIOV(J),QII)
00434 127*      S00(J) = PTENTR(PE(J+NP),T00)
00435 128*      DHIOB = HIOV(J) = HQ
00435 129*      DHIOF(J) = DHIOB + 778.26
00437 130*      HION(J) = DHIOF(J)/XN**2
00443 131*      RHF(J) = (DHIF(J) + DHIF(J+NP))/DHIOF(J)
00441 132*      ETAOV(J) = DHIOF(J)/(DHIF(J)/ETA(J)+DHIF(J+NP)/ETA(J+NP))
00442 133*      HP(J) = DHIOF(J)*WDOT(J)/550./ETAOV(J)
00443 134*      TORQ(J) = 550. * HP(J)/OMEG
00444 135*      150 TORQN(J) = TORQ(J)/XN**2
00445 136*      WRITE(LW,35)
00453 137*      WRITE(LW,37)
00452 138*      WRITE(LW,39)
00454 139*      WRITE(LW,41) (QN(J),DHIOF(J),HION(J),S00(J),RHF(J),ETAOV(J),HP(J),
00454 140*      1TORQ(J),TORQN(J),J=1,NP)
00472 141*      990 CONTINUE
00473 142*      GO TO 200
00474 143*      999 STOP
00475 144*      END

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. @ *DIAGNOSTIC* MESSAGE(S)

MULTI-STAGE LIQUID HYDROGEN PUMP
OVERALL PERFORMANCE BASED ON STAGE PERFORMANCE

SECTION CONDITION

PRESSURE	TEMPERATURE	SPEED XN	NO OF STAGES	NO OF POINTS
PSIA	DEG R	RPM		
21.800	36.400	27000.0	2	3
ENTHALPY HO BTU/LB	ENTROPY SO BTU/LB/DEG R	DENSITY RHO0 LB/FT**3		
-109.8995	1.8998	4.4160		

FIRST STAGE

G/N GPM/RPM	H/N**2 FT/RPM**2	ETA	HEAD RISE FT	SI BTU/LB/DEG	PRESSURE PE PSIA	TEMP TE DEG R
0.195	0.3750E-04	0.7100	27556.2	1.8999	880.601	47.130
0.220	0.3500E-04	0.7250	25515.0	1.8998	809.419	45.993
0.290	0.2850E-04	0.6400	20776.5	1.8998	660.513	46.321

G/N GPM/RPM	ISENTROPIC ENTHALPY RISE DHIS, BTU/LB	ACTUAL ENTHALPY RISE DHB, BTU/LB	DISCHARGE ENTHALPY HE BTU/LB	DISCHARGE ENTROPY SE BTU/LB/R	DISCHARGE DENSITY LB/FT**3
0.195	35.407	45.870	-60.029	2.223	4.477
0.220	32.765	45.220	-64.678	2.187	4.477
0.290	26.696	41.713	-68.186	2.254	4.395

SECOND STAGE

G/N GPM/RPM	H/N**2 FT/RPM**2	ETA	HEAD RISE FT	SI BTU/LB/DEG	PRESSURE PE PSIA	TEMP TE DEG R
0.195	0.3620E-04	0.6880	26389.8	2.2234	1728.537	57.840
0.220	0.3420E-04	0.6950	24931.8	2.1869	1614.314	55.965
0.290	0.2730E-04	0.6410	19901.7	2.2541	1272.553	55.556

G/N GPM/RPM	ISENTROPIC ENTHALPY RISE DHIS, BTU/LB	ACTUAL ENTHALPY RISE DHB, BTU/LB	DISCHARGE ENTHALPY HE BTU/LB	DISCHARGE ENTROPY SE BTU/LB/R	DISCHARGE DENSITY LB/FT**3	FLW RATE WDOT LB/S
0.195	33.909	45.286	-10.743	2.506	4.531	53.155
0.220	32.035	46.054	-19.584	2.453	4.543	60.122
0.290	25.572	39.894	-28.292	2.531	4.392	76.621

OVERALL PERFORMANCE

G/N GPM/RPM	ISENT	HEAD RISE FT	INLET ENTROPY CHECK	REHEAT FACTOR	OVERALL EFFICIENCY	POWER HP	TORQUE FTLB	NORM TORQUE FTLB/RPM**2
0.195	52948.5		1.2866	1.0188	0.686	7369.6	1433.56	0.1960E-05
0.220	49533.8		1.8878	1.0184	0.607	7655.8	1489.22	0.2043E-05
0.290	50007.8		1.8998	1.0376	0.617	8902.6	1700.00	0.2043E-05

N8300R:72-106
May 1972

8. CROSSOVER PASSAGE DESIGN

COMPUTER PROGRAM
CROSSOVER PASSAGE DESIGN

I. INTRODUCTION

This program presents a method for determining the passage surface shapes of crossover channels employed in multistage pumps. The meridional velocity as well as the tangential velocity distribution are prescribed as a function of meridional stream line length. Coordinates defining the channel shape along the mean line are calculated. Suction and pressure surface velocities are estimated from momentum considerations assuming a linear velocity distribution from the suction surface to the pressure surface of the passage.

The method of analysis employed was devised by M. C. Huppert and the program was first used to smooth out the crossover passages of the 2nd stage NERVA Turbopump discussed in Reference 1.

II. BASIC EQUATIONS

The tangential velocity distribution is described in the following way:

$$R C_u = R_1 C_{u1} + [R_2 C_{u2} - R_1 C_{u1}] \underbrace{Y^n (2 - Y^n)}_f \quad (1)$$

where:

- $R_1 C_{u1}$ = whirl at inlet of crossover passage
- $R_2 C_{u2}$ = whirl at exit of crossover passage
- f = whirl distribution factor
- Y = $\frac{m}{M}$ ratio of passage length to total passage length in meridional plane.
- m = distance along mean line of crossover passage in the meridional plane.
- M = Total length of crossover passage in the meridional plane.
- n = Exponent to specify whirl distribution (surface loading)

Reference 1 - Aerojet Nuclear Systems Company, Engineering Operations Report N8300R:71-076, NERVA Turbopump Design Report, Volume 1, September 1971

The whirl distribution factor f is plotted in Figure 1 as a function of Y for two values of n .

The geometry of typical pump crossover passages are depicted in Figures 2 and 3.

The meridional velocity distribution is directly input (C_m on card 2; refer to input format).

The tangential width of the crossover passage A is computed from continuity as follows:

$$A = \frac{Q}{Z B C_m} \quad (2)$$

where:

- Q = total flow, ft^3/s
- B = meridional width of the crossover passage
- Z = number of passages

The angle of the mean streamline of the crossover passage β is determined from C_m and the value of C_u obtained from expression (1).

$$\tan \beta = \frac{C_m}{C_u}$$

The wrap angle of the mean flow surface of the crossover passage is then given by:

$$\theta_m = \frac{180}{\pi} M \int \frac{dx}{R \tan \beta} \quad (3)$$

and the wrap angles of the passage surfaces are:

Suction Surface

$$\theta_s = \theta_m - \frac{A}{2R} \frac{180}{\pi}$$

Pressure Surface

$$\theta_p = \theta + \frac{A}{2R} \frac{180}{\pi}$$

Suction and pressure surface velocities on the mean streamline are estimated from momentum considerations.

$$H_p - H_s = \frac{Q}{g R B m Z} \frac{\partial(R C_u)}{\partial X} \quad (4)$$

H_p = pressure surface static head, ft

H_s = suction surface static head, ft

The rate of change in which $\frac{\partial(R C_u)}{\partial X}$ is obtained by differentiation of expression (1).

Thus:

$$\frac{\partial(R C_u)}{\partial X} = (R_2 C_{u2} - R_1 C_{u1}) 2nX^{n-1} (1 - X^n) \quad (5)$$

Assuming constant total head (no losses) the surface velocities are:

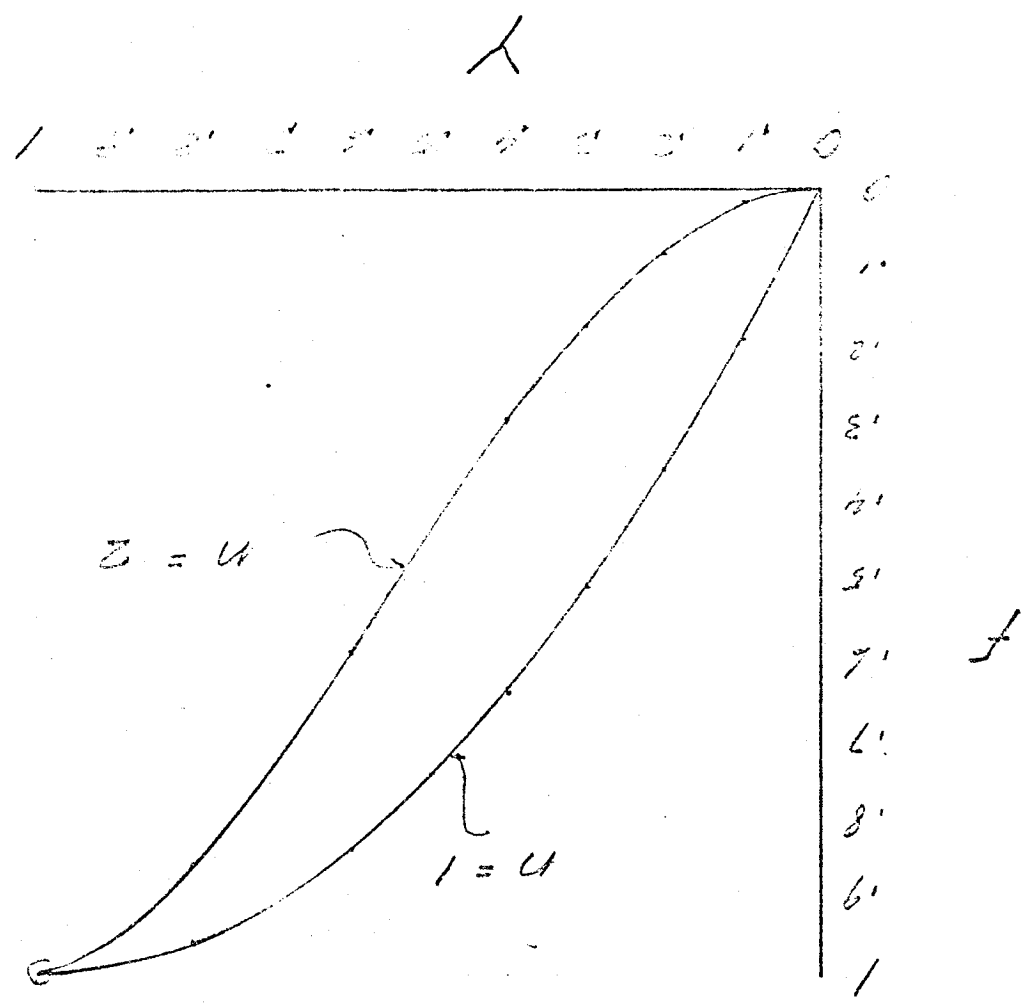
$$H_p - H_s = \frac{C_s^2 - C_p^2}{2g} = (C_s - C_p) \frac{C_{Ave}}{g} \quad (6)$$

where:

$$C_{Ave.} = \sqrt{C_m^2 + C_u^2}$$

Figure 1

For cuts over passages $n \approx 1$



$$f = 1 - (1 - Y^n)^2 = Y^n(2 - Y^n)$$

With distribution factor

Assuming a linear velocity distribution in the passage from the suction surface to the pressure surface the surface velocities C_s and C_p are:

$$C_s = C_{Ave} + \frac{C_s - C_p}{2}$$

and

$$C_p = C_{Ave} - \frac{C_s - C_p}{2}$$

A complete listing and a sample printout are presented on the following pages.

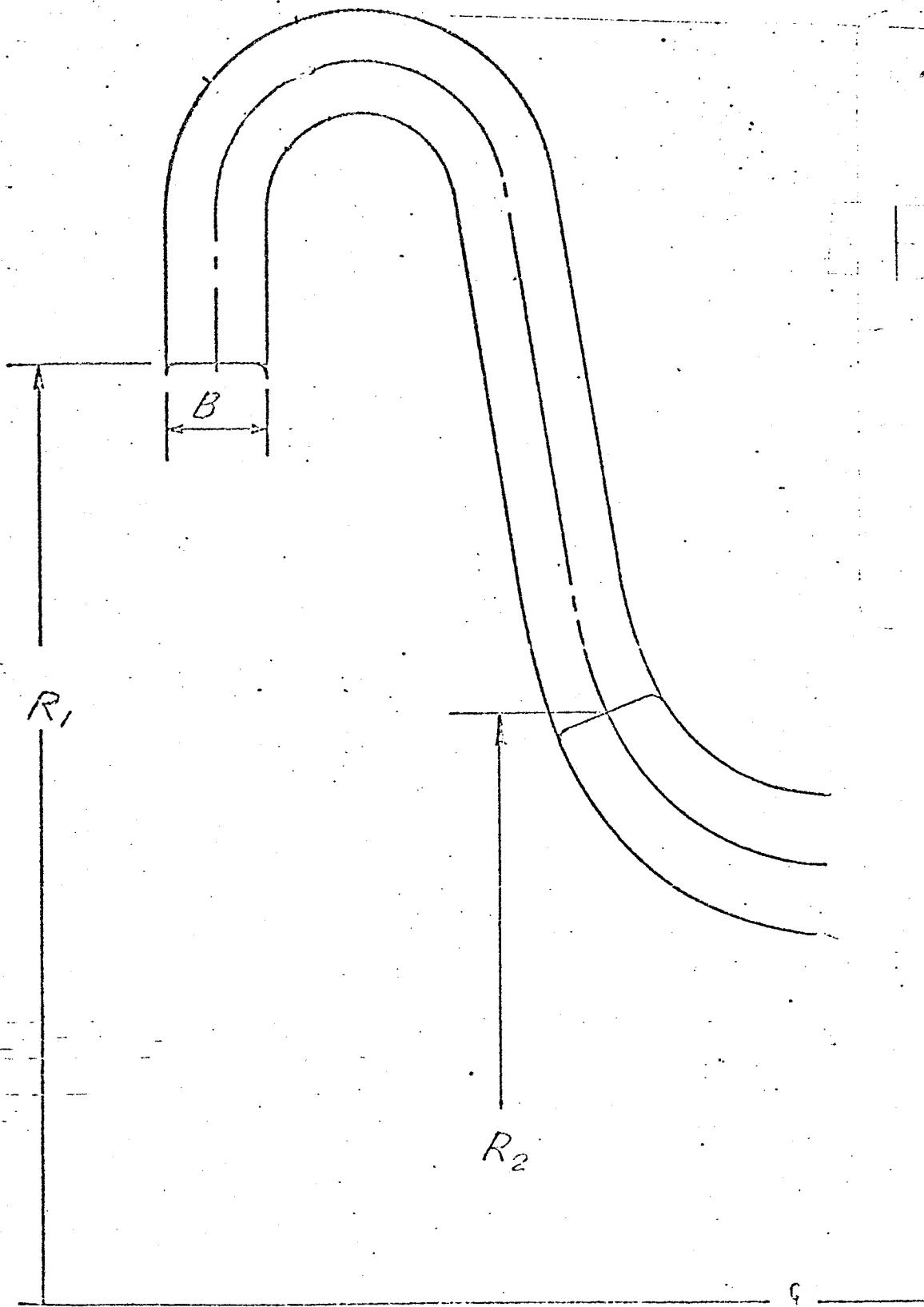
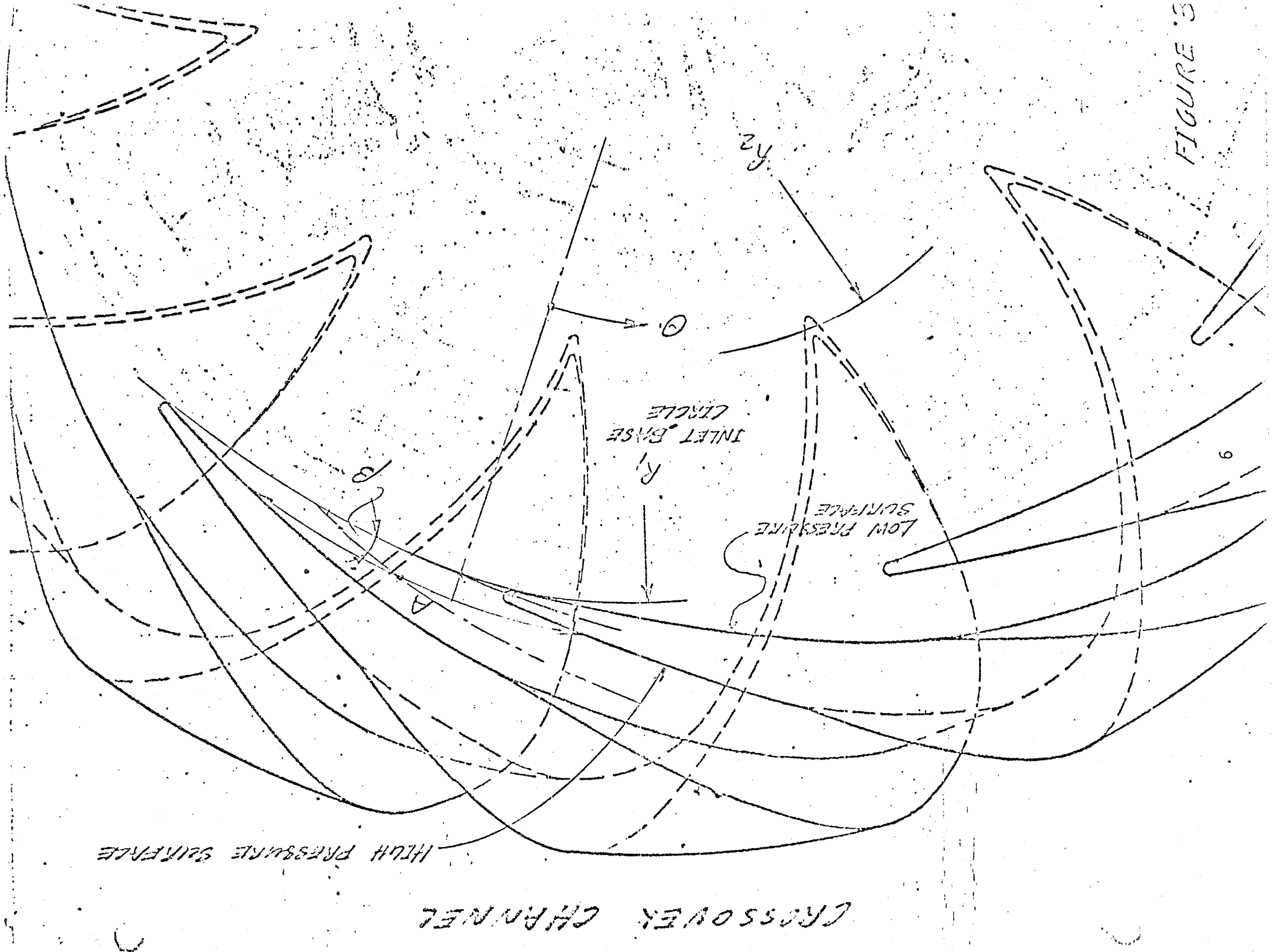


FIGURE 2 MERIDIONAL CROSS SECTION OF CROSS OVER PASSAGES

FIGURE 3

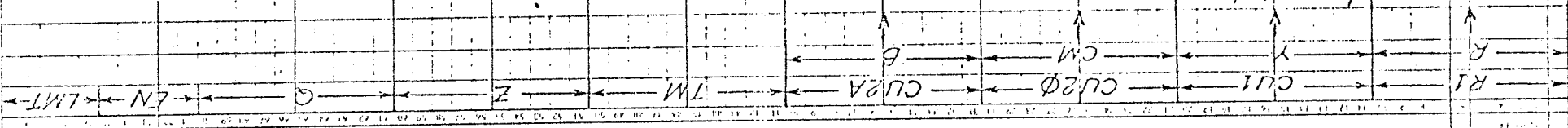


CROSSOVER PASSAGE DESIGN

FORTRAN Coding Form

PROJECTED	DATE
APPROVED	
GRAPHIC	
BRANCH	
PAGE	OF
CARD LENGTH NUMBER	

FORTRAN STATEMENT



Non-nature:

R1 = Inlet Radius

CU1 = Tangential Component, inlet absolute velocity, ft/sec

CU2φ = Tangential Component, ideal discharge absolute velocity, ft/sec

CU2A = Tangential Component, actual discharge absolute velocity, ft/sec

TM = Total passage length, inches

Z = Number of vanes

Q = Volumetric Flow, ft³/sec

EN = Expansion, Vane loading

LMT = Total length of array, total number of points input (30 max.)

R = Local radius, inches

Y = Ratio passage length to total passage length

CM = Local meridional velocity, ft/sec

B = Local passage height, inches

IBM CORPORATION, 1955 RELEASE UNDER E.O. 14176

```

COMPILER OPTIONS - NAME= MAIN,OPT=02,LINFCNT=72,SOURCE,FBCDIC,NOLIST,NOFCK,LOAD,MAP,NOEDIT,NOID,NOXREF
ISN 0002 DIMENSION TITLE (10)
ISN 0003 DIMENSION R(50),Y(50),CM(50),D(50),A(50),CU(50),THTA(50),THTS(50),
ISN 0004 THTP(50), THTA(50)
ISN 0005 DIMENSION CUA(50),CS(50),CP(50),CAV(50),RCP(50)
ISN 0006 KW=5
ISN 0007 KW=6
ISN 0008 1 FORMAT(7F10.3,F5.2,I5)
ISN 0009 2 FORMAT(4F10.3)
ISN 0010 READ(KW,1) TITLE
ISN 0011 READ(KW,1) Z0,CU1,CU20,CU2A,TM,Z0,FM,LMT
ISN 0012 READ(KW,2) (R(I),Y(I),CM(I),D(I),I=1,LMT)
ISN 0013 STORA=0.
ISN 0014 DYC=0.
ISN 0015 RCPAV=0.
ISN 0016 D2=R(LMT)
ISN 0017 THTS=R1*CU1/(R1*CU1-R2*CU20)
ISN 0018 THAT=1.-THTS
ISN 0019 DO 100 I=1,LMT
ISN 0020 A(I)=0/(Z*R(I))*CM(I)*144.
ISN 0021 RCU=4*CU1*(R2*CU20-R1*CU1)*(1.-(1.-Y(I)**FN)**2)
ISN 0022 CU(I)=RCU/D(I)
ISN 0023 IF(CU(I)) 32,33,32
ISN 0024 33 BETA(I) = 00.
ISN 0025 RCP(I) = 0
ISN 0026 GO TO 31
ISN 0027 32 TANB=CM(I)/CU(I)
ISN 0028 BETA(I)=ATAN(TANB)*57.2958
ISN 0029 RCP(I)=1./D(I)*TANB
ISN 0030 31 IF(I-1) 55,55,50
ISN 0031 50 PY=Y(I)-Y(I-1)
ISN 0032 RCPAV=(RCP(I)+RCP(I-1))*0.5
ISN 0033 55 CONTINUE
ISN 0034 THTA(I)=57.2958*TM*DY*RCPAV+STORA
ISN 0035 THTS(I)=THTA(I)-A(I)*57.2958/(2.*R(I))
ISN 0036 THTP(I)=THTA(I)+A(I)*57.2958/(2.*R(I))
ISN 0037 STORA=THTA(I)
ISN 0038 CUA(I)=(THIS*R(I)*CU(I)+THAT*R1*CU1)/P(I)
ISN 0039 IF(Y(I)) 34,35,34
ISN 0040 35 IF(FN-1) 36,37,36
ISN 0041 37 PRTL = 0
ISN 0042 GO TO 38
ISN 0043 34 CONTINUE
ISN 0044 36 PRTL=(R2*CU2A-R1*CU1)*2.*FN*(1.-Y(I)**FN)*Y(I)**(FN-1.)
ISN 0045 38 DF=0*144./((32.174*R(I)*R(I)*TM*7)*PRTL*(-1.))
ISN 0046 CAV(I)=SQRT(CM(I)**2+CUA(I)**2)
ISN 0047 DLTC=DF/CAV(I)*32.174
ISN 0048 CS(I)=CAV(I)+DLTC/2.
ISN 0049 CP(I)=CAV(I)-DLTC/2.
ISN 0050 100 CONTINUE
ISN 0051 WRITE(KW,1)
ISN 0052 WRITE(KW,13) TITLE
ISN 0053 WRITE(KW,7)
ISN 0054 WRITE(KW,6)
ISN 0055 WRITE(KW,12) Z0,FM,FM
ISN 0056 WRITE(KW,3)
ISN 0057 WRITE(KW,4) (R(I),A(I),THTA(I),THTS(I),THTP(I),I=1,LMT)
ISN 0058 WRITE(KW,5)
ISN 0059 WRITE(KW,6) (Y(I),CU(I),BETA(I),B(I),I=1,LMT)
ISN 0060 WRITE(KW,9)
ISN 0061 WRITE(KW,10) (CUA(I),CM(I),CAV(I),CS(I),CP(I),I=1,LMT)
ISN 0062 3 FORMAT(10X,'R',10X,'A',10X,'THTM',10X,'THTS',10X,'THTP',/)
ISN 0063 4 FORMAT(16X,F7.4,3X,F7.3,7X,F7.3,17X,F7.3,7X,F7.3)
ISN 0064 5 FORMAT(/,10X,'Y',10X,'CU',10X,'BETA',10X,'R',/)
ISN 0065 6 FORMAT(7X,F5.3,6X,F8.2,5X,F7.3,8X,F5.3)
ISN 0066 7 FORMAT(5X,'*** NOMENCLATURE ***',/)
ISN 0067 8 FORMAT(5X,'R=RADIUS',/5X,'A=TANGENTIAL WIDTH',/5X,'THYM=MFAN WRAP'
ISN 0068 1./5X,'THTS=SUCTION SURFACE WPAP',/5X,'THTP=PRESSURE SURFACE WRAP',
ISN 0069 2./5X,'Y=STREAMLINE PASSAGE LENGTH RATIO',/5X,'CAV=AVERAGE VELOCITY'
ISN 0070 3./)
ISN 0071 9 FORMAT(/9X,'CUA',10X,'CM',10X,'CAV',10X,'CS',10X,'CP',/)

```

15N 0068 10 FORMAT(IX,F7.3.6X,F7.3.5X,F7.3.6X,F7.3.5X,F7.3)
 15N 0069 11 FORMAT(11H1)
 15N 0070 12 FCMAT(SX,NO,OF PLADBS=,F5.1,5X,0=,F5.2,5X,
 15N 0071 13 FORMAT(1PA4) TOTAL STRMLINE LE
 15N 0072 INGT=,F5.2,5X,FKPOMENT N=,F5.2,/)
 15N 0073 END

11A	11B	11C	11D
690.000	700.357	700.357	700.357
676.063	650.205	650.205	600.065
547.732	605.030	605.030	564.922
541.074	564.395	564.395	512.636
409.420	524.203	524.203	473.724
450.833	491.200	491.200	437.968
422.017	450.402	450.402	406.501
369.877	410.205	410.205	375.670
357.578	384.454	384.454	346.354
303.030	361.212	361.212	305.617
270.636	343.504	343.504	297.521
258.301	328.287	328.287	272.226
240.145	315.000	315.000	258.918
221.722	303.672	303.672	247.667
205.000	293.330	293.330	237.364
188.000	284.058	284.058	228.101
177.205	275.827	275.827	220.052
165.465	268.627	268.627	213.113
153.583	262.440	262.440	207.140
142.281	256.246	256.246	200.811
131.257	249.357	249.357	195.154
120.477	241.202	241.202	176.779
109.844	216.774	216.774	163.104
97.604	204.163	204.163	152.380
82.140	186.000	186.000	142.085
72.000	178.000	178.000	130.581
60.405	171.000	171.000	134.618
46.374	162.500	162.500	134.622
0.0	158.000	158.000	158.000

36 A

*** CROSS OVER CHANNEL CASE 3 ... MAR 17 1971 ***
 *** NOMENCLATURE ***

R=RADIUS
 A=TANGENTIAL WIDTH
 TH=SEMI-ARC WRAP
 THRS=ARC SURFACE WRAP
 THRSURF=ARC SURFACE WRAP
 Y=STRAIGHT PASSAGE LENGTH RATIO
 CAV=AVERAGE VELOCITY

NO. OF BLADES= 11.0 C=16.70 TOTAL STRMLINE LENGTH= 6.96 EXPONENT N= 1.00

P	A	THM	THS	THP	Y
5.8500	2.800	0.0	-14.161	14.161	0.15
6.0242	2.500	8.033	-1.402	21.144	0.25
6.1981	2.301	14.981	5.071	24.002	0.35
6.3725	2.207	21.898	11.984	26.707	0.45
6.5464	2.090	26.871	17.984	29.369	0.55
6.7208	2.006	31.133	22.983	32.019	0.65
6.8947	1.933	34.808	26.986	34.647	0.75
7.0684	1.884	38.002	30.982	37.261	0.85
7.2426	1.836	40.707	33.986	39.871	0.95
7.4168	1.803	42.958	36.006	42.477	1.00
7.5909	1.779	44.785	37.604	45.079	1.05
7.7646	1.774	46.137	38.724	47.677	1.10
7.9379	1.783	47.073	39.418	50.271	1.15
8.1107	1.803	47.546	40.518	52.860	1.20
8.2830	1.834	47.506	41.979	55.444	1.25
8.4548	1.876	46.944	43.764	58.023	1.30
8.6261	1.929	45.806	45.914	60.597	1.35
8.7969	2.000	44.052	48.475	63.166	1.40
8.9672	2.087	40.724	51.492	65.730	1.45
9.1370	2.190	35.902	55.011	68.289	1.50
9.3063	2.307	29.588	59.077	70.843	1.55
9.4751	2.438	21.765	63.724	73.392	1.60
9.6434	2.582	12.422	68.994	75.936	1.65
9.8112	2.738	2.566	74.845	78.475	1.70
9.9785	2.905	0.0	81.342	81.009	1.75
10.1453	3.083	0.0	88.481	83.638	1.80
10.3116	3.271	0.0	96.271	86.361	1.85
10.4774	3.468	0.0	104.711	89.179	1.90
10.6427	3.674	0.0	113.801	92.093	1.95
10.8075	3.888	0.0	123.541	95.113	2.00
10.9718	4.110	0.0	133.931	98.248	2.05
11.1356	4.340	0.0	144.971	101.498	2.10
11.2989	4.578	0.0	156.661	104.863	2.15
11.4617	4.824	0.0	169.001	108.343	2.20
11.6240	5.078	0.0	182.091	111.938	2.25
11.7858	5.339	0.0	195.931	115.648	2.30
11.9471	5.607	0.0	210.521	119.473	2.35
12.1079	5.882	0.0	225.861	123.413	2.40
12.2682	6.164	0.0	241.951	127.468	2.45
12.4280	6.453	0.0	258.791	131.638	2.50
12.5873	6.749	0.0	276.371	135.923	2.55
12.7461	7.052	0.0	294.701	140.323	2.60
12.9044	7.362	0.0	313.881	144.838	2.65
13.0622	7.679	0.0	333.811	149.468	2.70
13.2195	8.003	0.0	354.491	154.213	2.75
13.3763	8.334	0.0	375.921	159.073	2.80
13.5326	8.672	0.0	398.101	164.048	2.85
13.6884	9.017	0.0	421.031	169.138	2.90
13.8437	9.369	0.0	444.711	174.343	2.95
14.0000	9.728	0.0	469.141	179.663	3.00
14.1563	10.094	0.0	494.321	185.098	3.05
14.3126	10.467	0.0	520.251	190.648	3.10
14.4689	10.847	0.0	546.931	196.313	3.15
14.6252	11.234	0.0	574.361	202.093	3.20
14.7815	11.628	0.0	602.541	208.088	3.25
14.9378	12.029	0.0	631.471	214.198	3.30
15.0941	12.437	0.0	661.151	220.423	3.35
15.2504	12.852	0.0	691.581	226.763	3.40
15.4067	13.274	0.0	722.761	233.218	3.45
15.5630	13.703	0.0	754.691	239.788	3.50
15.7193	14.139	0.0	787.371	246.473	3.55
15.8756	14.582	0.0	820.801	253.273	3.60
16.0319	15.032	0.0	854.981	260.188	3.65
16.1882	15.489	0.0	890.911	267.218	3.70
16.3445	15.953	0.0	927.591	274.363	3.75
16.5008	16.424	0.0	965.021	281.623	3.80
16.6571	16.901	0.0	1003.201	289.098	3.85
16.8134	17.384	0.0	1042.131	296.788	3.90
16.9697	17.873	0.0	1081.811	304.593	3.95
17.1260	18.368	0.0	1122.241	312.513	4.00
17.2823	18.869	0.0	1163.421	320.548	4.05
17.4386	19.376	0.0	1205.351	328.698	4.10
17.5949	19.889	0.0	1248.031	336.963	4.15
17.7512	20.408	0.0	1291.461	345.343	4.20
17.9075	20.933	0.0	1335.641	353.838	4.25
18.0638	21.464	0.0	1380.571	362.448	4.30
18.2201	22.001	0.0	1426.251	371.173	4.35
18.3764	22.544	0.0	1472.681	380.013	4.40
18.5327	23.093	0.0	1519.861	388.968	4.45
18.6890	23.648	0.0	1567.791	398.038	4.50
18.8453	24.209	0.0	1616.471	407.223	4.55
19.0016	24.776	0.0	1665.901	416.523	4.60
19.1579	25.349	0.0	1716.081	425.938	4.65
19.3142	25.928	0.0	1766.911	435.468	4.70
19.4705	26.513	0.0	1818.391	445.113	4.75
19.6268	27.104	0.0	1870.521	454.873	4.80
19.7831	27.701	0.0	1923.301	464.748	4.85
19.9394	28.304	0.0	1976.731	474.738	4.90
20.0957	28.913	0.0	2030.811	484.843	4.95
20.2520	29.528	0.0	2085.541	495.063	5.00
20.4083	30.149	0.0	2140.921	505.398	5.05
20.5646	30.776	0.0	2196.951	515.848	5.10
20.7209	31.409	0.0	2253.631	526.413	5.15
20.8772	32.048	0.0	2310.961	537.093	5.20
21.0335	32.693	0.0	2368.941	547.888	5.25
21.1898	33.344	0.0	2427.571	558.798	5.30
21.3461	34.001	0.0	2486.851	569.823	5.35
21.5024	34.664	0.0	2546.781	580.963	5.40
21.6587	35.333	0.0	2607.361	592.218	5.45
21.8150	36.008	0.0	2668.591	603.588	5.50
21.9713	36.689	0.0	2730.471	615.073	5.55
22.1276	37.376	0.0	2793.001	626.673	5.60
22.2839	38.069	0.0	2856.181	638.388	5.65
22.4402	38.768	0.0	2920.011	650.218	5.70
22.5965	39.473	0.0	2984.491	662.163	5.75
22.7528	40.184	0.0	3049.621	674.223	5.80
22.9091	40.901	0.0	3115.401	686.398	5.85
23.0654	41.624	0.0	3181.831	698.688	5.90
23.2217	42.353	0.0	3248.911	711.093	5.95
23.3780	43.088	0.0	3316.641	723.613	6.00
23.5343	43.829	0.0	3385.021	736.248	6.05
23.6906	44.576	0.0	3454.051	748.998	6.10
23.8469	45.329	0.0	3523.731	761.863	6.15
24.0032	46.088	0.0	3594.061	774.843	6.20
24.1595	46.853	0.0	3665.041	787.938	6.25
24.3158	47.624	0.0	3736.671	801.148	6.30
24.4721	48.401	0.0	3808.951	814.473	6.35
24.6284	49.184	0.0	3881.881	827.913	6.40
24.7847	49.973	0.0	3955.461	841.468	6.45
24.9410	50.768	0.0	4029.691	855.138	6.50
25.0973	51.569	0.0	4104.571	868.923	6.55
25.2536	52.376	0.0	4180.101	882.823	6.60
25.4099	53.189	0.0	4256.281	896.838	6.65
25.5662	54.008	0.0	4333.111	910.968	6.70
25.7225	54.833	0.0	4410.591	925.213	6.75
25.8788	55.664	0.0	4488.721	939.573	6.80
26.0351	56.501	0.0	4567.501	954.048	6.85
26.1914	57.344	0.0	4646.931	968.638	6.90
26.3477	58.193	0.0	4727.011	983.343	6.95
26.5040	59.048	0.0	4807.741	998.163	7.00
26.6603	59.909	0.0	4889.121	1013.098	7.05
26.8166	60.776	0.0	4971.151	1028.148	7.10
26.9729	61.649	0.0	5053.831	1043.313	7.15
27.1292	62.528	0.0	5137.161	1058.593	7.20
27.2855	63.413	0.0	5221.141	1073.988	7.25
27.4418	64.304	0.0	5305.771	1089.498	7.30
27.5981	65.201	0.0	5391.051	1105.123	7.35
27.7544	66.104	0.0	5476.981	1120.863	7.40
27.9107	67.013	0.0	5563.561	1136.718	7.45
28.0670	67.928	0.0	5650.791	1152.688	7.50
28.2233	68.849	0.0	5738.671	1168.773	7.55
28.3796	69.776	0.0	5827.201	1184.973	7.60
28.5359	70.709	0.0	5916.381	1201.288	7.65
28.6922	71.648	0.0	6006.211	1217.718	7.70
28.8485	72.593	0.0	6096.691	1234.263	7.75
29.0048	73.544	0.0	6187.821	1250.923	7.80
29.1611	74.501	0.0	6279.601	1267.698	7.85
29.3174	75.464	0.0	6372.031	1284.588	7.90
29.4737	76.433	0.0	6465.111	1301.593	7.95
29.6300	77.408	0.0	6558.841	1318.713	8.00
29.7863	78.389	0.0	6653.221	1335.948	8.05
29.9426	79.376	0.0	6748.251	1353.298	8.10
30.0989	80.369	0.0	6843.931	1370.763	8.15
30.2552	81.368	0.0	6940.261	1388.343	8.20
30.4115	82.373	0.0	7037.241	1406.038	8.25
30.5678	83.384	0.0	7134.871	1423.848	8.30
30.7241	84.401	0.0	7233.151	1441.773	8.35
30.8804	85.424	0.0	7332.081	1459.813	8.40
31.0367	86.453	0.0	7431.661	1477.968	8.45
31.1930	87.488	0.0	7531.891	1496.238	8.50
31.3493	88.529	0.0	7632.771	1514.623	8.55
31.5056	89.576	0.0	7734.301	1533.123	8.60
31.6619	90.629	0.0	7836.481	1551.738	8.65
31.8182	91.688	0.0	7939.311	1570.468	8.70
31.9745	92.753	0.0	8042.791	1589.313	8.75
32.1308	93.824	0.0	8146.921	1608.273	8.80
32.2871	94.901	0.0	8251.701	1627.348	8.85
32.4434	95.984	0.0	8357.131	1646.538	8.90
32.5997	97.073	0.0	8463.211	1665.843	8.95
32.7560	98.168	0.0	8569.941	1685.263	9.00
32.9123	99.269	0.0	8677.321	1704.798	9.05
33.0686	100.376	0.0	8785.351	1724.448	9.10
33.2249	101.489	0.0	8894.031	1744.213	9.15
33.3812					

N8300R:72-106
May 1972

9. AIR PUMP PERFORMANCE MAP

COMPUTER PROGRAM
AIR PUMP PERFORMANCE MAP

I. INTRODUCTION

This program generates data for plotting performance maps of pumps or blowers operating in air at low pressure ratios. Inlet condition and performance parameters in normalized form are input. Discharge pressure, temperature rise, torque, overall efficiency and flow rate at the specified speeds and flow parameters are printed out.

This program was written for producing predicted pump performance maps for the NERVA pump air test rig. The use of a digital computer for the calculation of the discharge conditions was necessary to achieve acceptable accuracy at very low pressure ratios ($r_p < 1.2$).

II. BASIC EQUATIONS

Performance parameters are obtained from a loss analysis and specified in terms of normalized flow Q/N , normalized head H/N^2 and efficiency. Inlet conditions are defined by pressure p_0 and temperature T_0 . Air is treated as an ideal gas.

The air inlet density ρ_0 can then be calculated as follows:

$$\rho_0 = \frac{144 p_0}{R T_0}$$

R = gas constant = 53.34 ft lb/lb, °F

The isentropic head rise is calculated from input parameters:

$$H = N^2 (H/N^2)$$

and the flow rate in ft^3/s

$$V_2 = N (Q/N)/448.8$$

Pressure Ratio r_p

$$r_p = \left(\frac{H + J (C_p) T_o}{J (C_p) T_o} \right)^{\frac{K}{K-1}}$$

J = mechanical equivalent of heat (778.26 ft lb/btu)

C_p = specific heat = 0.240 btu/lb/°F

Neglecting the discharge velocity head the discharge pressure P_2 is:

$$P_2 = r_p P_o$$

Temperature rise ΔT

$$\Delta T = \frac{T_o (r_p)^{\frac{K-1}{K}} - T_o}{\eta}$$

η = pump efficiency (input)

thus:

$$T_2 = T_o + \Delta T$$

and

$$\rho_2 = \frac{144 P_2}{R T_2}$$

Torque M_t in In. Lb.

$$M_t = 12 \frac{V_2 \rho_2 H}{\eta \omega}$$

$$\omega = \frac{\pi N}{30}$$

NOMENCLATURE

INPUT PARAMETERS

<u>SYMBOL</u>	<u>DESCRIPTION</u>	<u>UNITS</u>	<u>FORMAT</u>
XN(1)-(5)	Rotational Speed	rpm	F
NUMQ	Number of specified points (Q/N)	-	I5
NUMN	Number of Speeds	=	I5
TO	Inlet Temperature	Deg R	F
PO	Inlet Pressure	psia	F
QN(J)	Flow Parameter	gpm/rpm	F
HN(J)	Normalized Isentropic Head	ft/rpm ²	F
ETA(J)	Efficiency	-	F

FORTRAN V: ISD VERSION 2.2
 THIS COMPILATION WAS DONE ON 10 APR 72 AT 12:04:31

10 APR 72 12:04:31.789

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000277
 0000 *DATA 000441
 0002 *BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NROU\$
 0004 NIO2\$
 0005 NIO1\$
 0006 NWDU\$
 0007 NEXP6\$
 0010 NSTOP\$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	000233	10F	0000	000339	100F	0000	000337	102F	0000	000363	104F	0000	000407	106F	
0001	000046	133G	0000	000235	15F	0001	000113	161G	0001	000141	172G	0000	000240	20F	
0001	000023	200L	0001	000251	225G	0000	000242	25F	0000	000246	30F	0000	000255	32F	
0000	000310	34F	0001	000122	40L	0001	000004	500L	0001	000273	900L	0000	R	000113	DP
0000	R	000175	DT	0000	R	000125	DTI	0000	R	000024	ETA	0000	R	000043	H
0000	I	000232	I	0000	I	000227	J	0000	I	000221	LR	0000	I	000222	LW
0000	I	000223	NUM0	0000	R	000067	PR	0000	R	000226	P0	0000	R	000101	P2
0000	R	000231	RHC	0000	R	000151	RHO2	0000	R	000207	TMT	0000	R	000225	T0
0000	R	000230	V0	0000	R	000163	V0	0000	R	000055	V2	0000	R	000036	XN

00101 1* DIMENSION GN(10),HN(10),ETA(10),XN(5),H(10),V2(10),PR(10),P2(10),
 00101 2* 1DP(10),DTI(10),T2(10),RHO2(10),V0(10),DT(10),TMT(10)
 00103 3* LR=5
 00104 4* LW=6
 00105 5* 10 FORMAT('1')
 00106 6* 15 FORMAT(2I5,F10.1,2F10.3)
 00107 7* 20 FORMAT(5F10.1)
 00110 8* 25 FORMAT(F10.3,E10.3,F10.3)
 00111 9* 500 READ(LR,20) XN(1),XN(2),XN(3),XN(4),XN(5)
 00120 10* IF(XN(1)) 900,900,200
 00123 11* 200 READ(LR,15) NUM0,NUMN,T0,P0
 00131 12* READ(LR,25) (GN(J),HN(J),ETA(J),J=1,NUM0)
 00141 13* V0 = 0.370416* T0/P0
 00142 14* Rho = 1./V0
 00143 15* 30 FORMAT(30X,'AIR TEST PUMP PERFORMANCE MAP'///
 00144 16* 32 FORMAT(2X,'INLET TEMPERATURE T0 =',F7.2,2X,'DEG F',10X,'INLET PRE
 00144 17* SSURE P0 =',F8.3,2X,'PSIA'///
 00144 18* 2X,'LB/FT**3'///
 00145 19* 34 FORMAT(10X,'PUMP CHARACTERISTICS'///
 00145 19* 6X,'Q/N',7X,'ETA',10X,'H/N**2'

```

0015 20* 1111(F10.3,F10.3,E14.3)
0016 21* WRITE(LW,10)
0017 22* WRITE(LW,30)
0018 23* WRITE(LW,32) 10,P0,RHO
0019 24* WRITE(LW,34) (QN(J),ETA(J),HN(J),J=1,NUM0)
0020 25* I = 0
0021 26* I = I + 1
0022 27* DO 60 J=1,NUM0
0023 28* H(J) = HN(J) * XN(I)**2
0024 29* V2(J) = XN(I)*QN(J)/448.83
0025 30* PR(J) = ((H(J) + 186.768*10)/(186.768*10))**3*5.5335
0026 31* P2(J) = PR(J) * P0
0027 32* CP(J) = (P2(J)-P0) * 27.67
0028 33* DT(J) = 10*(PR(J))**0.283 - 10
0029 34* DT(J) = DT(J)/ETA(J)
0030 35* T2(J) = T0 + DT(J)
0031 36* RH02(J) = 1./(0.370416 * T2(J)/P2(J))
0032 37* TM1(J) = 114.587 * H(J)*V2(J) * RH02(J)/ETA(J) /XN(I)
0033 38* V0(J) = V2(J) * RH02(J)/RHO
0034 39* 100 FORMAT (////2X,SPED = ,F7.1, RPM,/)
0035 40* 102 FORMAT (5X,G/N, ,9X,V2, ,7X,DH, ,8X,PR, ,9X,PT, ,10X,DP, ,9X,DT,
0036 41* 17X,RH02, ,8X,V0, ,6X,TORQUE)
0037 42* 104 FORMAT (16X,FT/S, ,6X,FT, ,18X,PSIA, ,7X,IN H2O, ,6X,DEG F, ,4X,LT
0038 43* 18/ET**3, ,4X,FT**3/S, ,3X,INLB,/)
0039 44* 106 FORMAT (2F10.3,F11.3,F9.4,F12.4,F11.3,F10.3,F12.5,F10.3,F10.3)
0040 45* WRITE(LW,100) XN(I)
0041 46* WRITE(LW,102)
0042 47* WRITE(LW,104)
0043 48* WRITE(LW,106) (QN(J),V2(J),H(J),PR(J),P2(J),CP(J),DT(J),RH02(J),V0
0044 49* 1(J),TM1(J),J=1,NUM0)
0045 50* IF (NUM0-1) 500,500,40
0046 51* STOP
0047 52* END

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 0 *DIAGNOSTIC* MESSAGE(S)

AIR TEST PUMP PERFORMANCE MAP

INLET TEMPERATURE TO = 530.00 DEG F

INLET PRESSURE PO = 14.500 PSIA

INLET WEIGHT DENSITY RHO = .07386 LB/FT**3

PUMP CHARACTERISTICS

G/N	ETA	H/N**2
.050	.290	.845-04
.100	.495	.840-04
.150	.615	.800-04
.200	.675	.730-04
.220	.630	.694-04
.250	.670	.640-04
.300	.632	.540-04
.350	.551	.430-04
.400	.410	.295-04
.450	.140	.850-05

SPEED = 5000.0 RPM

G/N	V2 FT/S	DH FT	PR	P2 PSIA	DP IN H2O	DT DEG F	RHO2 LB/FT**3	VO FT**3/S	TORQUE INLB
.050	.357	2112.500	1.0775	15.6233	31.092	39.002	.07413	.559	6.893
.100	1.114	2100.000	1.0770	15.6165	30.893	22.714	.07628	1.150	8.262
.150	1.671	2000.000	1.0732	15.5620	29.385	17.412	.07675	1.736	9.558
.200	2.228	1825.000	1.0667	15.4669	26.754	14.476	.07669	2.313	10.587
.220	2.451	1735.000	1.0633	15.4182	25.405	13.661	.07656	2.541	10.972
.250	2.785	1600.000	1.0583	15.3453	23.388	12.786	.07632	2.878	11.633
.300	3.342	1350.000	1.0490	15.2109	19.671	11.437	.07584	3.432	12.408
.350	3.899	1075.000	1.0389	15.0641	15.609	10.446	.07525	3.972	13.118
.400	4.456	737.500	1.0266	14.8853	10.663	9.631	.07447	4.493	13.679
.450	5.013	212.500	1.0076	14.6103	3.052	8.127	.07330	4.975	12.781

SPEED = 6000.0 RPM

G/N	V2 FT/S	DH FT	PR	P2 PSIA	DP IN H2O	DT DEG F	RHO2 LB/FT**3	VO FT**3/S	TORQUE INLB
.050	.668	3042.000	1.1129	16.1368	45.290	56.163	.07432	.673	9.952

.100	1.337	3024.000	1.1122	16.1267	45.912	32.709	.07737	1.400	12.067
.150	2.065	2840.000	1.1067	16.0464	42.790	25.073	.07804	2.119	13.996
.200	2.674	2628.000	1.0970	15.9866	38.921	20.845	.07796	2.822	15.498
.220	2.941	2498.400	1.0921	15.8351	36.641	19.672	.07777	3.097	16.049
.250	3.342	2304.000	1.0847	15.7281	33.982	18.412	.07742	3.503	16.993
.300	4.010	1944.000	1.0711	15.5315	28.542	16.469	.07673	4.166	18.076
.350	4.679	1548.000	1.0564	15.3172	22.613	15.042	.07567	4.806	19.046
.400	5.347	1062.000	1.0384	15.0572	15.418	13.868	.07474	5.411	19.770
.450	6.016	306.000	1.0110	14.6590	4.400	11.703	.07306	5.950	18.345

SPEED = 7000.0 RPM

Q/N	V2 FT/S	DH FT	PR	P2 PSIA	DP IN H2O	DT DEG F	RHO2 LR/FT**3	V0 FT**3/S	TORQUE INLB
.050	.760	4140.500	1.1558	16.7591	62.510	76.444	.07461	.788	13.597
.100	1.560	4116.000	1.1548	16.7451	62.121	44.520	.07868	1.662	16.704
.150	2.339	3929.000	1.1471	16.6329	59.016	34.127	.07960	2.521	19.429
.200	3.119	3577.000	1.1336	16.4378	53.618	28.373	.07947	3.356	21.504
.220	3.431	3400.600	1.1268	16.3381	50.860	26.775	.07922	3.630	22.251
.250	3.899	3136.000	1.1165	16.1894	46.746	25.060	.07874	4.157	23.523
.300	4.679	2646.000	1.0977	15.9166	39.197	22.416	.07778	4.928	24.943
.350	5.459	2107.000	1.0773	15.6203	30.999	20.474	.07661	5.662	26.176
.400	6.238	1446.500	1.0526	15.2621	21.088	18.877	.07507	6.341	27.027
.450	7.018	416.500	1.0149	14.7167	5.997	15.928	.07278	6.915	24.874

SPEED = 8000.0 RPM

Q/N	V2 FT/S	DH FT	PR	P2 PSIA	DP IN H2O	DT DEG F	RHO2 LR/FT**3	V0 FT**3/S	TORQUE INLB
.050	.891	5408.000	1.2068	17.4984	82.964	99.845	.07500	.905	17.854
.100	1.782	5376.000	1.2055	17.4794	82.440	58.149	.08023	1.936	22.246
.150	2.674	5120.000	1.1951	17.3284	78.261	44.574	.08142	2.947	25.957
.200	3.565	4672.000	1.1770	17.0663	71.019	37.058	.08125	3.922	28.715
.220	3.921	4441.600	1.1678	16.9327	67.312	34.972	.08091	4.296	29.684
.250	4.456	4096.000	1.1540	16.7336	61.803	32.732	.08028	4.843	31.324
.300	5.347	3456.000	1.1289	16.3694	51.725	29.278	.07902	5.721	33.094
.350	6.238	2752.000	1.1017	15.9753	40.822	26.741	.07747	6.543	34.572
.400	7.130	1838.000	1.0690	15.5011	27.700	24.655	.07545	7.283	35.480
.450	8.021	544.000	1.0196	14.7635	7.846	20.805	.07246	7.869	32.347

N8300R:72-106
May 1972

10. PUMP AXIAL THRUST PREDICTION PROGRAM

PUMP AXIAL THRUST PREDICTION PROGRAM

1. INTRODUCTION

- a. The program was developed to predict the flow distribution and rotor axial thrust of the NERVA Turbopump. The variation in the parameters are also Monte Carlo'ed.
- b. The program listing and narrative along with an input list and rotor schematic are included.
- c. The program was debugged and modelled the "C" change turbopump.
- d. Changes to engine operating conditions can grossly effect the internal flow within the turbopump.
- e. No related activities.
- f. This program was developed by R. A. Livingston.

2. CONCLUSIONS

- a. Gross Conclusion
 - (1) The program appeared to represent the actual turbopump quite accurately.
 - (2) The program, analytically, performed all of its required functions.
 - (3) The next logical modification would be the inclusion of subroutines to determine influence coefficients.

PROJECT 121
W.S. f7
FLUID DYNAMIC ANALYSIS

b. Interpretation

- (1) The program does not derive conclusion, i.e., values only.
- (2) The accuracy of the analysis has great implication relative to thrust balancer performance .
- (3) The accurate representation of the correct thermodynamic properties and processes have significant implication as to the validity of the results.

3. RECOMMENDATIONS

- a. The program can allow determination of optimum clearance and yet maintain the desired reliability within the turbopump.
- b. No problems have arisen as a result of this work.
- c. The analytical prediction need, next, to be compared to actual test data.
- d. See b.(3) under conclusions.

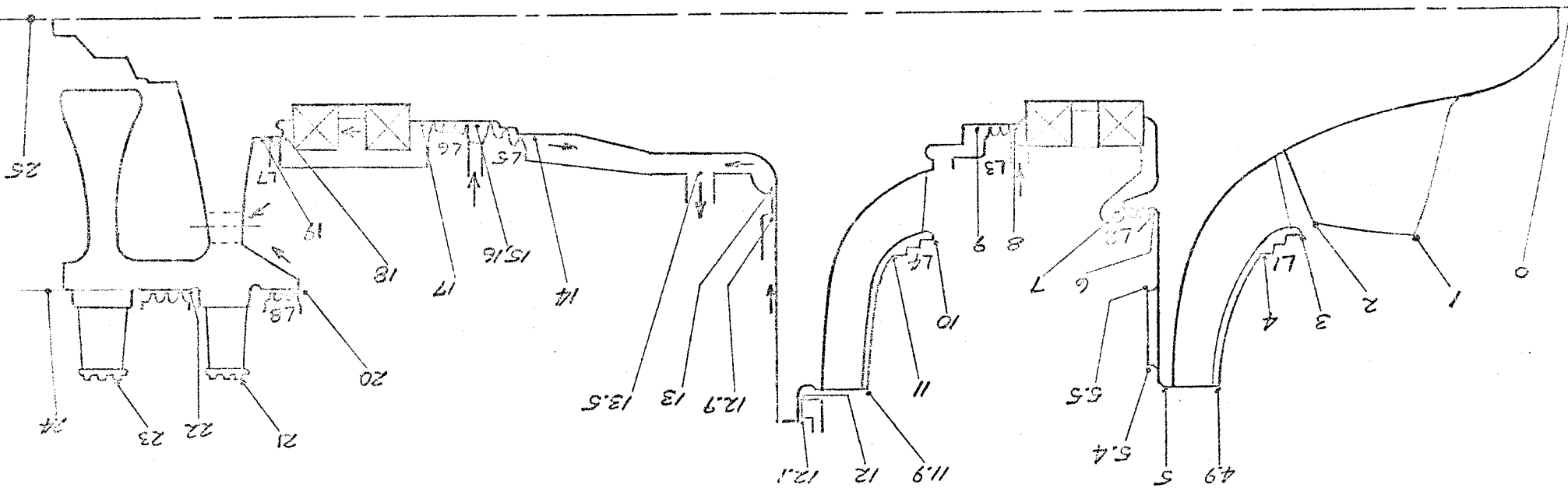
4. REFERENCES

None

I. INTRODUCTION

A mathematical model of the NERVA turbopump internal flow network was developed to permit both statistical and single point (i.e., data set) evaluation of the pump internal flows and balance piston position. The primary dependent parameters are the hydrostatic thrust balancer position in the housing and the flowrates thru the several labyrinth seals and flow circuits which include the bearing coolant and thrust balancer flow circuits. These "output" parameters are computed for each set of "input" parameters which consists of the pump component dimensions, various factors such as the rate of fluid to rotor angular velocity, and the pump operating conditions which include interface pressures, shaft speed and propellant conditions, see Table 1. For a single point computation, the mean values of the input parameters are used to compute a corresponding set of mean output parameters. For statistical analysis, the input data consists of the set of mean values of the input parameters plus a corresponding set of variances, one for each input parameter. The math model is programmed to execute any desired number of repetitive solutions of the output versus input parameters, each computation using a different set in input parameters as governed by the input variances and a random distribution within any specified distribution characteristic (Figure). The program output for a statistical analysis (Monte Carlo) case consists of the mean, standard deviation and range of each computed parameter. Since all the input parameters are not independent there are correlation equations to approximate the relationship of interacting parameters. In the current version of the program, the turbine inlet pressure variation is a function of the pump discharge pressure variation, and interstage turbine pressures are maintained in constant ratio. In a real pump, there exists a relationship between pump discharge pressure, flowrate and shaft speed. In this model of the turbopump they are left independent because of the relatively weak effect of shaft speed and flowrate on the output parameters as compared to pressure distribution factors and because an accurate accounting of the relationship between speed, flow, pressure and turbine flowrate would require an overall system analysis which would exceed the scope of this project. A future goal for improving this model might include the development of an influence coefficient

method predicting the interaction of these parameters. Figure 1 is a schematic of the turbopump rotor with the stations numbered for reference in the program, equations and parameter list (Reference Table 1 and the program listing).



TPA 1118101-C, ROTOR SCHEMATIC
FOR AXIAL THRUST ANALYSIS

TABLE 1
PARAMETER LIST

INPUT PARAMETERS

<u>NO.</u>	<u>CODE</u>	<u>NAME</u>
1	PPD	Pump Discharge Pressure (at flange), psia
2	P1F	Pump 1st Stage Pressure Rise Factor = $P(10)/PPD$
3	$\bar{P}S$	Suction Pressure at Inducer Inlet (0), psi
4	PIF	Inducer Discharge Pressure (2) Factor $P(2)/PPD$
5	PTI	Turbine Manifold Inlet Pressure, psia
6	PTE	Turbine Exhaust Pressure $P(24)$, psia
7	TTBP	Balance Piston Total Travel (0 Clearance to Clearance), in.
8	WPD	Pump Discharge Flowrate, lb/sec
9	RPM	Pump Shaft Speed, RPM
10	P5F	Pressure $P(5)$ Factor = $P(5)/PD1$
11	P12F	Pressure $P(12)$ Factor = $P(12)/(PPD-PD1)$
12	TBPR	Turbine Bypass Ratio = $(WPD - \dot{w}(Turb))/WPD$
13	P21	Static Pressure at Sta. (21)
14	P22	↓ ↓ ↓ (22)
15	P23	↓ ↓ ↓ (23)
16	P24	↓ ↓ ↓ (24)
17	$\bar{T}S$	Temperature of Hydrogen in Suction Line
18	TPD	Temperature of Hydrogen at Pump Discharge
19	AT1	Flow Area thru Impeller No. 1 Turn, in ²
20	AT2	Flow Area thru Impeller No. 2 turn, in ²
21	RHOTI	Turbine Inlet Gas Density, lb/in ³
22	THOTE	Turbine Discharge gas Density, lb/in ³
23	CL1	Labyrinth Seal No. 1 Flow Coefficient = $\rho\Delta P/\dot{w}^2$
24	CL2	↓ ↓ ↓ No. 2 ↓ ↓ ↓
25	CL3	↓ ↓ ↓ No. 3 ↓ ↓ ↓
26	CL4	↓ ↓ ↓ No. 4 ↓ ↓ ↓
27	CL5	↓ ↓ ↓ No. 5 ↓ ↓ ↓
28	CL6	↓ ↓ ↓ No. 6 ↓ ↓ ↓
29	CL7	↓ ↓ ↓ No. 7 ↓ ↓ ↓
30	CL8	↓ ↓ ↓ No. 8 ↓ ↓ ↓
31	RTEH	Resistance of Holes thru Turbine Discharge = $\rho\Delta P/\dot{w}^2$
32	RBPR	Resistance of Balance Piston Return Flow Circuit = $\rho\Delta P/\dot{w}^2$
33	RTBS	Resistance of Turbine Bearing Supply Circuit = $\rho\Delta P/\dot{w}^2$
34	RPBS	Resistance of Pump Bearing Supply Circuit

TABLE 1 (Continued)

NO.	CODE NAME	
35	YBV1	Inner Radius of Back Vanes (Sta. 5.5)
36	YBV2	Outer Radius of Back Vanes (Sta. 5.4)
37	XK4	Fluid-Rotor Angular Velocity Ratio, Sta. 4-4.9
38	XK5	5-5.4
39	XK55	5.5-6
40	XK7	7-8
41	XK11	11-11.9
42	XK12	12-12.1
43	XK121	12.1-12.9
44	XK129	12.9-13
45	XK13	13-14
46	XK17	17-18
47	XK19	19-20
48	XKBV	5.4-5.5
49	Z0	Static Pressure Profile Factor (= .5 for Linear Dist.) Sta. 0-1
50	Z3	3-4
51	Z6	6-7
52	Z8	8-9
53	Z10	10-11
54	Z14	14-15
55	Z16	16-17
56	Y0	Line Radius at Sta. 0
57	YIH	Inducer Hub Diameter at Blade L.E.
58	Y1	Radius at Station No. 1
59	Y2	No. 2
60	Y3	No. 3
61	Y4	No. 4
62	Y5	No. 5
63	Y6	No. 6
64	Y7	No. 7
65	Y8	No. 8
66	Y9	No. 9
67	Y10	No. 10
68	Y11	No. 11
69	Y12	No. 12
70	Y121	No. 12.1

TABLE 1 (Continued)

<u>NO.</u>	<u>CODE NAME</u>	
71	Y129	Radius at Station No. 12.9
72	Y13	No. 13
73	Y135	No. 13-5
74	Y14	No. 14
75	Y15	No. 15
76	Y16	No. 16
77	Y17	No. 17
78	Y18	No. 18
79	Y20	No. 20
80	Y21	No. 21
81	Y22	No. 22
82	Y23	No. 23
83	CD12	Balance Piston Orifice Discharge Coefficient Sta. 12
84	CD13	Balance Piston Orifice Discharge Coefficient Sta. 13
85	P5G	Pressure Gradient Between Stations 4.9 & 5 (+ if P5 > P4.9) psi
86	P12G	Pressure Gradient Between Stations 11.9 & 12 (+if P12 > P11.9) psi

OUTPUT PARAMETERS (COMPUTED)

<u>NO.</u>	<u>CODE NAME</u>	
1	T	Thrust Balancer Inner Orifice Land Clearance, In.
2	CFBP	Balance Piston Load (Sta. 12-13), lb.
3	SBP	Balance Piston Axial Stiffness, lb/in at T
4	P1	Pressure at Station 1
5	P4	4
6	P5	5
7	P54	5.4
8	P55	5.5
9	P6	6
10	P7	7
11	P8	8
12	P11	11
13	P12	12
14	P121	12.1
15	P129	12.9
16	P13	13
17	P135	13.5
18	P14	14

TABLE 1 (Continued)

NO.	CODE NAME	
19	P15	Pressure at Station 15
20	P16	16
21	P17	17
22	P18	18
23	P19	19
24	P20	20
25	WL1	Flowrate thru Labyrinth Seal No. 1, lb/sec
26	W7	No. 2
27	W8	No. 3
28	WL4	No. 4
29	WL5	No. 5
30	WL6	No. 6
31	WL8	No. 8
32	WPBS	Flowrate thru Pump Bearing Supply Circuit, lb/sec
33	WBPR	Flowrate thru Balance Piston Return Circuit, lb/sec
34	WBP	Flowrate thru Balance Piston, lb/sec
35	WTBS	Flowrate thru Turbine Bearing Supply Circuit, lb/sec
36	WTEH	Flowrate thru the Turbine Disc Vent Holes, lb/sec
37	F011	Summation of Axial Forces between Stations 0-11
38	F1325	13-25
39	FTURB	Summation of Axial Forces Acting on Turbine Blading
40	FM1	Fluid Turning Reaction thru Impeller No. 1
41	FM2	No. 2
42	FMOM	FM1 + FM2
43	F0	Pressure Force Between Stations 0-1, psia
44	F1	1-2
45	F2	2-3
46	F3	3-4
47	F4	4-4.9
48	F5	5-5.4
49	FBV	5.4-5.5
50	F55	5.5-6
51	F6	6-7
52	F7	7-8
53	F8	8-9
54	F9	9-10

TABLE 1 (Continued)

NO.	CODE NAME	
55	F10	Pressure Force Between Stations 10-11, psia
56	F11	11-12
57	F13	13-14
58	F14	14-15
59	F15	15-16
60	F16	16-17
61	F17	17-18
62	F19	19-20
63	F25	24-25
64	RH00	Fluid Density at Station 0, lb/in ³
65	RH05	5
66	RH06	6
67	RH07	7
68	RH012	12
69	RHOPD	Pump Discharge
70	R0129	12.9
71	R0135	13.5
72	RH018	18
73	P49	Pressure at Station 4.9, psia
74	P119	Pressure at Station 11.9, psia

I. Introduction

A mathematical model of the new developing internal flow network was developed to permit both statistical and single point (10 data set) evaluation of the pump internal flows and balance ^{piston position}. The primary dependant parameters are the hydrostatic thrust balance position in the housing and the pistons thru the several labyrinth seals and flow circuits which include the bearing coolant and fluid balance flow circuits. These "output" parameters are computed for each set of "input" parameters which consists of the pump component dimensions, various factors such as the ratio of fluid to rotor angular velocity, and the pumps operating conditions which include interface

method
program, shift speed and judgment conditions. In
a single test comparison, the mean values of the
input parameters are used to compute a corresponding
set of mean output parameters. For statistical analysis,
the input data consist of the set of mean values of the
input parameters plus a corresponding set of variances, one
for each input parameter. The math model is programmed
to locate any desired number of repetitive solutions of
the output versus input parameters, and comparison among
a different set in input parameters as given by the
input variances and a random distribution within any
specified distribution characteristic (figure —). The program
output for a statistical analysis (mean value) are similar
of the mean, standard deviation and range of each computer

parameter. Since all the input parameters are not independent, there are correlation equations to approximate the relationship of interacting parameters. On the current version of the program, the turbine inlet pressure^{variation} is a function of the pump discharge pressure variation, and interstage turbine pressures are maintained in constant ratios. On a real pump, there exists a relationship between pump discharge pressure, flowrate and shaft speed. In this model of the turbogroup they are left independent because of the relatively weak effects of shaft speed and flowrate on the output parameters as compared to pressure^{distribution pattern} and because an accurate accounting of the relationship between speed, flow, pressure and turbine flowrate would require a small system analysis which would exceed the scope of this project. A future goal for improving

This could might indicate the development of an influence coefficient method predicting the interaction of these parameters.

Figure 1 is a schematic of the Turlopump rotor with the stator numbered for reference in the program equations and parameter list (reference table 1 and the program listing.)

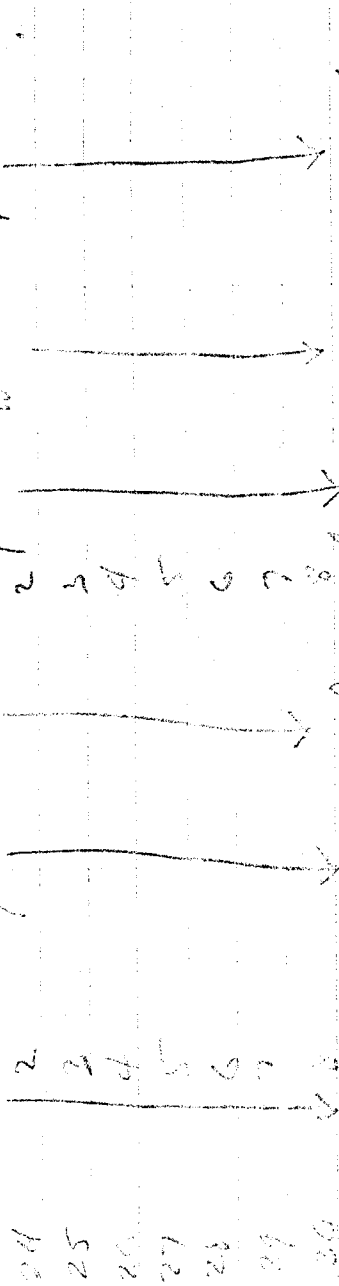
TABLE 1

PARAMETER LIST

INPUT PARAMETERS	NO.	NAME	DESCRIPTION
	1	PPD	pump discharge pressure (at flange), PSIA
	2	PIF	pump 1 st stage pressure rise factor = $P(10)/PPD$
	3	PS	medium pressure at inducer inlet (0) PSI
	4	PIF	inducer discharge pressure (2) factor $P(2)/PPD$
	5	PTI	turbine manifold inlet pressure PSIA
	6	PTE	turbine exhaust pressure $P(24)$ PSIA
	7	TTBP	balance piston total travel (0 clearance to 0 clearance) in.
	8	WPD	pumps discharge flowrate, lb/sec.
	9	RPM	pump shaft speed, RPM
	10	PSF	pressure $P(5)$ factor = $P(5)/PDI$
	11	PIRF	pressure $P(12)$ factor = $P(12)/(PIPD - PDI)$
	12	TBPR	turbine bypass ratio = $(WPD - W(TURB)) / WPD$
	13	P21	static pressure at st. (21)
	14	P22	" " (22)
	15	P23	" " (23)
	16	P24	" " (24)
	17	TS	temperature of bearings in suction line
	18	TPD	" " " " at pump discharge
	19	ATI	flow area thru impeller no. 1 - turn, in ²
	20	AT2	" " " " " " " " " " " "
	21	RHPTI	turbine inlet gas density, lb/in. ³
	22	RHOTE	" discharge " " " " " " " " " "

No. Name

23 CL1 Impedance and No. 1 flow coefficient = $\rho \Delta P / \dot{W}^2$



31 RTH Resistance of holes thru tank, dia. = $\rho \Delta P / \dot{W}^2$

32 RHC Resistance of laminar pipes when flow is laminar = $\rho \Delta P / \dot{W}^2$

33 RTE Resistance of turbine bearing supply circuit "

34 RPHS " pump " "

35 YGV1 inner radius of bead corner (STA. 5.5)

36 YGV2 outer " " (STA. 5.4)

37 XK4 fluid-rotor angular velocity ratio, sta. 4-4.9

38 XK5 " " sta. 5-5.4

39 XK55 55-6

40 XK7 7-8

41 XK11 11-16.9

42 XK12 12-12.1

43 XK121 12.1-12.9

44 XK129 12.9-13

45 XK13 13-14

46 XK17 17-18

47 XK19 19-20

48 XKBV 54-55

49 ZO STATIC PRESSURE PROFILE FACTOR (= 5 FOR LINEAR DISTRIBUTION) STA. 0-1



50 Z3 3-4

51 Z6 6-7

52 Z8 8-9

53 Z10 10-11

54 Z14 14-15

55 Z16 16-17

No.	CODE NAME	
56	Y0	line reading at Sta. 0
57	Y1H	induced fuel diameter at level L.B.
58	Y1	Radius at section no. 1
59	Y2	2
60	Y3	3
61	Y4	4
62	Y5	5
63	Y6	6
64	Y7	7
65	Y8	8
66	Y9	9
67	Y10	10
68	Y11	11
69	Y12	12
70	Y121	12.1
71	Y129	12.9
72	Y13	13
73	Y135	13.5
74	Y14	14
75	Y15	15
76	Y16	16
77	Y17	17
78	Y18	18
79	Y20	20
80	Y21	21
81	Y22	22
82	Y23	23
83	CD12	Balance piston orifice discharge coeff. Sta. 12
84	CD13	" " Sta. 13
85	PS4	pressure gradient between stations 7.9 & 5 (4 of PS > P11A)
86	P12G	" " 11.9 & 12 (4 of P12 > P11A)

No. Code Name

36 WTEH *horizontal flow thru turbine drive and turbo, etc/sec.*

37 F011 *summation of axial forces between stations 0-11*

38 FB2C *" " " " 13-25*

39 FTU2B *" " " setting on turbine bearing*

40 F011 *fluid turning moment thru impeller no. 1*

41 F012 *" " " " " 2*

PRIMARY

F00 *gross force between stations 0-1* PSIA

42	F01	1-2	↓	↓
43	F02	2-3		
44	F03	3-4		
45	F04	4-4.9		
46	F05	5-5.4		
47	F06	5.4-5.5		
48	F07	5.5-6		
49	F08	6-7		
50	F09	7-8		
51	F10	8-9		
52	F11	9-10		
53	F12	10-11		
54	F13	11-12		
55	F14	13-14		
56	F15	14-15		
57	F16	15-16		
58	F17	16-17		
59	F18	17-18		
60	F19	19-20		
61	F20	21-25		

fluid density at station 0

62	RH00	0	↓
63	RH05	5	
64	RH06	6	
65	RH07	7	
66	RH12	12	
67	RH12	12	
68	RH12	12	
69	RH12	12	
70	RH12	12	
71	RH12	12	
72	RH12	12	
73	RH12	12	

pump discharge

12.9

lb/in²

NO.	Code Name	Speed density of station	M. fin ²
71	P4135	13.5	"
72	P4118	18	"
73	P44	Density of station 19	PSIA
74	P1119	11.9	"

(LISTING)

COMPUTER PROGRAM FOR
PUMP ROTOR AXIAL FORCE BALANCE
INCL. MONTE-CARLO ANALYSIS OF BALANCE
PISTON POSITION VS. SYSTEM VARIABLES

SIR FOR TLU2

15 MAR 72 13:19:46.517

FORTRAN V: ISD VERSION 2.1

THIS COMPILATION WAS DONE ON 15 MAR 72 AT 13:19:46

SUBROUTINE TLU2 ENTRY POINT 000010

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000014
0000	*DATA	000007
0002	*BLANK	000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR05

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

00100	1*	C	DUMMY SUBROUTINE FOR H2 DENSITY (ZARG) AS A FUNCTION OF PRESS.
00100	2*	C	(UARG) AND TEMP. (VARG)
00101	3*		SUBROUTINE TLU2 (NDU,UV,Z,NU,NV,UARG,VARG,ZARG,IND)
00103	4*		ZARG=.0025
00104	5*		RETURN
00105	6*		END

END OF UNIVAC 1100 FORTRAN V COMPILATION. 0 *DIAGNOSTIC* MESSAGE(S)

SI FOR NORM
 FORTRAN V: ISO VERSION 2.1
 THIS COMPILATION WAS DONE ON 15 MAR 72 AT 13:19:47

15 MAR 72 13:19:47,579

FUNCTION NORM ENTRY POINT 000134

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000160
 0000 *DATA 000096
 0002 *BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR34

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000030	IL	0001	000061	J1L	0001	000050	1166	0001	000034	2L	0001	000111	20L			
0001	000066	7L	0001	000057	9L	0000	R	000003	BARG	0000	R	000005	CARG	0000	R	000006	DELTA
0000	I	000004	I	0000	I	000001	J	0000	R	000000	NORM	0000	R	000002	U		

THIS SUBROUTINE COMPARES THE INPUT PARAMETER VALUES FROM INPUT MEAN (AM) & STD. DEV. WITH RANDOM NORMAL DIST.

00101	1*	FUNCTION NORM (AM,S,IX,R,C)
00103	2*	REAL NORM
00104	3*	DIMENSION B(15),C(15)
00105	4*	J=IX+262147
00106	5*	IF(J) 1,2,2
00111	*DIAGNOSTIC*	THE INDICATED ARITHMETIC PERFORMED ON CONSTANTS PRODUCED OVERFLOW.
00111	6*	1 J=J+34359738367+1
00112	7*	2 U=J
00113	8*	BARG=0.734359738367.
00114	9*	IX=J
00115	10*	5 GO 11 IF=2,15
00120	11*	IF(P(I)-BARG) 11,9,7
00123	12*	9 CARG=C(I)
00124	13*	11 CONTINUE
00126	14*	60 TO 29
00127	15*	7 DELTA=(BARG-B(I-1))/(B(I)-B(I-1))
00130	16*	CARG=DELTA*(C(I)-C(I-1))+C(I-1)
00131	17*	29 NORM=AM+CARG*S
00132	18*	30 RETURN
00133	19*	END

* CROSS REFERENCE BY SEQUENCE NUMBER *

NAMES-----
 AM : 0101 0121
 B : 0104 0120 0127
 BARG : 0113 0120 0127
 C : 0101 0104 0123 0130
 CARG : 0123 0120 0127

```
DELTA : 0127 0130
I      : 0115 0120 0123 0127 0130
IX     : 0101 0105 0110
J      : 0106 0111 0112 0114
NORM   : 0101 0103 0131
S      : 0101 0131
U      : 0112 0113
```

LABELS-----

```
1: 0106 0111
2: 0106 0112
3: 0115
7: 0120 0127
9: 0120 0123
11: 0115 0120 0124
29: 0126 0131
30: 0132
```

INTEGER CONSTANTS-----

```
1: 0111 0127 0130
2: 0115
15: 0104 0115
202167: 0105
34359736367: 0111
```

REAL CONSTANTS-----

```
0.34359736+11: 0113
```

END OF UNIVAC 1106 FORTRAN V COMPILATION. 1 *DIAGNOSTIC* MESSAGE(S)

AIR FOR MAIN
 FORTRAN V: ISO VERSION 2.1
 THIS COMPILATION WAS DONE ON 15 MAR 72 AT 13:19:49

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 003702
 0000 *DATA 003345
 0002 *BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NORM
 0004 TL02
 0005 HROU5
 0006 NI015
 0007 NI025
 0010 HWD05
 0011 SORT
 0012 NEXP05
 0013 NSTOP5

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	002352	100L	0000	001773	1000F	0001	002357	101L	0001	002366	102L	0001	000006	107G
0000	001774	1100F	0000	001776	1105F	0001	003315	1114G	0001	002646	113L	0001	000020	115G
0001	000475	12L	0000	002001	1200F	0001	000032	123G	0001	000044	131G	0001	003572	1310G
0001	0003611	1372G	0001	003637	1333G	0001	003664	1347G	0001	000056	137G	0001	003127	140L
0001	003134	141L	0001	003150	140L	0001	003153	145L	0001	003161	146L	0001	003164	147L
0001	003214	158L	0001	003224	200L	0000	002100	2000F	0000	002116	2001F	0000	002145	2002F
0000	002167	2003F	0000	002215	2004F	0000	002254	2005F	0000	002272	2006F	0000	002333	2007F
0000	002354	2008F	0000	002374	2009F	0001	003231	201L	0000	002422	2010F	0000	002444	2011F
0001	003266	205L	0001	003356	209L	0000	002466	2100F	0000	002525	2101F	0000	002557	2102F
0000	002612	2103F	0000	002636	2104F	0000	002675	2105F	0000	002716	2106F	0001	000103	227G
0001	000151	209G	0001	003313	250L	0000	002003	2500F	0001	002027	2501F	0000	002040	2510F
0000	002066	2511F	0001	003335	254L	0001	003337	255L	0001	003345	256L	0001	003347	260L
0001	003174	300L	0000	002737	3000F	0000	002755	3001F	0000	001761	3002F	0001	003205	301L
0001	001545	30L	0001	001615	30L	0001	000024	4L	0001	001633	40L	0001	000376	400L
0000	002766	4000F	0001	000427	403L	0001	000431	404L	0001	000437	405L	0001	000441	410L
0000	002773	4100F	0001	001711	42L	0000	003013	4200F	0000	003030	4200F	0001	000403	431G
0001	000406	430G	0001	001724	44L	0001	001735	45L	0001	003604	460L	0001	001772	40L
0001	002141	56L	0000	003001	5000F	0001	003226	62L	0001	003677	900L	0000	R 001660	APV
0000	R 003065	AT1	0000	R 003066	AT2	0000	R 001652	A0	0000	R 001653	A1	0000	R 001666	A10
0000	R 001667	A11	0000	R 001670	A12	0000	R 001671	A121	0000	R 001672	A129	0000	R 001673	A13
0000	R 001674	A14	0000	R 001675	A15	0000	R 001676	A16	0000	R 001677	A17	0000	R 001700	A19
0000	R 001684	A2	0000	R 001685	A3	0000	R 001686	A4	0000	R 001687	A5	0000	R 001661	A55
0000	R 001682	A6	0000	R 001683	A7	0000	R 001684	A8	0000	R 001685	A9	0000	R 001560	0
0000	R 001577	C	0000	R 003165	CD12	0000	R 003166	CD13	0000	R 003172	CF0P	0000	R 003071	CL1
0000	R 003072	CL2	0000	R 003073	CL3	0000	R 003074	CL4	0000	R 003075	CL5	0000	R 003076	CL6
0000	R 003077	CL7	0000	R 003100	CL8	0000	R 001737	CP7	0000	R 001732	CYM	0000	R 001753	CP15
0000	R 001704	DP16	0000	R 001634	DP2124	0000	R 001733	DP76	0000	R 001734	DP89	0000	R 001724	DT
0000	R 001705	EP	0000	R 003281	FMV	0000	R 001720	FLAG1	0000	R 001721	FLAG2	0000	R 001630	FLAG3
0000	R 001706	FMV	0000	R 003282	FMV	0000	R 001722	FLAG2	0000	R 001723	FLAG3	0000	R 001631	FMV

0000 R 001623 FT0L	0000 R 003237 FTURR	0000 R 003243 F0	0000 R 003235 F011	0000 R 003244 F1
0000 R 003257 F10	0000 R 003260 F11	0000 R 001750 F12	0000 R 001751 F121	0000 R 001752 F129
0000 R 003261 F15	0000 R 003236 F1325	0000 R 003262 F14	0000 R 003263 F15	0000 R 003264 F16
0000 R 003265 F17	0000 R 003266 F19	0000 R 003245 F2	0000 R 003267 F25	0000 R 003246 F3
0000 R 003247 F4	0000 R 003250 F5	0000 R 003252 F55	0000 R 003253 F6	0000 R 003254 F7
0000 R 003255 F8	0000 R 003256 F9	0000 R 001624 G	0000 I 001616 I	0000 I 001726 JA
0000 I 001725 IC	0000 I 001650 IAD	0000 I 001622 IX	0000 I 001620 IS	0000 I 001617 J
0000 I 001621 L	0000 I 001760 L	0000 I 001631 N	0000 I 001627 NDU	0000 R 000000 M00M
0000 I 001625 NU	0000 I 001626 NV	0000 R 001730 PCRV	0000 R 001703 PC11	0000 R 001704 PC12
0000 R 001710 PC121	0000 R 001712 PC129	0000 R 001705 PC13	0000 R 001706 PC135	0000 R 001713 PC17
0000 R 001719 PC19	0000 R 001702 PC4	0000 R 001727 PC5	0000 R 001731 PC55	0000 R 001732 PC7
0000 R 001690 PD1	0000 R 001601 PD1	0000 R 001651 P1	0000 R 003046 P1F	0000 R 003043 PPD
0000 R 003045 P5	0000 R 003040 PTE	0000 R 003047 PTI	0000 R 003174 P1	0000 R 003044 P1F
0000 R 001717 P10	0000 R 003204 P11	0000 R 003302 P110	0000 R 003205 P12	0000 R 003055 P12F
0000 R 003170 P126	0000 R 003206 P121	0000 R 003207 P129	0000 R 003210 P13	0000 R 003211 P135
0000 R 003212 P14	0000 R 003213 P15	0000 R 003214 P16	0000 R 003215 P17	0000 R 003216 P18
0000 R 003217 P19	0000 R 003220 P20	0000 R 003057 P21	0000 R 001635 P21R	0000 R 003060 P22
0000 R 001636 P22F	0000 R 003061 P23	0000 R 001637 P23F	0000 R 003062 P24	0000 R 001715 P3
0000 R 003175 P4	0000 R 003301 P49	0000 R 003176 P5	0000 R 003054 P5F	0000 R 003167 P5G
0000 R 003177 P54	0000 R 003204 P55	0000 R 003201 P6	0000 R 003202 P7	0000 R 003203 P8
0000 R 001716 P9	0000 R 003102 RPPR	0000 R 001747 RH0AP	0000 R 003275 RH0APD	0000 R 003070 RH0TE
0000 R 003067 R00TI	0000 R 003270 RH00	0000 R 003274 RH012	0000 R 003300 RH018	0000 R 003271 RH05
0000 R 003272 RH06	0000 R 003273 RH07	0000 R 001745 R0121	0000 R 003276 R0129	0000 R 003277 R0135
0000 R 003104 R05	0000 R 003053 RPM	0000 R 003203 RTR5	0000 R 003101 RTFH	0000 R 001633 RTIL
0000 R 001741 R12	0000 R 001742 R13	0000 R 003173 SBP	0000 R 000150 SIGX	0000 R 000410 SIGY
0000 R 000634 SBRV	0000 R 000522 SUMY	0000 R 003171 T	0000 R 003056 TBPR	0000 R 000000 TITLE
0000 R 001740 T0	0000 R 003064 TP0	0000 R 003063 TS	0000 R 003051 TTAP	0000 R 001744 T121
0000 R 001746 T129	0000 R 001644 U	0000 R 001642 UARG	0000 R 001645 V	0000 R 001643 VARG
0000 R 003232 WAP	0000 R 003231 WAPR	0000 R 001743 WAPS	0000 R 003221 WL1	0000 R 001735 WL2
0000 R 001735 WL3	0000 R 003224 WL4	0000 R 003225 WL5	0000 R 003226 WL6	0000 R 001755 WL7
0000 R 003227 WL8	0000 R 003230 WPRS	0000 R 003052 WPD	0000 R 003233 WTR5	0000 R 003234 WTEH
0000 R 001632 W1	0000 R 003222 W7	0000 R 003223 W8	0000 R 003043 X	0000 R 001757 XCFRP
0000 R 003122 XK1V	0000 R 003113 XK11	0000 R 003114 XK12	0000 R 003115 XK121	0000 R 003116 XK129
0000 R 003117 XK13	0000 R 003120 XK17	0000 R 003121 XK19	0000 R 003107 YK4	0000 R 003110 YK5
0000 R 003111 XK15	0000 R 003112 XK7	0000 R 000022 XM	0000 R 001304 XMAX	0000 R 001432 YMTN
0000 R 001707 X0121	0000 R 001711 X0129	0000 R 001701 XRPMS	0000 R 003171 Y	0000 R 003105 YPV1
0000 R 003106 YB2	0000 R 003133 Y11	0000 R 000076 YX	0000 R 000746 YMAX	0000 R 001060 YMTN
0000 R 003132 Y0	0000 R 003134 Y1	0000 R 003145 Y10	0000 R 003146 Y11	0000 R 003147 Y12
0000 R 003150 Y121	0000 R 003151 Y129	0000 R 003152 Y13	0000 R 003153 Y135	0000 R 003154 Y14
0000 R 003155 Y15	0000 R 003156 Y16	0000 R 003157 Y17	0000 R 003160 Y1A	0000 R 003135 Y2
0000 R 003161 Y20	0000 R 003162 Y21	0000 R 003163 Y22	0000 R 003164 Y23	0000 R 003136 Y3
0000 R 003157 Y4	0000 R 003140 Y5	0000 R 003141 Y6	0000 R 003142 Y7	0000 R 003143 Y8
0000 R 003144 Y9	0000 R 001646 Z	0000 R 001647 ZARG	0000 R 003123 Z0	0000 R 003127 Z10
0000 R 003130 Z10	0000 R 003131 Z16	0000 R 003124 Z3	0000 R 003125 Z6	0000 R 003126 Z8

00100	1*	C	PROGRAM NAME IS TPA00
00100	2*	C	THIS PROGRAM IS A MATH MODEL OF THE TPA INTERNAL FLOW CIRCUITS AND
00100	3*	C	BALANCE PISTON WITH MONTE CARLO STATISTICAL ANALYSIS
00100	4*	C	R.A.LIVINGSTON 12-14-71
00101	5*		1 DIMENSION TITLE (18)
00103	6*		DIMENSION X(86), X0(86), SIGX(86), Y(74), YM(74), SIGY(74), SUMY(74),
00103	7*		ISLAV(74), YMAX(74), YMIN(74), CYM(74), XIMAY(86), XMIN(86)
00104	8*		DIMENSION S(15), C(15)
00105	9*		READ(S,1100) (R(T),T=1,15)
00113	10*		READ(S,1100) (C(J),J=1,15)
00121	11*		4 READ(S,1000) TITLE
00127	12*		11 READ(S,1000) (X(I),I=1,106)

```

00135 13* READ(5,5000)(SIGX(I),I=1,86)
00143 14* 5 READ(5,1105) K,IX,FTOL,6
00151 15* NDE7
00152 16* NV=5
00153 17* NDU=7
00154 18* REAL NORM
00154 19* C EQUATE X AND Y TO MAIN PROGRAM VARIABLES
00155 20* EQUIVALENCE (X(1),PP0),(X(2),PIE),(X(3),PS),(X(4),PIE),(X(5),PTI)
00156 21* EQUIVALENCE (X(6),PTE),(X(7),TTRP),(X(8),WPO),(X(9),RPM)
00157 22* EQUIVALENCE (X(10),P2F),(X(11),P12F),(X(12),TBPR)
00160 23* EQUIVALENCE (X(13),P21),(X(14),P22),(X(15),P23),(X(16),P24)
00161 24* EQUIVALENCE (X(17),TS),(X(18),TPD),(X(19),AT1),(X(20),AT2)
00162 25* EQUIVALENCE (X(21),RHOTI),(X(22),RHOTE),(X(23),CL1)
00163 26* EQUIVALENCE (X(24),CL2),(X(25),CL3),(X(26),CL4),(X(27),CL5)
00164 27* EQUIVALENCE (X(28),CL6),(X(29),CL7),(X(30),CL8),(X(31),RTEM)
00165 28* EQUIVALENCE (X(32),RPPR),(X(33),RTPS),(X(34),RPA5),(X(35),YBV1)
00166 29* EQUIVALENCE (X(36),YBV2),(X(37),XK4),(X(38),XK5),(X(39),XK55)
00167 30* EQUIVALENCE (X(40),XK7),(X(41),XK11),(X(42),XK12),(X(43),XK121)
00170 31* EQUIVALENCE (X(44),XK129),(X(45),XK13),(X(46),XK17),(X(47),XK19)
00171 32* EQUIVALENCE (X(48),XK14),(X(49),Z0),(X(50),Z3),(X(51),Z6)
00172 33* EQUIVALENCE (X(52),Z8),(X(53),Z10),(X(54),Z14),(X(55),Z16)
00173 34* EQUIVALENCE (X(56),Y0),(X(57),Y10),(X(58),Y1),(X(59),Y2)
00175 35* EQUIVALENCE (X(60),Y3),(X(61),Y4),(X(62),Y5),(X(63),Y6),(X(64),Y7)
00175 36* EQUIVALENCE (X(65),Y4),(X(66),Y9),(X(67),Y10),(X(68),Y11)
00176 37* EQUIVALENCE (X(69),Y12),(X(70),Y121),(X(71),Y129),(X(72),Y13)
00177 38* EQUIVALENCE (X(73),Y135),(X(74),Y14),(X(75),Y15),(X(76),Y16)
00200 39* EQUIVALENCE (X(77),Y17),(X(78),Y18),(X(79),Y20),(X(80),Y21)
00201 40* EQUIVALENCE (X(81),Y22),(X(82),Y23),(X(83),CO12),(X(84),CO13)
00202 41* EQUIVALENCE (X(85),P50),(X(86),P126)
00203 42* EQUIVALENCE (Y(1),T),(Y(2),CHD),(Y(3),SRP),(Y(4),P1),(Y(5),P4)
00204 43* EQUIVALENCE (Y(6),P5),(Y(7),P54),(Y(8),P55),(Y(9),P6),(Y(10),P7)
00205 44* EQUIVALENCE (Y(11),P4),(Y(12),P11),(Y(13),P12),(Y(14),P121)
00206 45* EQUIVALENCE (Y(15),P129),(Y(16),P13),(Y(17),P135),(Y(18),P14)
00207 46* EQUIVALENCE (Y(19),P15),(Y(20),P16),(Y(21),P17),(Y(22),P18)
00210 47* EQUIVALENCE (Y(23),P19),(Y(24),P20),(Y(25),WL1),(Y(26),W7)
00211 48* EQUIVALENCE (Y(27),W3),(Y(28),WL4),(Y(29),WL5),(Y(30),WL6)
00212 49* EQUIVALENCE (Y(31),WL3),(Y(32),RPS),(Y(33),RPR),(Y(34),WRP)
00213 50* EQUIVALENCE (Y(35),WBS),(Y(36),WTFH),(Y(37),F011),(Y(38),F1325)
00214 51* EQUIVALENCE (Y(39),FURP),(Y(40),F41),(Y(41),FM2),(Y(42),FMOH)
00215 52* EQUIVALENCE (Y(43),F0),(Y(44),F1),(Y(45),F2),(Y(46),F3),(Y(47),F4)
00216 53* EQUIVALENCE (Y(48),F5),(Y(49),FRV),(Y(50),F55),(Y(51),F6)
00217 54* EQUIVALENCE (Y(52),F7),(Y(53),F8),(Y(54),F9),(Y(55),F10)
00220 55* EQUIVALENCE (Y(56),F11),(Y(57),F13),(Y(58),F14),(Y(59),F15)
00221 56* EQUIVALENCE (Y(60),F16),(Y(61),F17),(Y(62),F19),(Y(63),F25)
00222 57* EQUIVALENCE (Y(64),PH00),(Y(65),PH05),(Y(66),RH06),(Y(67),RH07)
00223 58* EQUIVALENCE (Y(68),RH012),(Y(69),RH0PD),(Y(70),R0129)
00224 59* EQUIVALENCE (Y(71),R0135),(Y(72),RH018),(Y(73),P49),(Y(74),P119)
00225 60* FLAG3=0
00226 61* IO 310 N=1,86
00231 62* X(N)=X*(0)
00232 63* 316 X(N)=X*(0)
00234 64* RTI=PP0*(1.-TBPR)
00235 65* RTI=RHOTI*(PP0-PII)/RTI**2
00236 66* PP2124=PP21-PP24
00237 67* P21R=(PTI-PP21)/RTI**2
00238 68* PP2F=(P22-PP24)/PP2124
00241 69* P23F=(P23-PP24)/PP2124
00242 70* 9 WRITE(1,3000) TITLE
00244 71* WRITE(1,3010) K
00245 72* WRITE(1,3011) PP0,PIE,PS,PIE,PTI,TE,TTRP,WPO,PPM

```

00266	73*	WRITE(6,2002) RHOT1,RHOTE,ETOL,G,TPR,TS,TPD
00277	74*	WRITE(6,2003) CL1,CL2,CL3,CL4,CL5,CL6,CL7,CL8
00311	75*	WRITE(6,2009) RTEH,RUPR,RTBS,RPDS,P5F,P12F,P56,P126
00323	76*	WRITE(6,2007) Z0,Z3,Z6,Z8,Z10,Z14,Z16
00334	77*	WRITE(6,2004) XK4,XK5,XK55,XKBV,XK7,YK11,XK12,XK121,XK129,XK13,
00334	78*	LXK17,XK19
00352	79*	WRITE(6,2005) Y1,Y2,Y3,Y4,Y5,Y6,Y7,Y8,Y9,Y10,Y11,Y12,Y1H,Y0
00372	80*	WRITE(6,2006) Y121,Y129,Y13,Y135,Y14,Y15,Y16,Y17,Y18,Y20,Y21,
00372	81*	Y22,Y23
00411	82*	WRITE(6,2008) CD12,CD13, AT1,AT2,YBV1,YBV2
00421	83*	WRITE(6,4000) P21,P22,P23,P24
00427	84*	GO TO 12
00430	85*	400 DO 200 I=1,K
00433	86*	402 DO 410 J=1,86
00436	87*	X(J)=HORG(XM(J),SIGX(J),TX,B,C)
00437	88*	IF(X(J)-XMAX(J)) 404,404,403
00442	89*	403 XMAX(J)=X(J)
00443	90*	404 IF(X(J)-XMIN(J)) 405,410,410
00446	91*	405 XMIN(J)=X(J)
00447	92*	410 CONTINUE
00450	*DIAGNOSTIC*	THE TRANSFER TO 12 IS BAD BECAUSE 12 IS NOT IN THE INNERMOST DO OF A NEST.
00451	93*	BTI=PPD*(1.-TEPR)
00451	94*	C THE FOLLOWING 5 STATEMENTS REVISE TURB. PRESS. DISTRIBUTION
00452	95*	PTI=PPD-RTEL/RHOT1*BTI*42
00453	96*	PD1=PTI-PP1R*BTI*42
00454	97*	PD2124=PD1-P24
00455	98*	P22=P24-P22F*DP2124
00455	99*	P23=P24-P23F*DP2124
00457	100*	12 PD1=PPD*PTI
00458	101*	PD1=PPD*PD1F
00461	102*	PD1=PD1*PSF
00462	103*	PD9=PD1*PS6
00463	104*	P12=PPD-(1.-P12F)*(PPD-PD1)
00464	105*	P119=P12-P126
00465	106*	UARG=PS
00465	107*	VARG=TS
00467	108*	CALL TLU2 (NDU,U,V,Z,NU,NV,UARG,VARG,ZARG,IND)
00470	109*	RHO6=ZARG
00471	110*	UARG=PS
00472	111*	VARG=.5*(TS+TPD)
00473	112*	CALL TLU2 (NDU,U,V,Z,NU,NV,UARG,VARG,ZARG,IND)
00474	113*	RHO6=ZARG
00475	114*	UARG=.65*PS
00476	115*	VARG=TPD*7.
00477	116*	CALL TLU2 (NDU,U,V,Z,NU,NV,UARG,VARG,ZARG,IND)
00500	117*	RHO6=ZARG
00501	118*	UARG=PPD*.73
00502	119*	VARG=TPD
00503	120*	CALL TLU2 (NDU,U,V,Z,NU,NV,UARG,VARG,ZARG,IND)
00504	121*	RHO6=ZARG
00505	122*	UARG=PD12
00506	123*	VARG=TPD
00507	124*	CALL TLU2 (NDU,U,V,Z,NU,NV,UARG,VARG,ZARG,IND)
00510	125*	RHO12=ZARG
00511	126*	BU129=BU012
00512	127*	VARG=TPD*7.
00513	128*	UARG=PS*.5
00514	129*	CALL TLU2 (NDU,U,V,Z,NU,NV,UARG,VARG,ZARG,IND)
00515	130*	CO129=ZARG
00516	131*	UARG=PS.

00517	132*	VARG=TPD
00520	133*	CALL TLU2 (NDU,U,V,Z,NU,NV,UARG,VARG,ZARG,IND)
00521	134*	RHO1=ZARG
00522	135*	UARG=PPD
00523	136*	VARG=TPD
00524	137*	CALL TLU2 (NDU,U,V,Z,NU,NV,UARG,VARG,ZARG,IND)
00525	138*	RHO2=ZARG
00526	139*	CL1=CL1/RHO5
00527	140*	CL2=CL2/RHO7
00530	141*	CL3=CL3/RHO12
00531	142*	CL4=CL4/RHO12
00532	143*	CL5=CL5/RHO12
00533	144*	CL6=CL6/RHO12
00534	145*	CL7=CL7/RHO15
00535	146*	CL8=CL8/RHO11
00536	147*	RTEREN/ROTI
00537	148*	RPPER/RPZ/PO135
00540	149*	RTPS=RTPS/POPD
00541	150*	RPPS=RPSS/POPD
00542	151*	P1=3.14159
00543	152*	A0=P1*Y1**2
00544	153*	A1=P1*(Y1**2-Y2**2)
00545	154*	A2=P1*(Y3**2-Y2**2)
00546	155*	A3=P1*(Y4**2-Y3**2)
00547	156*	A4=P1*(Y5**2-Y4**2)
00548	157*	A5=P1*(Y5**2-Y6**2)
00549	158*	A6=P1*(Y6**2-Y6**2)
00551	159*	A7=P1*(Y6**2-Y6**2)
00552	159*	A8=P1*(Y6**2-Y6**2)
00553	160*	A9=P1*(Y6**2-Y7**2)
00554	161*	A7=P1*(Y7**2-Y7**2)
00555	162*	A8=P1*(Y9**2-Y8**2)
00556	163*	A9=P1*(Y10**2-Y9**2)
00557	164*	A10=P1*(Y11**2-Y10**2)
00558	165*	A11=P1*(Y12**2-Y11**2)
00561	166*	A12=P1*(Y12**2-Y12**2)
00562	167*	A12=P1*(Y12**2-Y12**2)
00563	168*	A12=P1*(Y12**2-Y13**2)
00564	169*	A13=P1*(Y13**2-Y14**2)
00565	170*	A14=P1*(Y14**2-Y15**2)
00566	171*	A15=P1*(Y15**2-Y16**2)
00567	172*	A16=P1*(Y17**2-Y16**2)
00570	173*	A17=P1*(Y16**2-Y17**2)
00571	174*	A19=P1*(Y20**2-Y18**2)
00572	175*	XRPMS=.0055*RPMS**2/6
00573	176*	C HITTAIIZE P15,P19,P20
00573	177*	P19=PTE+10.
00574	178*	P20=P19
00575	179*	15 P15=P19+.2*(PPD-PTE)
00576	180*	PC4=XRPMS*RHO5*XK4**2*(Y5**2-Y4**2)
00577	181*	PC11=XRPMS*RHO12*XK11**2*(Y12**2-Y11**2)
00600	182*	PC12=XRPMS*RHO12*(Y12**2-Y12**2)*XK12**2
00601	183*	20 PC13=XRPMS*RHO135*XK13**2*(Y13**2-Y135**2)
00602	184*	PC135=XRPMS*RHO135*XK13**2*(Y135**2-Y14**2)
00603	185*	XK121=XRPMS*(Y121**2-Y129**2)*XK121**2
00604	186*	PC121=XK121*RHO12
00605	187*	XK129=XRPMS*(Y129**2-Y13**2)*XK129**2
00606	188*	25 PC129=XK129*RHO12
00607	189*	PC17=XRPMS*RHO18*XK17**2*(Y18**2-Y17**2)
00610	190*	PC19=XRPMS*RHO11*XK19**2*(Y20**2-Y19**2)
00611	191*	26 P1=P1*(1-PPD)/2+(2.00*PPD)*(1./P1*(Y1**2-Y10**2))**2-1./P1*(Y0**2)*

00611	192*	1*2)	
00612	193*	P3=PD1	
00613	194*	P4=PD9-PC4	
00614	195*	P7=.5*(P91+PPD)	
00615	196*	P9=PD1	
00616	197*	P10=PD1	
00617	198*	36 P11=P119-PC11	
00620	199*	P135=PS+.020*(PPD-PS)	
00621	200*	P13=P135+PC13	
00622	201*	P16=P135-PC135	
00623	202*	SEB=A121*(P12-P13)/TTBP	
00624	203*	35 FLAG1=0	
00625	204*	FLAG2=0	
00626	205*	FLAG3=0	
00627	205*	FLAG7=0	
00630	207*	D1=0.	
00631	208*	ICEN	
00632	209*	IC=5	
00633	210*	38 PCL=XRPMS*RH06+ XK5**2*(Y5**2-YBV2**2)	
00634	210*	PCRV=XRPMS*RH05*XKRV**2*(YBV2**2-YBV1**2)	
00635	212*	PC55=XRPMS*RH06*XK55**2*(YRV1**2-Y6**2)	
00636	213*	P56=PS-PC5	
00637	214*	P13=PD9-PC1V	
00638	215*	P5=PD5-PC5V	
00641	216*	39 PC7=XRPMS*RH07*(Y7**2-YR**2)*XK7**2	
00642	217*	PC77=PC7	
00642	218*	C STATEMENTS 40-45 ITERATIVELY COMPUTE P7	
00643	219*	40 P77=P7-P6	
00644	220*	P79=PD9	
00645	221*	CL2=CL1*(ABS(OP76)/CL2)+OP76/ABS(OP76)	
00646	222*	CL3=CL1*(ABS(OPA9)/CL3)+OPA9/ABS(OPA9)	
00647	223*	OPRS=ALP*BL3	
00650	224*	CP7=PC7-RPMS*RP5**2/ABS(OPRS)	
00651	225*	IF (ABS(OP7-CP7)/CP7)-.0010) 44,44,42	
00654	228*	42 P7=.5*(P7+CP7)	
00655	227*	I=ITER1	
00656	226*	IF (I8-25)40,40,301	
00661	229*	46 P7=CP7	
00662	230*	P6=P7-PC7	
00663	231*	IF (FLAG7) 45,45,49	
00666	232*	45 UARG=P7	
00667	233*	VARG=TP9	
00670	234*	CALL TL92 (RH0, P, V, Z, NU, NV, UARG, VARG, ZARG, I'D)	
00671	235*	CL2=CL2*RH07/ZARG	
00672	236*	CL3=CL3*RH07/ZARG	
00673	237*	RH07=ZARG	
00674	238*	FLAG7=1	
00675	239*	GO TO 30	
00676	240*	49 F5=PS+.5*PI*XRPMS* XK5**2*RH06*(Y5**2+YBV2**2-.5*(Y5**4+YBV2**4))	
00677	241*	F55=PS+.5*PI*XRPMS* XK55**2*RH06*(YBV1**2+Y6**2-.5*(Y6**4+YBV1**4))	
00677	242*	1))	
00678	243*	F1V=PD4+ADV-PI*XRPMS*XKRV**2*RH06*(YBV2**2+YRV1**2-.5*(YBV2**4+YRV1**4))	
00678	244*	11**4))	
00679	245*	F6=Z6*(P5+P7)+A6	
00682	246*	F7=Z6*A7 -3.141*XRPMS*XK7**2*PHOPD*(Y8**2+Y7**2-.5*(Y7**4+Y6**4))	
00683	247*	F8=Z6*(P9+PD)	
00684	248*	IF (FLAG4) 50,50,62	
00687	249*	50 F8=AD*Z9*(P5+P1)	
00690	250*	F1=.5*(P1+P11)*A1	
00691	251*	F2=PD1**2	

```

00712 252* F3=Z3*(PDI+P4)*A3
00713 253* F4=P4**4*-3.141*XRPM5*XK4**2*PH05*(Y4**2+Y5**2-.5*(Y4**4+Y5**4))
00714 254* F9=FC1*A9
00715 255* 60 F10=Z10*(P01+P11)*A10
00716 256* F11=P11*A11 -3.141*XRPM5*XK11**2*RH012*(Y11**2+Y12**2-.5*(Y12**4+
00716 257* (Y11**4))
00717 258* F01=PH01*2/(3661*RH05*AT1)
00720 259* F10R=P1*(P21*(Y21**2-Y20**2)- P22*(Y21**2-Y22**2)+(P23-P24)*(Y23*
00720 260* 1*2-Y22**2))
00721 261* F25=P1*Y22**2*PTE
00722 262* 62 F011=F0-F1+F2+F3+F4-F5-F6-F7+F8+F9+F10+F11-F55-FR0
00723 263* IF (FLAG) 100,100,113
00723 264* C STATEMENTS 100-200 ITERATIVELY COMPUTE RAL. PISTON POSITION
00725 265* 100 T=.5*TRP
00727 266* TC=1160-T
00730 267* 101 IC=IC+1
00731 268* IF (IC-25)102,102,300
00734 269* 102 R12=.05070/(6*RH012*(CD12*(Y12+Y121)*(T0))**2)
00735 270* R13=.05070/(6*RH0129*(CD13*(Y129+Y13)*T)**2)
00736 271* W05=(P12-P13+PC12-PC121-PC129)/(R12+R13)
00737 272* P121=P12-R12*W05+PC12
00740 273* 104 UARG=P121
00740 274* C THE FOLLOWING IS AN EMPIRICAL FON.
00741 275* T121=TP016.2-375.*T0
00742 276* VARG=T121
00743 277* CALL TL02(INDU,U,V,Z,HU,HV,UARG,VARG,ZARG,IND)
00744 278* R0121=ZARG
00745 279* PC121= R0121*XM121
00746 280* P129=P121-PC121
00747 281* UARG=P129
00747 282* C THE FOLLOWING IS AN EMPIRICAL FON.
00750 283* T129=TP014.7/(1000.*T0)**.42
00751 284* VARG=T129
00752 285* CALL TL02(INDU,U,V,Z,HU,HV,UARG,VARG,ZARG,IND)
00753 286* R0129=ZARG
00754 287* W05P=.50*(R0121+R0129)
00755 288* PC121= R050P*XM121
00756 289* PC129=XM129*PC129
00757 290* P129=P121-PC121
00760 291* 106 F12=A12*P121
00761 292* F121=P129*A121-3.141*XRPM5*XK121**2*R0129*(Y121**2+Y129**2-.5*(Y12
00761 293* 11+Y121*(Y129**4))
00762 294* F129=A129*P13
00763 295* DPL5=P15-P14
00764 296* WLS=SQRT((ABS(DPL5)/CL5)*ABS(DPL5)/DPL5
00765 297* F12=.05070/(6*RH012*(CD12*(Y12+Y121)*(T0))**2)
00766 298* R13=.05070/(6*R0129*(CD13*(Y129+Y13)*T)**2)
00767 299* 111 W05=SQRT((P12-P13+PC12-PC121-PC129)/(R12+R13))
00770 300* W05P=W05+WLS
00771 301* 113 P135=P6+B05P+B05P**2
00772 302* 114 P13=P135+PC13
00773 303* P14=P135-PC135
00774 304* 115 P16=P15
00775 305* DPL6=P16-P19+PC17
00776 306* WLS=SQRT((ABS(DPL6)/(CL6+CL7))*ABS(DPL6)/DPL6
00777 307* P17=WLS
01000 308* R15=WLS+WLS
01001 309* P1=P10-W05P*TR05**2
01002 310* P15=P15
01003 311* 120 WLS=SQRT((P01-P20)/CL0)

```

01004	312*		WTEH=WL8+WL7
01005	313*		P20=PTE+RTEH*WTEH**2+.30*PC19
01006	314*		P19=P20-PC19
01007	315*		P18=P19+CL7*WL7**2
01010	316*		P17=P18-PC17
01011	317*		F15=F14+A15-3.141*XPMS*WK13**2*R0135*(Y13**2+Y14**2-.5*(Y13**4+Y14**4))
01012	318*	125	F14=A14 *Z14*(P18+P15)
01013	320*		F15=A15*.5*(P15+P16)
01014	321*		F16=A16 *Z16*(P16+P17)
01015	322*		F17=A17 *.5*(P17+P18)
01016	323*		F18=A18*P18-P1*XPMS*WK19**2*RH011*(Y20**2+Y18**2-.5*(Y20**4+Y18**4))
01017	324*		F1825=F15-F14-F15+F16+F17+F19+ETURB=F25
01020	326*	136	FR2=(LFD+LFR)*.2/(G+RH012*AT2)
01021	327*		FRON=FR1+FR2
01022	328*		FRP=FR1+F1325+FRON
01023	329*	137	CFRP=FR1+FR29-F12
01024	330*		WRITE(6,3002) T,T0,FRP,CFRP
01032	331*	3002	FORMAT(IX,RTZ,F8.5,5X,3HIO= F8.5,5Y,4HFOP= F12.4,5X,5HCFRP= F12.4
01032	332*		I7)
01033	333*	138	IF(LABS(FRP-CFRP)-FTOL)200,200,140
01035	334*	140	IF(FLAG2)1+1,141,150
01041	335*	141	B1=(CFRP-FRP)/SDP
01042	336*		FLAG2=1
01043	337*	142	IF(B1)
01044	338*	143	IF(1140,144,145
01047	339*	144	T=.00001
01050	340*		GO TO 147
01051	341*	145	IF(1140-1146,146,147
01054	342*	146	T=TD0-.00001
01055	343*	147	T0=TF0-T
01055	344*		XCFP=CFRP-F1325-FR2
01057	345*		GO TO 101
01059	346*	300	WRITE(6,3000) T,FRP,CFRP
01055	347*		GO TO 209
01055	348*	301	WRITE(6,3001) CP7
01071	349*		GO TO 999
01072	350*	150	SDPABS((CFRP-F1325-FR2-XCFP)/DT)
01073	351*		GO TO 141
01074	352*	200	IF(FLAG4)201,201,205
01074	353*	C	THE FOLLOWING 4 STATEMENTS CORRECT THE DENSITY AT STA. 6
01077	354*	201	VARG=(Y120+WSPR+TPD+WL2)/(WOPR+WL2)
01100	355*		WARG=V
01101	356*		CALL TL02 (NDU,U,V,Z,NU,NV,WARG,VARG,ZARG,IWD)
01102	357*		PH06=ZARG
01103	358*		FLAG4=1
01104	359*		FLAG7=0
01105	360*		GO TO 38
01105	361*	205	WL1=SQRT((P4-P3)/CL1)
01107	362*		WL2=SQRT((P11-P10)/CL4)
01110	363*		IF(FLAG5) 209,209,250
01113	364*	250	DO 266 J=1,72
01116	365*		SNV(J)=SNV(J)+Y(J)
01117	366*		SNV(J)=SNV(J)+(Y(J)-YM(J))**2
01139	367*		IF(Y(J)-YMAX(J))255,255,254
01123	368*	254	YMAX(J)=Y(J)
01124	369*	255	IF(Y(J)-YMIN(J))256,256,260
01127	370*	256	YMIN(J)=Y(J)
01130	371*	260	CONTINUE

01133	372*	450 GO TO 460
01134	373*	209 WRITE(6,2100) T,CFBP,SDP
01141	374*	210 WRITE(6,2101)PS,P1,PJ1,P4,P49,P5,P54,P55,P6,P7,P8
01155	375*	WRITE(6,2102) PD1,P11,P119,P12,P121,P129,P13,P135,P14,P15,P16
01173	376*	WRITE(6,2103) P17,P18,P19,P20,P21,P22,P23,P24
01205	377*	220 WRITE(6,2104) RL1,X7,MR,ML4,ML5,ML6,ML8,WBPS,WBPR,WBP,WTRS,WTEH
01223	378*	WRITE(6,2105)RH00,RH05,PH06,PH07,RH012,RH0PD
01243	379*	WRITE(6,2106)R121,T129,R0121,R0129,R0135,RH018
01243	380*	WRITE(6,2011) F011,F1325,FTURB,F01,F02,F0M
01253	381*	WRITE(6,4100)F0,F1,F2,F3,F4,F5,FBV,F55,F6,F7,F8,F9,F10,F11,F011
01274	382*	WRITE(6,4200)F13,F14,F15,F16,F17,F19,F25,F1325
01356	383*	FLAG3=1
01357	384*	224 DO 225 L=1,74
01312	385*	YMIN(L)=Y(L)
01313	386*	225 Y(L)=Y(L)
01315	387*	YMAX(J6)=Y(38)
01316	388*	226 IF(K) GO TO 229,400
01351	389*	460 DO 470 J=1,74
01354	390*	SIGY(J)=SORT(SDDV(J)/FLOAT(K))
01325	391*	470 CY(J)=SDY(J)/FLOAT(K)
01327	392*	WRITE(6,2500)
01331	393*	WRITE(6,2501) (J,YH(I),SIGX(I),YMIN(I),XMAX(I),I=1,92)
01343	394*	WRITE(6,2510)
01345	395*	WRITE(6,2511) (J,YH(J),CYH(J),SIGY(J),YMIN(J),YMAX(J),J=1,63)
01350	396*	999 CONTINUE
01351	397*	1000 FORMAT('R40')
01352	398*	1100 FORMAT(2F5.0)
01353	399*	1105 FORMAT(2F12.2F12.0)
01354	400*	1200 FORMAT(7F10.0)
01355	401*	2500 FORMAT('DEL', 5Y, 'INPUT VARIABLES', //, 10X, 'VARIABLE', 10X, 'MEAN', 12X
01355	402*	1, 'VARIANCE', 10X, 'MIN. Y', 10X, 'MAX. Y', //)
01356	403*	2501 FORMAT(1X, 1A, 13, 5X, E12.5, 5X, E12.5, 5X, E12.5, 5X, E12.5,)
01357	404*	2510 FORMAT('DEL', 5X, 'OUTPUT DATA', //, 5X, 'VARIABLE', 10X, 'MEAN', 10X, 'TRIA
01357	405*	1L 'MEAN', 3X, 'STO. DEV.', 10Y, 'MIN. Y', 10X, 'MAX. Y', //)
01370	406*	2511 FORMAT(5X, 'Y', 13, 6X, E12.5, 5X, E12.5, 5X, E12.5, 5X, E12.5, 5X, E12.5)
01371	407*	2000 FORMAT ('DEL', 'CUMULATIVE THRUST BALANCE AND INTERNAL FLOW PROGRAM', 'REV.
01371	408*	101-10-72, //, //, 1X, 19A, //)
01372	409*	2001 FORMAT(1X, 4HPD= F6.0, 5X, 4HRPI= F6.4, 5X, 3HPS= F6.0, 5X, 4HPI= F6.4, 5X,
01372	410*	14HPTE= F6.0, //, 1X, 4HPTE= F6.0, 5X, 5HTT= F6.5, 5X, 4HMPD= F6.0, 4X, 4HRP
01372	411*	2= F6.0, //)
01373	412*	2002 FORMAT(1X, 6HRHOTIE= F9.5, 5X, 6HRHOTIE= F9.5, 5X, 5HETOI= F8.1, 5X, 2HIG= F
01373	413*	18.2, //, 1X, 4HRHPP= F8.4, 5X, 3HTSE= F8.2, 5X, 4HTD= F8.2, //)
01374	414*	2003 FORMAT(1X, 4HCL1= E12.4, 5X, 4HCL2= E12.4, 5X, 4HCL3= E12.4, 5X, 4HCL4=
01374	415*	1E12.4, //, 1X,
01374	416*	4HCL5= E12.4, 5X, 4HCL6= F12.4, 5X, 4HCL7= E12.4, 5X, 4HCL8= E12.4,
01374	417*	3//)
01375	418*	2004 FORMAT(1X, 4HX4= F6.4, 5X, 4HX5= F6.4, 5X, 5HX55= F6.4, 5X, 5HX8V= F6.4,
01375	419*	15X, 4HRK7= F6.4, 5X, 5HX11= F6.4, //, 1X
01375	420*	2, 5HX12= F6.4, 5X, 6HX121= F6.4, 5X, 6HX120= F6.4, 5X, 5HX13= F6.4, 5X,
01375	421*	4HX17= F6.4, 5X, 5HX19= F6.4, //)
01376	422*	2005 FORMAT(1X, 10HY1 TH Y12= 5X, 6(F8.4, 5X), //, 16Y, 6(F8.4, 5X), //, 1X, 4HY
01376	423*	1H= F8.4, 5X, 3HY0= F8.4, //)
01377	424*	2006 FORMAT(1X, 5HY121= F8.4, 5X, 5HY120= F8.4, 5X, 4HY13= F8.4, 5X, 5HY135
01377	425*	1E F8.4, 5X, 4HY14= F8.4, 5X, 4HY15= F8.4, //, 1X, 4HY16= F8.4, 5X, 4HY17=
01377	426*	2 F8.4, 5X, 4HY18= F8.4, 5X, 4HY20= F8.4, 5X, 4HY21= F8.4, 5X, 4HY22=
01377	427*	5F8.4, 5X, 4HY23= F8.4, //)
01400	428*	2007 FORMAT(1X, 3HZ0= F6.3, 5X, 3HZ3= F6.3, 5X, 3HZ6= F6.3, 5X, 3HZ
01400	429*	28= F6.3, 5X, 4HZ10= F6.3, 5X, 4HZ14= F6.3, 5X, 4HZ16= F6.3, //)
01401	430*	2008 FORMAT(1X, 4HCD12= F6.4, 5X, 4HCD13= F6.4, //,
01401	431*	1E, 4HAT1= F7.3, 5X, 4HAT2= F7.3, 5X, 5HY11= F7.3, 5X, 5HY12= F7.3, //

```

01401 432*      1)
01402 433*      2000 FORMAT(1X,          5HRTEH= F12.4,5X,5HRPR=
01402 434*      / E12.4,5X,5HRTRSE= E12.4,///,1X,5HRPRS= E12.4,5X,4HP5F= F8.5, 5X,5HP
01402 435*      / 312F= F8.5,5X,4HP56= F10.2,5X,5HP12G= F10.2,///)
01403 436*      2010 FORMAT(1X, NUMBER OF TRIALS FOR MONTE CARLO ANALYSIS =,1X,I6,///,
01403 437*      / 11X, MEAN VALUES OF INPUT VARIABLES, //)
01404 438*      2011 FORMAT(5X,5HP11= E12.4,5X,6HP1325= E12.4,5X,6HPTRR= E12.4,5X,
01404 439*      / //,5X,4HP11= F8.0,5X,4HP12= F8.0,5X,5HPMOM= F9.0,///)
01405 440*      2100 FORMAT(10I,5X, COMPUTED PARAMETERS BASED ON MEAN VALUE OF INPUT VA
01405 441*      1RIABLES,
01405 442*      3CLEARANCE (T) =F8.4,///,5X,16HRAL, PISTON INHER LAND C
01405 443*      4SS = E12.4, ///)
01405 444*      2101 FORMAT(5X,3HP5= F7.2,4X,3HP1=F7.2,4X,4HP101=F7.2,4X,3HP4=F7.1,4X,5H
01405 445*      1R49= F7.1,5X,3HP5= F7.1,///,5X,4HP54= F7.1,
01406 446*      2 4X,4HP55=F7.1,4X,3HP6=F7.1,4X,3HP7=F7.1,4X,3HP8=F7.1,///)
01407 447*      2102 FORMAT(5X,4HP101= F7.1, 4X,4HP111=F7.1,4X,5HP119= F7.1,4X,4HP12= F7
01407 448*      1,1,4X,5HP121= F7.1,4X,5HP120= F7.1,4X,4HP13= F7.1,///,1X,5HP135=F7.1,
01407 449*      2HP14= F7.1,4X,4HP15= F7.1,4X,4HP16= F7.1, ///)
01410 450*      2103 FORMAT(
01410 451*      1F9.1,4X,4HP17=F6.1,4X,4HP18=F6.1,4X,4HP19=F6.1,4X,4HP20=
01410 452*      2 4HP23=F6.1,4X,4HP24=F6.1,///)
01411 453*      2104 FORMAT(5X,4HVL1=F7.3,4X,4HVL2=F7.3,4X,4HVL3=F7.3,4X,4HVL4=F7.3,4X,
01411 454*      1HVL5=F7.3,4X,4HVL6=F7.3,5X,4HVL7= F7.3,
01411 455*      3 //,5X,5HPDSE=F7.3,4X,5HPDPR= F7.3,///,5X,
01411 456*      4HRDPE= F7.3,4X,5HRDSE= F7.3,4X,5HRTEH= F7.3,///)
01412 457*      2105 FORMAT(1X,6HR100=F9.5,5X,5HP105=F9.5,5X,5HR106=F9.5,5X,5HR107=F9.5
01412 458*      /,5X,6HR101=F9.5,5X,6HR102= F9.5,///)
01413 459*      2106 FORMAT(1X,5HT121= F8.2,5X,5HT129= F8.2,5X,6HR0121= F9.5,5X,6HR0129
01413 460*      /E F9.5,///,1X,6HR0135= F9.5,5X,6HR0101= F9.5,///)
01414 461*      3000 FORMAT(10I,3OUT ITERATION FAILED TO CONVERGE AT TE F7.5,5X,4HRP=
01414 462*      1F12.4,5X,5,CFRPE= E12.4,///)
01415 463*      3001 FORMAT(10I,4ITERATION SOLUTION FOR P7 FAILED AT CP7= F6.0)
01416 464*      4000 FORMAT(1X,          7HP21=24= 4(F7.1,7X,))//)
01417 465*      4100 FORMAT(5X, 9HF0 TH 5 = 6F9.0,///,5X,          4HF1V=F9.0 ,5X,4
01417 466*      1HF55=F9.0 ,///,5X,10HF6 TH 11 = 6F9.0,5X,5HF11= F9.0,///)
01420 467*      4200 FORMAT(5X,10HF13 TH 17= 5F9.0,///,5X,4HF19=F9.0,5X,4HF25= F9.0,5X,6
01420 468*      1HF1325= F9.0,///)
01421 469*      4300 FORMAT(5X,'J',I3,10X,E12.4,20X,'J',I3,10X,E12.4)
01422 470*      5000 FORMAT(5F15.0)
01423 471*      GO TO 4
01424 472*      END

```

END OF UNIVAC 1100 FORTRAN V COMPILATION. 1 *DIAGNOSTIC* MESSAGE(S)

TPA THRUST BALANCE AND INTERNAL FLOW PROGRAM. REV. 01-10-72

TPA 24,239 RPM NORMAL MODE, DATA LIST DTD. 1-10-71

NUMBER OF TRIALS FOR MONTE CARLO ANALYSIS = 0

```
01420 460*      1HF1325= F9.0,/)
01421 469*      4300 FORMAT(5X,'J',I3,10X,F12.4,20X,'J',I3,10X,E12.4)
01422 470*      5000 FORMAT(5F15.0)
01423 471*      GO TO 4
01424 472*      END
```

END OF UHIVAC 1108 FORTRAN V COMPILATION. 1 *DIAGNOSTIC* MESSAGE(S)

© XOT HAINH

15 MAR 72 13:19:56.704

Q XOT MAIN

15 MAR 72 13:19:56.704

TPA THRUST BALANCE AND INTERNAL FLOW PROGRAM, REV. 01-10-72

TPA 24,239 RPM NORMAL MODE, DATA LIST DTD. 3-10-71

NUMBER OF TRIALS FOR MONTE CARLO ANALYSIS = 0

MEAN VALUES OF INPUT VARIABLES,

PPD= 1442. PIF= .5000 PS= 25. PIF= .0700 PTI= 1077.

PTE= 750. TTEP= .02500 WPD= 46. RPM=24239.

RHOTI= .00038 RHOE= .00029 FTOL= 100.0 G= 386.00

TBPR= .0500 TSE= 41.00 TPD= 60.00

CL1= .1590+00 CL2= .4250+00 CL3= .1430+01 CL4= .1590+00

CL5= .3020+01 CL6= .1710+01 CL7= .2000-01 CLA= .7600-01

RTEH= .1450-02 RUPK= .5000-02 RTBS= .3460+00

RPES= .1320+00 P5F= .70000 P12F= .75700 P5G= 10.00 P12G= 10.00

Z0= .50000 Z3= .500 Z6= .500 Z8= .500 Z10= .500 Z14= .500 Z16= .500

XK4= .4800 XK5= .6800 XK55= .2400 XK8V= .9800 XK7= .4800 XK11= .4800

XK12= .4800 XK121= .4800 XK129= .4800 XK13= .4800 XK17= .4800 XK19= .4800

Y1 TH Y12= 3.4500 3.2500 3.4500 3.6500 5.4750 2.7500
2.7500 1.5150 1.5150 3.4500 3.6500 5.5000

Y1H= 1.4000 Y6= 4.7500

Y121= 5.7000 Y129= 2.5000 Y13= 2.3000 Y135= 2.3000 Y14= 1.7500 Y15= 1.5150

Y16= 1.5150 Y17= 1.5150 Y18= 1.9000 Y20= 3.9000 Y21= 5.1830 Y22= 3.9000 Y23= 5.1830

CD12= .6500 CD13= .6500

AT1= 15.000 AT2= 15.000 YBV1= 4.000 YBV2= 5.000

P21-24= 964.2 901.6 798.9 749.8

T=	.01250	T0=	.01250	FBP=	.6121+05	CFBP=	.7012+05
T=	.01664	T0=	.00836	FBP=	.6177+05	CFBP=	.7031+05
T=	.02087	T0=	.00413	FBP=	.6194+05	CFBP=	.4734+05
T=	.01820	T0=	.00600	FBP=	.6173+05	CFBP=	.5939+05
T=	.01769	T0=	.00731	FBP=	.6165+05	CFBP=	.6400+05
T=	.01795	T0=	.00705	FBP=	.6172+05	CFBP=	.6257+05
T=	.01809	T0=	.00691	FBP=	.6169+05	CFBP=	.6174+05
T=	.01609	T0=	.00691	FBP=	.6175+05	CFBP=	.6174+05

Iteration data setting FBP = CFBP
(varying T)

COMPUTED PARAMETERS BASED ON MEAN VALUE OF INPUT VARIABLES.

BAL. PISTON INNER LAND CLEARANCE (T) = .0181

BAL. PISTON LOAD= 61744.3

STIFFNESS = .527e+07

P5= 25.00 P1= 24.09 P01= 100.94 P4= 470.3 P42= 559.6 P5= 569.6 4

P54= 521.4 P55= 540.5 P6= 330.4 P7= 1040.3 P8= 1014.9

P01= 721.0 P11= 1175.0 P119= 1256.8 P12= 1266.8 P121= 871.4 P129= 704.9 P13= 416.2
 P135= 416.2 P14= 465.4 P15= 1125.9 P16= 1125.9

P17= 753.8 P18= 780.1 P19= 755.7 P20= 764.2 P21= 964.2 P22= 901.6

P23= 798.9 P24= 749.8

WL1= 2.439 WL2= .000 WL3= .000 WL4= 2.672 WL5= .766 WL6= .745 WLA= 1.001

WMS= 2.750 WMR= 5.549

WDP= 5.784 WDS= 1.511 WTEH= 1.746

RH00= .00250 RH05= .00250 RH06= .00250 RH07= .00250 RH012= .00250 RH0PD= .00250

R121= 03.61 R129= 66.22 R0121= .00250 R0129= .00250

R0135= .00250 RH018= .00250

F011= .6707e+05 F1325= -.5648e+04 FTURB= .4000e+04

F01= 146. F02= 191. F00M= 337.

F0 TH 5 = 918. 263. 425. 1294. 27175. 9280.

F0V= 17301. F55= 9162.

F0 TH 11 = 0. 17397. 0. 21761. 4229. 64665. F011= 67065.

F13 TH 17= 2675. 1886. 0. 0. 3127.

F0V= 27694. F25= 35038. F1325= -5648.

N8300R:72-106
May 1972

11. LH₂ PUMP TEST DATA REDUCTION PROGRAM

09 RUN TAD.428249.2.100

05 APR 72 11:08:19.523

0 CTL UN=2422ZX

05 APR 72 11:08:19.523

01 ELT LIST

05 APR 72 11:08:19.504

0 ELT DATA

05 APR 72 11:08:22.514

LH² PUMP TEST DATA REDUCTION PROGRAM

SEE: Final Report -

LH² Pump Component Development

TESTING IN THE ELECTRIC PUMP

Room At Test Cell "C"

Project 121, MAY 1972

N8360 R:72-101;

FOR COMPLETE DESCRIPTION

AND LISTING -

TAD:428249.2,100

DATE 05 APR 72 PAGE 2

0 XOT CUR

1. LIST I

05 APR 72 11:00:23.907

11:08:24

05 APR 72 11:00:10.521

05 APR 72 11:00:10.504

Q ELT DATA:1,720405, 40102

05 APR 72 11:00:10.007

000001	9	10	11	13	15	16	16	17	17	18	19	20	43	43	43	43	42	42	42	42	41	#0410	11:00:10.007
000002	40	40	39	39	38																		
000003		24.9029		25.2000		27.0000		28.8000		30.6000		32.4000		34.2000		36.0000							
000004		36.4823																					
000005		0.20788		0.20828		0.21058		0.21305		0.21575		0.21869		0.22187		0.22528							
000006		0.22632																					
000007		-132.27		-131.80		-128.88		-125.77		-122.46		-118.96		-115.25		-111.28							
000008		-110.18																					
000009		1.186		1.205		1.316		1.427		1.539		1.650		1.761		1.874							
000010		1.905																					
000011		24.9336		25.2000		27.0000		28.8000		30.6000		32.4000		34.2000		36.0000							
000012		37.8000		39.6000		41.4000		43.2000		45.0000		46.8000		48.6000		50.4000							
000013	7	0.20780		0.20812		0.21042		0.21289		0.21559		0.21853		0.22163		0.22512							
000014		0.22834		0.23196																			
000015		-131.97		-131.55		-128.65		-125.53		-122.25		-118.75		-115.02		-111.07							
000016		-106.85		-103.63																			
000017		1.186		1.202		1.314		1.425		1.536		1.648		1.759		1.872							
000018		1.985		2.070																			
000019		24.9641		25.2000		27.0000		28.8000		30.6000		32.4000		34.2000		36.0000							
000020		37.8000		39.6000		41.4000		43.2000		45.0000		46.8000		48.6000		50.4000							
000021		0.20772		0.20804		0.21026		0.21281		0.21543		0.21829		0.22147		0.22489							
000022		0.22870		0.23291		0.23697																	
000023		-131.67		-131.31		-128.39		-125.30		-122.01		-118.51		-114.80		-110.86							
000024		-106.66		-102.16		-98.04																	
000025		1.186		1.201		1.312		1.424		1.534		1.645		1.757		1.869							
000026		1.985		2.099		2.201																	
000027		25.0254		25.2000		27.0000		28.8000		30.6000		32.4000		34.2000		36.0000							
000028		37.8000		39.6000		41.4000		43.2000		44.3376													
000029		0.20756		0.20780		0.21003		0.21249		0.21511		0.21797		0.22107		0.22449							
000030		0.22814		0.23236		0.23705		0.24237		0.24618													
000031		-131.10		-130.82		-127.92		-124.83		-121.54		-118.07		-114.38		-110.45							
000032		-106.27		-101.79		-96.99		-91.85		-88.38													
000033		1.187		1.197		1.309		1.420		1.530		1.641		1.752		1.863							
000034		1.977		2.092		2.211		2.333		2.412													
000035		25.0885		25.2000		27.0000		28.8000		30.6000		32.4000		34.2000		36.0000							
000036		37.8000		39.6000		41.4000		43.2000		45.0000		46.8000		48.6000		50.4000							
000037		0.20740		0.20756		0.20979		0.21225		0.21479		0.21766		0.22067		0.22401							
000038		0.22767		0.23180		0.23641		0.24157		0.24769		0.25493		0.25508									
000039		-130.52		-130.35		-127.45		-124.36		-121.10		-117.62		-113.95		-110.03							
000040		-105.87		-101.43		-96.67		-91.56		-86.03		-79.95		-79.80									
000041		1.187		1.194		1.305		1.415		1.526		1.636		1.747		1.859							
000042		1.971		2.086		2.203		2.324		2.450		2.581		2.709		2.837							
000043		25.1459		25.2000		27.0000		28.8000		30.6000		32.4000		34.2000		36.0000							
000044		37.8000		39.6000		41.4000		43.2000		45.0000		46.8000		48.6000		50.4000							
000045		0.20724		0.20732		0.20955		0.21193		0.21456		0.21734		0.22036		0.22362							
000046		0.22719		0.23124		0.23577		0.24086		0.24674		0.25381		0.26232		0.26414							
000047		-129.95		-129.86		-126.96		-123.89		-120.63		-117.17		-113.50		-109.60							
000048		-105.46		-101.05		-96.33		-91.26		-85.80		-79.80		-73.17		-71.85							
000049		1.188		1.192		1.302		1.412		1.522		1.631		1.743		1.853							
000050		1.965		2.079		2.196		2.316		2.439		2.570		2.709		2.837							
000051		25.2071		27.0000		28.8000		30.6000		32.4000		34.2000		36.0000		37.8000							
000052		39.6000		41.4000		43.2000		45.0000		46.8000		48.6000		50.4000		50.7564							
000053		0.20709		0.20931		0.21162		0.21424		0.21694		0.21996		0.22322		0.22679							
000054		0.23009		0.23514		0.24014		0.24587		0.25262		0.26089		0.27130		0.27368							
000055		-129.37		-126.49		-123.44		-120.18		-116.72		-113.08		-109.19		-105.06							

000057	1.188	1.298	1.408	1.517	1.628	1.738	1.848	1.959
000058	2.073	2.189	2.308	2.430	2.559	2.695	2.844	2.876
000059	25.2665	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000060	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000061	52.3745							
000062	0.20693	0.20907	0.21138	0.21392	0.21662	0.21956	0.22282	0.22632
000063	0.23021	0.23450	0.23943	0.24507	0.25159	0.25945	0.26923	0.28242
000064	0.28401							
000065	-128.79	-126.02	-122.97	-119.71	-116.28	-112.63	-108.77	-104.65
000066	-100.30	-95.63	-90.66	-85.29	-79.48	-73.09	-65.90	-57.50
000067	-56.58							
000068	1.189	1.295	1.405	1.514	1.623	1.733	1.843	1.953
000069	2.067	2.182	2.299	2.421	2.547	2.682	2.827	2.990
000070	3.008							
000071	25.3278	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000072	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000073	53.8380							
000074	0.20677	0.20883	0.21114	0.21360	0.21630	0.21924	0.22242	0.22584
000075	0.22965	0.23395	0.23871	0.24420	0.25055	0.25810	0.26748	0.27964
000076	0.29561							
000077	-128.22	-125.53	-122.48	-119.26	-115.83	-112.18	-108.34	-104.25
000078	-99.92	-95.29	-90.34	-85.03	-79.29	-73.00	-65.98	-57.92
000079	-48.92							
000080	1.189	1.291	1.401	1.510	1.619	1.728	1.837	1.949
000081	2.060	2.175	2.291	2.412	2.538	2.669	2.810	2.968
000082	3.137							
000083	25.3871	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000084	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000085	54.0000	55.1717						
000086	0.20661	0.20860	0.21082	0.21336	0.21599	0.21893	0.22203	0.22544
000087	0.22918	0.23339	0.23808	0.24340	0.24960	0.25683	0.26573	0.27710
000088	0.29315	0.30896						
000089	-127.64	-125.06	-122.01	-118.79	-115.38	-111.75	-107.91	-103.84
000090	-99.53	-94.93	-90.02	-84.77	-79.10	-72.89	-66.05	-58.24
000091	-48.84	-41.01						
000092	1.189	1.289	1.407	1.506	1.615	1.724	1.833	1.943
000093	2.054	2.168	2.284	2.404	2.527	2.657	2.795	2.948
000094	3.124	3.267						
000095	25.4465	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000096	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000097	54.0000	55.8000	56.4029					
000098	0.20645	0.20836	0.21058	0.21305	0.21567	0.21853	0.22163	0.22505
000099	0.22870	0.23283	0.23744	0.24261	0.24865	0.25564	0.26414	0.27487
000100	0.28933	0.31238	0.32525					
000101	-127.07	-124.59	-121.54	-118.32	-114.91	-111.31	-107.49	-103.44
000102	-99.15	-94.56	-89.70	-84.50	-78.87	-72.79	-66.07	-58.48
000103	-48.56	-37.94	-32.54					
000104	1.190	1.285	1.394	1.502	1.611	1.719	1.828	1.938
000105	2.048	2.162	2.277	2.394	2.517	2.644	2.780	2.929
000106	3.096	3.308	3.404					
000107	25.5960	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000108	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000109	54.0000	55.8000	57.6000	59.1047				
000110	0.20613	0.20772	0.20995	0.21241	0.21495	0.21773	0.22075	0.22401
000111	0.22751	0.23148	0.23585	0.24078	0.24542	0.25294	0.26057	0.26994
000112	0.28186	0.29847	0.32597	0.41744				
000113	-125.62	-123.40	-120.37	-117.17	-113.78	-110.20	-106.42	-102.41
000114	-98.17	-93.65	-88.87	-83.77	-78.29	-72.40	-65.96	-58.85
000115	-50.78	-41.12	-28.19	-1.36				
000116	1.192	1.277	1.385	1.502	1.600	1.708	1.816	1.925

000117	2.034	3.038	3.214	3.442	2.589	2.374	2.494	2.617	2.747	2.888
000118	2.145	3.038	3.214	3.442	2.589	2.374	2.494	2.617	2.747	2.888
000119	25.7435	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000120	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	56.8000
000121	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000
000122	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000
000123	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000
000124	97.2000	99.0000	100.8000	0.20574	0.21170	0.21424	0.21694	0.21980	0.22288	0.22591
000125	0.22640	0.23021	0.23442	0.23911	0.24436	0.25014	0.25644	0.26324	0.27058	0.27841
000126	0.27674	0.28391	0.29141	0.30025	0.30941	0.31894	0.32894	0.33938	0.35024	0.36154
000127	0.37324	0.38591	0.40000	0.41541	0.43214	0.44936	0.46704	0.48518	0.50374	0.52274
000128	1.11047	1.19673	1.27473	1.34799	1.41808	1.48531	1.55016	1.61310	1.67465	1.73500
000129	1.67436	1.73428	1.79201	1.85062	1.90728	1.96315	2.01830	2.07295	2.12725	2.18125
000130	2.12653	2.17970	2.23238	2.28452	2.33608	2.38708	2.43753	2.48743	2.53678	2.58558
000131	-124.19	-122.20	-119.20	-116.02	-112.68	-109.09	-105.33	-101.53	-97.62	-93.62
000132	-97.17	-92.73	-88.02	-83.00	-77.65	-71.91	-65.73	-59.07	-51.97	-44.97
000133	-51.44	-42.02	-32.46	-18.36	-12.47	-6.159	0.853	157.01	304.19	451.37
000134	104.16	113.40	121.76	129.52	136.84	143.81	150.53	157.01	163.32	169.47
000135	163.32	169.47	175.50	181.41	187.21	192.95	198.60	204.19	209.73	215.22
000136	209.73	215.22	220.68	226.08	231.44	236.75	242.01	247.22	252.39	257.52
000137	1.193	1.269	1.376	1.483	1.591	1.697	1.804	1.912	2.019	2.126
000138	2.021	2.130	2.241	2.355	2.471	2.592	2.717	2.849	2.981	3.112
000139	2.990	3.147	3.330	3.571	4.080	4.874	5.772	6.771	7.870	8.969
000140	5.527	6.660	7.778	8.884	9.982	10.958	11.918	12.871	13.818	14.760
000141	6.317	6.391	6.461	6.528	6.595	6.658	6.718	6.777	6.835	6.891
000142	6.835	6.891	6.945	7.000	7.054	7.108	7.161	7.214	7.267	7.320
000143	26.0369	27.0000	28.0000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000
000144	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	56.8000
000145	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000
000146	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000
000147	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000
000148	97.2000	99.0000	100.8000	0.21042	0.21391	0.21835	0.22383	0.22937	0.23497	0.24064
000149	0.24172	0.24605	0.25020	0.25501	0.26048	0.26661	0.27240	0.27884	0.28494	0.29169
000150	0.29773	0.30414	0.31080	0.31770	0.32484	0.33221	0.33981	0.34764	0.35570	0.36399
000151	0.37252	0.38080	0.38927	0.39791	0.40681	0.41596	0.42536	0.43501	0.44491	0.45506
000152	0.46536	0.47518	0.48533	0.49589	0.50685	0.51812	0.52970	0.54159	0.55379	0.56630
000153	1.17293	1.22339	1.27234	1.31994	1.36651	1.41204	1.45670	1.50065	1.54390	1.58645
000154	1.54388	1.58647	1.62835	1.66954	1.71008	1.75004	1.78949	1.82835	1.86661	1.90428
000155	-121.33	-119.82	-118.83	-117.69	-116.37	-114.87	-113.16	-111.36	-109.56	-107.76
000156	-95.14	-90.81	-86.22	-81.36	-76.24	-70.76	-64.94	-58.67	-51.97	-44.97
000157	-51.86	-44.42	-36.06	-26.48	-14.92	0.00	20.68	45.94	70.69	94.94
000158	66.65	82.43	95.16	106.04	115.70	124.49	132.55	140.29	147.71	154.82
000159	147.67	154.75	161.60	168.23	174.69	181.03	187.21	193.29	199.26	205.17
000160	199.26	205.17	211.04	216.85	222.60	228.29	233.93	239.52	245.06	250.56
000161	1.196	1.253	1.360	1.465	1.571	1.676	1.782	1.888	1.994	2.100
000162	1.994	2.102	2.209	2.320	2.431	2.546	2.664	2.786	2.914	3.049
000163	2.914	3.049	3.198	3.361	3.522	3.792	4.117	4.501	4.944	5.400
000164	4.808	5.037	5.365	5.494	5.609	5.712	5.808	5.898	5.984	6.067
000165	5.898	5.983	6.063	6.140	6.212	6.281	6.348	6.412	6.474	6.534
000166	6.474	6.534	6.594	6.654	6.714	6.773	6.831	6.888	6.945	7.002
000167	26.3268	27.0000	28.0000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000
000168	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	56.8000
000169	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000
000170	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000
000171	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000
000172	97.2000	99.0000	100.8000	0.20915	0.21446	0.22032	0.22674	0.23372	0.24128	0.24940
000173	0.25002	0.25502	0.26071	0.26714	0.27430	0.28218	0.29070	0.29984	0.30960	0.31998
000174	0.32242	0.32934	0.33723	0.34619	0.35621	0.36730	0.37946	0.39269	0.40699	0.42236
000175	0.43880	0.45417	0.47064	0.48821	0.50688	0.52666	0.54754	0.56952	0.59260	0.61678

000177	0.08208	0.12651	0.16934	0.21074	0.25087	0.29013	0.32843	0.36602
000178	0.40281	0.43897	0.47433	0.50970	0.54507	0.58044	0.61581	0.65118
000179	-118.47	-117.741	-117.016	-116.291	-115.566	-114.841	-114.116	-113.391
000180	-93.09	-88.83	-84.57	-79.366	-74.166	-68.966	-63.766	-58.566
000181	-51.59	-44.81	-37.40	-29.30	-20.24	-9.96	1.98	16.01
000182	32.24	49.35	65.54	79.83	92.37	103.48	113.55	122.80
000183	131.44	139.59	147.33	154.77	161.94	168.89	175.65	182.29
000184	188.75	195.10	201.42	207.79	214.15	220.57	227.01	233.46
000185	1.199	1.238	1.273	1.304	1.335	1.366	1.397	1.428
000186	1.969	2.074	2.180	2.288	2.395	2.506	2.618	2.733
000187	2.853	2.976	3.106	3.246	3.395	3.561	3.749	3.962
000188	4.202	4.449	4.676	4.873	5.041	5.186	5.315	5.430
000189	5.535	5.634	5.724	5.809	5.890	5.966	6.039	6.109
000190	6.176	6.242	6.304	6.360	6.410	6.456	6.499	6.539
000191	26.6130	27.6000	28.6000	30.6000	32.6000	34.6000	36.6000	37.6000
000192	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000193	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000
000194	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000
000195	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000
000196	97.2000	99.0000	100.8000					
000197	0.20367	0.20407	0.20597	0.20800	0.21019	0.21257	0.21503	0.21773
000198	0.22060	0.22369	0.22711	0.23077	0.23474	0.23911	0.24396	0.24936
000199	0.25540	0.26224	0.27002	0.27916	0.28981	0.30268	0.31834	0.33789
000200	0.36236	0.39280	0.42936	0.47092	0.51918	0.55984	0.60379	0.64614
000201	0.68699	0.72624	0.76415	0.80611	0.84164	0.87620	0.90982	0.94272
000202	0.17490	0.20645	0.23744					
000203	-115.64	-115.62	-112.09	-109.02	-105.278	-102.235	-98.774	-94.997
000204	-90.96	-86.82	-82.45	-77.84	-73.00	-67.92	-62.55	-56.90
000205	-50.90	-44.53	-37.72	-30.41	-22.50	-13.86	-4.37	6.14
000206	17.78	30.62	44.02	57.71	70.66	83.57	96.42	105.42
000207	115.25	124.44	133.15	141.60	149.31	156.91	164.26	171.39
000208	178.32	185.10	191.86	198.32	204.35	210.63	217.01	223.43
000209	1.201	1.224	1.249	1.275	1.302	1.330	1.358	1.388
000210	1.946	2.049	2.152	2.257	2.362	2.469	2.578	2.688
000211	2.801	2.917	3.036	3.162	3.292	3.432	3.580	3.740
000212	3.913	4.097	4.287	4.475	4.653	4.814	4.961	5.093
000213	5.213	5.323	5.425	5.519	5.608	5.692	5.771	5.847
000214	5.918	5.988	6.056					
000215	26.8955	27.0000	28.0000	30.0000	32.4000	34.2000	36.0000	37.8000
000216	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000217	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000
000218	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000
000219	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000
000220	97.2000	99.0000	100.8000					
000221	0.20295	0.20511	0.20994	0.21693	0.22499	0.21130	0.21368	0.21622
000222	0.21893	0.22187	0.22505	0.22846	0.23220	0.23625	0.24070	0.24555
000223	0.25095	0.25691	0.26367	0.27122	0.27996	0.28997	0.30165	0.31548
000224	0.33177	0.35116	0.37397	0.40035	0.42983	0.46186	0.49539	0.52948
000225	0.56358	0.59703	0.62985	0.66196	0.69319	0.72370	0.75350	0.78267
000226	0.01652	0.04458	0.07199					
000227	-112.80	-112.63	-109.73	-105.68	-101.46	-100.09	-98.53	-96.79
000228	-88.87	-84.77	-80.47	-75.97	-71.28	-66.30	-61.10	-55.66
000229	-49.90	-43.87	-37.45	-30.66	-23.43	-15.60	-7.40	1.13
000230	11.17	21.81	32.84	44.06	55.85	67.63	79.08	90.00
000231	100.54	110.43	119.82	129.73	137.26	145.45	153.32	160.94
000232	168.30	175.55	182.67					
000233	1.205	1.210	1.214	1.217	1.218	1.220	1.222	1.223
000234	1.924	2.026	2.128	2.230	2.333	2.436	2.541	2.647
000235	2.756	2.866	2.978	3.094	3.214	3.339	3.469	3.605
000236	3.747	3.897	4.049	4.203	4.360	4.520	4.683	4.850

000237	4.933	5.052	5.161	5.264	5.359	5.449	5.534	5.615
000238	5.692	5.765	5.836					
000239	27.1745	28.0000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000240	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000241	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000242	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000243	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000244	99.0000	100.8000						
000245	0.20232	0.20399	0.20589	0.20788	0.21003	0.21233	0.21479	0.21742
000246	0.22020	0.22322	0.22640	0.22989	0.23363	0.23776	0.24221	0.24706
000247	0.25238	0.25834	0.26494	0.27233	0.28067	0.29013	0.30094	0.31325
000248	0.32740	0.34369	0.36213	0.38287	0.40575	0.43047	0.45653	0.48355
000249	0.51097	0.53886	0.56880	0.59290	0.61952	0.64574	0.67157	0.69692
000250	0.72179	0.74635						
000251	-109.96	-107.36	-104.33	-101.15	-97.81	-94.29	-90.60	-86.74
000252	-82.70	-78.46	-74.05	-69.44	-64.60	-59.54	-54.25	-48.73
000253	-42.91	-36.81	-30.39	-23.63	-16.46	-8.89	-0.85	7.67
000254	16.69	26.21	36.19	46.51	57.07	67.69	78.23	88.55
000255	98.53	108.17	117.43	126.34	134.92	143.19	151.21	158.97
000256	166.52	173.99						
000257	1.207	1.299	1.401	1.503	1.603	1.703	1.803	1.904
000258	2.003	2.103	2.203	2.304	2.405	2.507	2.610	2.714
000259	2.821	2.927	3.038	3.150	3.265	3.384	3.506	3.632
000260	3.763	3.897	4.033	4.172	4.309	4.445	4.577	4.704
000261	4.822	4.935	5.041	5.141	5.236	5.325	5.410	5.490
000262	5.567	5.642						
000263	27.4500	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000264	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000265	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000266	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000267	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000268	99.0000	100.8000						
000269	0.20168	0.20303	0.20486	0.20677	0.20891	0.21106	0.21344	0.21591
000270	0.21861	0.22139	0.22449	0.22775	0.23124	0.23506	0.23919	0.24364
000271	0.24849	0.25381	0.25969	0.26613	0.27336	0.28131	0.29021	0.30022
000272	0.31151	0.32496	0.33821	0.35386	0.37103	0.38978	0.40981	0.43102
000273	0.45304	0.47561	0.49849	0.52154	0.54450	0.56731	0.58996	0.61237
000274	0.63454	0.65539						
000275	-107.13	-104.99	-101.99	-98.83	-95.52	-92.03	-88.40	-84.56
000276	-80.59	-76.43	-72.08	-67.56	-62.83	-57.90	-52.74	-47.36
000277	-41.76	-35.89	-29.75	-23.33	-16.59	-9.51	-2.06	5.73
000278	13.92	22.50	31.43	40.71	50.22	59.93	69.72	79.51
000279	89.17	98.68	107.94	116.96	125.70	134.19	142.44	150.46
000280	158.27	165.99						
000281	1.209	1.286	1.387	1.487	1.587	1.686	1.785	1.884
000282	1.982	2.080	2.179	2.277	2.376	2.476	2.577	2.677
000283	2.780	2.884	2.988	3.094	3.204	3.315	3.427	3.544
000284	3.661	3.782	3.905	4.028	4.153	4.277	4.399	4.519
000285	4.635	4.746	4.852	4.954	5.050	5.141	5.229	5.311
000286	5.391	5.469						
000287	27.7235	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000288	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000289	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000290	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000291	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000292	99.0000	100.8000						
000293	0.20105	0.20208	0.20391	0.20574	0.20772	0.20987	0.21217	0.21456
000294	0.21710	0.21980	0.22266	0.22576	0.22910	0.23267	0.23649	0.24062
000295	0.24507	0.24992	0.25524	0.26096	0.26732	0.27424	0.28186	0.29037
000296	0.31151	0.32496	0.33821	0.35386	0.37103	0.38978	0.40981	0.43102

000297	0.41298	0.43150	0.45057	0.46996	0.48959	0.50938	0.52909	0.54879
000298	0.56834	0.58781						
000299	-104.33	-102.63	-99.64	-96.50	-93.22	-89.79	-86.18	-82.41
000300	-78.46	-74.37	-70.10	-65.64	-60.99	-56.17	-51.14	-45.89
000301	-40.45	-34.78	-28.87	-22.71	-16.27	-9.55	-2.55	4.75
000302	12.37	20.28	28.51	37.00	45.74	54.70	63.79	72.98
000303	82.17	91.30	100.34	109.24	117.96	126.49	134.83	142.96
000304	150.91	158.80						
000305	1.213	1.272	1.373	1.472	1.571	1.669	1.767	1.865
000306	1.962	2.059	2.155	2.252	2.349	2.448	2.546	2.644
000307	2.744	2.843	2.944	3.047	3.150	3.256	3.362	3.470
000308	3.580	3.692	3.804	3.918	4.033	4.147	4.260	4.373
000309	4.482	4.590	4.693	4.792	4.888	4.981	5.069	5.154
000310	5.234	5.314						
000311	28.2617	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000312	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000313	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000314	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000315	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000316	99.0000	100.8000						
000317	0.19985	0.20033	0.20200	0.20383	0.20566	0.20764	0.20971	0.21193
000318	0.21432	0.21678	0.21940	0.22218	0.22520	0.22838	0.23172	0.23538
000319	0.23919	0.24332	0.24777	0.25262	0.25771	0.26335	0.26931	0.27582
000320	0.28290	0.29053	0.29879	0.30769	0.31731	0.32764	0.33860	0.35029
000321	0.36268	0.37564	0.38914	0.40313	0.41759	0.43230	0.44724	0.46241
000322	0.47767	0.49309						
000323	-98.72	-97.87	-94.95	-91.88	-88.63	-85.24	-81.70	-78.03
000324	-74.17	-70.19	-66.01	-61.70	-57.20	-52.55	-47.71	-42.69
000325	-37.51	-32.11	-26.55	-20.77	-14.71	-8.59	-2.17	4.45
000326	11.30	18.38	25.70	33.20	40.90	48.79	56.83	65.00
000327	73.28	81.60	89.96	98.32	106.63	114.91	123.08	131.14
000328	130.10	147.05						
000329	1.218	1.247	1.346	1.444	1.541	1.637	1.733	1.829
000330	1.924	2.019	2.112	2.207	2.301	2.395	2.489	2.584
000331	2.679	2.773	2.868	2.964	3.060	3.157	3.256	3.354
000332	3.452	3.552	3.653	3.752	3.853	3.954	4.054	4.155
000333	4.253	4.351	4.446	4.540	4.633	4.721	4.808	4.891
000334	4.973	5.052						
000335	28.7910	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000336	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000337	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000338	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000339	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000340	99.0000	100.8000						
000341	0.19874	0.19874	0.20033	0.20200	0.20375	0.20558	0.20756	0.20963
000342	0.21177	0.21408	0.21646	0.21909	0.22179	0.22465	0.22767	0.23085
000343	0.23434	0.23792	0.24181	0.24595	0.25032	0.25500	0.26001	0.26534
000344	0.27106	0.27718	0.28369	0.29069	0.29808	0.30594	0.31429	0.32311
000345	0.33241	0.34218	0.35235	0.36292	0.37389	0.38517	0.39669	0.40853
000346	0.42061	0.43277						
000347	-93.13	-93.11	-90.26	-87.21	-84.03	-80.70	-77.22	-73.60
000348	-69.82	-65.92	-61.85	-57.64	-53.27	-48.75	-44.06	-39.24
000349	-34.23	-29.07	-23.73	-18.23	-12.58	-6.71	-0.70	5.50
000350	11.87	18.42	25.14	32.03	39.09	46.30	53.63	61.10
000351	68.69	76.35	84.09	91.88	99.70	107.53	115.34	123.12
000352	130.86	138.67						
000353	1.224	1.224	1.321	1.417	1.513	1.607	1.702	1.796
000354	1.888	1.981	2.073	2.166	2.257	2.348	2.439	2.530
000355	2.622	2.713	2.804	2.894	2.987	3.078	3.169	3.262
000356	3.353	3.445	3.538	3.630	3.722	3.814	3.906	3.997

000357	4.087	4.178	4.266	4.354	4.439	4.524	4.606	4.687
000358	4.766	4.845						
000359	29.3093	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000
000360	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000
000361	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000
000362	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000
000363	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000
000364	100.8000							
000365	0.19763	0.19866	0.20025	0.20192	0.20367	0.20550	0.20748	0.20947
000366	0.21162	0.21304	0.21622	0.21869	0.22131	0.22409	0.22703	0.23013
000367	0.23339	0.23681	0.24046	0.24428	0.24833	0.25262	0.25723	0.26208
000368	0.26716	0.27257	0.27837	0.28441	0.29076	0.29752	0.30459	0.31198
000369	0.31969	0.32780	0.33614	0.34480	0.35386	0.36308	0.37254	0.38223
000370	0.39216							
000371	-87.59	-85.54	-82.56	-79.42	-76.14	-72.72	-69.16	-65.45
000372	-61.61	-57.62	-53.51	-49.24	-44.83	-40.09	-35.57	-30.73
000373	-25.74	-20.60	-15.31	-9.87	-4.28	1.45	7.33	13.37
000374	19.55	25.89	32.35	38.96	45.68	52.55	59.52	66.60
000375	73.77	81.02	88.34	95.72	103.12	110.56	118.00	125.45
000376	133.00							
000377	1.228	1.297	1.392	1.487	1.579	1.673	1.765	1.856
000378	1.946	2.038	2.126	2.216	2.305	2.394	2.483	2.571
000379	2.658	2.747	2.835	2.923	3.009	3.097	3.185	3.271
000380	3.359	3.445	3.532	3.618	3.704	3.790	3.875	3.959
000381	4.044	4.127	4.208	4.290	4.369	4.449	4.526	4.602
000382	4.675							
000383	29.8137	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000
000384	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000
000385	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000
000386	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000
000387	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000
000388	100.8000							
000389	0.19660	0.19715	0.19866	0.20025	0.20192	0.20367	0.20542	0.20732
000390	0.20939	0.21146	0.21368	0.21599	0.21837	0.22091	0.22362	0.22640
000391	0.22934	0.23252	0.23577	0.23919	0.24277	0.24658	0.25055	0.25477
000392	0.25922	0.26390	0.26875	0.27392	0.27924	0.28488	0.29084	0.29696
000393	0.30340	0.31008	0.31699	0.32414	0.33153	0.33916	0.34695	0.35497
000394	0.36316							
000395	-82.09	-80.85	-77.91	-74.81	-71.57	-68.20	-64.68	-61.04
000396	-57.26	-53.36	-49.31	-45.15	-40.82	-36.38	-31.80	-27.06
000397	-22.22	-17.23	-12.11	-6.84	-1.47	4.05	9.70	15.48
000398	21.41	27.42	33.59	39.86	46.26	52.76	59.37	66.07
000399	72.85	79.74	86.67	93.69	100.75	107.85	114.97	122.14
000400	129.41							
000401	1.254	1.274	1.368	1.462	1.553	1.645	1.735	1.825
000402	1.914	2.003	2.092	2.180	2.266	2.353	2.439	2.526
000403	2.611	2.696	2.782	2.866	2.950	3.034	3.118	3.201
000404	3.284	3.367	3.450	3.532	3.613	3.694	3.776	3.855
000405	3.935	4.014	4.092	4.169	4.245	4.320	4.394	4.468
000406	4.510							
000407	30.3191	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000
000408	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000
000409	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000
000410	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000
000411	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000
000412	100.8000							
000413	0.19556	0.19580	0.19715	0.19866	0.20025	0.20192	0.20359	0.20542
000414	0.20732	0.20923	0.21130	0.21344	0.21575	0.21805	0.22060	0.22314
000415	0.22530	0.22870	0.23164	0.23474	0.23800	0.24142	0.24499	0.24873

000417	0.29084	0.29649	0.30237	0.30841	0.31468	0.32112	0.32780	0.33455
000418	0.34146							
000419	-76.61	-76.16	-73.26	-70.21	-67.01	-63.68	-60.20	-56.62
000420	-52.91	-49.05	-45.08	-40.97	-36.74	-32.37	-27.89	-23.29
000421	-18.55	-13.69	-8.70	-3.58	1.64	6.99	12.45	18.04
000422	23.73	29.53	35.48	41.48	47.60	53.83	60.14	66.56
000423	73.06	79.63	86.29	92.99	99.77	106.59	113.46	120.35
000424	127.39							
000425	1.239	1.253	1.346	1.437	1.528	1.618	1.708	1.797
000426	1.885	1.972	2.059	2.144	2.231	2.315	2.400	2.484
000427	2.567	2.650	2.733	2.815	2.897	2.978	3.060	3.141
000428	3.220	3.299	3.379	3.458	3.536	3.613	3.692	3.769
000429	3.843	3.919	3.994	4.067	4.141	4.213	4.284	4.354
000430	4.425							
000431	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000	43.2000	45.0000
000432	45.0000	46.6000	48.4000	50.4000	52.2000	54.0000	55.8000	57.6000
000433	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000
000434	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000
000435	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000
000436	0.19366	0.19366	0.19366	0.19723	0.19866	0.20025	0.20184	0.20329
000437	0.20534	0.20717	0.20907	0.21106	0.21313	0.21527	0.21750	0.21988
000438	0.22226	0.22401	0.22743	0.23021	0.23399	0.23601	0.23903	0.24221
000439	0.24455	0.24697	0.25254	0.25628	0.26009	0.26406	0.26920	0.27241
000440	0.27678	0.28131	0.29076	0.29469	0.30070	0.30586	0.31111	0.31410
000441	-65.71	-63.96	-60.77	-57.86	-54.62	-51.22	-47.73	-44.10
000442	-40.37	-36.51	-32.52	-28.43	-24.22	-19.89	-15.46	-10.89
000443	-6.22	-1.45	0.40	13.50	27.60	41.68	55.77	69.84
000444	34.82	40.39	46.04	51.78	57.60	63.53	69.52	75.58
000445	81.72	87.93	94.20	100.54	106.91	113.35	119.84	126.47
000446	1.246	1.304	1.393	1.482	1.571	1.657	1.744	1.830
000447	1.914	1.998	2.083	2.164	2.247	2.329	2.410	2.490
000448	2.570	2.649	2.727	2.805	2.882	2.959	3.036	3.111
000449	3.187	3.262	3.335	3.408	3.481	3.554	3.625	3.696
000450	3.766	3.826	3.905	3.974	4.041	4.108	4.174	4.240
000451	32.2467	32.4000	34.0000	35.6000	37.8000	39.6000	41.4000	43.2000
000452	45.0000	46.6000	48.4000	50.4000	52.2000	54.0000	55.8000	57.6000
000453	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000
000454	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000
000455	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000
000456	0.19183	0.19191	0.19318	0.19445	0.19588	0.19731	0.19874	0.20025
000457	0.20184	0.20351	0.20701	0.20991	0.21082	0.21281	0.21487	0.21687
000458	0.21702	0.21916	0.22214	0.22385	0.22532	0.22886	0.23148	0.23418
000459	0.23697	0.23991	0.24595	0.24912	0.25246	0.25580	0.25930	0.26280
000460	0.26237	0.26653	0.27026	0.27416	0.27813	0.28218	0.28631	0.29061
000461	-54.94	-54.70	-51.78	-48.73	-45.55	-42.22	-38.81	-35.27
000462	-31.80	-27.85	-23.97	-19.98	-15.88	-11.68	-7.37	-2.96
000463	1.55	6.16	10.67	15.67	20.58	25.57	30.64	35.78
000464	41.05	46.34	51.76	57.22	62.78	68.42	74.11	79.87
000465	65.69	69.60	73.55	77.59	81.64	85.78	89.95	94.10
000466	1.258	1.265	1.340	1.410	1.527	1.612	1.696	1.780
000467	1.883	1.945	2.027	2.107	2.187	2.266	2.344	2.423
000468	2.500	2.576	2.651	2.727	2.802	2.875	2.949	3.021
000469	3.093	3.164	3.236	3.305	3.374	3.443	3.512	3.579
000470	3.645	3.712	3.777	3.842	3.906	3.970	4.033	4.097
000471	33.1758	34.2000	35.0000	35.8000	36.6000	37.4000	38.2000	39.0000
000472	46.2000	48.4000	50.4000	52.2000	54.0000	55.8000	57.6000	59.4000
000473	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000	73.8000
000474	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000	88.2000
000475	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000	102.6000
000476	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000477	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000478	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000479	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000480	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000481	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000482	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000483	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000484	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000485	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000486	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000487	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000488	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000489	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000490	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000491	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000492	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000493	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000494	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000495	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000496	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000497	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000498	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000499	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822
000500	0.19616	0.19616	0.19709	0.19709	0.19861	0.19861	0.19730	0.19822

000477	0.20033	0.20192	0.20351	0.20518	0.20693	0.20875	0.21058	0.21249
000478	0.21448	0.21646	0.21861	0.22075	0.22298	0.22528	0.22767	0.23013
000479	0.23259	0.23522	0.23784	0.24062	0.24340	0.24626	0.24920	0.25222
000480	0.25532	0.25850	0.26176	0.26510	0.26851	0.27193	0.27551	
000481	-44.27	-42.61	-39.62	-36.49	-33.25	-29.88	-26.40	-22.84
000482	-19.15	-15.35	-11.45	-7.46	-3.34	0.85	5.14	9.53
000483	14.01	18.59	23.26	28.02	32.84	37.77	42.76	47.81
000484	52.95	58.16	63.42	68.78	74.20	79.68	85.22	90.83
000485	96.50	102.22	108.00	113.84	119.73	125.66	131.76	
000486	1.266	1.316	1.401	1.485	1.570	1.652	1.735	1.816
000487	1.897	1.976	2.054	2.132	2.209	2.286	2.362	2.437
000488	2.512	2.585	2.658	2.731	2.803	2.873	2.944	3.013
000489	3.081	3.150	3.218	3.284	3.350	3.416	3.481	3.545
000490	3.609	3.672	3.734	3.796	3.856	3.917	3.978	
000491	34.0793	34.2000	36.0000	37.8000	39.6000	41.4000	43.2000	45.0000
000492	46.0000	48.0000	50.4000	52.2000	54.0000	55.8000	57.6000	59.4000
000493	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000	73.8000
000494	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000	88.2000
000495	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000	
000496	0.18857	0.18865	0.18976	0.19095	0.19215	0.19342	0.19469	0.19604
000497	0.19747	0.19890	0.20041	0.20192	0.20351	0.20518	0.20685	0.20860
000498	0.21034	0.21217	0.21408	0.21599	0.21805	0.22012	0.22218	0.22433
000499	0.22656	0.22886	0.23124	0.23363	0.23609	0.23855	0.24118	0.24380
000500	0.24650	0.24920	0.25206	0.25493	0.25787	0.26081	0.26383	
000501	-33.69	-33.48	-30.54	-27.47	-24.27	-20.96	-17.55	-14.03
000502	-10.40	-6.69	-2.87	1.04	5.05	9.17	13.37	17.65
000503	22.05	26.51	31.07	35.70	40.41	45.19	50.05	54.98
000504	59.97	65.02	70.14	75.35	80.59	85.90	91.28	96.72
000505	102.20	107.74	113.35	118.98	124.70	130.44	136.34	
000506	1.276	1.260	1.365	1.449	1.530	1.612	1.693	1.773
000507	1.852	1.930	2.007	2.084	2.160	2.234	2.308	2.381
000508	2.455	2.526	2.597	2.668	2.738	2.807	2.875	2.943
000509	3.009	3.076	3.141	3.206	3.270	3.334	3.397	3.458
000510	3.520	3.581	3.642	3.701	3.760	3.820	3.879	
000511	34.9613	36.0000	37.8000	39.6000	41.4000	43.2000	45.0000	46.8000
000512	48.6000	50.4000	52.2000	54.0000	55.8000	57.6000	59.4000	61.2000
000513	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000	73.8000	75.6000
000514	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000	88.2000	90.0000
000515	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000		
000516	0.18706	0.18770	0.18881	0.18992	0.19111	0.19231	0.19358	0.19485
000517	0.19620	0.19755	0.19898	0.20049	0.20205	0.20351	0.20510	0.20669
000518	0.20844	0.21011	0.21193	0.21368	0.21559	0.21750	0.21940	0.22147
000519	0.22346	0.22560	0.22775	0.22989	0.23212	0.23442	0.23681	0.23919
000520	0.24157	0.24404	0.24658	0.24920	0.25183	0.25445		
000521	-23.18	-21.49	-18.47	-15.31	-12.05	-8.70	-5.22	-1.66
000522	1.98	5.73	9.59	13.52	17.55	21.69	25.89	30.17
000523	34.57	39.03	43.55	48.15	52.85	57.58	62.40	67.28
000524	72.21	77.20	82.28	87.40	92.58	97.81	103.09	108.45
000525	113.84	119.30	124.81	130.35	135.94	141.70		
000526	1.284	1.331	1.413	1.495	1.575	1.655	1.733	1.811
000527	1.887	1.963	2.039	2.112	2.186	2.259	2.330	2.401
000528	2.472	2.542	2.611	2.680	2.747	2.814	2.880	2.945
000529	3.009	3.073	3.136	3.200	3.262	3.322	3.384	3.443
000530	3.502	3.561	3.619	3.677	3.734	3.792		
000531	-8.0377310E-07	1.2281445E-06	-2.1059322E-06	-3.8373024E-06	-8.7732374E-06			
000532	-1.5259414E-05	-2.6335328E-05	-4.1334596E-05	-6.5248416E-05	-9.5611221E-05			
000533	-1.3180607E-04	-1.7020696E-04	-2.1873437E-04	-2.5922335E-04	-3.1173105E-04			
000534	-3.6397233E-04	-4.2257714E-04	-4.5541749E-04	-5.0527305E-04	-5.4852158E-04			
000535	-5.8699584E-04	-6.1718419E-04	-6.4309287E-04	-6.5827184E-04	-6.5781804E-04			
000536	-6.0096148E-04	-6.2885972E-04	-6.4952177E-04	-6.5821366E-04	-6.49570093E-04			

00537	-4.364393E-04	-3.706998E-04	-3.298888E-04	-2.913531E-04	-2.700973E-04
00538	-2.769572E-04	-2.981212E-04	-3.504450E-04	-4.244012E-04	-5.244012E-04
00539	-6.412554E-04	-7.621249E-04	-9.344805E-04	-1.093478E-03	-1.255932E-03
00540	-1.369857E-03	-1.547438E-03	-1.721902E-03	-1.892843E-03	-2.056172E-03
00541	-2.214347E-03	-2.627248E-03	-3.042715E-03	-3.467071E-03	-3.891427E-03
00542	-3.209740E-03	-3.413366E-03	-3.422715E-03	-4.058322E-03	-4.035186E-03
00543	-5.202367E-03	-5.325757E-03	-6.206972E-03	-6.667892E-03	-7.180399E-03
00544	-7.071325E-03	-7.071325E-03	-9.123819E-03	-9.557506E-03	-1.101505E-02
00545	-1.059132E-02	-1.388618E-02	-1.559519E-02	-1.740006E-02	-2.012458E-02
00546	-2.490844E-02	-2.300643E-02	-2.361225E-02	-2.113185E-02	-1.578707E-02
00547	-7.229774E-02	-1.115793E-02	-2.057210E-02	-9.120150E-02	-3.698844E-02
00548	-2.596736E-01	-2.039673E-02	-4.126616E-02	-6.857065E-02	-1.476663E-01
00549	-4.167114E-02	-8.341508E-02	-1.242096E-01	-1.733171E-01	-2.203154E-01
00550	-2.047957E-01	-3.149551E-01	-3.725594E-01	-4.288904E-01	-4.881444E-01
00551	-5.501563E-01	-6.144192E-01	-6.817529E-01	-7.448230E-01	-8.203019E-01
00552	-8.931632E-01	-9.688953E-01	-1.035638E-01	-1.115847E+00	-1.191861E+00
00553	-1.268011E+00	-1.343631E+00	-1.419585E+00	-1.493887E+00	-1.565767E+00
00554	-1.639929E+00	-1.706442E+00	-1.773210E+00	-1.840358E+00	-1.905647E+00
00555	-1.971365E+00	-2.039041E+00	-2.110702E+00	-2.186896E+00	-2.269260E+00
00556	-2.365869E+00	-2.445727E+00	-2.564723E+00	-2.679944E+00	-2.802890E+00
00557	-2.832136E+00	-3.071363E+00	-3.214929E+00	-3.362374E+00	-3.512983E+00
00558	-3.653227E+00	-3.812208E+00	-3.972517E+00	-4.135542E+00	-4.295320E+00
00559	-4.457295E+00	-4.632610E+00	-4.819301E+00	-4.991753E+00	-5.148219E+00
00560	-5.359527E+00	-5.538552E+00	-5.691780E+00	-5.967975E+00	-6.119607E+00
00561	-6.495823E+00	-6.723615E+00	-7.008333E+00	-7.284581E+00	-7.599178E+00
00562	-7.757348E+00	-7.992704E+00	-8.357104E+00	-8.608392E+00	-9.009685E+00
00563	-9.338994E+00	-9.604497E+00	-1.022200E+01	-1.066035E+01	-1.124179E+01
00564	-1.174049E+01	-1.201633E+01	-1.227566E+01	-1.220592E+01	-1.193371E+01
00565	-1.114370E+01	-1.128386E+01	-1.077441E+01	-1.018601E+01	-1.490911E+01
00566	-3.786338E+01	-1.050802E+01	-9.619111E+00	-8.309369E+00	-4.383187E+00
00567	-5.718471E-02	-1.809304E-01	-4.978239E-01	-8.673739E-01	-1.443949E+00
00568	-2.130016E+00	-4.096801E+00	-1.549693E+01	-4.455333E+01	-7.065343E+01
00569	-8.907931E+00	-1.009132E+01	-2.319491E+01	-1.540969E+01	-1.788280E+01
00570	-2.064126E+01	-2.349480E+01	-2.502529E+01	-2.860152E+01	-3.127031E+01
00571	-3.368051E+01	-3.631293E+01	-3.867686E+01	-4.077012E+01	-4.252112E+01
00572	-4.805742E+01	-4.529185E+01	-4.617127E+01	-4.682381E+01	-4.718534E+01
00573	-4.740820E+01	-5.306612E+01	-5.564884E+01	-5.872777E+01	-6.233962E+01
00574	-6.623977E+01	-7.079838E+01	-7.544072E+01	-8.021628E+01	-8.494517E+01
00575	-8.878554E+01	-9.320990E+01	-9.777474E+01	-1.028851E+02	-1.079818E+02
00576	-1.054704E+02	-1.137972E+02	-1.177864E+02	-1.213972E+02	-1.228782E+02
00577	-1.273735E+02	-1.303220E+02	-1.303115E+02	-1.384302E+02	-1.373074E+02
00578	-1.505101E+02	-1.586494E+02	-1.586494E+02	-1.656492E+02	-1.642636E+02
00579	-1.657642E+02	-1.659384E+02	-1.722178E+02	-1.718991E+02	-1.782576E+02
00580	-1.642762E+02	-1.884620E+02	-1.941032E+02	-2.004923E+02	-2.093282E+02
00581	-2.150404E+02	-2.011894E+02	-1.794258E+02	-1.794258E+02	-1.449853E+02
00582	-9.806702E+01	-9.744041E+01	-8.894428E+01	-2.201621E+00	-1.532437E+02
00583	-9.621559E+02	-3.677677E+02	-7.276252E+01	-1.145665E+02	-1.952522E+02
00584	-2.495297E-01	-2.332859E+00	-2.068247E+00	-3.216571E+00	-2.609454E+00
00585	-1.244724E+00	-3.216868E+00	-1.134612E+01	-2.537882E+01	-4.449425E+01
00586	-6.944082E+01	-9.514165E+01	-1.286617E+02	-1.549520E+02	-1.955501E+02
00587	2.254016E+02	2.756494E+02	3.124937E+02	3.007372E+02	3.170158E+02
00588	3.257607E+02	3.237363E+02	3.124937E+02	2.860230E+02	2.410966E+02
00589	1.022871E+02	1.064775E+02	1.064775E+02	9.647216E+01	2.208320E+02
00590	-4.952140E+02	-6.301110E+02	-7.301110E+02	-7.596744E+02	-8.779361E+02
00591	-9.761134E+02	-1.002950E+03	-1.123629E+03	-1.166544E+03	-1.189602E+03
00592	-1.196520E+03	-1.186117E+03	-1.165216E+03	-1.142738E+03	-1.118093E+03
00593	-1.143805E+03	-1.095710E+03	-1.045729E+03	-1.026417E+03	-1.002304E+03
00594	-1.073325E+03	-1.034914E+03	-1.034914E+03	-1.026417E+03	-1.002304E+03
00595	-1.030000E+03	-1.030000E+03	-1.030000E+03	-1.030000E+03	-1.030000E+03

000597	-7.3317710E+02	-7.1729678E+02	-6.1916306E+02	-5.2271128E+02	-5.3825927E+02
000598	-5.1531466E+02	-5.1639302E+02	-3.6579871E+02	-3.6543501E+02	-1.8416297E+02
000599	-5.7846658E+01	1.5419294E+02	3.5588009E+02	5.7942490E+02	8.7722455E+02
000600	1.1212214E+03	1.1541824E+03	1.1518611E+03	9.4203092E+02	5.4030442E+02
000601	-3.5545003E+01	1.5041468E+02	-5.6987252E+02	-8.9772310E+02	1.9715175E+03
000602	1.5643871E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000603	1.0761355E+00	9.0125519E+00	-1.6858820E+01	-3.7102804E+01	-8.6642049E+01
000604	-1.5703564E+02	-2.7513041E+02	-4.5130837E+02	-7.0776183E+02	-1.0446450E+03
000605	-1.4487078E+03	-1.8692702E+03	-2.3880154E+03	-2.8067078E+03	-3.3410802E+03
000606	-3.8559030E+03	-4.3843916E+03	-4.5542515E+03	-4.8694049E+03	-5.0390446E+03
000607	-5.0769555E+03	-4.9279847E+03	-4.6275005E+03	-4.0775766E+03	-3.2393895E+03
000608	-2.1710548E+03	-8.3495872E+02	7.8810918E+02	2.6316170E+03	4.7142330E+03
000609	6.9491255E+03	9.2604127E+03	1.1524025E+04	1.3685515E+04	1.5672403E+04
000610	1.7362219E+04	1.8840761E+04	1.9943022E+04	2.0737451E+04	2.1205585E+04
000611	2.1388423E+04	2.1278368E+04	2.0977596E+04	2.0559050E+04	2.0065004E+04
000612	2.0212249E+04	1.9492025E+04	1.8829911E+04	1.8237987E+04	1.7749108E+04
000613	1.7442580E+04	1.6669838E+04	1.5978421E+04	1.5412986E+04	1.5529079E+04
000614	1.4476561E+04	1.3941732E+04	1.4340021E+04	1.2070660E+04	1.2720182E+04
000615	9.6641905E+03	8.6428251E+03	7.4271301E+03	6.3105084E+03	6.3673451E+03
000616	6.0708932E+03	6.0532802E+03	4.8294821E+03	4.9320575E+03	3.5624987E+03
000617	2.9059444E+03	1.1351017E+03	-3.1705787E+02	-1.8692257E+03	-3.8552011E+03
000618	-5.4197643E+03	-5.4462613E+03	-5.1573924E+03	-3.6215951E+03	-9.1656659E+02
000619	2.7670921E+03	2.0174573E+03	6.5948069E+03	8.2338889E+03	-9.3307466E+03
000620	-9.3572403E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000621	0.0005 0.0010	0.0015 0.0020	0.0025 0.0030	0.0035 0.0040	0.0045 0.0050
000622	0.0055 0.0060	0.0065 0.0070	0.0075 0.0080	0.0085 0.0090	0.0095 0.0100
000623	0.0105 0.0110	0.0115 0.0120	0.0125 0.0130	0.0135 0.0140	0.0145 0.0150
000624	0.0155 0.0160	0.0165 0.0170	0.0175 0.0180	0.0185 0.0190	0.0195 0.0200
000625	0.0205 0.0210	0.0215 0.0220	0.0225 0.0230	0.0235 0.0240	0.0245 0.0250
000626	0.0255 0.0260	0.0265 0.0270	0.0275 0.0280	0.0285 0.0290	0.0295 0.0300
000627	0.0305 0.0310	0.0315 0.0320	0.0325 0.0330	0.0335 0.0340	0.0345 0.0350
000628	0.0355 0.0360	0.0365 0.0370	0.0375 0.0380	0.0385 0.0390	0.0395 0.0400
000629	0.0405 0.0410	0.0415 0.0420	0.0425 0.0430	0.0435 0.0440	0.0445 0.0450
000630	0.7323460E-02	-0.44074261E-03	0.66207946E-03	-0.29226363E-03	0.0E+00
000631	0.40084907E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000632	-0.27176666E+02	0.21129340E+03	0.13364318E+02	-0.19311670E+04	0.0E+00
000633	0.67461013E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000634	-0.71967720E-02	0.14495527E-02	0.32403130E-02	-0.44640177E-02	0.0E+00
000635	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000636	0.17724540E+01	-0.44368880E+02	0.20554680E-01	0.0E+00	0.0E+00
000637	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000638	0.20006200E+01	-0.50097080E+02	0.10044000E+01	0.17484950E-01	0.0E+00
000639	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000640	-0.87239000E+03	0.26248000E+02	-0.09787200E+01	0.00271270E+01	0.0E+00
000641	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000642	0.10111000E+04	-0.29485000E+02	0.25312000E+01	-0.00666590E+01	0.0E+00
000643	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000644	-0.22172000E+02	0.52157000E+01	-0.02737800E+01	0.58282000E-02	0.0E+00
000645	0.04826500E+01	-0.29189000E-01	0.0E+00	0.0E+00	0.0E+00
000646	-0.06839500E+01	0.18552000E+01	-0.00378920E+01	0.40527000E+02	0.0E+00
000647	0.54573000E+01	-0.32436000E+01	-0.01769100E+01	0.00641000E+01	0.0E+00

000001 COMPILER (DATA=SHORT)

000002 COMMON /TITLE/ TESTID(12),DAY(2),RUNTIME(2),IPAGE

000003 COMMON /TAPEN/ CHAN1(100),CHAN2(100),CHAN3(100),

000004 COMMON /TAPEN/ CHAN1(100),CHAN2(200),DEC(200),MPAR

000005 COMMON /TAPEN/ TSTART,TSTOP,INT1,INT2,IAVE,NSETS,INPUT(100,50),

000006 ATIME(50),TIME,END

000007 COMMON /CALC/ INPT(100),GEOM(50),OUT(120)

000008 INTEGER TESTID,DAY,PARID,CHAN1,CHAN2,CHAN3,CHAN4,CHANID,UNITS,DEC,

000009 TAPEN,TAPEOT

000010 REAL INPUT,INPT

000011 DIMENSION OUTPUT(120,50)

000012 DATA NSAT,MPAR,MPAR /22,33,95/

000013 CALL IMPROB

000014 CALL SATUR(SAT)

000015 CALL CHIMP(TAPEIN,TAPEOT)

000016 CALL GEOMT

000017 CALL OUTROM(MPAR)

000018 NSETS=0

000019 IFILE=0

000020 10 READ (5,1000) TSTART,TSTOP,INT1,INT2,IAVE,IFLAG,NRTHR,END

000021 1000 FORMAT(F10.0,F10.0,F10.0,F10.0)

000022 GO TO 50

000023 20 CALL TAP2

000024 GO TO 55

000025 50 CALL TAP1

000026 55 IF (NSETS.GE.50) GO TO 60

000027 IF (IEND.EQ.0) GO TO 10

000028 DO 540 I=1,NSETS

000029 DO 100 J=1,MPAR

000030 100 INPT(J)=INPT(J,I)

000031 CALL FLOW(JFLAG)

000032 IF (JFLAG.GT.1) GO TO 540

000033 CALL SUCTON (IFLAG,JFLAG)

000034 IF (JFLAG.GT.1) GO TO 540

000035 CALL RADTHR (NRTHR)

000036 CALL AXFOR

000037 CALL PERFOR(JFLAG)

000038 IF (JFLAG.GT.1) GO TO 540

000039 DO 500 J=1,36

000040 500 OUTPUT(J,I)=OUT(J)

000041 DO 510 J=40,75

000042 510 OUTPUT(K,I)=OUT(J)

000043 K=J-3

000044 DO 520 J=80,83

000045 520 OUTPUT(K,I)=OUT(J)

000046 K=J-7

000047 DO 530 J=85,103

000048 530 OUTPUT(K,I)=OUT(J)

000049 K=J-8

000050 540 CONTINUE

000051 CALL QUPT (OUTPUT,ATIME,MPAR,NSETS,IFLAG,TAPEIN,TAPEOT)

000052 END FILE 2

000053 IF (TIME.LT.TSTOP) GO TO 20

000054 END FILE 2


```

000057      IF (IEND.EQ.1) GO TO 10
000058      STOP
000059      END
000060      SUBROUTINE CHINPT(TAPEIN,TAPEOT)
000061      COMPILER (DATA=SHORT)
000062      COMMON /TAPEIN/ CHAN1(100),CHAN2(100),CHAN3(100),CHAN4(100),
000063      1PARID(100),CHANID(200),UNITS(200),DEC(200),NPAR
000064      COMMON /TITLE/ TESTID(12),DAY(2),RUNTME(2),IPAGE
000065      INTEGER CHAN1,CHAN2,CHAN3,CHAN4,PARID,CHANID,UNITS,DEC,END,
000066      1PARCK(100),TAPEIN,TAPEOT
000067      DIMENSION DEF(100,10),ICHAN(4),IDN(4),DEFIN(10)
000068      DATA BLANK /'
000069      DATA PARID /'PATM ','PSD ','TD ','PLFI ','PLFO ','PLRI ','
000070      1'PLRO ','MREF ','DPORF1','DPORF2','PORE ','PTK ','TTK ','
000071      2'PI ','TI ','PR ','T2 ','PID ','P708 ','P725 ','
000072      3'PDIFI1','PDIFI2','PDIFI3','PDIFI4','PDIFI5','PDIFI6','PDIFI7',
000073      4'PDIFI8','PDIFI9','PDIFO ','N ','P707 ','P725 '/
000074      DATA END/'END '/
000075      LINE=0
000076      IPAGE=1
000077      READ (1) DAY,RUNTME,TESTID,TAPEIN,TAPEOT
000078      READ (1) MWORDS,(CHANID(I),I=1,MWORDS)
000079      READ (1) MWORDS,(UNITS(I),I=1,MWORDS)
000080      READ(1) MWORDS,(DEC(I),I=1,MWORDS)
000081      TAPEIN=TAPEOT
000082      DO 100 I=1,2
000083      DAY(I)=BLANK
000084      100 RUNTME(I)=BLANK
000085      CALL DATE (9,DAY)
000086      CALL TOD (8,RUNTME)
000087      IFLAG=0
000088      DO 210 I=1,NPAR
000089      210 PARCK(I)=0
000090      READ (5,20) TAPEOT
000091      240 READ (5,20) IDENT,(DEFIN(J),J=1,10),(ICHAN(I),I=1,4)
000092      20 FORMAT (A6,1X,10A6,1X,4I3)
000093      K=0
000094      250 K=K+1
000095      IF (IDENT.EQ.END) GO TO 270
000096      IF (PARID(K).EQ.IDENT) GO TO 260
000097      IF (K.GE.NPAR) GO TO 255
000098      GO TO 250
000099      255 WRITE (6,1000) IDENT
000100      1000 FORMAT (//10X,A6,' IS AN UNRECOGNIZABLE PARAMETER IDENTIFICATION')
000101      GO TO 240
000102      260 PARCK(K)=1
000103      CHAN1(K)=ICHAN(1)
000104      CHAN2(K)=ICHAN(2)
000105      CHAN3(K)=ICHAN(3)
000106      CHAN4(K)=ICHAN(4)
000107      N=1
000108      DO 265 I=2,4
000109      IF (ICHAN(I).EQ.0) GO TO 266
000110      265 N=I
000111      266 DO 267 I=1,N
000112      J=ICHAN(I)
000113      267 IDN(I)=CHANID(J)
000114      GO 268 I=1,10
000115      268 DEF(K,I)=DEFIN(I)

```

```

000117 WRITE (6,1100) IPAGE
1100 FORMAT (11.52X,LH2 PUMP TEST,44X,PAGE,12)
1110 FORMAT (12A6,12X,DATE,2A6,TIME,2A6)
WRITE (6,1110) TESTID,DAY,RUNTIME
1130 FORMAT (/,INPUT TAPE = ,A6)
WRITE (6,1130) TAPEIN,TAPEOT
WRITE (6,1120)
WRITE (6,1120) PARAMETER,20X,DEFINITION,33X,CHANNELS USED,/)
1120 FORMAT (1X,PARAMETER,20X,DEFINITION,33X,CHANNELS USED,/)
209 WRITE (6,1010) PARID(K),(DEF(K),L,1,10),(CHAN(I),IDN(I),I=1,N)
1010 FORMAT (1X,A6,2X,10A6,4(2X,13,1X,A6))
IF (LINE.LT.50) GO TO 240
LINE=0
IPAGE=IPAGE+1
GO TO 240
270 DO 300 I=1,NPAR
IF (PARCK(I).EQ.1) GO TO 300
WRITE (6,1020) PARID(I)
1020 FORMAT (/,19X,/, NO CHANNEL IDENTIFICATION FOR ,A6)
IFLAG=1
300 CONTINUE
IF (IFLAG.EQ.0) STOP
RETURN
END
SUBROUTINE OUTNOM(NPAR)
COMMON /TITLE/ TESTID(12),DAY(2),RUNTIME(2),IPAGE
COMMON /NOMEN/ HED(120),DEC(120),UN(120)
DIMENSION HED(120),DEC(120),UN(120)
INTEGER HED,DEC,UN,BLANK,TESTID,DAY,RUNTIME,IPAGE,UN(I)
DATA BLANK /
DATA V(1),V(2),V(3),V(4),V(5),V(6),V(7),V(8),V(9),V(10),V(11),V(12),V(13),V(14)
V(15),V(16),V(17),V(18),V(19),V(20),V(21),V(22),V(23),V(24),V(25),V(26),V(27),V(28),V(29),V(30)
END
SUBROUTINE OUTPT (OUTPUT,LINE,NPAR,HSETS,FILE,TAPEIN,TAPEOT)
END
000166
000167
000168 COMMON /TITLE/ TESTID(12),DAY(2),RUNTIME(2),IPAGE
000169 COMMON /NOMEN/ HED(120),DEC(120),UN(120)
000170 INTEGER HED,DEC,UN,TESTID,DAY,RUNTIME,IPAGE,UN(I),BLANK,
000171 TAPEIN,TAPEOT
000172 DIMENSION OUTPUT(120,50),ALINE(50),NUM(10)
000173 DATA V(1),V(2),V(3),V(4),V(5),V(6),V(7),V(8),V(9),V(10),V(11),V(12),V(13),V(14)
000174 V(15),V(16),V(17),V(18),V(19),V(20),V(21),V(22),V(23),V(24),V(25),V(26),V(27),V(28),V(29),V(30)
000175
000176
000177
000178
000179
000180
000181
000182
000183
000184
000185
000186
000187
000188
000189
000190
000191
000192
000193
000194
000195
000196
000197
000198
000199
000200
000201
000202
000203
000204
000205
000206
000207
000208
000209
000210
000211
000212
000213
000214
000215
000216
000217
000218
000219
000220
000221
000222
000223
000224
000225
000226
000227
000228
000229
000230
000231
000232
000233
000234
000235
000236
000237
000238
000239
000240
000241
000242
000243
000244
000245
000246
000247
000248
000249
000250
000251
000252
000253
000254
000255
000256
000257
000258
000259
000260
000261
000262
000263
000264
000265
000266
000267
000268
000269
000270
000271
000272
000273
000274
000275
000276
000277
000278
000279
000280
000281
000282
000283
000284
000285
000286
000287
000288
000289
000290
000291
000292
000293
000294
000295
000296
000297
000298
000299
000300
000301
000302
000303
000304
000305
000306
000307
000308
000309
000310
000311
000312
000313
000314
000315
000316
000317
000318
000319
000320
000321
000322
000323
000324
000325
000326
000327
000328
000329
000330
000331
000332
000333
000334
000335
000336
000337
000338
000339
000340
000341
000342
000343
000344
000345
000346
000347
000348
000349
000350
000351
000352
000353
000354
000355
000356
000357
000358
000359
000360
000361
000362
000363
000364
000365
000366
000367
000368
000369
000370
000371
000372
000373
000374
000375
000376
000377
000378
000379
000380
000381
000382
000383
000384
000385
000386
000387
000388
000389
000390
000391
000392
000393
000394
000395
000396
000397
000398
000399
000400
000401
000402
000403
000404
000405
000406
000407
000408
000409
000410
000411
000412
000413
000414
000415
000416
000417
000418
000419
000420
000421
000422
000423
000424
000425
000426
000427
000428
000429
000430
000431
000432
000433
000434
000435
000436
000437
000438
000439
000440
000441
000442
000443
000444
000445
000446
000447
000448
000449
000450
000451
000452
000453
000454
000455
000456
000457
000458
000459
000460
000461
000462
000463
000464
000465
000466
000467
000468
000469
000470
000471
000472
000473
000474
000475
000476
000477
000478
000479
000480
000481
000482
000483
000484
000485
000486
000487
000488
000489
000490
000491
000492
000493
000494
000495
000496
000497
000498
000499
000500
000501
000502
000503
000504
000505
000506
000507
000508
000509
000510
000511
000512
000513
000514
000515
000516
000517
000518
000519
000520
000521
000522
000523
000524
000525
000526
000527
000528
000529
000530
000531
000532
000533
000534
000535
000536
000537
000538
000539
000540
000541
000542
000543
000544
000545
000546
000547
000548
000549
000550
000551
000552
000553
000554
000555
000556
000557
000558
000559
000560
000561
000562
000563
000564
000565
000566
000567
000568
000569
000570
000571
000572
000573
000574
000575
000576
000577
000578
000579
000580
000581
000582
000583
000584
000585
000586
000587
000588
000589
000590
000591
000592
000593
000594
000595
000596
000597
000598
000599
000600

```

```

000177      26H)/4X,' 6HSEC',3,'X',' '(5X,A6,' ')/'/'
000178      DATA G(22) /'/'/
000179      DATA NUM/'1','2','3','4','5','6','7','8','9','10'/
000180      DATA BLANK /' '/
000181      IF (JFILE.GT.0) GO TO 100
000182      WRITE(2) DAY,RUNTIME,TESTID,TAPEIN,TAPEOT
000183      WRITE (2) MPAR,(HED(I),I=1,MPAR)
000184      WRITE (2) MPAR,(UN(I),I=1,MPAR)
000185      WRITE (2) MPAR,(DEC(I),I=1,MPAR)
000186      100 DO 200 K=1,MPAR,10
000187          IPAGE=IPAGE+1
000188          L=K+9
000189          NCOL=10
000190          IF (L.LE.MPAR) GO TO 150
000191          L=MPAR
000192          NCOL=MPAR-K+1
000193      150 V(2)=NUM(NCOL)
000194          V(7)=NUM(NCOL)
000195          V(12)=NUM(NCOL)
000196          WRITE (6,2000) IPAGE
000197          WRITE (6,2010) TESTID,DAY,RUNTIME
000198          WRITE (6,V) (I,I=K,L),(HED(I),I=K,L),(UN(I),I=K,L)
000199          M=1
000200          DO 180 I=K,L
000201              M=M+2
000202      180 F(M)=DEC(I)
000203          DO 182 I=1,M
000204      182 G(I)=F(I)
000205          IF (N.EQ.21) GO TO 200
000206          N=N+1
000207          DO 185 I=N1,21
000208      185 G(I)=BLANK
000209          200 WRITE (6,G) (ATIME(M),(OUTPUT(I,V),I=K,L),M=1,NSETS)
000210          DO 300 J=1,NSETS
000211      300 WRITE (2) MPAR,ATIME(J),(OUTPUT(I,J),I=1,MPAR)
000212          DO 400 J=1,NSETS
000213          DO 400 J=1,50
000214      400 OUTPUT(I,J)=0.0
000215          IFILE=1
000216          2000 FORMAT ('1',52X,'LH2 PUMP TEST',44X,'PAGE ',I4)
000217          2010 FORMAT (12A6,12X,'DATE ',2A6,'TIME ',2A6/)
000218          RETURN
000219          END
000220          SUBROUTINE GEOMT
000221          COMMON /CALC/ INPT(100),GEOM(50),OUT(120)
000222          COMMON /TITLE/ TESTID(12),DAY(2),RUNTIME(2),IPAGE
000223          PEAL INPT
000224          DATA NUM/30/
000225          EQUIVALENCE ((GEOM(1),DSL1),(GEOM(2),DSL2),(GEOM(3),ALBF),
000226      1          (GEOM(4),CLARF),(GEOM(5),ALRR),(GEOM(6),CLABR),
000227      2          (GEOM(7),A12),(GEOM(8),D12),(GEOM(9),RFT2),
000228      3          (GEOM(10),Z2),(GEOM(11),RPTAP),(GEOM(12),ADFN),
000229      4          (GEOM(13),DDL),(GEOM(14),RHORFF),(GEOM(15),OPFD),
000230      5          (GEOM(16),ORFCOE),(GEOM(17),ORFBTA),(GEOM(18),R),
000231      6          (GEOM(19),R723),(GEOM(20),R727),(GEOM(21),R728),
000232      7          (GEOM(22),R724),(GEOM(23),R725),(GEOM(24),R726),
000233      8          (GEOM(25),RLF),(GEOM(26),RLM),(GEOM(27),RLI),
000234      9          (GEOM(28),RIN),(GEOM(29),RLD),(GEOM(30),PLS)
000235          IPAGE=IPAGE+1

```

```

000237 1010 FORMAT('1',52X,'LH2 PUMP TEST',44X,'PAGE ',I4)
000238 WRITE (6,1020) TEST10,DAY,RUNTIME
000239 1020 FORMAT(12A6,12X,'DATE ',2A6,'TIME ',2A6)
000240 READ (5,1000) (GEOM(I),I=1,NUM)
000241 1000 FORMAT(8F10.0)
000242 WRITE(6,2000) DSL1
000243 2000 FORMAT (' DSL1 SUCTION LINE DIAMETER UPSTREAM FLOW COND.',F6.3,
000244 1,F6.3,' IN')
000245 WRITE(6,2010) DSL2
000246 2010 FORMAT (' DSL2 SUCTION LINE DIAMETER DOWNSTREAM FLOW COND.',
000247 12FX,F6.3,' IN')
000248 WRITE(6,2020) ALBF
000249 2020 FORMAT (' ALBF FRONT LABYRINTH FLOW AREA',6FX,F6.3,' SQ-IN')
000250 WRITE(6,2030) CLARF
000251 2030 FORMAT (' CLARF FRONT LABYRINTH COEFFICIENT',44X,F6.4)
000252 WRITE(6,2040) ALBR
000253 2040 FORMAT (' ALBR REAR LABYRINTH FLOW AREA',47X,F6.3,' SQ-IN')
000254 WRITE(6,2050) CLARR
000255 2050 FORMAT (' CLARR REAR LABYRINTH COEFFICIENT',45X,F6.4)
000256 WRITE (6,2060) AI2
000257 2060 FORMAT (' AI2 IMPELLER DISCHARGE BLOCKED AREA',40X,F6.2
000258 1' SQ-IN')
000259 WRITE (6,2070) DI2
000260 2070 FORMAT (' DI2 IMPELLER DISCHARGE DIAMETER',44X,F6.3,' IN')
000261 WRITE (6,2080) BET2
000262 2080 FORMAT (' BET2 IMPELLER DISCHARGE BLADE ANGLE',41X,F6.2,
000263 1' DEG')
000264 WRITE (6,2090) Z2
000265 2090 FORMAT (' Z2 NUMBER OF IMPELLER BLADES',50X,I2)
000266 WRITE (6,3000) RPTAP
000267 3000 FORMAT ('RPTAP DIFFUSER INLET PRESSURE TAP RADIAL LOCATION',
000268 12FX,F6.3,' IN')
000269 WRITE (6,3010) ADFD
000270 3010 FORMAT (' ADFD DIFFUSER DISCHARGE FLOW AREA',42X,F6.2,
000271 1'SQ-IN')
000272 WRITE (6,3020) DDL
000273 3020 FORMAT (' DDL DISCHARGE LINE DIAMETER',48X,F6.3,' IN')
000274 WRITE (6,3030) RHOREF
000275 3030 FORMAT (' RHOREF REFERENCE DENSITY',54X,F6.4,' LB/CU-FT')
000276 WRITE (6,3040) ORFD
000277 3040 FORMAT (' ORFD BEARING COOLANT ORIFICE DIAMETER',39X,F6.4,
000278 1' IN')
000279 WRITE (6,3050) ORFCOE
000280 3050 FORMAT (' ORFCOE BEARING COOLANT ORIFICE COEFFICIENT',36X,
000281 1F6.4)
000282 WRITE (6,3060) ORFBTA
000283 3060 FORMAT (' ORFBTA BEARING COOLANT ORIFICE BETA',43X,F6.4)
000284 3070 FORMAT (' R707 RADIAL LOCATION OF PRESSURE TAP 707',35X,
000285 1F6.4,' IN')
000286 WRITE (6,3070) R707
000287 3070 FORMAT (' R707 DIFFUSER VANE INLET WIDTH',45X,F6.4,' IN')
000288 3090 FORMAT (' R706 RADIAL LOCATION OF PRESSURE TAP 706',35X,
000289 1F6.4,' IN')
000290 WRITE (6,3090) R706
000291 4000 FORMAT (' R708 RADIAL LOCATION OF PRESSURE TAP 708',35X,
000292 1F6.4,' IN')
000293 WRITE (6,4000) R708
000294 4010 FORMAT (' R709 RADIAL LOCATION OF PRESSURE TAP 709',35X,
000295 1F6.4,' IN')
000296 WRITE (6,4010) R709

```



```

000357 COMMON /SAT/ HSAT(25),PSAT(25),TSAT(25),SSAT(25),RHOSAT(25),
000358 1EMPT(25),EMPS(25),EMTS(25),EMHS(25),EMRHOS(25)
000359 21100,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000360 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000361 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000362 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000363 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000364 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000365 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000366 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000367 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000368 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000369 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000370 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000371 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000372 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000373 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000374 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000375 21000,21000,21000,21000,21000,21000,21000,21000,21000,21000,
000376 C*** COMPUTE TANK CONDITIONS
000377 CALL PTENTH(PTK,TTK,1,HTK,JFLG)
000378 IF (JFLG.GT.1) RETURN
000379 CALL SPLNT (H,TSAT,PSAT,EMPT,TTK,PVAPTK)
000380 C*** CHECK FOR VAPOR UPSTREAM OF FLOW CONDITIONER
000381 IF (P1.GT.PVAPTK) GO TO 90
000382 WRITE (6,1020)
000383 1020 FORMAT (' POSSIBLE VAPOR UPSTREAM OF FLOW CONDITIONER')
000384 90 CALL PTDEHS(P1,T1,1,RH01,JFLG)
000385 IF (JFLG.GT.1) RETURN
000386 V1=144.*.0017/(RH01*A1)
000387 H1=H*(1.+V1/2.*H1,JFLG)
000388 H1=H1*(1.+V1/2.*H1,778.16)
000389 CALL SPLNT (H,TSAT,PSAT,EMPT,T1,PVAP1)
000390 IF (P2.LE.(PVAP1+.3)) GO TO 100
000391 C*** SINGLE PHASE DOWNSTREAM OF FLOW CONDITIONER
000392 CALL PTDEHS(P2,T2,2,RH02,JFLG)
000393 IF (JFLG.GT.1) RETURN
000394 CALL PTENTH(P2,T2,2,HT2,JFLG)
000395 IF (JFLG.GT.1) RETURN
000396 V2=144.*.0017/(RH02*A2)
000397 H2=H2+V2*.2/(2.*32.174*778.16)
000398 CALL PTENTR(P2,T2,1,S2,JFLG)
000399 IF (JFLG.GT.1) RETURN
000400 RH010=RH02
000401 X2=0.0
000402 R=0.
000403 ALPHA=0.
000404 RHOVAP=0.
000405 GO TO 160
000406 C*** POSSIBLE TWO PHASE DOWNSTREAM OF FLOW CONDITIONER
000407 100 H2=H1
000408 IF (IFLAG.NE.0) GO TO 105
000409 HT0=HT
000410 GO TO 106
000411 HT0=HTK
000412 105 ICOUNT=0
000413 106 ICOUNT=ICOUNT+1
000414 110 ICOUNT=ICOUNT+1
000415 CALL PHTEMP(P2,H2,1,T2CALC,X2,JFLG)

```

```

000417 CALL PHDENS(P2,H2,1,RH02,RHOLI0,Y2,JFL6)
000418 IF (JFL6.GT.1) RETURN
000419 IF (RHOLI0.GT.0.0) GO TO 120
000420 RHOLI0=RH02
000421 120 V2=144.*NDOT/(RH02*A2)
000422 H2HEWHTOT-V2**2/(2.*32.174*778.16)
000423 IF (ABS(1.-H2/RH02).LE.0.00001) GO TO 150
000424 IF (ICOUNT.GE.30) GO TO 315
000425 WRITE (6,1000)
000426 1000 FORMAT (' SOLUTION FOR ENTHALPY DOWNSTREAM OF FLOW CONDITIONER DID
000427 1 NOT CONVERGE IN 30 ITERATIONS')
000428 150 CALL PHEINTR(P2,H2,1,S2,JFL6)
000429 IF (JFL6.GT.1) RETURN
000430 H21=H2+V2**2/(2.*32.174*778.16)
000431 RH021=V2+RHOLI0/(H21/RH02+X2-1.0)
000432 B=X2*RHOLI0/((1.-X2)*RHOVAP)
000433 ALPHA=B/(B+1.)
000434 C *** FIND SATURATION PRESSURE CORRESPONDING TO S2
000435 160 CALL SPLNT (N,SSAT,TSAT,EMTS,S2,T2CALC)
000436 CALL SPLNT (N,SSAT,PSAT,EMPS,S2,PVAP2)
000437 CALL SPLNT (N,SSAT,HSAT,EMHS,S2,HLI02)
000438 CALL SPLNT (N,SSAT,RHOSAT,ENRHOS,S2,RHOL2)
000439 GS=448.86*NDOT/RH02
000440 300 P2T=P2+RH02*V2**2/(2.*32.174*144.)
000441 PTEST=P2T+0.5
000442 CALL PHEINTR(PTEST,H2T,2,S11,JFL6)
000443 IF (JFL6.GT.1) RETURN
000444 DP=PTEST-P2T
000445 ICOUNT=1
000446 315 CALL PHEINTR(P2T,H2T,2,S11,JFL6)
000447 IF (JFL6.GT.1) RETURN
000448 DS=S11-STEST
000449 DPDS=DP/DS
000450 IF (ABS(1.-STEST/DS)-1.0E-05) 350,350,320
000451 320 IF (ICOUNT=30) 330,340,340
000452 330 ICOUNT=ICOUNT+1
000453 S11=STEST
000454 DP=DPDS*(STEST-S2)
000455 P2T=P2T-DP
000456 GO TO 315
000457 340 P2T=P2T-DP
000458 350 P2T=P2T-DP
000459 1000 FORMAT (' NO SOLUTION FOR P2T')
000460 350 NPSP=P2T-PVAP2
000461 NPSHA=144.*NPSP/RHOL2
000462 450 NPSHB=778.16*(H2T-HLI02)
000463 500 RETURN
000464 END
000465 SUBROUTINE FLOW(JFL6)
000466 COMMON / CALC/ IUPI(100),GEOM(50),OUT(120)
000467 REAL INPT
000468 EQUIVALENCE (GEOM(3),ALBF),(GEOM(4),CLARF),(GEOM(5),ALBR),
000469 1 (GEOM(6),CLARB),(GEOM(13),DPL),(GEOM(14),RHOREF),
000470 2 (GEOM(15),ORFD),(GEOM(16),ORFOE),(GEOM(17),ORFBTA)
000471 EQUIVALENCE (INPT(2),PS0),(INPT(3),TD),(INPT(4),PLF1),
000472 1 (INPT(5),PLF0),(INPT(6),PLR1),(INPT(7),PLR0),
000473 2 (INPT(8),WREF),(INPT(9),DPORF1),(INPT(10),DPORF2),
000474 3 (INPT(11),PORF)
000475 EQUIVALENCE (OUT(1),PH00),(OUT(2),W0),(OUT(3),OD),(OUT(4),HSD0),

```

(OUT(9),RHORL),(OUT(10),WLRB),(OUT(11),WS),(OUT(103),WRG)

CALL PIDENS(PSD,T0,3,RHOD,JFLG)

IF (JFLG.GT.1) RETURN

WD=MKF(RHOD)/RHORF

OR=448.00*WD/RHOB

CALL PTCHN(HSD,T0,4,HSRB,JFLG)

IF (JFLG.GT.1) RETURN

CALL PHOENS(PORF,HSDR,2,RHOBGR,RHOLRG,QUAL,JFLG)

IF (JFLG.GT.1) RETURN

WH1=0.5252*ORFCOF*ORFRTA**2*ORFD**2*SORT(HHOBGR*DPORF1)

WH2=0.5252*ORFCOF*ORFRTA**2*ORFD**2*SORT(HHOBGR*DPORF2)

WBO=WH1+W2

FRONT LAYER INTN FLOW

C

CALL PHOENS(PLEF,HSDR,3,RHOF, RHOLF,QUAL,JFLG)

IF (JFLG.GT.1) RETURN

DPL=F-PLF1-PLF0

PLF0=PLF1-PLF0

PLF1=PLF1-PLF0

C

CALL PHOENS(PHRO,HSDR,4,RHOKL,RHOLRL,QUAL,JFLG)

IF (JFLG.GT.1) RETURN

KLRR=0.60447*CLVRR*ALBR*SORT(RHOLP*DLR)

LEAKING HOUSING FLOW

C

SUCTION FLOW

C

WSD=DLR/HS

RECH=LEAK/HS

ELDR=WLRB/HS

RETURN

END

SUBROUTINE AXFOR

COMMON /CALC/ INPT(100),GEOM(50),OUT(120)

REAL INPT

GEOM(21),R70A),(GEOM(22),R72A),(GEOM(23),R725),

GEOM(24),R726),(GEOM(25),PLF),(GEOM(26),RLM),

GEOM(27),RLI),(GEOM(28),RIN),(GEOM(29),RLD),

GEOM(30),PLS)

EQUIVALENCE (INPT(16),PS),(INPT(20),P726),

INPT(4),P70A),(INPT(5),P705),(INPT(6),P724),

INPT(7),P723),(INPT(32),P707),(INPT(33),P725),

INPT(31),SN)

EQUIVALENCE (OUT(11),VWIN),(OUT(34),RHORL),(OUT(45),P2F),

OUT(46),PLF),(OUT(47),XKSOV),(OUT(48),XKSOV),

OUT(49),FE),(OUT(90),FELR),(OUT(91),FIN),

OUT(92),FOV),(OUT(93),FMT),(OUT(94),P2R),

OUT(95),PLD),(OUT(96),XKROV),(OUT(97),XKROV),

OUT(98),FB),(OUT(99),F723),(OUT(100),FAS),

OUT(101),FROV),(OUT(102),FAX),(OUT(20),RH02)

C-CONSTANTS

R2 = D2/2.

R70A = R70A**2

R707 = R707**2

R70G = R70G**2

R726 = R726**2

R725 = R725**2

R724 = R724**2

R70 = R70**2


```

000537 PLM0 = PLM**2
000538 RL10 = RL1**2
000539 R1N0 = R1N**2
000540 P7260 = P726**2
000541 P7250 = P725**2
000542 R7240 = R724**2
000543 PLD0 = PLD**2
000544 PL50=RL5**2
000545 C-PRESSURE EXTRAPOLATIONS SI ROUND
P2F = (R20-R7070)*(P708-P707)/(R7080-R7070)+P707
P2F = (R20-R7070)*(P708-P706)/(R7070-R7060)
000547 C-K-VALUES SHK00D
XKK = 11028./5H/SORT(RH02)
XKS0U = XKK * SORT((P708-P707)/(R7080-P7070))
XKS0V = XKK * SORT((P708-P706)/(R7080-R7060))
000551 C-SHROUD PRESSURE FORCES
FE27 = 1.5708*(R20-P7070)*(P2F+P707)
FE7L = 1.5708*(R7070-RLF0)*(P707+PLF)
000553 FE = FE27 + FE7L
000554 C-LABYRINTH PRESSURES
PLF1 = P705 + (PLF - P705)/3.
000557 PLF1 = P705 + (PLF - P705)/3.
000558 PLF0 = PLF - (PLF - P705)/3.
000559 C-PRESSURE FRONT LABYRINTH
FLM0 = 3.1417*(RLM0 - R1N0)**PLF0
000560 FLF1 = 3.1417*(RLF0 - RL10)**PLF1
000561 F705 = 3.1417*(RL10 - R1N0)*P705
000562 FFL0 = FLM0 + FLF1 + F705
000563 C-PRESSURE FORCE INDUCER
FIN = 3.1417 * R1N0 * PS
000564 C-MONITORING FORCE
FNT = 0.1495 * WH1**2/RH0SL
000567 C-FRONT SIDE PRESSURE FORCE
FFOV = FF + FFL1 + FIN
000569 C-PRESSURE EXTRAPOLATIONS DISK
P2K = (R20-R7250)*(P726-P725)/(R7260-R7250)+P725
000571 PLD = P725 - (R7250-PLD0)*(P725-P724)/(R7250-R7240)
000572 C-K-VALUES DISK
XK0U = XKK * SORT((P726-P725)/(R7260-P7250))
000573 XK0V = XKK * SORT((P726-P724)/(R7260-R7240))
000574 C-DISK PRESSURE FORCES
FK2D = 1.5708*(R20 - R7250)*(P2F+P705)
000575 FK2L = 1.5708*(R7250 - RL00)*(P725+PLN)
000576 FK = FK25 + FK2L
000577 F723 = 3.1417*(RL00-RL50)*P723
000578 FAS = 3.1417 * RL5**2 * PAMB
000581 C-BACKSIDE PRESSURE FORCE
FROV = FR + F723 + FAS
000582 C-AXIAL THRUST POSITIVE TOWARDS SUCTION
FAX=EROV-FFOV-FMT
000584 RETURN
000585 END
000587 SUBROUTINE RADTRN(N)
000588 COMMON /CALC/ IMP1(100),GEOM(50),CUT(120)
000589 DIMENSION P(9),THETA(10),FX(9),FY(9)
000591 EQUIVALENCE (IMP1(21),P(1))
000592 EQUIVALENCE (GEOM(8),D12),(GEOM(18),R)
000593 EQUIVALENCE (CUT(100),RUSL),(CUT(81),BETA),(CUT(82),RFP),
000594 (CUT(83),PAVE)
000595 DIM T1=509./1

```

```

000597      DO 10 I=2,N
000598      10 THETA(I)=THETA(I-1)+DTHETA
000599      THETA(N+1)=THETA(1)+360.
000600      SUMFY=0.0
000601      SUMPY=0.0
000602      DO 110 I=1,N
000603      PHI = (THETA(I+1)-THETA(I)) / 2.+ THETA(I)
000604      IF (PHI.LT.0.0) GO TO 40
000605      IF (PHI.LE.90.0) GO TO 50
000606      IF (PHI.LE.180.0) GO TO 60
000607      IF (PHI.LE.270.0) GO TO 70
000608      IF (PHI.LE.360.0) GO TO 80
000609      40 WRITE (6,1000)
000610      1000 FORMAT (' ANGLE LESS THAN 0 OR GREATER THAN 360 DEG, RADIAL THRUST
000611      ICALCULATION TERMINATED')
000612      RETURN
000613      50 PSI=PHI
000614      SIGNY=-1.
000615      SIGNX=-1.
000616      GO TO 100
000617      60 PSI=180.-PHI
000618      SIGNY=-1.
000619      SIGNX=1.
000620      GO TO 100
000621      70 PSI=PHI-180.0
000622      SIGNY=1.
000623      SIGNX=1.0
000624      GO TO 100
000625      80 PSI=360.-PHI
000626      SIGNY=1.
000627      SIGNX=-1.
000628      100 F=P(I)+W*DI2*ABS(SIN((THETA(I+1)-THETA(I))/(2.*57.296)))
000629      FX(I)=F*SIGNX*COS(PSI/57.296)
000630      FY(I)=F*SIGNY*SIN(PSI/57.296)
000631      SUMFX=SUMFX+FX(I)
000632      110 SUMFY=SUMFY+FY(I)
000633      IF (SUMFX.LE.0.0) GO TO 150
000634      IF (SUMFY.LE.0.0) GO TO 130
000635      BETA=57.296*ATAN(SUMFY/SUMFX)
000636      GO TO 200
000637      130 BETA=57.296*ATAN(SUMFY/SUMFX)+360.
000638      GO TO 200
000639      150 BETA=57.296*ATAN(SUMFY/SUMFX)+180.0
000640      200 RUSL=SQRT(SUMFX**2+SUMFY**2)
000641      SUMP=0.0
000642      DO 300 I=1,N
000643      300 SUMP=SUMP+P(I)
000644      PAVE=SUMP/N
000645      PFP=RUSL/PAVE
000646      RETURN
000647      END
000648      SUBROUTINE PERFOR(JFLG)
000649      COMMON /CALC/ INPT(100),GEOM(50),OUT(120)
000650      REAL INPT,N
000651      EQUIVALENCE (GEOM(9),RET2),(GEOM(10),Z2),(GFOM(13),DDL),
000652      1 (GEOM(8),DI2),(GFOM(7),AT2),(GEOM(11),RPTAP),
000653      2 (GEOM(12),ADFD)
000654      EQUIVALENCE (INPT(2),PSD),(INPT(3),TD),(INPT(1A),PTD),
000655      1 (INPT(19),PTIQ),(INPT(20),RPTP),(INPT(21),PDIPI1),
000656      (INPT(22),RPTIC),(INPT(23),RPTI3),(INPT(24),RPTI4),

```

(INPT(25),PDI15), (INPT(26),PDI16), (INPT(27),PDI17),
(INPT(28),PDI18), (INPT(29),PDI19), (INPT(30),PDI20),

(INPT(31),M), (INPT(16),PS)
EQUIVALENCE (OUT(1),RHOD), (OUT(2),RD), (OUT(3),QD), (OUT(4),HSDR),

(OUT(6),WLR), (OUT(9),WLR), (OUT(11),WS), (OUT(12),OS),
(OUT(25),SS), (OUT(40),US), (OUT(41),VDS),

(OUT(42),HTR), (OUT(43),PRD), (OUT(44),PTD),
(OUT(45),DHIS), (OUT(46),HRS), (OUT(47),HCO),

(OUT(48),GND), (OUT(49),DHAR), (OUT(50),DHI),
(OUT(51),EFTD), (OUT(52),EFTD), (OUT(53),PPSIN),

(OUT(54),PHSIN), (OUT(55),PHSIN), (OUT(56),ONS),
(OUT(57),PHI2), (OUT(58),PSIH), (OUT(59),HRIMP),

(OUT(60),PHOIN), (OUT(61),HIS), (OUT(62),PHIS),
(OUT(63),HNS), (OUT(64),HNS), (OUT(65),HCT),

(OUT(66),PHI1), (OUT(67),HNS), (OUT(68),EIMP),
(OUT(69),PHCG), (OUT(70),PHIS), (OUT(71),HNS),

(OUT(72),DHI), (OUT(73),HCT), (OUT(74),DHGF),
(OUT(75),DCHV),

EQUIVALENCE (OUT(83),PDI1A)
EQUIVALENCE (OUT(83),HIS), (OUT(22),HIS), (OUT(27),PTS),

CONSTANTS (OUT(34),PHOSL)

000078

000079

000080

000081

000082

000083

000084

000085

000086

000087

000088

000089

000090

000091

000092

000093

000094

000095

000096

000097

000098

000099

000100

000101

000102

000103

000104

(INPT(25),PDI15), (INPT(26),PDI16), (INPT(27),PDI17),
(INPT(28),PDI18), (INPT(29),PDI19), (INPT(30),PDI20),

(INPT(31),M), (INPT(16),PS)
EQUIVALENCE (OUT(1),RHOD), (OUT(2),RD), (OUT(3),QD), (OUT(4),HSDR),
(OUT(6),WLR), (OUT(9),WLR), (OUT(11),WS), (OUT(12),OS),
(OUT(25),SS), (OUT(40),US), (OUT(41),VDS),
(OUT(42),HTR), (OUT(43),PRD), (OUT(44),PTD),
(OUT(45),DHIS), (OUT(46),HRS), (OUT(47),HCO),
(OUT(48),GND), (OUT(49),DHAR), (OUT(50),DHI),
(OUT(51),EFTD), (OUT(52),EFTD), (OUT(53),PPSIN),
(OUT(54),PHSIN), (OUT(55),PHSIN), (OUT(56),ONS),
(OUT(57),PHI2), (OUT(58),PSIH), (OUT(59),HRIMP),
(OUT(60),PHOIN), (OUT(61),HIS), (OUT(62),PHIS),
(OUT(63),HNS), (OUT(64),HNS), (OUT(65),HCT),
(OUT(66),PHI1), (OUT(67),HNS), (OUT(68),EIMP),
(OUT(69),PHCG), (OUT(70),PHIS), (OUT(71),HNS),
(OUT(72),DHI), (OUT(73),HCT), (OUT(74),DHGF),
(OUT(75),DCHV),
EQUIVALENCE (OUT(83),PDI1A)
EQUIVALENCE (OUT(83),HIS), (OUT(22),HIS), (OUT(27),PTS),
CONSTANTS (OUT(34),PHOSL)

000105

000106

000107

000108

000109

000110

000111

000112

000113

000114

000115

000116

000117

000118

000119

000120

000121

000122

000123

000124

000125

000126

000127

000128

000129

000130

000131

000132

000133

000134

000135

000136

000137

000138

000139

000140

000141

000142

000143

000144

000145

000146

000147

000148

000149

000150

000151

000152

000153

000154

000155

000156

000157

000158

000159

000160

000161

000162

000163

000164

000165

000166

000167

000168

000169

000170

000171

000172

000173

000174

000175

000176

000177

000178

000179

000180

000181

000182

000183

000184

000185

000186

000187

000188

000189

000190

000191

000192

000193

000194

000195

000196

000197

000198

000199

000200

000201

000202

000203

000204

000205

000206

000207

000208

000209

000210

000211

000212

000213

000214

000215

000216

000217

000218

000219

000220

000221

000222

000223

000224

000225

000226

000227

000228

000229

000230

000231

000232

000233

000234

000235

000236

000237

000238

000239

000240

000241

000242

000243

000244

000245

000246

000247

000248

000249

000250

000251

000252

000253

000254

000255

000256

000257

000258

000259

000260

000261

000262

000263

000264

000265

000266

000267

000268

000269

000270

000271

000272

000273

000274

000275

000276

000277

000278

000279

000280

000281

000282

000283

000284

000285

000286

000287

000288

000289

000290

000291

000292

000293

000294

000295

000296

000297

000298

000299

000300

000301

000302

000303

000304

000305

000306

000307

000308

000309

000310

000311

000312

000313

000314

000315

000316

000317

000318

000319

000320

000321

000322

000323

000324

000325

000326

000327

000328

000329

000330

000331

000332

000333

000334

000335

000336

000337

000338

000339

000340

000341

000342

000343

000344

000345

000346

000347

000348

000349

000350

000351

000352

000353

000354

000355

000356

000357

000358

000359

00

```

000717 CALL PHDENS(PIMP,HBIMP,2,RHOD,RHOL,QUAL,JFLG)
000718 IF (JFLG.GT.1) RETURN
000719 IF (ABS(1.-RHOD/RHOD)-1.0E-05) 150,150,100
000720 C IMPELLER STATIC HEAD COEFFICIENT
000721 150 CALL PHTEMP(PDIFIA,HRIMP,2,TID,QI2,JFLG)
000722 IF (JFLG.GT.1) RETURN
000723 CALL PSENTH(PDIFIA,SS,2,HISIR,JFLG)
000724 IF (JFLG.GT.1) RETURN
000725 DHISI=(HISIR-HSB)*778.16
000726 HN2IS=DHISI/N**2
000727 HCIS=32.174*DHISI/U2**2
000728 C IMPELLER TOTAL HEAD COEFFICIENT
000729 HCIT=HCIS+(DI2/2./RPTAP)**2*(PSITH**2+PHI2**2)/2.
000730 DHITI=U2**2*HCIT/32.174
000731 HN2IT=DHITI/N**2
000732 EFIMP=HCIT/PSITH
000733 C HOUSING HEAD LOSS COEFFICIENT
000734 DHCHS=HCIT-HCO
000735 C DIFFUSER AND VOLUTE LOSSES
000736 CALL PSENTH(PDIF0,SS,3,HISDB,JFLG)
000737 IF (JFLG.GT.1) RETURN
000738 DHISD=(HISDB-HSB)*778.16
000739 HN2DS=DHISD/N**2
000740 C DIFFUSER DISCHARGE ANGLE BASED ON PFLRIDERS DEVIATION CRITERION
000741 CMS2=144.*(WS-WLRR)/RHOD/ADF0
000742 CUTH2=U2*PSITH
000743 ALS2R=ATAN(1./((2.01+0.245*CUTH2/CMS2)))
000744 HVDF=.975*(CMS2/SIN(ALS2R))**2/(2.*32.174)
000745 DHITD=DHISD+HVDF
000746 HCTD=32.174*DHITD/U2**2
000747 DHCDF=HCIT-HCTD
000748 DHCVD=HCTD-HCO
000749 RETURN
000750 END
000751 SUBROUTINE TAPE1
000752 COMMON / TITLE / TFSID(12),DAY(2),RUNTME(2),IPAGE
000753 COMMON /TAPEIN/ CHAN1(100),CHAN2(100),CHAN3(100),CHAN4(100),
000754 IPARID(100),CHANID(200),UNITS(200),DEC(200),NPAR
000755 COMMON /TAPE/ TSTART,TSTOP,INT1,INT2,IAVE,NSETS,INPUT,ATIME,TIME,
000756 IEND
000757 INTEGER CHAN1,CHAN2,CHAN3,CHAN4,PARID,CHANID,UNITS,UN(100),D(100)
000758 REAL INPUT
000759 DIMENSION INPUT(100,50),ATIME(50),DATA(200),NUM(10)
000760 INTEGER PGAGE
000761 INTEGER BLANK,F(22),G(22),V(14)
000762 INTEGER DEC,DAY,RUNTME,TESTID
000763 DATA BLANK /' ' //
000764 DATA PGAGE /'PSIG' //
000765 DATA F(1),F(2),F(4),F(6),F(8),F(10),F(12),F(14),F(16),F(18),F(20),
000766 1F(22) /'(F9.1',10*'F11.',') //
000767 DATA V(1),V(3),V(4),V(5),V(6),V(8),V(9),V(10),V(11),V(13),V(14)
000768 1/'(6X',10*'I3',6H)/3X',6HTIME',10*'3X',10*'5X,A6',
000769 26H)/4X',10*'6HSEC',3*'X',10*'5X,A6',') //
000770 DATA G(22) /' ' //
000771 DATA NUM /'1',2',3',4',5',6',7',8',9',10' //
000772 KENTR=1
000773 100 READ(1) NCHAN,TIME, (DATA(I),I=1,NCHAN)
000774 IF (TIME.LT.TSTART) GO TO 100
000775 BACKSPACE 1

```

```

000777      ENTRY TAPE2
000778      250 KENTR=2
000779      260 NSETS=NSETS+1
000780      DO 270 J=1,NPAR
000781      /270 INPUT(J,NSETS)=0.0
000782      ATIME(NSETS)=0.0
000783      DO 300 I=1,INT1
000784      READ(1) NCHAN,TIME,(DATA(J),J=1,NCHAN)
000785      IF (KENTR.EQ.1) GO TO 310
000786      IF (TIME.GE.TSTOP) GO TO 310
000787      300 CONTINUE
000788      310 NAVE=1
000789      320 ATIME(NSETS)=ATIME(NSETS)+TIME
000790      DO 350 J=1,NPAR
000791      N=1
000792      K=CHAN1(J)
000793      PAR=DATA(K)
000794      UN(J)=UNITS(K)
000795      D(J)=DEC(K)
000796      IF (CHAN2(J).EQ.0) GO TO 350
000797      N=2
000798      K=CHAN2(J)
000799      PAR=PAR+DATA(K)
000800      IF (CHAN3(J).EQ.0) GO TO 350
000801      N=3
000802      K=CHAN3(J)
000803      PAR=PAR+DATA(K)
000804      IF (CHAN4(J).EQ.0) GO TO 350
000805      N=4
000806      K=CHAN4(J)
000807      PAR=PAR+DATA(K)
000808      350 INPUT(J,NSETS)=INPUT(J,NSETS)+PAR/N
000809      IF (NAVE.GE.NAVE.OR.TIME.GE.TSTOP) GO TO 450
000810      DO 400 I=1,INT2
000811      READ(1) NCHAN,TIME,(DATA(J),J=1,NCHAN)
000812      IF (TIME.GE.TSTOP) GO TO 410
000813      400 CONTINUE
000814      410 NAVE=NAVE+1
000815      GO TO 320
000816      450 DO 500 J=1,NPAR
000817      INPUT(J,NSETS)=INPUT(J,NSETS)/NAVE
000818      IF (UN(J).NE.PGAGE) GO TO 500
000819      INPUT(J,NSETS)=INPUT(J,NSETS)+INPUT(1,NSETS)/2.036
000820      UN(J)='PSIA'
000821      500 CONTINUE
000822      ATIME(NSETS)=ATIME(NSETS)/NAVE
000823      IF (NSETS.LT.50.AND.TIME.LT.TSTOP) GO TO 260
000824      IF (IEND.EQ.0) RETURN
000825      DO 600 K=1,NPAR,10
000826      IPAGE=IPAGE+1
000827      L=K+9
000828      NCOL=10
000829      IF (L.LE.NPAR) GO TO 550
000830      L=NPAR
000831      NCOL=NPAR-K+1
000832      550 V(2)=NUM(NCOL)
000833      V(7)=NUM(NCOL)
000834      V(12)=NUM(NCOL)
000835      WRITE(6,6050) IPAGE

```

```

000837      WRITE (6,V) (I,I=K,L),(PARID(I),J=K,L),(UN(I),I=K,L)
000838      M=1
000839      DO 580 I=K,L
000840      M=M+2
000841      580 F(M)=D(I)
000842      DO 582 I=1,M
000843      582 G(I)=F(I)
000844      IF (M.EQ.21) GO TO 600
000845      M1=M+1
000846      DO 585 I=M1,21
000847      585 G(I)=BLANK
000848      600 WRITE (6,G) (ATIME(M),(INPUT(I,M),I=K,L),M=1,NSETS)
000849      6000 FORMAT (12A6,12X,'DATE ',2A6,'TIME ',2A6)
000850      6050 FORMAT ('1',52X,'LH2 PUMP TEST',44X,'PAGE ',I4)
000851      RETURN
000852      END
000853      C
000854      C SPLINT CALCULATES INTERPOLATED POINTS AND DERIVATIVES
000855      C FOR A SPLINE CURVE
000856      SUBROUTINE SPLINT (N,X,Y,EM,XX,YINT)
000857      DIMENSION Z(10),X(25),Y(25),EM(25)
000858      1000 FORMAT (' SPLINT USED FOR EXTRAPOLATION',3E20.7)
000859      MAX=1
000860      Z(1)=XX
000861      DO 140 I=1,MAX
000862      K=2
000863      IF (Z(I)-X(1))70,60,90
000864      60 YINT =Y(1)
000865      SK=X(K)-X(K-1)
000866      GO TO 130
000867      70 IF (Z(I)-(1.1*X(1)-0.1*X(2))) 75,120,120
000868      75 WRITE (6,1000) Z(I),X(1),X(2)
000869      SKW=16
000870      GO TO 120
000871      80 K=N
000872      IF (Z(I)-(1.1*X(N)-0.1*X(N-1))) 120,120,85
000873      85 WRITE (6,1000) Z(I),X(N-1),X(N)
000874      SKN=16
000875      GO TO 120
000876      90 IF (Z(I)-X(K))120,100,110
000877      100 YINT =Y(K)
000878      SK=X(K)-X(K-1)
000879      GO TO 130
000880      110 K=K+1
000881      IF (K-N)90,90,80
000882      120 CONTINUE
000883      SK=X(K)-X(K-1)
000884      YINT =EM(K-1)*(X(K)-Z(I))**3/6. /SK+EM(K)*(Z(I)-X(K-1))**3/6.
000885      1/SK+(Y(K)/SK-EM(K)*SK/6. )*(Z(I)-X(K-1))+(Y(K-1)/SK-EM(K-1)*SK/6.
000886      2 )*(X(K)-Z(I))
000887      130 DYDX =-EM(K-1)*(X(K)-Z(I))**2/2.0 /SK+EM(K)*(X(K-1)-Z(I))** 2/2
000888      1 /SK+(Y(K)-Y(K-1))/SK-(EM(K)-EM(K-1))*SK/6.
000889      D2YDX=(X(K)-Z(I))*EM(K-1)/SK+(Z(I)-X(K-1))*EM(K)/SK
000890      RCURV=((1.+DYDX**2)**1.5)/ABS(D2YDX)
000891      140 CONTINUE
000892      500 RETURN
000893      END
000894      SUBROUTINE SPLNE (N,X,Y,EM)
000895      INTEGER SR

```

```

000897 C SPLINE CALCULATES FIRST AND SECOND DERIVATIVES AT SPLINE POINTS 3K
000898 C END CONDITION-SECOND DERIVATIVES ARE THE SAME AT END POINT AND
000899 C ADJACENT POINT
000900 C
000901 DIMENSION X(25),Y(25),EM(25),G(25),SR(25),SLOPE(25),CURV(25)
000902 SRW=0
000903 SB(1)=-1.0
000904 G(1)=0.
000905 NO=N-1
000906 IF (NO-2) 20,7,7
000907 7 DO10 I=2,NO
000908 A=(X(I)-X(I-1))/6.
000909 C=(X(I+1)-X(I))/6.
000910 W=2. *(A+C)-A*SB(I-1)
000911 SB(I)=C/W
000912 F=(Y(I+1)-Y(I))/(X(I+1)-X(I))-(Y(I)-Y(I-1))/(X(I)-X(I-1))
000913 10 G(I)=(F-A+G(I-1))/W
000914 20 EM(N)=G(N-1)/(1. +SB(N-1))
000915 DO30 I=2,N
000916 K=N+1-I
000917 30 EM(K)=G(K)-SB(K)*EM(K+1)
000918 SLOPE(1)=(X(1)-X(2))/6. *(2. *EM(1)+EM(2))+(Y(2)-Y(1))/(X(2)-X(1
000919 1))
000920 DO40 I=2,N
000921 40 SLOPE(I)=(X(I)-X(I-1))/6. *(2. *EM(I)+EM(I-1))+(Y(I)-Y(I-1))/(X(
000922 1)-X(I-1))
000923 DO 45 I=1,N
000924 45 CURV(I)=((1.+SLOPE(I)**2)**1.5)/ABS(EM(I))
000925 IF (SRW) 50,100,50
000926 50 WRITE (6,1000) D, (X(I),Y(I),SLOPE(I),EM(I),CURV(I),I=1,N)
000927 100 D=1000
000928 1000 FORMAT ('1',15HNO. OF POINTS =,I3/10X,1HX,19X,1HY,19X,5HSLOPE,15X,
000929 A2HEM,15X,4HCURV/(5E20.8))
000930 END
000931 SUBROUTINE SATUR(N)
000932 COMPILER (DATA$SHORT)
000933 COMMON /SAT/ HSAT(25),PSAT(25),TSAT(25),SSAT(25),RHOSAT(25),
000934 1EMPT(25),EMPS(25),ENTS(25),EMHS(25),EMRHOS(25),EMTP(25),
000935 2HSATV(25),SSATV(25),TRHOSTV(25),EMHLP(25),EMHVP(25),EMSLP(25),
000936 3EMSV(25),EMROL(25),EMROVP(25),EMPH(25)
000937 C*** SATURATION DATA
000938 DATA HSAT /-132.81,-172.25,-129.29,-126.13,-122.79,-119.2,-115.38,
000939 1-111.31,-110.19,-106.96,-102.31,-97.32,-91.966,-86.208,-79.959,
000940 2-73.176,-65.733,-57.436,-48.009,-36.976,-22.458,16.550/
000941 DATA PSAT /1.0214,1.1433,1.9546,3.1302,4.7762,6.9953,9.8904,13.564
000942 1,14.596,18.120,23.705,30.406,38.371,47.688,58.519,70.967,85.149,
000943 2101.21,119.30,139.63,162.40,187.51/
000944 DATA TSAT /24.845,25.2,27.9,28.8,30.6,32.4,34.2,36.0,36.482,37.8,
000945 139.6,41.4,43.2,45.0,46.8,48.6,50.4,52.2,54.0,55.8,57.6,59.3568/
000946 DATA SSAT /1.18491,1.20743,1.31999,1.43138,1.54157,1.65296,1.76315
000947 1,1.87572,1.90534,1.98628,2.10204,2.21816,2.33665,2.45751,2.58193,
000948 22.71227,2.84853,2.99428,3.15306,3.33553,3.56422,4.19696/
000949 DATA RHOSAT /4.8086,4.7975,4.7434,4.6884,4.6298,4.5693,4.5055,
000950 14.4371,4.4185,4.3664,4.2889,4.2086,4.1205,4.0256,3.9226,3.8086,
000951 23.6805,3.5350,3.3664,3.1578,2.8711,1.9619/
000952 DATA HSATV / 60.315,61.104,64.965,68.612,72.045,75.223,78.103,
000953 180.683,81.408,82.987,84.690,86.207,87.124,87.539,87.316,86.357,
000954 284.489,81.472,76.866,69.891,58.502,16.358 /
000955 DATA SSATV / 8.9615,8.9821,8.6147,8.1936,7.9093,7.6545,7.4223,

```

25.8310.5.6568.5.4672.5.2492.4.9707.4.1946/
DATA RHOSIV / .007837.008666.07390.021130.030722.043083.
1.058647.077066.08351.10105.12927.16304.20317.25074.
2.3072.3745.4855.5547.6795.8452.1.0422.1.0619 /

CALL SPLINE (N,TSAT,PSAT,EMPT)
CALL SPLINE (N,SSAT,PSAT,EMPT)
CALL SPLINE (N,SSAT,TSAT,EMTS)
CALL SPLINE (N,SSAT,RHOSAT,EMRHOS)
CALL SPLINE (N,PSAT,HSAT,EMHLP)
CALL SPLINE (N,PSAT,HSATV,EMHVP)
CALL SPLINE (N,PSAT,SSAT,EMSLP)
CALL SPLINE (N,PSAT,SSATV,EMSLVP)
CALL SPLINE (N,PSAT,RHOSAT,EMRSLP)
CALL SPLINE (N,PSAT,RHOSATV,EMRSLVP)
RETURN
END
SUBROUTINE PARM
COMMON /PROP / T(30,50) ,SV(30,50) ,H(30,50) ,S(30,50) ,NUM(30) ,P(30) ,
IAA(5,90) ,RHOX(90) ,B(9,8)
COMMON /SAT /HSAT(25) ,PSATUR(25) ,TSAT(25) ,SSAT(25) ,RHOSAT(25) ,
EMPT(25) ,EMPS(25) ,EMTS(25) ,EMRHOS(25) ,EMTP(25) ,
EMSLP(25) ,EMSLVP(25) ,SSATV(25) ,RHOSIV(25) ,EMHLP(25) ,EMHVP(25) ,
EMSLP(25) ,EMSLVP(25) ,EMRSLP(25) ,EMRSLVP(25) ,EMRH(25)

DATA I/22/
ENTRY POINT FOR DENSITY (PP,TT)
C
C
ENTRY PDBMS (PP,TT,K,RHO,JFLG)
ENRMS=PDBMS
IF (PP.GT.PCRIT) GO TO 100
CALL SPLNT(N,TSAT,PSATUR,EMPT,TT,PSAT)
IF (PP.LT.PSAT) GO TO 160
CALL HROP (PP,TT,SV,T,I,2,C,JFLG,XMIN,XMAX)
RHO=1 /C
RETURN
C
C
ENTRY FOR ENTHALPY (PP,TT)
RETURN
C
C
ENTRY PENTH (PP,TT,K,ENTH,JFLG)
ENRMS=PENTH
IF (PP.GT.PCRIT) GO TO 101
CALL SPLNT(N,TSAT,PSATUR,EMPT,TT,PSAT)
IF (PP.LT.PSAT) GO TO 160
CALL HROP (PP,TT,H,T,I,3,ENTH,JFLG,XMIN,XMAX)
RETURN
C
C
ENTRY FOR ENTROPY (PP,TT)
RETURN
C
C
ENTRY PENTR (PP,TT,K,ENTRO,JFLG)
ENRMS=PENTR
IF (PP.GT.PCRIT) GO TO 102
CALL SPLNT(N,TSAT,PSATUR,EMPT,TT,PSAT)
IF (PP.LT.PSAT) GO TO 160
CALL HROP (PP,TT,S,T,I,4,ENTRO,JFLG,XMIN,XMAX)
IF (JFLG.GT.1) GO TO 110
105 RETURN

102 CALL HROP (PP,TT,S,T,I,4,ENTRO,JFLG,XMIN,XMAX)
IF (JFLG.GT.1) GO TO 110
101 CALL HROP (PP,TT,H,T,I,3,ENTH,JFLG,XMIN,XMAX)
IF (JFLG.GT.1) GO TO 110
RETURN
C
C
ENTRY FOR ENTROPY (PP,TT)
RETURN
C
C
ENTRY PENTR (PP,TT,K,ENTRO,JFLG)
ENRMS=PENTR
IF (PP.GT.PCRIT) GO TO 102
CALL SPLNT(N,TSAT,PSATUR,EMPT,TT,PSAT)
IF (PP.LT.PSAT) GO TO 160
CALL HROP (PP,TT,S,T,I,4,ENTRO,JFLG,XMIN,XMAX)
IF (JFLG.GT.1) GO TO 110
105 RETURN


```

001017      120 WRITE (6,2000) XMIN,XMAX,PP,ENTR,K
001018      2000 FORMAT (' MINIMUM TABULATED PRESSURE IS GREATER THAN P'//
001019      1' PMIN=',F10.2,5X,'PMAX=',F10.2,5X,'P=',F10.2,5X,A6,I2)
001020      RETURN
001021      130 WRITE (6,2010) XMIN,XMAX,PP,ENTR,K
001022      2010 FORMAT (' MAXIMUM TABULATED PRESSURE IS LESS THAN P'//
001023      1' PMIN=',F10.2,5X,'PMAX=',F10.2,5X,'P=',F10.2,5X,A6,I2)
001024      RETURN
001025      140 WRITE (6,2020) XMIN,XMAX,TT,ENTR,K
001026      2020 FORMAT (' MINIMUM TABULATED TEMPERATURE IS GREATER THAN T'//
001027      1' TMIN=',F10.2,5X,'TMAX=',F10.2,5X,'T=',F10.2,5X,A6,I2)
001028      RETURN
001029      150 WRITE (6,2030) XMIN,XMAX,TT,ENTR,K
001030      2030 FORMAT (' MAXIMUM TABULATED TEMPERATURE IS LESS THAN T'//
001031      1' TMIN=',F10.2,5X,'TMAX=',F10.2,5X,'T=',F10.2,5X,A6,I2)
001032      RETURN
001033      160 WRITE (6,2040) PSAT,PP,ENTR,K
001034      2040 FORMAT (' P IS LESS THAN SAT. PRESS. CORRESPONDING TO T'//
001035      1' PSAT=',F10.2,5X,'P=',F10.2,5X,A6,I2)
001036      JFLG=6
001037      RETURN
001038      C      ENTRY FOR TEMPERATURE(PP,HH)
001039      C
001040      ENTRY PHTEMP(PP,HH,K,TEMP,X,JFLG)
001041      ENTR='PHTEMP'
001042      IF (PP.GT.PCRIT) GO TO 200
001043      CALL SPLNT(N,HSAT,PSATUR,EMPH,HH,PSAT)
001044      IF (PP.LT.PSAT) GO TO 260
001045      200 CALL HDROP(PP,HH,T,H,3,1,TEMP,JFLG,XMIN,XMAX)
001046      IF (JFLG.GT.1) GO TO 210
001047      X=0.0
001048      RETURN
001049      C      ENTRY FOR DENSITY(PP,HH)
001050      C
001051      ENTRY PHDENS(PP,HH,K,RHO,RHOL,X,JFLG)
001052      ENTR='PHDENS'
001053      IF (PP.GT.PCRIT) GO TO 201
001054      CALL SPLNT(N,HSAT,PSATUR,EMPH,HH,PSAT)
001055      IF (PP.LT.PSAT) GO TO 280
001056      201 CALL HDROP(PP,HH,S,H,3,2,C,JFLG,XMIN,XMAX)
001057      IF (JFLG.GT.1) GO TO 210
001058      RHO=1./C
001059      X=0.0
001060      RHOL=0.0
001061      RETURN
001062      C      ENTRY FOR ENTROPY(PP,HH)
001063      C
001064      ENTRY PHENTR(PP,HH,K,ENTRO,JFLG)
001065      ENTR='PHENTR'
001066      IF (PP.GT.PCRIT) GO TO 202
001067      CALL SPLNT(N,HSAT,PSATUR,EMPH,HH,PSAT)
001068      IF (PP.LT.PSAT) GO TO 290
001069      202 CALL HDROP(PP,HH,S,H,3,4,ENTRO,JFLG,XMIN,XMAX)
001070      IF (JFLG.GT.1) GO TO 210
001071      205 RETURN
001072      210 GO TO (205,120,130,240,250),JFLG
001073      240 WRITE (6,3000) XMIN,XMAX,HH,ENTR,K
001074      3000 FORMAT (' MINIMUM TABULATED ENTHALPY IS GREATER THAN H'//
001075      1' HMIN=',F10.4,5X,'HMAX=',F10.4,5X,'H=',F10.4,5X,A6,I2)

```

```

001077      250 WRITE (6,3010) XMIN,XMAX,HH,ENTR,K
001078      3010 FORMAT (' MAXIMUM TABULATED ENTHALPY IS LESS THAN H'/
001079      1' HMIN=',F10.4,5X,'HMAX=',F10.4,5X,'H=',F10.4,5X,A6,I2)
001080      RETURN
001081      260 CALL SPLNT(N,PSATUR,HSAT,EMHLP,PP,HSATL)
001082      CALL SPLNT(N,PSATUR,HSATVP,EMHVP,PP,HSATV)
001083      CALL SPLNT(N,PSATUR,TSAT,EMTP,PP,TEMP)
001084      IF (HH.GT.HSATV) GO TO 270
001085      X=(HH-HSATL)/(HSATV-HSATL)
001086      RETURN
001087      270 WRITE (6,3020) PSAT,PP,HSATV,HH,ENTR,K
001088      3020 FORMAT (' P IS LESS THAN SAT. PRESS. CORRESPONDING TO H AND H IS G
001089      1'REATER THAN H SATURATED VAPOR/' PSAT=',F10.2,5X,'P=',F10.2,5X,
001090      2'HSATV=',F10.4,5X,'H=',F10.4,5X,A6,I2)
001091      JFLG=6
001092      RETURN
001093      280 CALL SPLNT(N,PSATUR,RHOSAT,EMROL,PP,RHOL)
001094      CALL SPLNT(N,PSATUR,RHOV,EMROVP,PP,RHOV)
001095      CALL SPLNT(N,PSATUR,HSAT,EMHLP,PP,HSATL)
001096      CALL SPLNT(N,PSATUR,HSATVP,EMHVP,PP,HSATV)
001097      IF (HH.GT.HSATV) GO TO 270
001098      X=(HH-HSATL)/(HSATV-HSATL)
001099      RHO=RHOL+RHOV/(X+RHOL+(1.-X)*RHOV)
001100      RETURN
001101      290 CALL SPLNT(N,PSATUR,SSAT,EMSLP,PP,SL)
001102      CALL SPLNT(N,PSATUR,SSATV,EMSV,PP,SVP)
001103      CALL SPLNT(N,PSATUR,HSAT,EMHLP,PP,HSATL)
001104      CALL SPLNT(N,PSATUR,HSATVP,EMHVP,PP,HSATV)
001105      IF (HH.GT.HSATV) GO TO 270
001106      XS=(HH-HSATL)/(HSATV-HSATL)
001107      ENTRO=XS+SVP+(1.-XS)*SL
001108      RETURN
001109      C      ENTRY FOR ENTHALPY(PP,SS)
001110      C
001111      ENTRY PSEINTH(PP,SS,K,ENTH,JFLG)
001112      ENTH=PSEINTH
001113      IF (PP.GT.PCRIT) GO TO 300
001114      CALL SPLNT(N,SSAT,PSATUR,EMPS,SS,PSAT)
001115      IF (PP.LT.PSAT) GO TO 360
001116      300 CALL HPROP(PP,SS,H,S,4,3,ENTH,JFLG,XMIN,XMAX)
001117      IF (JFLG.GE.1) GO TO 310
001118      305 RETURN
001119      310 GO TO (305,120,130,340,350), JFLG
001120      340 WRITE (6,4000) XMIN,XMAX,SS,ENTR,K
001121      4000 FORMAT (' MINIMUM TABULATED ENTROPY IS GREATER THAN S'/
001122      1' SMIN=',F10.5,5X,'SMAX=',F10.5,5X,'S=',F10.5,5X,A6,I2)
001123      RETURN
001124      350 WRITE (6,4010) XMIN,XMAX,SS,ENTR,K
001125      4010 FORMAT (' MAXIMUM TABULATED ENTROPY IS LESS THAN S'/
001126      1' SMIN=',F10.5,5X,'SMAX=',F10.5,5X,'S=',F10.5,5X,A6,I2)
001127      RETURN
001128      360 CALL SPLNT(N,PSATUR,HSAT,EMHLP,PP,HSATL)
001129      CALL SPLNT(N,PSATUR,HSATVP,EMHVP,PP,HSATV)
001130      CALL SPLNT(N,PSATUR,SSAT,EMSLP,PP,SL)
001131      CALL SPLNT(N,PSATUR,SSATV,EMSV,PP,SVP)
001132      IF (SS.GE.SVP) GO TO 370
001133      XS=(SS-SL)/(SVP-SL)
001134      ENTH=XS*HSATV+(1.-XS)*HSATL
001135      RETURN
001136      370 WRITE (6,5000) PSAT,PP,SVP,SS,ENTR,K

```

```

001137      4020 FORMAT (' P IS LESS THAN SAT. PRESS. CORRESPONDING TO S AND S IS G
001138          1 GREATER THAN S SATURATED VAPOR.'/ PSAT='F10.2,5X,'P='F10.2,5X,
001139          2'SV='F10.5,5X,'SE='F10.5,5X,A6,I2)
001140          JFL6=6
001141          RETURN
001142          END
001143      C**** THIS SUBROUTINE READS IN THE HYDROGEN PROPERTIES DATA TO BE USED FILE 001
001144      C**** IN SUBROUTINE HPROP FILE 002
001145      C FILE 003
001146          SUBROUTINE INPROP
001147          DIMENSION A(30)
001148          COMMON /PROP/ T(30,50),SV(30,50),H(30,50),S(30,50),NUM(30),P(30),
001149          1AA(5,90),RHOX(90),R(9,8)
001150          10 FORMAT (4F10.0)
001151          20 FORMAT (25I3)
001152      C FILE 009
001153      C**** READ NUMBER OF DATA POINTS FOR EACH ISOBAR FILE 010
001154      C FILE 011
001155          READ (5,20) (NUM(I),I=1,30)
001156          DO 50 I=1,30
001157          M=NUM(I)
001158          C FILE 016
001159      C**** READ TEMPERATURES FOR ISOBAR I FILE 017
001160      C FILE 018
001161          READ (5,10) (T(I,J),J=1,M)
001162      C FILE 019
001163      C**** READ SPECIFIC VOLUMES FOR ISOBAR I
001164      C FILE 021
001165          READ (5,10) (SV(I,J),J=1,M)
001166      C FILE 022
001167      C**** READ ENTHALPIES FOR ISOBAR I
001168      C FILE 023
001169          READ (5,10) (H(I,J),J=1,M)
001170      C FILE 029
001171      C**** READ ENTROPIES FOR ISOBAR I
001172      C FILE 030
001173          50 READ (5,10) (S(I,J),J=1,M)
001174      C FILE 031
001175      C**** CONVERT PRESSURES FROM ATMOSPHERES TO PSIA
001176      C FILE 038
001177          A(1)=1.
001178          A(2)=1.5
001179          DO 55 I=2,10
001180          55 A(I+1)=I
001181          A(12)=12.5
001182          DO 60 I=1,8
001183          60 A(I+12)=10+5*I
001184          DO 65 I=1,5
001185          65 A(I+20)=50+10*I
001186          DO 70 I=1,5
001187          70 A(I+25)=100+20*I
001188          DO 80 I=1,30
001189          80 P(I)=14.696*A(I)
001190          25 FORMAT (5E16.7)
001191          30 FORMAT (10F8.4)
001192          35 FORMAT (4E20.8)
001193      C FILE 050
001194      C**** READ EMPIRICAL COEFFICIENTS FILE 057
001195      C FILE 058
001196          READ (5,25) ((AA(I,J),J=1,90),I=1,5)
001197          C FILE 059
001198          C FILE 060
001199          C FILE 061
001200          C FILE 062

```

001197	READ (5,30) (RHOX(I),I=1,90)	
001198	READ (5,35) ((B(I,J),J=1,A),I=1,9)	
001199	RETURN	FILE 066
001200	END	
001201	C**** SUBROUTINE HPROP ****	HPROP000
001202	C**** THIS SUBROUTINE PROVIDES THE FOLLOWING HYDROGEN PROPERTIES DATA TO	HPROP001
001203	C**** THE MAIN PROGRAM:	HPROP002
001204	C**** SUCTION LINE SPNIC VELOCITY AS A FUNCTION OF TEMPERATURE AND	HPROP003
001205	C**** PRESSURE	HPROP004
001206	C**** INDUCER INLET SPECIFIC VOLUME AS A FUNCTION OF TEMPERATURE AND	HPROP005
001207	C**** PRESSURE	HPROP006
001208	C**** PUMP INLET SPECIFIC VOLUME AS A FUNCTION OF TEMPERATURE AND	HPROP007
001209	C**** PRESSURE	HPROP008
001210	C	HPROP009
001211	SUBROUTINE HPROP (A,B,Y,X,KJ,K,C,JFLG,XMIN,XMAX)	
001212	DIMENSION X(30,50),Y(30,50),CP(2)	
001213	COMMON /PROP/ T(30,50),SV(30,50),H(30,50),S(30,50),N(30),P(30),	
001214	1AA(5,90),RHOX(90),D(9,8)	
001215	COMMON /SAT/ HSAT(25),PSAT(25),TSAT(25),SSAT(25),RHOSAT(25),	
001216	1EMPT(25),EMPS(25),EMTS(25),EMUS(25),EMRHOS(25),EMTP(25),	
001217	2HSATV(25),SSATV(25),RHOSV(25),EMHLP(25),EMHVP(25),EMSLP(25),	
001218	3EMSPV(25),EMROLP(25),EMROVP(25),EMPH(25)	
001219	C	HPROP012
001220	C**** P IS THE PRESSURE ARRAY	HPROP013
001221	C**** X IS THE INDEPENDENT PROPERTY ARRAY	HPROP014
001222	C**** Y IS THE DEPENDENT PROPERTY ARRAY	HPROP015
001223	C**** N IS THE OF DATA POINTS FOR EACH ISOBAR ARRAY	HPROP016
001224	C**** A IS PRESSURE	HPROP017
001225	C**** B IS THE SECOND INDEPENDENT VARIABLE	HPROP018
001226	C**** KJ DETERMINES THE INDEPENDENT PARAMETER USED	HPROP019
001227	C**** KJ=1,H IS TEMPERATURE	HPROP020
001228	C**** KJ NOT=1,B IS SPECIFIC VOLUME,ENTHALPY,ENTROPY OR SONIC VELOCITY	HPROP021
001229	C**** K DETERMINES THE DEPENDENT PARAMETER REQUESTED	HPROP022
001230	C**** K=1,C IS TEMPERATURE	HPROP023
001231	C**** K=2,C IS SPECIFIC VOLUME	HPROP024
001232	C**** K=3,C IS ENTHALPY	HPROP025
001233	C**** K=4,C IS ENTROPY	HPROP026
001234	C**** K=5,C IS SONIC VELOCITY	HPROP027
001235	C**** C IS THE REQUESTED DEPENDENT PROPERTY	HPROP028
001236	C**** D IS THE ARRAY OF EMPIRICAL CONSTANTS USED IN THE SATURATED	HPROP029
001237	C**** PRESSURE SUBPROGRAM SVSL	HPROP030
001238	C	HPROP031
001239	NSAT=22	HPROP032
001240	JFLG=1	HPROP033
001241	I=0	HPROP034
001242	LIMIT=0	HPROP035
001243	C	HPROP036
001244	C**** SET XMIN=MINIMUM TABULATED PRESSURE	HPROP037
001245	C	HPROP038
001246	XMIN=P(1)	HPROP039
001247	C	HPROP040
001248	C**** SET XMAX=MAXIMUM TABULATED PRESSURE	HPROP041
001249	C	HPROP042
001250	XMAX=P(25)	HPROP043
001251	50 I=I+1	HPROP044
001252	C	HPROP045
001253	C**** SEARCH PRESSURE TABLE FOR VALUE CORRESPONDING TO A	HPROP046
001254	C	HPROP047
001255	IF(P(I)-A) 60,80,55	HPROP048

001257	C**** TABULATED PRESSURE IS GREATER THAN A,TEST FOR MINIMUM TABLE VALUE	HPROP049
001258	C	HPROP050
001259	55 IF (I-1) 200,200,150	HPROP051
001260	C	HPROP052
001261	C**** TABULATED PRESSURE IS LESS THAN A,TEST FOR MAXIMUM TABLE VALUE	HPROP053
001262	C	HPROP054
001263	60 IF (I-25) 50,250,250	HPROP055
001264	C	HPROP056
001265	C**** TABULATED PRESSURE=A	HPROP057
001266	C	HPROP058
001267	80 M=N(I)	HPROP059
001268	C	HPROP060
001269	C**** SET XMIN=MINIMUM TABULATED INDEPENDENT PROP.	HPROP061
001270	C	HPROP062
001271	XMIN=X(I,1)	HPROP063
001272	C	HPROP064
001273	C**** SET XMAX=MAXIMUM TABULATED INDEPENDENT PROP.	HPROP065
001274	C	HPROP066
001275	XMAX=X(I,M)	HPROP067
001276	J=0	HPROP068
001277	85 J=J+1	HPROP069
001278	C	HPROP070
001279	C**** SEARCH INDEPENDENT PROPERTY TABLE FOR VALUE CORRESPONDING TO B	HPROP071
001280	C	HPROP072
001281	IF (X(I,J)-B) 95,100,90	HPROP073
001282	C	HPROP074
001283	C**** TABULATED PROP. IS GREATER THAN B,TEST FOR MINIMUM TABLE VALUE	HPROP075
001284	C	HPROP076
001285	90 IF (J-1) 300,300,110	HPROP077
001286	C	HPROP078
001287	C**** TABULATED PROP. IS LESS THAN B,TEST FOR MAXIMUM TABLE VALUE	HPROP079
001288	C	HPROP080
001289	95 IF (J-M) 85,350,350	
001290	C	HPROP082
001291	C**** TABULATED PROP=B,SET C=TABULATED VALUE	HPROP083
001292	C	HPROP084
001293	100 C=Y(I,J)	HPROP085
001294	GO TO 500	HPROP086
001295	C	HPROP087
001296	C**** INTERPOLATE ALONG ISOBAR I FOR C	HPROP088
001297	C	HPROP089
001298	110 C=Y(I,J-1)+(B-X(I,J-1))/(X(I,J)-X(I,J-1))*(Y(I,J)-Y(I,J-1))	HPROP090
001299	GO TO 500	HPROP091
001300	C	HPROP092
001301	C**** A LIES BETWEEN TWO TABULATED ISOBARS,INTERPOLATE ALONG EACH ISOBAR	HPROP093
001302	C**** FOR PROPER B	HPROP094
001303	C	HPROP095
001304	150 NM=I-1	HPROP096
001305	DO 160 IK=NM,I	HPROP097
001306	M=N(IK)	HPROP098
001307	JK=IK-I+2	HPROP099
001308	J=0	
001309	C	HPROP101
001310	C**** SET XMIN=MINIMUM TABULATED INDEPENDENT PROP.	HPROP102
001311	C	HPROP103
001312	XMIN=X(IK,1)	HPROP104
001313	C	HPROP105
001314	C**** SET XMAX=MAXIMUM TABULATED INDEPENDENT PROP.	HPROP106
001315	C	HPROP107
001316	XMAX=X(IK,M)	HPROP108

001317	155 J=J+1	HPROP109
001318	C	HPROP110
001319	C**** SEARCH INDEPENDENT PROPERTY TABLE FOR VALUE CORRESPONDING TO B	HPROP111
001320	C	HPROP112
001321	IF (X(IK,J)-B) 165,170,160	HPROP113
001322	C	HPROP114
001323	C**** TABULATED PROP. IS GREATER THAN B,TEST FOR MINIMUM TABLE VALUE	HPROP115
001324	C	HPROP116
001325	160 IF (J-1) 300,300,550	HPROP117
001326	C	HPROP118
001327	C**** TABULATED PROP. IS LESS THAN B,TEST FOR MAXIMUM TABLE VALUE	HPROP119
001328	C	HPROP120
001329	165 IF (J-N(IK)) 155,510,510	HPROP121
001330	C	HPROP122
001331	C**** TABULATED VALUE=B,SET CP=TABULATED VALUE	HPROP123
001332	C	HPROP124
001333	170 CP(JK)=Y(IK,J)	HPROP125
001334	GO TO 180	HPROP126
001335	C	HPROP127
001336	C**** MAXIMUM TABULATED VALUE IS LESS THAN B,IF ISOBAR LESS THAN A SET	HPROP128
001337	C**** LIMIT=1 AND CONTINUE,IF ISOBAR GREATER THAN A SET ERROR FLAG AND	HPROP129
001338	C**** RETURN	HPROP130
001339	C	HPROP131
001340	510 IF (JK-1) 520,520,350	HPROP132
001341	520 LIMIT = 1	HPROP133
001342	GO TO 180	
001343	C	HPROP135
001344	C**** CHECK LIMIT SET=1	HPROP136
001345	C	HPROP137
001346	550 IF (LIMIT) 175,175,600	HPROP138
001347	C	HPROP139
001348	C**** LIMIT=0,NORMAL INTERPOLATION SEQUENCE ON ISOBAR	HPROP140
001349	C	HPROP141
001350	175 CP(JK)=Y(IK,J-1)+(B-X(IK,J-1))/(X(IK,J)-X(IK,J-1))*	HPROP142
001351	1(Y(IK,J)-Y(IK,J-1))	HPROP143
001352	180 CONTINUE	HPROP144
001353	C	HPROP145
001354	C**** NORMAL INTERPOLATION FOR C	HPROP146
001355	C	HPROP147
001356	C=CP(1)+(A-P(I-1))/(P(I)-P(I-1))*(CP(2)-CP(1))	HPROP148
001357	GO TO 500	HPROP149
001358	C	HPROP150
001359	C**** LIMIT=1,CHECK FOR TEMPERATURE AS INDEPENDENT PROPERTY	HPROP151
001360	C	HPROP152
001361	600 IF (KJ.EQ.1) GO TO 610	
001362	IF (KJ.EQ.3) GO TO 611	
001363	IF (KJ.EQ.4) GO TO 612	
001364	GO TO 350	
001365	C	HPROP154
001366	C**** TEMPERATURE IS INDEPENDENT PROPERTY,FIND CORRESPONDING VAPOR	HPROP155
001367	C**** PRESSURE	HPROP156
001368	C	HPROP157
001369	610 CALL SPLNT(NSAT,TSAT,PSAT,EMPT,B,PSL)	
001370	GO TO 615	
001371	611 CALL SPLNT(NSAT,HSAT,PSAT,EMPH,B,PSL)	
001372	GO TO 615	
001373	612 CALL SPLNT(NSAT,SSAT,PSAT,EMPS,B,PSL)	
001374	615 GO TO (620,620,630,640,645)*K	
001375	C	HPROP160
001376	C**** FIND STABILIZED LIQUID SPEC. VOL. CORRESPONDING TO TEMPERATURE=B	HPROP161

001377	C		HPPROP162
001378		620 CALL SPLNT(NSAT,PSAT,RHOSAT,EMROL,PSL,CP(2))	
001379		CP(2)=1./CP(2)	
001380		GO TO 650	HPPROP164
001381	C		HPPROP165
001382	C****	FIND SATURATED LIQUID ENTHALPY CORRESPONDING TO TEMPERATURE=B	HPPROP166
001383	C		HPPROP167
001384		630 CALL SPLNT(NSAT,PSAT,HSAT,EMHLP,PSL,CP(2))	
001385		GO TO 650	HPPROP169
001386	C		HPPROP170
001387	C****	FIND SATURATED LIQUID ENTROPY CORRESPONDING TO TEMPERATURE=B	HPPROP171
001388	C		HPPROP172
001389		640 CALL SPLNT(NSAT,PSAT,SSAT,EMSLP,PSL,CP(2))	
001390		GO TO 650	HPPROP174
001391	C		HPPROP175
001392	C****	SET SATURATED LIQUID SONIC VELOCITY	HPPROP176
001393	C		HPPROP177
001394		645 CP(2)=3940.	HPPROP178
001395	C		HPPROP179
001396	C****	INTERPOLATE FOR CP ON ISOBAR GREATER THAN A	HPPROP180
001397	C		HPPROP181
001398		650 CP(1)=Y(I,J-1)+(B-X(I,J-1))*(Y(I,J)-Y(I,J-1))/(X(I,J)-X(I,J-1))	HPPROP182
001399	C		HPPROP183
001400	C****	INTERPOLATE FOR C USING SATURATED CONDITIONS	HPPROP184
001401	C		HPPROP185
001402		C=CP(1)+(A-P(I))*(CP(2)-CP(1))/(PSL-P(I))	HPPROP186
001403		GO TO 500	HPPROP187
001404	C		HPPROP188
001405	C****	MINIMUM TABULATED PRESSURE IS GREATER THAN A,SET ERROR FLAG	HPPROP189
001406	C		HPPROP190
001407		200 JFLG=2	HPPROP191
001408		GO TO 500	HPPROP192
001409	C		HPPROP193
001410	C****	MAXIMUM TABULATED PRESSURE IS LESS THAN A,SET ERROR FLAG	HPPROP194
001411	C		HPPROP195
001412		250 JFLG=3	HPPROP196
001413		GO TO 500	HPPROP197
001414	C		HPPROP198
001415	C****	MINIMUM TABULATED INDEPENDENT PROP. IS GREATER THAN B,SET ERROR	HPPROP199
001416	C****	FLAG	HPPROP200
001417	C		HPPROP201
001418		300 JFLG=4	HPPROP202
001419		GO TO 500	HPPROP203
001420	C		HPPROP204
001421	C****	MAXIMUM TABULATED INDEPENDENT PROP. IS LESS THAN B,SET ERROR FLAG	HPPROP205
001422	C		HPPROP206
001423		350 JFLG=5	HPPROP207
001424		500 RETURN	HPPROP208
001425		END	HPPROP20
001426		NTAB= 10	
001427		TAPE 1,'B' . KEN KIRK 'S TAPE	
001428		TAPE 2,'K' . OUTPUT TAPE FOR KIRK.	
001429		READ 5	
001430		PRINT 6	
001431		END	

N8300R:72-106
May 1972

12. AXIAL BLADE DESIGN PROGRAM

AXIAL BLADE DESIGN PROGRAM

1. INTRODUCTION

a. A computer program has been developed to assist in defining the blade profiles for axial machines. Given basic blade data such as inlet and discharge angles, leading and trailing edge radii, aspect ratio, and thickness to chord ratio; a profile can be developed using this program which minimizes local fluid acceleration on the blade surface.

b. Included is a listing of the program with a brief description of its application. A complete description of the analysis associated with this program appears in the NERVA Turbopump Design Report, N8300R:71-076.

c. The program is complete and was used to develop the NERVA turbine blade profiles.

d. This program is applicable as long as the turbine remains axial flow.

e. No related activities.

f. This program was developed by K. G. Kirk.

2. CONCLUSIONS

a. Gross Conclusions

(1) This program was used successfully to develop the blade profiles for the NERVA Turbine. The program also provides the data necessary for defining the blade profiles in a plane normal to a stacking line and the data used in velocity distribution calculations.

(2) The program is complete in its present form.

3. RECOMMENDATIONS

a. Achieving a satisfactory blade with this program requires an iterative process. A set of spline points are selected, the surface is spline fit and checked, spline points are adjusted as needed and the process is repeated until a satisfactory blade profile is obtained. With some programming effort this iterative process could be done within the program, resulting in considerable savings in time and effort.

b. The program can be used to supply digital data alone, or digital data and punched output which serves as input to a section property program, velocity distribution program, and blade stacking program. In addition, it is recommended that the program be used with the plot option if a plotter is available.

W ELT CDINI,1,720519, 31505

```
000001      SUBROUTINE CDINI (LREC,TITLE,XC,YC)
000002      DIMENSION LREC(6),X(2),Y(2),TITLE(20),XC(1000,2),YC(1000,2)
000003      10  FORMAT (4E20,9)
000004      20  FORMAT (20A4)
000005      30  FORMAT (15)
000006      LREC(J)=N
000007      READ (5,20) TITLE
000008      DO 100 J=1,2
000009      READ (5,30) N
000010      READ (5,10) (XC(I,J),YC(I,J),I=1,N)
000011      100 CONTINUE
000012      RETURN
000013      END
```

AXIAL BLADE DESIGN PROGRAM

@ ELT CDOUT,1,720519, 31498

```
000001 SUBROUTINE CDOUT(LREC,TITLE,XC,YC)
000002 DIMENSION LREC(6),XX(2),YY(2),TITLE(20),XC(1000,2),YC(1000,2)
000003 10 FORMAT (4E20,9)
000004 20 FORMAT (20A4)
000005 30 FORMAT (I5)
000006 WRITE (2,20) TITLE
000007 DO 50 J=1,2
000008 N=LREC(J)
000009 WRITE (2,30) N
000010 ICONT=0
000011 DO 50 I=1,N
000012 ICONT=ICONT+1
000013 X=XC(I,J)
000014 Y=YC(I,J)
000015 XX(ICONT)=X
000016 YY(ICONT)=Y
000017 IF (ICONT-2) 35,40,40
000018 35 IF (I-N) 50,40,40
000019 40 WRITE (2,10) (XX(K),YY(K),K=1,ICONT)
000020 ICONT=0
000021 50 CONTINUE
000022 RETURN
000023 END
```

D ELT C PLOT,1,720519, 31516

```

000001      SUBROUTINE C PLOT (ARGX, ARGY, INARG)
000002      C THE ARRAY 'A' IS THE 'DATA' STORAGE CONTAINING 50 'PLOT' CURVES EACH WITH A
000003      C MAXIMUM OF 50 'X-Y' PAIRS. NP DEFINES NUMBER OF DATA PAIRS PER CURVE.
000004      COMMON /SPLFIT/
000005      1      6(100), SB(100), EM(50), SLOPE(50), CURV(50), X(50), Y(50)
000006      COMMON /DATA/ A(2,50,50), NP(51)
000007      DIMENSION ARGX(1000,6), ARGY(1000,6), INARG(6)
000008      DIMENSION Z(1000), YINT(1000)
000009      DIMENSION XTITL(10), TTITL(10)
000010      DIMENSION AYLEN(5), YMIN(5), YMAX(5), NYSTRT(5), NYSCAL(5), NYSIZE(5)
000011      1, NYFRAC(5), YTITL(10,5)
000012      C THESE CELLS TO BE USED BY SPLINE CURVE FIT
000013      C ***
000014      C THE PLOT ROUTINE READS INPUT CARDS FOR PLOT SETUP AND CONTROL
000015      1 FORMAT (I2, I1)
000016      2   FORMAT (I2, 3F9.0, 3I3, I2, 6A6, A4 )
000017      C READ CARD 00
000018      3 READ (5,1) ID, NYAXIS
000019      IF (ID.NE.0) GO TO 999
000020      IF (NYAXIS.GT.5) GO TO 999
000021      C READ CARD 01 FOR X-AXIS CONTROL
000022      READ (5,2) ID, AXLEN, XMIN, XMAX, NXSTRT, NXSCAL, NXSIZE, NXFRAC
000023      1  , (XTITL(J), J=1,7)
000024      IF (ID.NE.1) GO TO 999
000025      IF (NXSIZE.EQ.0) NXSIZE = 2
000026      C READ CARDS 02 FOR Y-AXIS CONTROL
000027      DO 10 I=1, NYAXIS
000028      READ (5,2) ID, AYLEN(I), YMIN(I), YMAX(I), NYSTRT(I), NYSCAL(I)
000029      1  , NYSIZE(I), NYFRAC(I), (YTITL(J,I), J=1,7)
000030      IF (ID.NE.2) GO TO 999
000031      IF (NYSEIZE(I).EQ.0) NYSIZE(I) = 2
000032      10 CONTINUE
000033      C COMPUTE PRELIMINARY CONTROL FOR SETUP OF X AND Y AXIS
000034      C SET UP THE X-AXIS AND THE BASIC Y-AXIS
000035      IF (NXSTRT.EQ.0) NXSTRT=50
000036      C X-AXIS UP 1 INCH ON PLOT
000037      IF (NYSTRT(1).EQ.0) NYSTRT(1) = 500
000038      C Y-AXIS STARTS 3 INCHES FROM MARGIN ON DEFAULT
000039      C COMPUTE PRELIMINARY CONTROL FOR SETUP OF X AND Y AXIS
000040      XLABLD = (XMAX - XMIN) / AXLEN
000041      YLABLD = (YMAX(1) - YMIN(1)) / AYLEN(1)
000042      NXLINE = NXSTRT - 25
000043      NYLINE = NYSTRT(1)
000044      MAXX=IFIX(100.*AXLEN)+NYSTRT(1)
000045      MAXY=IFIX(100.*AYLEN(1))+NXSTRT
000046      CALL PLTSU (0, XMIN, YMIN(1), NYSTRT(1), NXSTRT, XLABLD, YLABLD, 100, 100
000047      1, NXFRAC, NYFRAC(1), NXLINE, NYLINE, MAXX, MAXY, NXSCAL, NYSCAL(1))
000048      NXBEGB = NYSTRT(1) + (100 * IFIX(AXLEN)) / 2 - 320
000049      CALL PLTBC (YTITL, 40, NXBEGB, NXLINE-35, NXSIZE, 0)
000050      C HORIZONTAL AXIS NOW LABELED
000051      NYBEGB = NXSTRT + (100 * IFIX(AYLEN(1))) / 2 - 320
000052      NXBEGB = NYLINE-50
000053      CALL PLTBC (YTITL(1,1), 40, NXBEGB, NYBEGB, NYSIZE(1), 1)
000054      C BASIC Y AXIS NOW COMPLETED
000055      HCODE = 1
000056      ZMAX = AYLEN(1)

```

```

000057       IF (NYAXIS.EQ.1) GO TO 21
000058       C SET UP SECONDARY Y AXIS
000059       DO 20 I=2,NYAXIS
000060       MAXY=IFIX(100.*AYLEN(I))+NXSTRT
000061       IF (AYLEN(I).GT.ZMAX) ZMAX = AYLEN(I)
000062       IF (NYSTRT(I).EQ.0) NYSTRT(I) = NYSTRT(I-1) - 100
000063       YLABD = (YMAX(I) - YMIN(I)) / AYLEN(I)
000064       NYLINE = NYSTRT(I)
000065       CALL PLTSU (1,XMIN,YMIN(I),NYSTRT(I),NXSTRT,XLABD,YLABD,100,100
000066       1,NXFRAC,NYFRAC(I),0,NYLINE,MAXX,MAXY,NXSCAL,NYSCAL(I))
000067       NXBEGN = NYLINE - 60
000068       NYBEGN = NXSTRT + (100 * IFIX(AYLEN(I))) / 2 - 320
000069       CALL PLTRC (YTITL(1,I),40,NXBEGN,NYBEGN,NYSIZE(I),1)
000070       20 NCODE = I
000071       21 CONTINUE
000072       MAXY = IFIX(100. * ZMAX) + NXSTRT
000073       C SET UP FOR TEST OF LAST POSITION OF THE PEN
000074       XCOD = 0.
000075       YCOD = 0.
000076       MARG = 0
000077       30 READ (5,31,END=201)
000078       1 ID,NFILE,NAXIS,LFIT,LPRINT,LARGPL,NSYMBL,INTV,LINE
000079       1 ,XSTART, YSTART, (TITLES(K), K=1,7)
000080       31 FORMAT (2I2, 4I1, 2I3, I1, T21, 2F10.0, 6A6, A4 )
000081       IF (ID.NE.3) GO TO 100
000082       IF (NFILE.GT.50) GO TO 98
000083       IF (NAXIS.GT.NYAXIS) GO TO 98
000084       IF (LARGPL.GT.6) GO TO 98
000085       C IF(NSYMBL.EQ.0) NSYMBL=64
000086       C GO TO PLOT THE DATA GIVEN THROUGH THE ARGUMENT TO CPLOT
000087       N = NP(NFILE)
000088       IF (NAXIS.EQ.NCODE) GO TO 40
000089       I = NAXIS
000090       NCODE = NAXIS
000091       YLABD = (YMAX(I) - YMIN(I)) / AYLEN(I)
000092       CALL PLTSU (1,XMIN,YMIN(I),NYSTRT(1),NXSTRT,XLABD,YLABD,100,100
000093       1,NXFRAC,NYFRAC(I),0,0,MAXX,MAXY,NXSCAL,NYSCAL(I))
000094       40 IF (LARGPL.NE.0) GO TO 90
000095       IF (LFIT.EQ.0) GO TO 80
000096       DO 41 J=1,N
000097       X(J) = A(1,J,NFILE)
000098       Y(J) = A(2,J,NFILE)
000099       41 CONTINUE
000100       CALL SPLINE (N,LPRINT)
000101       XMIND = .05 * XLABD
000102       DELTAX = (X(N) - X(1)) / 999.
000103       IF (DELTAX.LT.XMIND) DELTAX = XMIND
000104       MAX = IFIX( (X(N) - X(1)) / DELTAX ) + 1
000105       M = MAX - 1
000106       Z(1) = X(1)
000107       Z(MAX) = X(N)
000108       DO 42 L=2,M
000109       42 Z(L) = Z(L-1) + DELTAX
000110       CALL SPLINT (N,Z,YINT,MAX)
000111       P1 = (YCOD - Z(1))**2 + (YCOD - YINT(1))**2
000112       P2 = (YCOD - Z(MAX))**2 + (YCOD - YINT(MAX))**2
000113       IF (P1.GT.P2) GO TO 43
000114       YCOD = Z(MAX)
000115       YCOD = YINT(MAX)
000116       LOC = 1

```

```

000117      INC = 4
000118      GO TO 44
000119      43 XCOD = Z(1)
000120      YCOD = YINT(1)
000121      LOC = MAX
000122      INC = -4
000123      44 CALL PLTPT (LINE,MAX,INC,INC,NSYMBL,INTV,Z(LOC),YINT(LOC))
000124      GO TO 30
000125      C PLOT THE DATA FROM RAW POINTS
000126      80 R1 = (XCOD - A(1,1,NFILE))**2 + (YCOD - A(2,1,NFILE))**2
000127      R2 = (XCOD - A(1,N,NFILE))**2 + (YCOD - A(2,N,NFILE))**2
000128      IF (R1.GT.R2) GO TO 81
000129      YCOD = A(1,N,NFILE)
000130      YCOD = A(2,N,NFILE)
000131      LOC = 1
000132      INC = 8
000133      GO TO 82
000134      81 XCOD = A(1,1,NFILE)
000135      YCOD = A(2,1,NFILE)
000136      LOC = N
000137      INC = -8
000138      82 CALL PLTPT (LINE,N,INC,INC,NSYMBL,INTV,
000139      1 A(1,LOC,NFILE),A(2,LOC,NFILE))
000140      GO TO 30
000141      C PLOT FROM THE ARGUMENT TO CPLOT
000142      ENTRY CPLOT1 (ARGX,ARGY,INARG)
000143      90 K = LARGPL
000144      NARG = INARG(K)
000145      IF (NARG.GT.1000) GO TO 98
000146      R1 = (XCOD - ARGX(1,K))**2 + (YCOD - ARGY(1,K))**2
000147      R2 = (XCOD - ARGX(NARG,K))**2 + (YCOD - ARGY(NARG,K))**2
000148      IF (R1.GT.R2) GO TO 91
000149      YCOD = ARGX(NARG,K)
000150      YCOD = ARGY(NARG,K)
000151      LOC = 1
000152      INC = 4
000153      GO TO 92
000154      91 XCOD = ARGX(1,K)
000155      YCOD = ARGY(1,K)
000156      LOC = NARG
000157      INC = -4
000158      92 WRITE (6,1000) LINE,NARG,INC,INC,NSYMBL,INTV,(ARGX(IK,K),ARGY(IK,K)
000159      1),IK=1,NARG)
000160      1000 FORMAT ('1 ENTRY PLTPT',/6I5/(2E20.6))
000161      CALL PLTPT (LINE,NARG,INC,INC,NSYMBL,INTV
000162      1,ARGX(LOC,K),ARGY(LOC,K))
000163      GO TO 30
000164      98 WRITE (6,99) NFILE,NAXIS,LARGPL,NARG
000165      99 FORMAT (' CHECK ONE OF THE FOLLOWING INPUT ON 03 CARD. NFILE=',I2,
000166      1' NAXIS=',I1,' LARGPL=',I1,' NARG=',I4)
000167      GO TO 30
000168      C PLOT THE TITLES FROM THE 04 AND 05 CARDS
000169      100 NXBEGN = NYSTRT(1) + (100 * IFIX(AXLEN)) / 2 - 320
000170      101 IF ((ID.NE.4).AND.(ID.NE.5) ) GO TO 200
000171      IF (XSTART.NE.0.) NXBEGN = IFIX(XSTART)
000172      IF (YSTART.NE.0.) MAXY = IFIX(YSTART)
000173      IF (ID.EQ.4) MAXY = MAXY - 31
000174      IF (ID.EQ.5) MAXY = MAXY - 24
000175      ISIZE = 7 - ID
000176      CALL PLTBC (TTITLE,40,NXBEGN,MAXY,ISIZE,0)

```


1KIRK,427025,1,100

DATE 19 MAY 72 PAGE 76

```
000177      READ (5,102,END=201)
000178      1  ID,XSTART,YSTART, (TTILES(K), K=1,7)
000179      102) FORMAT (I2, 18X, 2F10.0, 6A6, A4)
000180      GO TO 101
000181      200 IF (ID.EQ.88) GO TO 3
000182      IF (ID.EQ.77) RETURN
000183      201 CALL PLTFIN
000184      RETURN
000185      999 WRITE (6,998) ID
000186      998 FORMAT (' THE CARD WITH ID OF ',I2,' WAS ENCOUNTERED UNEXPECTEDLY,
000187      I ID OF 0,1 OR 2 WAS EXPECTED')
000188      RETURN
000189      END
```

ELT INPUT,1,720519, 31500

000001 SUBROUTINE INPUT (NUM,DELX,FLAG)

000002 INTEGER SURF

000003 DIMENSION NUM(2),IFLAG(14)

000004 COMMON /SURF11/ 6(100),SB(100),EM(50),SLOPE(50),CURV(50),X(50),

000005 1Y(50)

000006 COMMON IM,JD,IY,ITITLE(20),DATA(28),XB(2,25),YB(2,25),NBL,NBRI

000007 EQUIVALENCE (DATA(1),GAM),(DATA(2),AR),(DATA(3),TF),(DATA(4),

000008 TRHOIP),(DATA(5),WTFEL),(DATA(6),OMEGA),(DATA(7),ORF),(DATA(8),

000009 2RELI),(DATA(9),BETO),(DATA(10),CHORD),(DATA(11),STGR),

000010 3(DATA(12),REDEFA),(DATA(13),DENTO),(DATA(14),R11),(DATA(15),R01),

000011 4(DATA(16),R211),(DATA(17),R210),(DATA(18),DUMY1),(DATA(19),R12),

000012 5(DATA(20),R02),(DATA(21),R212),(DATA(22),BETO2),(DATA(23),DUMY2)

000013 EQUIVALENCE (DATA(24),P0),(DATA(25),W),(DATA(26),

000014 1RAV),(DATA(27),CP),(DATA(28),W2)

000015 5 FORMAT (3A2,4X,14I5)

000016 6 FORMAT (20A4)

000017 20 FORMAT (F10.0/F10.0/3F10.0,2I5)

000018 30 FORMAT (I5,4F10.0)

000019 40 FORMAT (G10.0)

000020 60 FORMAT (4X, ,GAM, ,9X,CP, ,8X,R, ,7X,SPED, ,7X,W, ,8X,TTI, ,7X,

000021 1,PTI, ,7X,BETA1, ,4X,BETA0, ,6X,WX, ,7X,RADIUS, ,4X,W2, ,/13X,

000022 2,BTU/LB-R, ,2X,FT/DEG-R, ,4X,RPM, ,6X,LR/SEC, ,4X,DEG-R, ,6X,PSIA,

000023 3,7X,DEG, ,6X,DEG, ,6X,FT/SEC, ,6X,IN, ,4X,FT/SEC, ,14X,LB/FT3, ,5X

000024 4, ,11X, ,9X, ,IN, ,8X, ,IN, ,/)

000025 61 FORMAT (F9.3,F11.3,SF10.2,F10.1,F10.4,F10.1/)

000026 65 FORMAT (3X,REDFAC, ,5X,DENTOL, ,4X,CHORD, ,5X,STGR, ,6X,DELX, ,6X,

000027 1,SCALE, ,5X,ORF, ,6X,NBL, ,7X,NBRI, ,14X,LB/FT3, ,5X,IN, ,9X,IN,

000028 2,8X, ,14I, /)

000029 66 FORMAT (F8.3,F12.4,F9.3,F10.4,F10.5,19,110/)

000030 70 FORMAT (144X,BLADE COORDINATES, SURFACE, ,11 /6X,5(X,9X,1, ,9X)

000031 1, ,X, ,9X, ,Y, ,/)

000032 71 FORMAT (12F10.6)

000033 75 FORMAT (5X, ,R1, ,9X, ,R0, ,6X, ,BETA1, ,5X, ,BETO, /5X, ,IN, ,9X, ,IN, ,7X,

000034 1,DEG, ,7X, ,DEG, /)

000035 76 FORMAT (SF10.4, ,SF10.2)

000036 1000 FORMAT (1,DATE, ,1A2, ,1, ,A2, ,1, ,A2, ,36X, ,BLADE PROFILE PROGRAM, /)

000037 1005 FORMAT (1X,20A4/)

000038 1020 FORMAT (56X,INPUT DATA, /)

000039 READ (5,5)IM,JD,IY,IFLAG

000040 IF (IFLAG(10)) 200,78,200

000041 78 IF (IFLAG(11)) 200,79,200

000042 79 WRITE (6,1000) IM,JD,IY

000043 READ (5,6) TITLE

000044 WRITE (6,1005) TITLE

000045 WRITE (6,1020)

000046 READ (5,20) GAM,CP,AR,OMEGA,WTFEL,TF,P0,BETI ,BETO ,W,W2,RAD,ORF,

000047 1,REDEFA,DENTO,CHORD,STGR,DELX,SCALE,NBL,NBRI

000048 IF (SCALE) 300,300,310

000049 300 SCALE=1.0

000050 310 WRITE (6,60)

000051 WRITE (6,61) GAM,CP,AR,OMEGA,WTFEL,TF,P0,BETI ,BETO ,W ,RAD,W2

000052 WRITE (6,65)

000053 WRITE (6,66) REDFA,DENTO,CHORD,STGR,DELX,SCALE,ORF,NBL,NBRI

000054 STGR=STGR*SCALE

000055 CHORD=CHORD*SCALE

000056 GO 100 SURF=1,2

```
000057      READ (5,30) NUM(SURF),RI,RO,BETAI,BETA0
000058      IF (SURF-1) 80,80,90
000059      80  RI1=RI*SCALE
000060      RO1=RO*SCALE
000061      BETI1=BETAI
000062      BETO1=BETA0
000063      GO TO 95
000064      90  RI2=RI*SCALE
000065      RO2=RO*SCALE
000066      BETI2=BETAI
000067      BETO2=BETA0
000068      95  NM1=NUM(SURF)-1
000069      READ (5,40) (X(I),Y(I),I=2,NM1)
000070      DO 150 I=2,NM1
000071      XB(SURF,I)=X(I)*SCALE
000072      150  YB(SURF,I)=Y(I)*SCALE
000073      WRITE (6,70) SURF
000074      WRITE (6,71) (X(I), Y(I), I=2,NM1)
000075      WRITE (6,75)
000076      100 WRITE (6,76) RI,RO,BETAI,BETA0
000077      200 RETURN
000078      END
```

@ ELT MAIN,1,720519, 31485

```

000001      INTEGER SURF
000002      DIMENSION Z(500 ),LREC(6),NUM(2),DATA(28),XB(2,25),YB(2,25),
000003      1IFLAG(14),XC(1000,2),YC(1000,2),SLO(1000,2),RCURVE(1000,2),
000004      2XSH(1000,2),YSH(1000,2),XST(1000,2),YST(1000,2),SLENTH(2),
000005      3ARGX(6000),ARGY(6000)
000006      COMMON /SPLFIT/ G(100),SR(100),EM(50),SLOPE(50),CURV(50),X(50),
000007      1Y(50)
000008      COMMON IM, ID, IY, TITLE(20),DATA,XB,YB,NBL,IBRI
000009      EQUIVALENCE (DATA(1),GAM),(DATA(2),AP),(DATA(3),TIP),(DATA(4),
000010      1RHOIP),(DATA(5),WTFL),(DATA(6),OMEGA),(DATA(7),ORF),(DATA(8),
000011      2BETI ),(DATA(9),BETO ),(DATA(10),CHORD),(DATA(11),STGR),
000012      3(DATA(12),REDA),(DATA(13),DENTO),(DATA(14),RI1),(DATA(15),RO1),
000013      4(DATA(16),BETI1),(DATA(17),BETO1),(DATA(18),DUMY1),(DATA(19),RI2), 4
000014      5(DATA(20),RO2),(DATA(21),BETI2),(DATA(22),BETO2),(DATA(23),DUMY2)
000015      EQUIVALENCE (DATA(24),PO),(DATA(25),WX),(DATA(26),
000016      1RAD),(DATA(27),CP),(DATA(28),X2)
000017      EQUIVALENCE (ARGX(1),XC(1,1),XST(1,1))
000018      EQUIVALENCE (ARGX(2001),XSH(1,1))
000019      EQUIVALENCE (ARGY(1),YC(1,1),YST(1,1))
000020      EQUIVALENCE (ARGY(2001),YSH(1,1))
000021      EQUIVALENCE (ARGY(4001),RCURVE(1,1))
000022      10 FORMAT (/// ' SURFACE LENGTH=' ,F10.3)
000023      CALL ERRSET(259,300,-1,0,0,0)
000024      ISTK=0
000025      50 CALL INPUT (NUM,DELX,IFLAG)
000026      IF (IFLAG(10)) 60,65,60
000027      60 CALL CDINH (LREC,TITLE,XC,YC)
000028      GO TO 659
000029      65 IF (IFLAG(11)) 70,75,70
000030      70 CALL CDINH (LREC,TITLE,XC,YC)
000031      GO TO 651
000032      75 DUMY1=0.0
000033      DUMY2=0.0
000034      RHOIP=0.0
000035      JFLAG=0
000036      KFLAG=0
000037      N1=NUM(1)
000038      N2=NUM(2)
000039      BETAI=BETI1/57.295779
000040      CALL XYI (BETAI,RI1,1.,XB(1,1),YB(1,1),DYDX)
000041      BETAI=BETI2/57.295779
000042      CALL XYI (BETAI,RI2,-1.,XB(2,1),YB(2,1),DYDX)
000043      BETAO=BETO1/57.295779
000044      CALL XYO (BETAO,RO1,CHORD,STGR,1.,XB(1,N1),YB(1,N1),DYDX)
000045      BETAO=BETO2/57.295779
000046      CALL XYO (BETAO,RO2,CHORD,STGR,-1.,XB(2,N2),YB(2,N2),DYDX)
000047      DO 650 SURF=1,2
000048      LFLAG=0
000049      NM1=NUM(SURF)-1
000050      M=NUM(SURF)
000051      IF (SURF-1) 80,80,90
000052      80 L=1
000053      RI=RI1
000054      RO=RO1
000055      BETAI=BETI1
000056      BETAO=BETO1

```

```

000057      GO TO 95
000058      90 L=2
000059      RI=RI2
000060      RO=RO2
000061      BETA1=BETA12
000062      BETA0=BETA02
000063      95 BETA1=BETA1/57.295779
000064      BETA0=BETA0/57.295779
000065      SLOPI=TAN(BETA1)
000066      SLOPO=TAN(BETA0)
000067      96 IF (L-1) 110,100,110
000068      100 SIGN=1.
000069      GO TO 150
000070      110 SIGN=-1.
000071      150 DO 160 I=1,N
000072      X(I)=X0(SURF,I)
000073      160 Y(I)=Y0(SURF,I)
000074      SLENTH(SURF)=RI*(1.570795-SIGN*BETA1)
000075      IF (SURF-1) 170,170,410
000076      170 DTHET=0.001*SIGN/RI
000077      THETA=3.14159*SIGN/2.
000078      S=0.0
000079      T=0.0
000080      XC(1,SURF)=S
000081      YC(1,SURF)=T
000082      RCURVE(1,SURF)=RI
000083      SLO(1,SURF)=1.0E50*SIGN
000084      I=1
000085      200 I=I+1
000086      THETA=THETA-DTHET
000087      CALL XYI (THETA,RI,SIGN,S,T,DYDX)
000088      IF (JFLAG) 210,210,240
000089      210 IF (S-XB(2,1)) 240,240,220
000090      220 JFLAG=1
000091      S=XB(2,1)
000092      T=SQRT(RI**2-ABS(S-RI)**2)
000093      240 IF(S-X(1)) 250,300,300
000094      250 XC(I,SURF)=S
000095      YC(I,SURF)=T
000096      RCURVE(I,SURF)=RI
000097      SLO(I,SURF)=DYDX
000098      J=I
000099      GO TO 200
000100      300 I=1
000101      Z(1)=X(1)
000102      IF (JFLAG) 360,360,350
000103      350 I=I+1
000104      Z(I)=Z(I-1)+DELX
000105      IF (Z(I)-XB(1,N1)) 370,375,375
000106      370 IF (Z(I)-XB(2,N2)) 350,380,380
000107      375 Z(I)=XB(1,N1)
000108      GO TO 490
000109      380 KFLAG=1
000110      Z(I)=XB(2,N2)
000111      THETA=-BETA02/57.295779
000112      DTHET=0.001*SIGN/RO
000113      385 I=I+1
000114      THETA=THETA-DTHET
000115      CALL XYO(THETA,RO,CHORD,STGR,SIGN,S,T,DYDY)
000116      IF (S-XB(1,N1)) 390,375,375

```

```

000117      390 Z(I)=S
000118      GO TO 385
000119      360 I=I+1
000120      CALL XYI (THETA,RI,SIGN,S,T,DYDX)
000121      IF (S-XB(2,1)) 361,365,365
000122      361 Z(I)=S
000123      THETA=THETA-DTHET
000124      GO TO 360
000125      365 Z(I)=XB(2,1)
000126      GO TO 350
000127      410 IRM1=0
000128      I=0
000129      412 IRM1=IRM1+1
000130      S=XC(IRM1,1)
000131      Y=YC(IRM1,1)
000132      DYDX=SLO(IRM1,1)
000133      IF (JFLAG) 415,415,430
000134      415 IF (S-XB(1,1)) 420,420,430
000135      420 T=-T
000136      DYDX=-DYDX
000137      425 XC(IRM1,SURF)=S
000138      YC(IRM1,SURF)=T
000139      RCURVE(IRM1,SURF)=RI
000140      SLO(IRM1,SURF)=DYDX
000141      J=IRM1
000142      GO TO 412
000143      430 IF (S-XB(2,1)) 440,450,460
000144      440 T=-SQRT(RI**2-ABS(S-RI)**2)
000145      IF (T) 442,441,442
000146      441 DYDX=1.0E50*SIGN
000147      GO TO 425
000148      442 DYDX=(RI-S)/T
000149      GO TO 425
000150      450 I=I+1
000151      Z(I)=S
000152      GO TO 412
000153      460 IF (S-XB(2,N2)) 450,450,490
000154      490 CALL SPLN2 (N,SURF,SLOPI,SLOPO)
000155      CALL SPLNT (N,SURF,Z,J,I,L,LREC,XC,YC,SLO,RCURVE,SLNTH)
000156      SLNTH(SURF)=SLNTH(SURF)+RO*(1.570795+SIGN*BETA0)
000157      WRITE (6,I0) SLNTH(SURF)
000158      THETA=BETA0
000159      DTHET=0.001*SIGN/RO
000160      M=0
000161      500 J=J+1
000162      THETA=THETA-DTHET
000163      IF (SIGN*THETA+3.14159/2.) 550,600,600
000164      550 THETA=-SIGN*3.14159/2.
000165      M=1
000166      600 CALL XYO(THETA,RO,CHORD,STGR,SIGN,S,T,DYDX)
000167      IF (LFLAG) 601,601,624
000168      601 IF (SURF-1) 602,602,605
000169      602 IF (KFLAG) 603,603,624
000170      603 IF (S-XB(2,N2)) 624,624,604
000171      604 THETA=-BETO2/57.295779
000172      LFLAG=1
000173      GO TO 600
000174      605 IF (KFLAG) 624,624,606
000175      606 IF (S-XB(1,N1)) 624,624,607
000176      607 THETA=-BETO1/57.295779

```

```
000177          LFLAG=1
000178          GO TO 600
000179          624 XC(J,SURF)=S
000180          YC(J,SURF)=T
000181          RCURVE(J,SURF)=R0
000182          SLO(J,SURF)=DYDX
000183          IF (M) 625,500,625
000184          625 LREC(L)=J
000185          LREC(L+4)=J
000186          DO 640 LOC=1,J
000187          LOCA=LOC+1000*(SURF+3)
000188          640 ARGX(LOCA)=XC(LOC,SURF)
000189          650 CONTINUE
000190          IF (IFLAG(9)) 654,658,654
000191          654 CALL CDOUT (LREC,TITLE,XC,YC)
000192          658 IF (IFLAG(8)) 651,659,651
000193          651 IF (ISTK) 653,652,653
000194          652 ISTK=1
000195          CALL STAK(1,RAD,LREC,XHT,YHT,YCENT,TITLE,IM,ID,IY,
000196          IXTTRAN,YTRAN,XC,YC,XSH,YSH,XST,YST)
000197          GO TO 50
000198          653 CALL STAK(2,RAD,LREC,XHT,YHT,YCENT,TITLE,IM,ID,IY,
000199          IXTTRAN,YTRAN,XC,YC,XSH,YSH,XST,YST)
000200          659 IF (IFLAG(5)) 660,670,660
000201          660 IF (IFLAG(6)) 661,665,661
000202          661 PITCH=2.*3.14159*RAD/NRL
000203          CALL OFSET (LREC,PITCH,XC,YC,ARGX,ARGY)
000204          665 CALL CPLOT (ARGX,ARGY,LREC)
000205          670 IF (IFLAG(2)) 730,760,730
000206          730 CALL VELIN(NUM)
000207          760 IF (IFLAG(7)) 761,765,761
000208          761 CALL SECIN(LREC(1),N1,N2,IM,ID,IY,TITLE,XR,DELX,XC,YC)
000209          765 IF (IFLAG(1)) 50,800,50
000210          800 STOP
000211          END
```

IKIRK*427825*1*100

DATE 19 MAY 72 PAGE 03

0 ELI N1A85*1*720519* 31518

000001	N1A85 TO 00000000
000002	TAPE 9*IKIRK*PROXTAPE.
000003	READ 5
000004	PRINT 6
000005	END

ELT OFFSET, 1.720519, 31492

SUBROUTINE ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)
DIMENSION LREC(6), XC(1000, 2), YC(1000, 2), ARGX(6000), ARGY(6000)

DO 100 J=1, 20000

N=LREC(J)

LREC(J+2)=LREC(J)

DO 100 I=1, N

L=I+1000*(J+1)

ARGX(L)=XC(I, J)+PITCH

ARGY(L)=YC(I, J)+PITCH

RETURN

END

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

CALL ROSET(LREC, PITCH, XC, YC, ARGX, ARGY)

Q ELT PLTSU,1,720519, 31512

```

000001      SUBROUTINE PLTSU (MOVEON,XORIG, YORIG, NXPLOT,NYPLOT,XLABD.
000002      1 YLABD,NXLAB,NYLAB,NXFRAC,NYFRAC,NXLINE,NYLINE,
000003      2 MAXX,MAXY,NXSCAL,NYSCAL)
000004      COMMON /PLOTCM/ IPLOTF, NPLOTS
000005      DIMENSION IBUF(1000)
000006      C-----
000007      IF(IPLOTF.EQ. 1)      GO TO 10
000008      CALL PLOTS (IBUF,1000,9)
000009      C-----
000010      C  CONVERT OFF-SET ORIGIN TO INCHES.
000011      C-----
000012      IPLOTF = 1
000013      NPLOTS = 0
000014      XCONST = 0.
000015      YORI=0.
000016      SUMY=0.0
000017      GO TO 15
000018      C10  XLEN = MAXLEN
000019      C    CALL PLOT (XLEN,0.,998)
000020      10  CONTINUE
000021      IF(MOVEON.EQ. 1)      GO TO 15
000022      XCONST=FLOAT(MAXLEN)
000023      YCONST=YORI
000024      15  SCALEY = 1.
000025      IF(NYSCAL.NE. 0)      SCALEY = 10.**NYSCAL
000026      YORIGN = YORIG*SCALEY
000027      YORI=FLOAT(NYPLOT)/100.
000028      DYI = FLOAT(NYLAB )/100.
000029      DELTAY = YLABD/DYI*SCALEY
000030      IF (NXLINE.EQ.0) GO TO 105
000031      NPLOTS = NPLOTS+1
000032      SCALEX = 1.
000033      IF(NXSCAL.NE. 0)      SCALEX = 10.**NXSCAL
000034      XORIGN = XORIG*SCALEX
000035      XORI = FLOAT(NXPLOT)/100.
000036      DXI = FLOAT(NXLAB )/100.
000037      DELTAX = XLABD/DXI*SCALEX
000038      MAXLEN=(MAXX-NXPLOT)/100+3
000039      C-----
000040      C  SET-UP NEW LOGICAL ORIGIN.
000041      C-----
000042      XNEW=XORI+XCONST
000043      YNEW=YORI-YCONST
000044      SUMY=SUMY+YNEW
000045      CALL PLOT(XNEW,YNEW,-3)
000046      LEN=MAXX-NXPLOT
000047      C-----
000048      C  CONVERT LENGTH OF X-AXIS TO INCHES.
000049      C-----
000050      ITICK = LEN/NXLAB + 1
000051      XLEN = FLOAT(ITICK-1)*DXI
000052      XL = XLEN + DXI
000053      XV = FLOAT(ITICK) *XLABD*SCALEX+XORIGN
000054      XLIMIT=XV
000055      IF (NXLINE.EQ.0) GO TO 105
000056      HEIGHT=0.14

```

```

000057 C-----
000058 C   DRAW X-AXIS
000059 C-----
000060 C   CALL PLOT (0.,0.,3)
000061 C   CALL PLOT (XLEN,0.,2)
000062 C-----
000063 C   DRAW TICK MARKS AND LABELS.
000064 C-----
000065 C-----
000066 C   WRITE (6,6000) NPLOTS, XORI, YORI, XLEN, DXL, XORIGN, YORIGN,
000067 C   1 ITICK
000068 C-----
000069 C   DO 100 I=1,ITICK
000070 C     XL = XL - DXL
000071 C     CALL PLOT (XL,0.,3)
000072 C     CALL PLOT (XL,-0.14,2)
000073 C     XV = XV-XLABLD*SCALEX
000074 C     CALL NUMBER (XL,-.35,HEIGHT,XV,0.,NXFRAC)
000075 C   100 CONTINUE
000076 C-----
000077 C   DRAW Y-AXIS.
000078 C-----
000079 C   105 YLEN=MAXY
000080 C     YLEN=YLEN-YORI*100.
000081 C     ITICK = IFIX(YLEN/NYLAB + 1)
000082 C     YLEN = FLOAT(ITICK-1)*DYL
000083 C     YL = YLEN+DYL
000084 C     YV = FLOAT(ITICK) *YLABLD*SCALEY+YORIGN
000085 C     YLIMIT=YV
000086 C     IF(NYLINE.EQ.0) RETURN
000087 C     HEIGHT=0.14
000088 C     OFFSET=FLOAT(NXPLOT/100)-XORI
000089 C     XO=OFFSET
000090 C     CALL PLOT (XO,0.,3)
000091 C     CALL PLOT (XO,YLEN,2)
000092 C     DO 110 I=1,ITICK
000093 C     YL = YL - DYL
000094 C     XO=OFFSET
000095 C     CALL PLOT (XO,YL,3)
000096 C     XO=OFFSET-0.14
000097 C     CALL PLOT (XO,YL,2)
000098 C     YV = YV-YLABLD*SCALEY
000099 C     XO=OFFSET-0.25
000100 C     CALL NUMBER (XO,YL,HEIGHT,YV,90.,NYFRAC)
000101 C   110 CONTINUE
000102 C     RETURN
000103 C-----
000104 C   ENTRY PLTBC (BCI,NUMBCI,NXBEGN,NYREGN,ISIZE,IVERT)
000105 C-----
000106 C   CONVERT TO INCHES.
000107 C-----
000108 C   XPAGE = FLOAT(NXBEGN)/100.-XORI
000109 C   YPAGE = FLOAT(NYREGN)/100.-YORI
000110 C   NCHAR = NUMBCI
000111 C   ANGLE = 0.
000112 C   IF(IVERT .EQ. 1) ANGLE = 90.
000113 C   HEIGHT = FLOAT(ISIZE)*0.07
000114 C   CALL SYMBOL (XPAGE,YPAGE,HEIGHT,BCI,ANGLE,NCHAR)
000115 C   RETURN
000116 C-----

```

```

000117      ENTRY PLTPT (IPLOT,NUMPT,INCX,INCY,ICODE,INCSYM,X,Y)
000118      C-----
000119      DIMENSION XARRAY(102),YARRAY(102),X(1), Y(1)
000120      C-----
000121      INTEG = ICODE
000122      LINTYP = INCSYM
000123      IF(IPLOT.EQ. 1)      LINTYP = - LINTYP
000124      ICOUNT = NUMPT
000125      IX = INCX/4
000126      IY = INCY/4
000127      II = 1
000128      JJ = 1
000129      GO TO 190
000130      180  JJ=JJ+1
000131          II=II+1
000132          ICOUNT=ICOUNT-1
000133          IF (ICOUNT.LT.1) RETURN
000134      190  XARRAY(1)=X(II)*SCALEX
000135          YARRAY(1)=Y(JJ)*SCALEY
000136          IF ((XARRAY(1).LT.XORIGN) .OR. (XARRAY(1).GT.XLIMIT) .OR.
000137              1(YARRAY(1).LT.YORIGN) .OR. (YARRAY(1).GT.YLIMIT)) GO TO 180
000138      200  I=1
000139      210  I=I+1
000140      215  II=II+IX
000141          JJ=JJ+IY
000142          ICOUNT=ICOUNT-1
000143          IF (ICOUNT.LE.0) GO TO 220
000144          XARRAY(I)=X(II)*SCALEX
000145          YARRAY(I)=Y(JJ)*SCALEY
000146          IF ((XARRAY(I).LT.XORIGN) .OR. (XARRAY(I).GT.XLIMIT) .OR.
000147              1(YARRAY(I).LT.YORIGN) .OR. (YARRAY(I).GT.YLIMIT)) GO TO 215
000148          NPTS=I
000149          IF (I.GE.100) GO TO 230
000150          GO TO 210
000151      220  IF (I.LE.2) RETURN
000152      230  XARRAY(NPTS+1)=XORIGN
000153          XARRAY(NPTS+2) = DELTAX
000154          YARRAY(NPTS+1) = YORIGN
000155          YARRAY(NPTS+2) = DELTAY
000156          CALL LINE (XARRAY,YARRAY,NPTS,1, LINTYP,INTEG)
000157          XARRAY(1) = XARRAY(100)
000158          YARRAY(1) = YARRAY(100)
000159          IF(ICOUNT .GT. 0)      GO TO 200
000160          RETURN
000161      C-----
000162      ENTRY PLTNU (XLOC,NUMDEC,NXLOC,NYLOC,ISIZE,IVERT)
000163      C-----
000164      XORR = FLOAT (NXLOC)/100. - XORI
000165      YORR = FLOAT (NYLOC)/100. - YORI
000166      HEIGHT = FLOAT (ISIZE)*.14
000167      ANGLE = 0.
000168      IF(IVERT .GT. 0)      ANGLE = 90.
000169      CALL NUMBER (XORR,YORR,HEIGHT,XLOC,ANGLE,NUMDEC)
000170      RETURN
000171      C-----
000172      ENTRY PLTFIN
000173      C-----
000174      XLEN = MAXLEN
000175      CALL PLOT (XLEN,-SUMY,999)
000176      IPLOTF=0

```

000177
000178
000179
000180
000181
000182
000183

RETURN
6000 FORMAT ('1 ENTRY PLTSU, PLOT NO.',I3/ ' Y-ORIG DIST = ', F10.6/
1 ' Y-ORIG DIST = ', F10.6 / ' PLOT SIZE = ', F10.4, ' INCHES'/
2 ' TICK MARK INCR. = ', F10.6, ' INCHES'/ ' 1ST TICK MARK AT : '/
3 ' X = ', F10.6, ' Y = ', F10.6 /
4 ' NO. OF TICK MARKS ON X-AXIS = ', I6)
END

D ELT SECIN,1,720519, 31504

```

000001 SUBROUTINE SECIN (N,N1,N2,IM,IO,IY,TITLE,XB,DELX,XC,YC)
000002 DIMENSION TITLE(20),XB(2,25),XC(1000,2),YC(1000,2)
000003 5 FORMAT('1DATE ',A2,'-',A2,'-',A2,36X,'BLADE PROFILE PROGRAM'/)
000004 10 FORMAT(41X,'SECTION PROPERTIES PROGRAM INPUT DATA'/)
000005 15 FORMAT(' X COORDINATES OF UPPER AND LOWER SURFACES ARE NOT THE SA
000006 1ME'/10X,'XU=',E15.8,'XL=',E15.8,'YU=',E15.8,'YL=',E15.8)
000007 20 FORMAT(15,5X,3F10.6)
000008 6 FORMAT(20A4)
000009 24 FORMAT(25X,'YU',18X,'YL',18X,'XU'//)
000010 25 FORMAT(10X,3F20.7)
000011 30 FORMAT (' MORE THAN 49 POINTS')
000012 K=1
000013 WRITE(6,5) IM,IO,IY
000014 WRITE(6,10)
000015 WRITE(6,6) TITLE
000016 WRITE(2,6) TITLE
000017 DX=5.*DELX
000018 J=0
000019 DO 200 I=1,N
000020 XU=XC(I,1)
000021 YU=YC(I,1)
000022 XL=XC(I,2)
000023 YL=YC(I,2)
000024 IF (ABS(XU-XL)-0.0000001) 60,50,50
000025 50 WRITE(6,15)XU,XL,YU,YL
000026 GO TO 300
000027 60 IF(I-1)65,65,70
000028 65 WRITE(6,24)
000029 GO TO 190
000030 70 IF(I-N)80,190,190
000031 80 IF(XOLD-XB(1,1))100,100,90
000032 90 IF(XOLD-XB(2,1))100,100,110
000033 100 IF(XU-(XOLD+DELX))200,190,190
000034 110 IF(XU-XB(1,N1))120,120,100
000035 120 IF(XU-XB(2,N2))130,130,100
000036 130 IF(XU-(XOLD+DX))200,190,190
000037 190 XOLD=XU
000038 WRITE(2,20)K,YU,YL,XU
000039 WRITE(6,25)YU,YL,XU
000040 J=J+1
000041 IF(J-49)200,200,250
000042 200 CONTINUE
000043 GO TO 300
000044 250 WRITE(6,30)
000045 300 RETURN
000046 END

```

@ ELT SPLINE,1,720519, 31507

```

000001      SUBROUTINE SPLINE (N,SRW)
000002      INTEGER SRW
000003      C
000004      C SPLINE CALCULATES FIRST AND SECOND DERIVATIVES AT SPLINE POINTS      3KIRK917
000005      C END CONDITION-SECOND DERIVATIVES ARE THE SAME AT END POINT AND      3KIRK918
000006      C ADJACENT POINT
000007      C
000008      COMMON /SPLFIT/
000009      1      G(100),SB(100),EM(50),SLOPE(50),CURV(50),X(50),Y(50)
000010      SB(1)=-1.0
000011      G(1)=0.
000012      NO=N-1
000013      IF (NO-2) 20,7,7
000014      7 DO10I=2,NO
000015      A=(X(I)-X(I-1))/6.
000016      C=(X(I+1)-X(I))/6.
000017      W=2. *(A+C)-A*SB(I-1)
000018      SB(I)=C/W
000019      F=(Y(I+1)-Y(I))/(X(I+1)-X(I))-(Y(I)-Y(I-1))/(X(I)-X(I-1))      3K
000020      10 G(I)=(F-A*G(I-1))/W
000021      20 EM(N)=G(N-1)/(1. +SB(N-1))
000022      DO30I=2,N
000023      K=N+1-I
000024      30 EM(K)=G(K)-SB(K)*EM(K+1)
000025      SLOPE(1)=(X(1)-X(2))/6. *(2. *EM(1)+EM(2))+(Y(2)-Y(1))/(X(2)-X(1)      13KIRK940
000026      1)
000027      DO40I=2,N
000028      40 SLOPE(I)=(X(I)-X(I-1))/6. *(2. *EM(I)+EM(I-1))+(Y(I)-Y(I-1))/(X(3KIRK943
000029      I)-X(I-1))
000030      DO 45 I=1,N
000031      45 CURV(I)=((1.+SLOPE(I)**2)**1.5)/ABS(EM(I))
000032      IF (SRW) 50,100,50
000033      50 WRITE (6,1000) N, (X(I),Y(I),SLOPE(I),EM(I),CURV(I),I=1,N)
000034      100 RETURN
000035      1000 FORMAT ('1',15HNO. OF POINTS =,I3/10X,1HX,19X,1HY,19X,5HSLOPE,15X, 3KIRK94
000036      A2HEM,15X,4HCURV/(5E20.8))
000037      END

```

Q ELT SPLINT,1,720519, 31509

```

000001      SUBROUTINE SPLINT (N,Z,YINT,MAX)
000002      C
000003      C  SPLINT CALCULATES INTERPOLATED POINTS AND DERIVATIVES
000004      C  FOR A SPLINE CURVE
000005      DIMENSION Z(1000),YINT(1000)
000006      COMMON /SPLFIT/
000007      1      G(100),SB(100),EM(50),SLOPE(50),CURV(50),X(50),Y(50)
000008      1000 FORMAT (' SPLINT USED FOR EXTRAPOLATION',E15.7/)
000009      D0140I=1,MAX
000010      K=2
000011      IF(Z(I)-X(1))70,60,90
000012      60 YINT(I) = Y(1)
000013      SK=X(K)-X(K-1)
000014      GO TO 130
000015      70 IF (Z(I)-(1.1*X(1)-0.1*X(2))) 75,120,120
000016      75 WRITE (6,1000) Z(I)
000017      GO TO 120
000018      80 K=N
000019      IF (Z(I)-(1.1*X(N)-0.1*X(N-1))) 120,120,85
000020      85 WRITE (6,1000) Z(I)
000021      GO TO 120
000022      90 IF(Z(I)-X(K))120,100,110
000023      100 YINT(I) = Y(K)
000024      SK=X(K)-X(K-1)
000025      GO TO 130
000026      110 K=K+1
000027      IF(K-N)90,90,80
000028      120 CONTINUE
000029      SK=X(K)-X(K-1)
000030      YINT(I)=EM(K-1)*(X(K)-Z(I))**3/6. /SK+EM(K)*(Z(I)-X(K-1))**3/6. 3KIRK #1
000031      1/SK+(Y(K)/SK-EM(K)*SK/6. )*(Z(I)-X(K-1))+Y(K-1)/SK-EM(K-1)*SK/6.3KIRK #2
000032      2 )*(X(K)-Z(I))
000033      130 DYDX =-EM(K-1)*(X(K)-Z(I))**2/2.0 /SK+EM(K)*(X(K-1)-Z(I))** 2/2.359R2 4
000034      1 /SK+(Y(K)-Y(K-1))/SK-(EM(K)-EM(K-1))*SK/6.
000035      D2YDX=(X(K)-Z(I))*EM(K-1)/SK+(Z(I)-X(K-1))*EM(K)/SK
000036      RCURV=((1.+DYDX**2)**1.5)/ABS(D2YDX)
000037      140 CONTINUE
000038      500 RETURN
000039      END

```


@ ELT SPLNT,1,720519, 31494

```

000001 SUBROUTINE SPLNT (N,SURF,Z,J,MAX,L,LREC,XC,YC,SLO,RCURVE,SLENTH)
000002 C
000003 C SPLINT CALCULATES INTERPOLATED POINTS AND DERIVATIVES 3K1RK990
000004 C FOR A SPLINE CURVE
000005 INTEGER SURF
000006 DIMENSION Z(1000),LREC(6),XC(1000,2),YC(1000,2),SLO(1000,2),
000007 1RCURVE(1000,2),SLENTH(2)
000008 COMMON /SPLFIT/ G(100),SB(100),EM(50),SLOPE(50),CURV(50),X(50),
000009 1Y(50)
000010 COMMON IM, ID, IY, TITLE(20),DATA(28),XB,YB,NBL,NBBI
000011 WRITE (6,1030) IM, ID, IY
000012 1030 FORMAT ('1DATE ',A2,'-',A2,'-',A2,36X,'BLADE PROFILE PROGRAM'/)
000013 WRITE (6,1040) TITLE
000014 1040 FORMAT (1X,20A4/)
000015 WRITE (6,1050) SURF
000016 1050 FORMAT (' INTERPOLATED X-Y COORDINATES FOR BLADE SURFACE ',I1)
000017 IF (MAX) 500,500,5
000018 5 III=SRW
000019 DO140I=1,MAX 3K1RK 18
000020 J=J+1 3K1RK 19
000021 K=2 3K1RK 20
000022 IF (Z(I)-X(1))70,60,90
000023 60 YINT =Y(1) 3K1RK 22
000024 SK=X(K)-X(K-1) 3K1RK 23
000025 GO TO 130
000026 70 IF (Z(I)-(1.1*X(1)-0.1*X(2))) 75,120,120
000027 75 WRITE (6,1000) Z(I) 3K1RK 26
000028 SRW=16
000029 GO TO 120
000030 80 K=N
000031 IF (Z(I)-(1.1*X(N)-0.1*X(N-1))) 120,120,85
000032 85 WRITE (6,1000) Z(I) 3K1RK 31
000033 SRW=16 3K1RK 32
000034 GO TO 120 3K1RK 33
000035 90 IF (Z(I)-X(K))120,100,110
000036 100 YINT =Y(K) 3K1RK 35
000037 SK=X(K)-X(K-1) 3K1RK 36
000038 GO TO 130
000039 110 K=K+1
000040 IF (K-N)90,90,80 3K1RK 39
000041 120 CONTINUE 3K1RK 40
000042 SK=X(K)-X(K-1) 3K1RK 41
000043 YINT =EM(K-1)*(X(K)-Z(I))*3/6. /SK+EM(K)*(Z(I)-X(K-1))*3/6. 3K1RK 42
000044 1/SK+(Y(K)/SK-EM(K)*SK/6. )*(Z(I)-X(K-1))+(Y(K-1)/SK-EM(K-1)*SK/6.
000045 2 )*(X(K)-Z(I))
000046 130 XC(J,L)=Z(I)
000047 YC(J,L)=YINT
000048 DYDX =-EM(K-1)*(X(K)-Z(I))*2/2.0 /SK+EM(K)*(X(K-1)-Z(I))*2/2. 3K1RK 44
000049 1 /SK+(Y(K)-Y(K-1))/SK-(EM(K)-EM(K-1))*SK/6.
000050 SLO(J,L)=DYDX
000051 D2YDX=(X(K)-Z(I))*EM(K-1)/SK+(Z(I)-X(K-1))*EM(K)/SK
000052 RCURV=((1.+DYDX**2)**1.5)/ABS(D2YDX)
000053 RCURVE(J,L)=RCURV
000054 IF (I-1) 155,155,160
000055 155 WRITE (6,1010) N,MAX
000056 GO TO 170

```

```

000057 160 SLENTH(L)=SLENTH(L)+SORT((Z(I)-Z(I-1))**2+(YINT-YSAVE)**2)
000058 170 WRITE(6,1020) Z(I),YINT,DYDX,D2YDX,RCURV,SLENTH(L)
000059 YSAVE=YINT
000060 140 CONTINUE
000061 SRW=III
000062 500 RETURN
000063 1000 FORMAT (54H SPLINT USED FOR EXTRAPOLATION, EXTRAPOLATED VALUE = ,3KIRK 52
000064 1E14.6)
000065 1010 FORMAT ( 22H NO. OF POINTS GIVEN =,13,3CH, NO. OF INTERPOLATED P
000066 10POINTS =,13/
000067 1 5X,11HX-INTERPOL.,9X,11HY-INTERPOL.,8X,14HDYDX-INTERPOL.
2,6X,15HD2YDX-INTERPOL.,5X,15HRCURV-INTERPOL.,5X,16HLENTH-INTERPOL
3.)
000070 1020 FORMAT(6E20.8)
000071 END
3KIRK 57

```

Q ELT SPLN2,1,720519, 31490

```

000001      SUBROUTINE SPLN2 (N,SURF,YIP,YNP)
000002      INTEGER SURF
000003      C
000004      C SPLN22 CALCULATES FIRST AND SECOND DERIVATIVES AT SPLINE POINTS
000005      C END CONDITION - DERIVATIVES SPECIFIED AT END POINTS
000006      COMMON /SPLFIT/ G(100),SR(100),EM(50),SLOPE(50),CURV(50),X(50),
000007      1Y(50)
000008      COMMON IM, ID, IY, TITLE(20), DATA(28), XB(2,25), YB(2,25), NBL, NBBI
000009      WRITE (6,1010) IM, ID, IY
000010      1010 FORMAT ('1DATE ',A2,'-',A2,'-',A2,36X,'BLADE PROFILE PROGRAM'/)
000011      WRITE (6,1005) TITLE
000012      1005 FORMAT (1X,20A4/)
000013      WRITE (6,1020) SURF
000014      1020 FORMAT (' INPUT SPLINE POINTS FOR SURFACE ',I1)
000015      SB(1)=0.5
000016      F=(Y(2)-Y(1))/(X(2)-X(1))-YIP
000017      G(1)=F*3. / (X(2)-X(1))
000018      NO=N-1
000019      IF (NO-2) 20,7,7
000020      7 DO10 I=2,NO
000021      A=(X(I)-X(I-1))/6.
000022      C=(X(I+1)-X(I))/6.
000023      W=2. *(A+C)-A*SB(I-1)
000024      SB(I)=C/W
000025      F=(Y(I+1)-Y(I))/(X(I+1)-X(I))-(Y(I)-Y(I-1))/(X(I)-X(I-1))
000026      10 G(I)=(F-A*G(I-1))/W
000027      20 F=YIP-(Y(N)-Y(N-1))/(X(N)-X(N-1))
000028      W=(X(N)-X(N-1))/6. *(2. -SB(N-1))
000029      EM(N)=(F-(X(N)-X(N-1))*G(N-1)/6. )/W
000030      DO30 I=2,N
000031      K=I+1-I
000032      30 EM(K)=G(K)-SB(K)*EM(K+1)
000033      SLOPE(1)=(X(1)-X(2))/6. *(2. *EM(1)+EM(2))+(Y(2)-Y(1))/(X(2)-X(1))
000034      1)
000035      DO40 I=2,N
000036      40 SLOPE(I)=(X(I)-X(I-1))/6. *(2. *EM(I)+EM(I-1))+(Y(I)-Y(I-1))/
000037      1 (X(I)-X(I-1))
000038      DO 45 I=1,N
000039      45 CURV(I)=((1.+SLOPE(I)**2)**1.5)/ABS(EM(I))
000040      WRITE (6,1000) N, (X(I),Y(I),SLOPE(I),EM(I),CURV(I),I=1,N)
000041      RETURN
000042      1000 FORMAT ( 16H NO. OF POINTS =,I3/10X,1HX,19X,1HY,19X,5HSLOPE,15X,
000043      A2HEM,15X,4HCURV/(5E20.8))
000044      END

```

3KIRK952

3KIRK953

3KIRK954

3KIRK960

3KIRK962

3KIRK968

3KIRK969

3KIRK970

3KIRK971

3KIRK974

3KIRK975

3KIRK977

3KIRK979

3KIRK94

3KIRK986

Q ELT STAK,1,720519, 31502

```

000001      SUBROUTINE STAK (L,RAD,LREC,XHT,YHT,YCENT,TITLE,IM, ID,IY,
000002      1XTRAN,YTRAN,XC,YC,XSH,YSH,XST,YST)
000003      DIMENSION LREC(6),TITLE(20),XX(2),YY(2),XC(1000,2),YC(1000,2),
000004      1XSH(1000,2),YSH(1000,2),XST(1000,2),YST(1000,2)
000005      5 FORMAT (4E20.9)
000006      10 FORMAT (6F10.0)
000007      20 FORMAT (2F20.8)
000008      1000 FORMAT ('1DATE ',A2,'-',A2, '-',A2,36X' BLADE PROFILE PROGRAM'/)
000009      1005 FORMAT (1X,20A4)
000010      1010 FORMAT (42X,'WRAPPED BLADE COORDINATES,HUB,UPPER SURFACE',
000011      1//9X,'X',19X,'Y'/)
000012      1015 FORMAT (42X,'WRAPPED BLADE COORDINATES,HUB,LOWER SURFACE',
000013      1//9X,'X',19X,'Y'/)
000014      1020 FORMAT (42X,'WRAPPED BLADE COORDINATES,TIP,UPPER SURFACE',
000015      1//9X,'X',19X,'Y'/)
000016      1025 FORMAT (42X,'WRAPPED BLADE COORDINATES,TIP,LOWER SURFACE',
000017      1//9X,'X',19X,'Y'/)
000018      1030 FORMAT (20A4)
000019      1035 FORMAT (I5)
000020      1045 FORMAT (' X-Y COORDINATES OF HUB CENTROID, X=',F20.8,'Y=',F20.8/)
000021      GO TO (30,50),L
000022      30 RADH=RAD
000023      READ (5,10) XHT,YHT,XCENT,YCENT,XTRAN,YTRAN
000024      WRITE (2,1030) TITLE
000025      DO 50 J=1,2
000026      ICONT=0
000027      WRITE (6,1000) IM, ID,IY
000028      WRITE (6,1005) TITLE
000029      IF (J-1) 35,35,40
000030      35 WRITE (6,1010)
000031      WRITE (6,1045) XTRAN,YTRAN
000032      XTRAN=XTRAN-XCENT
000033      GO TO 45
000034      40 WRITE (6,1015)
000035      45 N=LREC(J)
000036      WRITE (2,1035) N
000037      LREC(J+2)=N
000038      DO 50 I=1,N
000039      ICONT=ICONT+1
000040      X=XC(I,J)
000041      Y=YC(I,J)
000042      Y=Y-YCENT
000043      Y=RADH*SIN(Y/RADH)+YTRAN
000044      X=X+XTRAN
000045      XX(ICONT)=X
000046      YY(ICONT)=Y
000047      XSH(I,J)=X
000048      YSH(I,J)=Y
000049      IF (ICONT-2) 46,47,47
000050      46 IF (I-N) 50,47,47
000051      47 WRITE (2,5) (XX(IN),YY(IN),IN=1,ICONT)
000052      ICONT=0
000053      50 WRITE (6,20) X,Y
000054      GO TO 200
000055      60 RADT=RAD
000056      WRITE (2,1030) TITLE

```

```
000057      DO 100 J=1,2 ,
000058          ICONT=0
000059          WRITE (6,1000) IM, ID, IY
000060          WRITE (6,1005) TITLE
000061          IF (J-1) 65,65,70
000062      65  WRITE (6,1020)
000063          GO TO 75
000064      70  WRITE (6,1025)
000065      75  N=LREC(J)
000066          WRITE (2,1035) N
000067          DO 100 I=1,N
000068          ICONT=ICONT+1
000069          X=XC(I,J)
000070          Y=YC(I,J)
000071          Y=Y-YCENT+YHT
000072          Y=RADT*SIN(Y/RADT)+YTRAN
000073          X=X+XHT+XTRAN
000074          XX(ICONT)=X
000075          YY(ICONT)=Y
000076          YST(I,J)=X
000077          YST(I,J)=Y
000078          IF (ICONT-2) 80,85,85
000079      80  IF (I-N) 100,85,85
000080      85  WRITE (2,5) (XX(IN),YY(IN),IN=1,ICONT)
000081          ICONT=0
000082      100 WRITE (6,20) X,Y
000083      200 RETURN
000084          END
```

W ELT VELIN,1,720519, 31488

```

000001  SUBROUTINE VELIN (N)
000002  DIMENSION DATA(28),TITLE(20),N(2)
000003  COMMON /SPLFIT/ G(100),SR(100),EM(50),SLOPE(50),CURV(50),XXX(50),
000004  1YYY(50)
000005  COMMON IM, ID, IY, TITLE, DATA, X(2,25), Y(2,25), NBL, NRBI
000006  EQUIVALENCE (DATA(1), GAM), (DATA(2), AR), (DATA(3), T1P), (DATA(4),
000007  1RHOIP), (DATA(5), WTFL), (DATA(6), OMEGA), (DATA(7), ORF), (DATA(8),
000008  2BETAI), (DATA(9), BETAO), (DATA(10), CHORD), (DATA(11), STGR),
000009  3(DATA(12), REDFA), (DATA(13), DENTO), (DATA(14), RI1), (DATA(15), RO1),
000010  4(DATA(16), BETI1), (DATA(17), BETO1), (DATA(18), SPLN1), (DATA(19), RI2),
000011  5(DATA(20), RO2), (DATA(21), BETI2), (DATA(22), BETO2), (DATA(23), SPLN2)
000012  EQUIVALENCE (DATA(24), P0), (DATA(25), W ), (DATA(26),
000013  1RAD), (DATA(27), CP), (DATA(28), W2)
000014  5 FORMAT (20A4)
000015  10 FORMAT (F10.3,2F10.1,2F10.6,10X,F10.2,F10.6)
000016  20 FORMAT (2F10.3,2F10.6)
000017  30 FORMAT (F10.2,F10.6)
000018  40 FORMAT (2I5,10X,4I5)
000019  50 FORMAT (2F10.6,2F10.3,F10.1)
000020  60 FORMAT (8F10.7)
000021  1000 FORMAT ('11DATE ',A2,'-',A2,'-',A2,36X,'BLADE PROFILE PROGRAM'/)
000022  1005 FORMAT (1X,20A4/)
000023  1020 FORMAT (40X,'VELOCITY DISTRIBUTION PROGRAM INPUT DATA'/)
000024  1110 FORMAT (7X,3HGAM,14X,2HAR,13X,3HTIP,12X,5HRHOIP,12X,4HWTF,11X,6H
000025  1 ,10X,5HOMEGH,12X,3HORF)
000026  1040 FORMAT (1X,F16.6,F16.2,F16.3,2F16.7,10X ,F16.2,F16.5/)
000027  1120 FORMAT (6X,5HBETAI,10X,5HBETAO,11X,6HCORDF,11X,5HSTGRF)
000028  1121 FORMAT (2F16.5,2F16.7/)
000029  1125 FORMAT (6X,6HREDFAC,10X,6HDENTOL)
000030  1126 FORMAT (2F16.7/)
000031  1130 FORMAT (41H MBI MBO MM NRBI NBL NRSP)
000032  1010 FORMAT (2I5,10X,4I5/)
000033  1140 FORMAT (40H BLADE SURFACE 1 -- UPPER SURFACE)
000034  1180 FORMAT (7X,2HRI,11,12X,2HRO,11,12X,4HBETI,11,11X,4HBETO,11,11X,5HS
000035  1PLNO,11)
000036  1181 FORMAT (2F16.7,2F16.5,F16.1/)
000037  1190 FORMAT (7X,3HMSP,11,2X,5HARRAY)
000038  1191 FORMAT (1X,8F16.7/)
000039  1200 FORMAT (7X,4HTHSP,11,2X,5HARRAY)
000040  1150 FORMAT (39H BLADE SURFACE 2 -- LOWER SURFACE)
000041  1210 FORMAT (7X,8HMR ARRAY)
000042  1220 FORMAT (7X,11HRMSP ARRAY)
000043  1230 FORMAT (7X,11HBESP ARRAY)
000044  SPLN1=N(1)
000045  SPLN2=N(2)
000046  OMEGA=2.*3.14159*OMEGA/60.
000047  RAD=RAD/12.
000048  AR=32.174*AR
000049  RHOIPE=144./T1P/AR
000050  WTFL=WTFL/32.174/NBL
000051  WU=W*SIN(BETAI/57.296)
000052  WX=W*COS(BETAI/57.296)
000053  U=RAD*OMEGA
000054  VU=WU+U
000055  V=SQRT(VU**2+WX**2)
000056  T1=IIP-V **2/(2.*32.174*778.16*CP)

```

```

000057      P1=P0*(T1/T1P0)**(GAM/(GAM-1.))
000058      RHO=P1*144./T1/AR
000059      AN=WTFL/RHO/WX
000060      PITCH=2.*3.14159*RAD/NBL
000061      H1=AN/PITCH
000062      H2=H1
000063      WX2=W2*COS(BETA0/57.296)
000064      TTR=T1+W**2/(2.*32.174*778.16*CP)
000065      PTR=P1*(TTR/T1)**(GAM/(GAM-1.))
000066      T2=TTR-W2**2/(2.*32.174*778.16*CP)
000067      P2=PTR*(T2/TTR)**(GAM/(GAM-1.))
000068      RHO2=P2*144./T2/AR
000069      AN2=WTFL/RHO2/WX2
000070      H3=AN2/PITCH
000071      H4=H3
000072      CHORD=CHORD/12.
000073      STGR=STGR/RAD/12.
000074      DO 200 I=1,2
000075      K=N(I)
000076      DO 200 J=1,K
000077      X(I,J)=X(I,J)/12.
000078      200 Y(I,J)=Y(I,J)/RAD/12.
000079      RI1=R11/12.
000080      RI2=R12/12.
000081      PO1=P01/12.
000082      RO2=R02/12.
000083      HT=PITCH/NBBI
000084      NUM=CHORD/HT
000085      MBI=15
000086      MBO=NUM+MBI
000087      MM=RHO+15
000088      NRSP=4
000089      X1=-14.*HT
000090      X2=0.0
000091      X3=CHORD
000092      X4=14.*HT+CHORD
000093      WRITE (2,5) TITLE
000094      WRITE (2,10) (DATA(I),I=1,7)
000095      WRITE (2,20) (DATA(I),I=8,11)
000096      WRITE (2,30) (DATA(I),I=12,13)
000097      WRITE (2,40) MBI,MBO,MM,NBBI,NBL,NRSP
000098      WRITE (2,50) (DATA(I),I=14,18)
000099      J=1
000100      205 IF (N(1)-J-7) 210,210,215
000101      210 MAX=N(1)
000102      GO TO 220
000103      215 MAX=J+7
000104      220 WRITE (2,60) (X(1,I),I=J,MAX)
000105      J=MAX+1
000106      IF (N(1)-MAX) 225,225,205
000107      225 J=1
000108      230 IF (N(1)-J-7) 235,235,240
000109      235 MAX=N(1)
000110      GO TO 245
000111      240 MAX=J+7
000112      245 WRITE (2,60) (Y(1,I),I=J,MAX)
000113      J=MAX+1
000114      IF (N(1)-MAX) 250,250,230
000115      250 WRITE (2,50) (DATA(I),I=19,23)
000116      J=1

```

```

000117      255 IF (N(2)-J-7) 260,260,265
000118      260 MAX=N(2)
000119      GO TO 270
000120      265 MAX=J+7
000121      270 WRITE (2,60) (X(2,I),I=J,MAX)
000122      J=MAX+1
000123      IF (N(2)-MAX) 275,275,255
000124      275 J=1
000125      280 IF (N(2)-J-7) 285,285,290
000126      285 MAX=N(2)
000127      GO TO 295
000128      290 MAX=J+7
000129      295 WRITE (2,60) (Y(2,I),I=J,MAX)
000130      J=MAX+1
000131      IF (N(2)-MAX) 296,296,280
000132      296 WRITE (2,60) X1,X2,X3,X4
000133      WRITE (2,60) RAD,RAD,RAD,RAD
000134      WRITE (2,60) H1,H2,H3,H4
000135      WRITE (6,1000) IM, ID, IY
000136      WRITE (6,1005) TITLE
000137      WRITE (6,1020)
000138      WRITE (6,1110)
000139      WRITE (6,1040) (DATA(I),I=1,7)
000140      WRITE (6,1120)
000141      WRITE (6,1121) (DATA(I),I=8,11)
000142      WRITE (6,1125)
000143      WRITE (6,1126) (DATA(I),I=12,13)
000144      WRITE (6,1130)
000145      WRITE (6,1010) MBI, MBO, MM, NBBI, NBL, NRSP
000146      WRITE (6,1140)
000147      J=1
000148      MAX=N(1)
000149      WRITE (6,1180) J,J,J,J,J
000150      WRITE (6,1181) (DATA(I),I=14,18)
000151      WRITE (6,1190) J
000152      WRITE (6,1191) (X(1,I),I=1,MAX)
000153      WRITE (6,1200) J
000154      WRITE (6,1191) (Y(1,I),I=1,MAX)
000155      WRITE (6,1150)
000156      J=2
000157      MAX=N(2)
000158      WRITE (6,1180) J,J,J,J,J
000159      WRITE (6,1181) (DATA(I),I=19,23)
000160      WRITE (6,1190) J
000161      WRITE (6,1191) (X(2,I),I=1,MAX)
000162      WRITE (6,1200) J
000163      WRITE (6,1191) (Y(2,I),I=1,MAX)
000164      WRITE (6,1210)
000165      WRITE (6,1191) X1,X2,X3,X4
000166      WRITE (6,1220)
000167      WRITE (6,1191) RAD,RAD,RAD,RAD
000168      WRITE (6,1230)
000169      WRITE (6,1191) H1,H2,H3,H4
000170      DO 300 I=1,2
000171      K=N(I)
000172      DO 300 J=1,K
000173      300 X(I,J)=12.*X(I,J)
000174      RETURN
000175      END

```


N8300R:72-106
May 1972

13. MULTISTAGE AXIAL FLOW TURBINE PERFORMANCE ANALYSIS PROGRAM

MULTISTAGE AXIAL FLOW TURBINE PERFORMANCE ANALYSIS PROGRAM

1. INTRODUCTION

a. A computer program has been developed for performance analysis of multistage axial flow gas turbines. Its primary purpose is for predesign analysis of axial flow turbines to establish turbine operating characteristics, pressures, temperatures, gas velocities, flow channel geometry, and approximate blade root stresses.

b. Included is Report 7740R-70-032 which describes the program in detail and includes a listing of the program, input instructions, and example case.

c. The program is complete and was used for predesign performance analysis of the NERVA turbine.

d. The program is application as long as the turbine remains axial flow.

e.

f. This program was developed by K. G. Kirk.

2. CONCLUSIONS

a. Gross Conclusions

(1) This program evolved over the past several years of NERVA work. It proved to be an extremely valuable tool, both in the parametric phase of component selection and the final turbine design.

(2) The blade root stress predictions of the program required prior knowledge of the blade geometry, hence it was not extremely useful in predesign calculations.

3. RECOMMENDATIONS

a. Since the program has evolved over a several year period and was originally written for a small scale computer with limited storage, there is room for improvement in the coding to make a cleaner more efficient program.

b. The program has been used principally in connection with rocket engine turbopump applications; however, there are no known program limitations which prevent its use on any other axial flow gas turbine application.

4. REFERENCES

The method of analysis used in the turbine loss analysis is based on the work of Reference (a).

- (a) Stewart, Warner L.; A Study of Axial-Flow Turbine Efficiency Characteristics in Terms of Velocity Diagram Parameters; ASME Paper Number 61-WA-37.

23 July 1968
774OR-68-0010

NERVA THREE-STAGE AXIAL FLOW TURBINE
PERFORMANCE AND AERODYNAMIC ANALYSIS
REFERENCE TURBOPUMP

Approved by:

S. A. Lorenc

S. A. Lorenc, Supervisor
Turbomachinery Section
Engineering Department
NRO

W. E. Campbell
W. E. Campbell, Manager
Turbomachinery Section
Engineering Department
NRO

Prepared by:

K. G. Kirk

K. G. Kirk, Engineer
Turbomachinery Section
Engineering Department
NRO

I. INTRODUCTION

The three-stage axial flow turbine discussed here is the result of an extensive turbopump parametric analysis, including turbopump structural and reliability considerations, leading to the following turbine requirements:

Shaft Horsepower	= 7,280
Turbine Inlet Temperature	= 1,660°R
Turbine Inlet Pressure	= 305 psia
Turbine Pressure Ratio	= 7.01 (Total to Static)
Rotative Speed	= 19,000 rpm

The basic design philosophy maintained for this turbine and those which preceded it during the parametric study included the following:

1. Insure impulse or slightly positive reaction at the blade root by selecting some small amount of reaction at the mean line.
2. Twisted blades are unnecessary because the NERVA turbine blades are relatively short.
3. Maintain constant rotor tip diameter for all stages to maximize tip speed for the first stage which has lower blade stresses, to reduce the total turbine rotor overhung moment and to simplify the turbine housing.
4. Distribute stage loading such that the first stage produces the most work and the last stage produces the least. This assures turbine flow control by the first stage nozzle, resulting in more reliable off-design performance predictions without sacrificing turbine performance.
5. A single tangential inlet line and dual tangential exhaust lines are used, with line sizes being selected as a compromise between line weight and pressure losses.

II. METHOD OF ANALYSIS

Performance analysis for the turbine centers around the method of predicting losses for both the blading and associated inlet and exhaust ducting. The loss analysis selected for the blading is similar to that of Reference (1) and includes these several major assumptions.

1. One-dimensional flow at the mean radius.
2. Adiabatic flow through static components, i.e., manifolds and nozzles.
3. Blading losses may be satisfactorily predicted on the basis of
 - a. Reynolds Number
 - b. Nozzle Exit Angle
 - c. Average Kinetic energy level of the stage
 - d. Rotor Tip Clearance

Losses in the inlet manifold and exhaust collector are based on a total pressure loss coefficient.

Utilizing the required shaft power and assumed turbine flow rate, (which eventually must satisfy the pressure ratio requirement) the specific work requirement of the turbine is determined from the relation

$$\overline{\Delta h} = \frac{\text{SHP } 550}{\dot{W} \text{ J}} \quad (1)$$

and is distributed to each individual stage in a manner consistent with the basic design philosophy.

For the turbine considered here, the stage loading is:

First Stage	40%
Second Stage	33%
Third Stage	27%

Further reduction in last stage loading would result in insufficient axial acceleration of the flow.

Selection of nozzle angles is based on the following criteria:

1. Performance
2. Blade Height
3. Flow Passage
4. Manufacturing Feasibility

Use of hot hydrogen drive gas tends to result in short turbine blades, especially for the first stage, and a pronounced rotor tip clearance effect on turbine performance. Hence, a high nozzle angle (measured from the axial direction) is desirable for the first stage to produce maximum blade length, however, excessively high nozzle angles degrade performance because of the increased wetted area, and increases manufacturing difficulty. These considerations have led to a first stage nozzle angle of 75 degrees. The remaining nozzle angles of 70.5 degrees for the second stage and 66 degrees for the third stage were selected to produce a reasonably good flow passage within the constant rotor tip diameter constraint.

First stage blade speed was selected primarily to satisfy critical speed considerations by maintaining low disc weight. The trade-off between disc weight and turbine performance has led to a first stage mean blade speed of 1200 ft/sec. Remaining stage blade speeds satisfy a constant tip configuration resulting in an average blade speed of 1185 ft/sec.

The above parameters, namely stage load, nozzle angle, degree of reaction and blade speed dictate the gas velocities for the stages and with the gas velocities determined, the blade loss analysis is conducted resulting in interstage pressures and temperatures as well as blade heights and efficiencies. The loss coefficient used for the blade loss analysis was based on data presented in Reference (1) together with correlations made with the M-1 scale model fuel pump test data and NASA three-stage turbine test data. Inasmuch as the effect of rotor tip clearance on stage loss is a function of rotor blade height, it was necessary to provide for blade loss coefficient variation from stage to stage. This was done based on tip clearance leakage data presented in Reference (2).

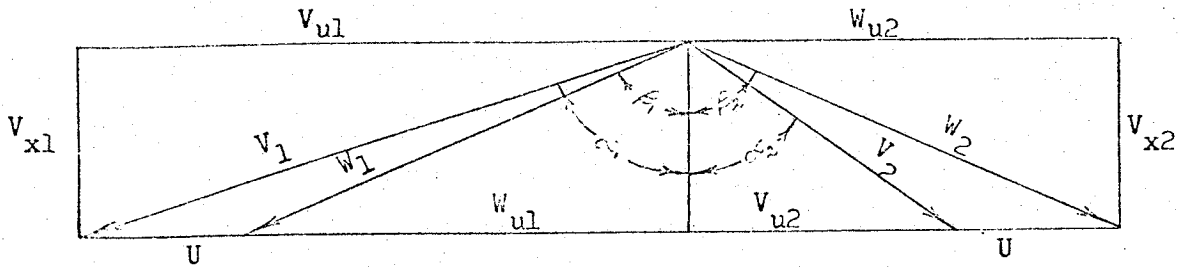
Loss coefficients for the inlet manifold and exhaust collector were based on limited data obtained from the technology turbopump.

In order to facilitate the parametric study that has been made on the NERVA turbine, the above performance analysis procedure has been computerized. A detailed report on this turbine performance program is currently being written and will be published as "Design Point Performance Analysis of Multi-stage Turbines," RN-TM-0411. A brief preliminary explanation of the program and its use together with an example case are included as Appendix B.

The results of this analysis for the three-stage turbine considered here are summarized as follows:

		<u>FIRST</u> <u>STAGE</u>	<u>SECOND</u> <u>STAGE</u>	<u>THIRD</u> <u>STAGE</u>	<u>THREE</u> <u>STAGE</u>
Flow Rate	Lb/Sec	4.05	4.05	4.05	4.05
Pressure Ratio (Total-to-Static)	---	2.519	2.169	1.808	7.01
Velocity Ratio	U/Co	0.147	0.164	0.190	0.106
Actual Enthalpy Drop	BTU/Lb	508	419	342	1,269
Static Efficiency	%	38.1	40.3	45.6	51.7

VELOCITY DIAGRAMS



NOZZLE EXIT (1)				ROTOR EXIT (2)		
1	2	3		1	2	3
1,200	1,186	1,170	U	1,200	1,186	1,170
6,434	5,500	4,683	V_u	4,154	3,342	2,646
1,724	1,948	2,085	V_x	1,724	1,948	2,085
6,662	5,835	5,126	V	4,498	3,868	3,369
75.0	70.5	66.0	α	67.5	59.8	51.8
5,234	4,314	3,512	W_u	5,354	4,528	3,817
5,511	4,734	4,084	W	5,625	4,929	4,349
71.8	65.7	59.3	β	72.2	66.7	61.4
ABSOLUTE NOZZLE EXIT			MACH NO.	RELATIVE ROTOR EXIT		
0.958	0.866	0.784		0.811	0.735	0.668

A complete computer output for the base case is included as Appendix A.

The above aerodynamic analysis is, of necessity, a predesign analysis; following it, the blade profiles are designed to satisfy the velocity triangle requirements. Once the blade profiles have been generated two more phases of the turbine aerodynamics are executed. First a detailed blade loss analysis based on blade section properties is made using Soderberg's Method. The performance prediction from this method of analysis is compared with the pre-design analysis and any significant discrepancies are resolved through blade profile and/or clearance modifications. Secondly, the surface velocity distribution is analyzed for adverse diffusion characteristics using the NASA velocity distribution program.

Design of the NERVA turbine has not progressed to the point of conducting these final aerodynamic design studies, however, the final turbine design will have these considerations incorporated.

REFERENCES

1. A Study of Axial-Flow Turbine Efficiency Characteristics in Terms of Velocity Diagram Parameters, by Warner L. Stewart, ASME Paper 61-WA-37
2. Experimental Investigation of Three Tip-Clearance Configurations Over a Range of Tip Clearance Using a Single-Stage Turbine of High Hub-to-Tip Radius Ratio, by Milton G. Kofskey, NASA TMX-472.

APPENDIX A

BASE CASE

COMPUTER PRINTED OUTPUT

DATE07-19-68

3 STAGE GAS TURBINE DESIGN ANALYSIS

SPOOL NUMBER 1 OF 1

CASE NUMBER

0180-05

GAS PROPERTIES

ABSOLUTE VISCOSITY
LB/FT-SEC
0.134E-04

CONSTANT PRESSURE
SPECIFIC HEAT
BTU/LB-DEG R
3.504

SPECIFIC HEAT
RATIO
1.391

GAS
CONSTANT
FT/DEG R
766.97

CASE CONDITIONS

E.C. LOSS
COEFFICIENT
5.000

MAN. LOSS
COEFFICIENT
0.750

ROTATIVE
SPEED
RPM
19000.0

MEAN BLADE
SPEED
FT/SEC
1200.0

INLET TOTAL
PRESSURE
PSIA
305.0

INLET TOTAL
TEMPERATURE
DEG R
1660.0

FLOW
RATE
LB/SEC
4.05

SHAFT
HORSEPOWER
7280.0

BLADE CROSS SECTION AREA DISTRIBUTION DELTA OVERSPEED FACTOR OVERSPEED EXPONENT

0.1000E 01 0.0000E 00 0.0000E 00 1.000 1.000 3.000

STRESS LIMIT PSI 50000.0
MATERIAL DENSITY LB/CU-IN 0.300
PARAMETER INDEX DATA SWITCHES ON

STAGE INPUT PARAMETERS

STAGE	REACTION	ANGLE	LOAD	MEAN	RADIUS	VELOCITY	NOZZLE	ROTOR	ROTOR	ROTOR	ASPECT	TH/CD	SECTION	SOLIDITY
1	0.050	75.00	1.000	1.000	1.000	0.400	0.400	0.400	0.035	1.25	0.35	0.40	1.650	1.700
2	0.090	70.50	0.825	0.987	1.000	0.400	0.400	0.400	0.035	1.50	0.30	0.30	1.650	1.600
3	0.130	66.00	0.675	0.975	1.000	0.400	0.400	0.400	0.035	1.50	0.30	0.30	1.650	1.600

DATE 07-19-68

STAGE VELOCITIES

PAGE 2

NON TWISTED BLADES

STAGE	U FT/SEC	VU1 FT/SEC	VX1 FT/SEC	V1 FT/SEC	WU1 FT/SEC	W1 FT/SEC	VU2 FT/SEC	VX2 FT/SEC	V2 FT/SEC	WU2 FT/SEC	W2 FT/SEC	REACTION
1	1161.2	6587.3	1765.1	6819.7	5426.1	5706.0	-4353.7	1775.9	4701.9	-5514.9	5793.8	0.039
	1200.0	6432.7	1723.6	6659.6	5232.7	5509.2	-4152.7	1723.6	4496.2	-5352.7	5623.4	0.050
	1238.7	6285.3	1684.1	6507.1	5046.6	5320.2	-3972.2	1678.0	4312.1	-5211.0	5474.5	0.055
2	1132.3	5693.4	2016.1	6039.9	4561.1	4986.8	-3560.8	2018.9	4093.3	-4693.1	5109.0	0.058
	1185.5	5498.5	1947.1	5833.1	4313.0	4732.2	-3340.9	1947.1	3866.9	-4526.4	4927.4	0.090
	1238.7	5317.3	1883.0	5640.9	4078.5	4492.2	-3150.0	1887.9	3672.4	-4388.8	4777.6	0.126
3	1101.7	4895.9	2179.8	5359.3	3794.2	4375.8	-2868.0	2168.6	3595.6	-3969.7	4523.4	0.076
	1170.2	4681.5	2084.3	5124.5	3511.2	4083.3	-2645.2	2084.3	3367.7	-3815.5	4347.7	0.130
	1238.7	4486.6	1997.6	4911.2	3247.9	3813.0	-2457.5	2019.2	3180.7	-3696.3	4211.8	0.166

DATE 07-19-68

STAGE MACH NUMBERS

PAGE 3

NON TWISTED BLADES

STAGE	ABSOLUTE NOZZLE EXIT	RELATIVE ROTOR EXIT
1	0.985 0.958 0.932	0.839 0.811 0.787
2	0.902 0.866 0.833	0.765 0.734 0.710
3	0.824 0.783 0.747	0.697 0.668 0.645

DATE07-19-68

STAGE GEOMETRY

NON TWISTED BLADES

STAGE	MEAN RADIUS IN	BLADE HEIGHT 1 IN	BLADE HEIGHT 2 IN	ANNULUS AREA 1 SQ-IN	ANNULUS AREA 2 SQ-IN	ALPHA1 DEG	BETA1 DEG	ALPHA2 DEG	BETA2 DEG
1	7.2373	0.366	0.467	16.749	21.275	75.00	71.98	-67.80	-72.15
2	7.1501	0.553	0.642	24.996	28.847	75.00	71.76	-67.45	-72.15
3	7.0579	0.742	0.826	33.141	36.643	70.50	66.12	-52.90	-61.35
						70.50	65.30	-51.76	-61.35
						70.50	58.40	-50.59	-61.35

DATE 07-19-68

STAGE PERFORMANCE

PAGE 6

STAGE	LAWDA	DEL H BTU/LB	ETS	ETT	U/CO
1	0.113	507.3	0.381	0.528	0.147
2	0.134	418.5	0.403	0.550	0.164
3	0.159	342.4	0.456	0.642	0.190

OVERALL BLADE PERFORMANCE

DEL H BTU/LB	UVA FT/SEC	U/CO	U/CO'	PRST	PRTT	ETST	ETTT	RET	RES
1268.4	1185.2	0.110	0.115	5.953	4.964	0.552	0.601	1.068	1.077

OVERALL TURBINE PERFORMANCE INCLUDING MANIFOLD

U/CO	U/CO'	PRST	PRTT	ETST	ETTT
0.110	0.114	6.075	5.065	0.548	0.595

OVERALL TURBINE PERFORMANCE INCLUDING MANIFOLD AND EXHAUST COLLECTOR

U/CO	U/CO'	PRST	PRTT	ETST	ETTT
0.106	0.108	7.011	6.589	0.517	0.530

INLET MANIFOLD CONDITIONS

AREA SQ-IN	MACH NUM	P PSIA	T DEG-R	PTME PSIA
11.48	0.200	296.6	1647.1	298.8

EXHAUST COLLECTOR EXIT FLANGE CONDITIONS

AREA SQ-IN	MACH NUM	PT PSIA	P PSIA	TT DEG R	T DEG R
45.94	0.300	46.2	43.5	1298.0	1275.5

DATE 07-19-68

ROTOR BLADE ROOT STRESS

STAGE	MEAN RADIUS IN	AVERAGE BLADE HEIGHT IN	STAGE LOAD PERCENT	CENTRIPETAL STRESS PSI	BENDING STRESS PSI	TOTAL STRESS PSI
1	7.2373	0.416	40.0	9283.4	1293.8	10577.2
2	7.1501	0.597	33.0	13143.3	1725.3	14868.7
3	7.0579	0.784	27.0	17029.8	2324.8	19414.6

APPENDIX B
MULTISTAGE AXIAL FLOW TURBINE
PERFORMANCE ANALYSIS PROGRAM

ABSTRACT

A computer program has been developed for performance analysis of multistage axial flow gas turbines. Its primary purpose is for predesign analysis of turbines to establish turbine operating characteristics, pressures, temperatures, gas velocities, flow channel geometry and approximate blade root stresses. The program has been used principally in connection with rocket engine turbopump applications, however there are no known program limitations which prevent its use on any other axial flow gas turbine application.

This program is in the IBM 1130 version of Fortran IV.

A. PROGRAM DESCRIPTION

This computer program has been devised for parametric analysis of multi-stage, single or two-spool, axial flow gas turbines. Because of the fact that a large number of independent variables are considered during parametric analysis of turbines and because of the many mathematical relations involved (some requiring numerical solution), it was necessary to employ a high-speed digital computer. The program is in the IBM 1130 version of Fortran IV and is used on that machine. All major parameters consistent with conventional gas turbine design have been included in the analytic procedure. Specific information determined by the program includes the following:

1. Velocity diagrams
2. Mach numbers
3. Flow channel geometry
4. Gas state at each axial station
5. Performance
6. Blade root stresses

B. METHOD OF SOLUTION

The analysis utilized in this program is based on the following major assumptions:

1. One-dimensional flow at the mean radius
2. Subsonic and/or transonic flow
3. Adiabatic flow in stators

The loss analysis used in the performance section of the program is a modified version of that discussed by Stewart in Reference (1). In this loss analysis blade row losses are assumed to be a function primarily of the average kinetic energy of the blade row. Hence, specification of the velocity triangle for a stage through the specific work requirement, stage reaction, nozzle discharge angle and blade speed leads to turbine performance and associated parameters such as gas state.

Inlet manifold and exhaust collector losses are calculated using a total pressure loss coefficient defined by

$$Y_P = \frac{P_{o1} - P_{o2}}{P_{o2} - P_2}$$

where

Y_P = Total pressure loss coefficient

P_{o1} = Inlet total pressure

P_{o2} = Exhaust total pressure

P_2 = Exhaust static pressure

These two component losses are included in over-all turbine performance.

Although performance is based on a one dimensional analysis at the mean line, the radial variation of flow properties based on the mean line values is determined assuming simple radial equilibrium.

This is accomplished for either of the following two types of blading:

1. Free Vortex
2. Non-twisted

Determination of the radial variation of flow properties serves at least these three purposes;

1. Evaluation of axial bearing loads
2. Evaluation of blade gas bending loads
3. Evaluation of blade root reaction

Distribution of work between stages is specified by the "stage load ratio" defined as follows:

$$X_i = \frac{\Delta h_i}{\Delta h_1}$$

where

X_i = Stage load ratio of stage i

Δh_i = The specific work of stage i

Δh_1 = The specific work of the first stage

Obviously the stage load ratio for the first stage is always one (1).

The meridional curvature of the turbine is determined by the "mean radius ratio" defined by

$$Y_i = \frac{U_{m_i}}{U_{m_1}}$$

where

Y_i = The mean radius ratio of stage i

U_{m_i} = Mean blade speed of stage i

U_{m_1} = Mean blade speed of stage 1

Also for the first stage this parameter is always one by definition.

Axial acceleration of the flow across the rotor is given by the "axial velocity ratio" defined as

$$Z_i = \frac{V_{x_{2,i}}}{V_{x_{1,i}}}$$

where

Z_i = the axial velocity ratio of stage i

$V_{x_{1,i}}$ = rotor inlet axial velocity of stage i

$V_{x_{2,i}}$ = rotor exit axial velocity of stage i

In addition to the aero-thermal aspects of the program, provision is made for determining blade root stress for each rotor. Blade root stress is determined for uniform cross section blades, hollow blades, tapered blades or a combination of hollowing and tapering. The radial distribution of blade cross section area is given by

$$\frac{A(r)}{A_b} = B + C \phi + D \phi^2$$

$$\phi = \frac{r - R_h}{R_T - R_h}$$

$$C = \frac{R_b - R_h}{R_T - R_h}$$

where

- $A(r)$ = blade cross section area at any radius r
- A_b = blade cross section area at the point where area begins to change
- B = constant
- C = constant
- D = constant
- r = radius corresponding to $A(r)$
- R_h = hub radius
- R_T = tip radius
- R_b = radius at which area begins to change
- ϕ = non-dimensional radius
- δ = ϕ at which area begins to change

The centripetal stress equation is then dependent only on the constants B , C , D and δ . Although the precise blade geometry will generally not be known in the initial turbine design phase, the required constants may be determined from a similar family of blades with reasonable accuracy. If the blades are of uniform cross section, then

$$\begin{aligned} B &= 1 \\ C &= 0 \\ D &= 0 \end{aligned}$$

and the stress equation is independent of δ .

Assuming symmetrical beam bending, the bending stress at the blade root is given by

$$\sigma_b = \frac{M}{Z}$$

where

$$\begin{aligned} \sigma_b &= \text{bending stress} \\ M &= \text{bending moment} \\ Z &= \text{section modulus} \end{aligned}$$

and the section modulus is assumed to be

$$Z = \xi Ct^2$$

where

ξ = section modulus constant

C = blade chord

t = blade thickness

The bending stress equation can then be reduced to a form which is dependent on the following blade properties:

Solidity

Aspect Ratio

Thickness/Chord ratio

Section modulus constant (ξ)

If a blade were of rectangular cross section then

$$\xi = 1/6$$

For actual blades, ξ may be only fifty or sixty percent of this theoretical value.

The stress calculation may be done at a speed other than that for which nominal performance is done. The speed at which stress is determined is given by

$$N_s = N_n \times F_{os}$$

where

N_s = stress speed (or overspeed)

N_n = nominal speed

F_{os} = overspeed factor

The power used for gas bending stress is then given by

$$SHP_s = SHP_n \times F_{os}^{E_{os}}$$

where

SHP_s = stress shaft power

SHP_n = nominal shaft power

E_{os} = overspeed exponent (normally 3 for turbopumps)

Special features of the program provide for the following:

1. Specification of turbine pressure ratio or turbine weight flow rate, whichever is considered independent.
2. Internal modification of the meridional flow curvature to give all rotors the same tip diameter.
3. Internal modification of one of the following parameters to arrive at some blade root stress limit:
 - a. Rotative speed
 - b. Mean blade speed
 - c. Pressure Ratio
 - d. Inlet pressure
4. Single turbine or two turbines in series (two spool).

The maximum number of stages per turbine is ten (ten for each spool in the two spool configuration).

The above discussion is only a brief explanation of the methods employed in this program and is intended to provide the minimum information necessary for program use. A complete report with all equations and numerical solutions employed (AGC RW-TM-0411, Design Point Performance Analysis of Multi Stage Turbines) is currently being written.

C. OPERATING INSTRUCTIONS

Two types of cases should be considered in the following discussion. The first which is the basic case contains all information necessary for the case to be executed and must be the first case for any given job loading. The second type of case may not be used as the first case and is used to change one or more parameters in the previous case. This provides a convenient method of stacking cases, requiring only a few cards. Base cases may also be stacked and is advised if a large number of parameters are to be changed. Loading of each type of case is discussed in detail in the following section. All options are controlled by either a flag or a data switch.

1. Base Case

The card format for each data card is shown on the attached loading sheets (Pages 18, 19, and 20).

Parameters appearing on each card are as follows:

CARD 1 - The date is placed on this card using three two digit fields.

- *① Month
- ② Day
- ③ Year

Leading zeros should be used where necessary to make two digits.

CARD 2 - This card is for gas property data.

- ④ Gas constant ft/°R
- ⑤ Specific heat ratio ---
- ⑥ Constant pressure specific heat BTU/lb - °R
- ⑦ Absolute viscosity lb/ft - sec

These first two cards are unique in that this data may not be altered for successive stacked cases in a given job load.

*NOTE: Circled numbers are parameter numbers and correspond to load sheet numbers.

CARD 3 - This card is for an identifying case number consisting of any six alpha-numeric characters.

- ⑧ Case number

CARDS 4, 5, and 6 - These three cards are title cards and may contain any alpha-numeric data. This information has been divided into three categories (one for each card).

- ⑨ Turbine Application (Card 1)
- ⑩ Turbine Characteristics (Card 2)
- ⑪ Case Objectives (Card 3)

CARD 7 - This card is for the six option control flags and number of spools (one or two). The values to be assigned each flag for the desired case options are shown on page 25.

- (12) Radial velocity distribution option flag
- (13) Stress option flag
- (14) Index page option flag - This option provides for printing a duplicate of the case input data, identical to the first page of output, to be used for filing purposes.
- (15) Typewriter option flag - If one of the stress adjusting options is selected (via flag (13)), intermediate values of the adjusting parameter may be observed on the 1130 console typewriter during the adjusting cycle. This is a diagnostic device and is controlled by this flag.
- (16) Pressure ratio option flag
- (17) Number of spools
- (18) Case flag - indicates whether next case is a change case or base case.

CARD 8 - The required pressure ratio is placed on the card. If flag (16) is option five (5), this card must be omitted.

- (19) Pressure ratio

The next two cards contain information which is independent of whether the case is for a single or two-spool configuration.

CARD 9

- (20) Turbine flow rate lb/sec
- (21) First spool, first rotor mean blade speed ft/sec
- (22) Exhaust collector flange Mach number ---

A value must be input for this parameter regardless of whether an exhaust collector exists on the turbine analyzed or not. Its value must be greater than zero (0) and less than one (1).

- (23) Spool radius ratio ---
 Defined as the ratio of first spool last rotor mean blade radius to second spool first rotor mean blade radius. If the case is for a single spool, any value may appear in this field.
- (24) Inlet total temperature °R
- (25) Inlet total pressure psia
- (26) Inlet manifold flange Mach number required as is parameter (22).
- (27) Inlet manifold total pressure loss coefficient ---
 defined on page 2.

CARD 10

- (28) Exhaust collector total pressure loss coefficient ---
 defined on page 2.

Parameters (27) and (28) must be input but may be zero (0) in which case the losses of the manifold and/or exhaust collector are zero.

- (29) Inlet tangential velocity ft/sec
 This parameter is used only if data switch two is up.
 Its primary use is in single spool analysis of the second spool of a two spool pair where the tangential velocity component leaving the first spool is known.

CARD 11 - This is the first card containing individual spool information. Specifically it contains information pertaining to stress calculations and must be omitted if flag (13) is option five (5).

- (30) Rotor material density lb/in³
- (31) First spool rotor stress limit psi
- (32) Over speed factor ---
 defined on page 5.

- ③③ Over speed exponent
defined on page 5.
- ③④ Delta
defined on page 3.

CARD 12

- ③⑤ Shaft power of spool Hp
- ③⑥ Rotative speed of spool RPM
- ③⑦ Number of stages in spool ---

The next series of cards contain information pertaining to individual stages. Each card must have as many values as there are stages. Additional values will be ignored.

CARD 13

- ③⑧ Stage reactions ---

CARD 14

- ③⑨ Stage nozzle angles Degrees

CARD 15

- ④⑩ Stage load ratios - defined on page 2. ---

CARD 16

- ④① Mean radius ratio - defined on page 3. ---

CARD 17

- ④② Axial velocity ratios - defined on page 3. ---

CARD 18

- ④③ Nozzle blade loss coefficients ---
defined in reference (1)

CARD 19

- ④④ Rotor blade loss coefficients ---
defined in Reference (1)

CARD 20

- ④⑤ Rotor tip clearance in.

CARD 21

(46) Rotor aspect ratio ---

CARD 22

(47) Rotor thickness/chord ratio ---

CARD 23

(48) Rotor solidity ---

CARD 24

(49) Rotor blade section modulus constant ---
defined on page 5.

CARD 25 - This card has the coefficients determining the blade radial cross sectional area distribution. They are the coefficients of a quadratic equation as defined on pages 3 and 4.

(50) Constant term

(51) Linear term coefficient

(52) Quadratic term coefficient

For a constant cross section blade, the following parameter values

must be used:

34 = 1.0

50 = 1.0

51 = 0.0

52 = 0.0

Cards 21 through 25 contain information pertaining to the stress analysis portion of the program only. They may be omitted if flag 13 is option five (5) but must be included if blade root stress is desired.

The above cards constitute a complete base case for a single spool turbine. If there are two spools, cards 11 through 25 must be repeated for the second spool.

Additional base cases may be stacked by starting over with Card 3. This requires flag 13 to be two (2) for each case preceding a base case.

For a change case flag (18) must be one (1) on the preceding case and the following cards make up the change case:

CARD 1a - This card contains a new case number.

(8) Case number

CARD 2a - This card contains the number of parameters to be changed and the code number of each.

(53) Number of parameters to be changed

(54) Parameter code numbers (as many as indicated by (53)).

Code numbers for each parameter appear on pages 21 through 24 together with restrictions on their use. Code numbers should not be confused with circled parameter numbers.

CARD 3a

(55) New parameter values

New parameters must appear in the same order as the corresponding code numbers on Card 2a, one parameter per card except for parameters with code numbers (25) thru (46) (see page 24).

In addition to those options controlled by the flags on Card 7, other options may be exercised through use of the IBM 1130 Console data switches. Switch 1 is used to control the type of velocity triangle. The normal selection is with this switch off (down) and this normal switch position should be used almost exclusively.

Switch 2 is used in conjunction with the inlet tangential velocity (parameter (29)) and must be on whenever it is desired to input this parameter.

Switch 3 is used to control the constant tip radius option. It causes internal adjustment of the mean radius ratio of successive stages after the first until all rotors have the same tip radius.

For switch positions and their effect, see page 26.

D. RESTRICTIONS

This program is restricted to a maximum of ten stages per spool. The blade loss analysis includes no provision for shock losses, therefore use of the program should be restricted to subsonic and transonic flow.

Selecting the option of controlling blade root stress by internal adjustment of mean blade speed should be done with caution since blade root stress is relatively insensitive to blade speed, at constant rotative speed, and only small adjustments can be made.

E. TIMING (IBM 1130 COMPUTER)

Initial loading of the program requires approximately seven (7) minutes in object deck form. Execution of each case thereafter requires between two (2) and ten (10) minutes depending on the number of stages and the options selected.

F. STORAGE REQUIREMENTS

The core-storage requirement of the mainline program and all of its associated subroutines is approximately 20000 word bits. However, the program is used on the IBM 1130, with only 5000 (aprox.) word bits of core storage, by maintaining the subroutines on a "load on call" (LOCAL) basis.

G. LISTING

A listing of the program with all control cards required for compilation, production of an object, deck and execution of the program on the IBM 1130 computer is attached. Data cards for the following example case are also listed at the end of the program following the "LOCAL" cards.

H. EXAMPLE CASE

The printed output for an example case is attached to exemplify the information generated by the program. This case is for a twin-spool case with seven (7) stages on the first spool and three (3) stages on the second spool. Hydrogen gas properties are used for this case.

Input data for the case is listed on page one (1) and the optional index page of the output. Some of the parameter values listed here may differ from the values appearing on the input data cards. This is the result of program modification of certain input data to satisfy specified options. In any case, the data printed on the first page is consistent with the remaining information generated by the program. Two additional pieces of input information, inlet manifold and exhaust collector Mach numbers, appear on succeeding pages of the output.

Listed on page two (2) of the output are the blade and gas velocities. The radial distribution used (free vortex or non-twisted blades) is listed at the top of this page and on all other pages where it has an effect on the parameters listed. The velocities or velocity components are given for three radial blade positions; hub, mean, and tip; in that order.

The absolute nozzle exit and relative rotor exit Mach numbers are printed on page three (3), again for three radial blade positions.

Mean rotor radius, blade heights, annulus areas, and gas angles are given on page four (4).

On page five (5) pressures and temperatures are given at the various axial stations. One (1) denotes stator exit conditions and two (2) denotes rotor exit conditions.

Turbine performance is listed on page six (6) with individual stage performance preceding over-all performance.

Stress information is given on page seven (7) for each rotor.

If the case is for a two-spool configuration (as is this example), then pages one (1) through seven (7) are repeated for the second spool as pages eight (8) through fourteen (14). Over-all two-spool performance is given on page fifteen (15) and is based on the following four (4) loss configurations:

1. Both spools excluding manifold and exhaust collector losses.
2. Both spools including manifold losses.
3. Both spools including exhaust collector losses.

4. Both spools including manifold and exhaust collector losses.

Parameters listed on the printed output in symbolic form which are not explained elsewhere are defined as follows:

Page 2 and 9 Output

U = Mean blade speed
VU1 = Stator exit tangential gas velocity component
VX1 = Stator exit axial gas velocity component
V1 = Stator exit gas velocity
WU1 = Rotor inlet relative tangential gas velocity component
W1 = Rotor inlet relative gas velocity
VU2 = Rotor exit absolute tangential gas velocity component
VX2 = Rotor exit absolute axial gas velocity component
V2 = Rotor exit absolute gas velocity
WU2 = Rotor exit relative tangential gas velocity component
W2 = Rotor exit relative gas velocity

Page 4 and 11 Output

Blade Height 1 - Stator trailing edge blade height
Blade Height 2 - Rotor trailing edge blade height
Annulus Area 1 - Stator trailing edge annulus area
Annulus Area 2 - Rotor trailing edge annulus area

Page 5 and 12 Output

PT1 - Stator exit total pressure
P1 - Stator exit static pressure
PT2 - Rotor exit total pressure
P2 - Rotor exit static pressure
TT1 - Stator exit total temperature
T1 - Stator exit static temperature
TT2 - Rotor exit absolute total temperature
T2 - Rotor exit static temperature

STAGE PERFORMANCE

- LAMDA - Stage Work-Speed Parameter (Reference 1)
- DEL H - Stage Specific Work
- ETS - Stage Total to Static Efficiency
- ETT - Stage Total to Total Efficiency
- U/Co - Stage Isentropic Spouting Velocity Ratio

OVER-ALL BLADE PERFORMANCE

(No manifold or exhaust collector losses)

- DEL H - Over-all turbine specific work
- UMA - Average mean blade speed
- U/Co - Over-all isentropic spouting velocity ratio
(based on static pressure ratio)
- U/Co' - Over-all isentropic spouting velocity ratio
(based on total pressure ratio)
- PRST - Over-all total to static pressure ratio
- PRTT - Over-all total to total pressure ratio
- ETST - Over-all total to static efficiency
- ETTT - Over-all total to total efficiency
- RET - Total reheat factor
- RES - Static reheat factor

Following the above performance data is essentially the same information including the manifold loss (page 6) or exhaust collector loss (page 13).

INLET MANIFOLD CONDITIONS

- AREA - Inlet manifold flow area
- P - Static pressure corresponding to inlet conditions
and inlet Mach number

T - Static temperature corresponding to inlet conditions
and inlet Mach number
PTME - Manifold exit total pressure

REFERENCE:

- (1) Stewart, Warner L.; A Study of Axial-Flow Turbine Efficiency Characteristics
In Terms of Velocity Diagram Parameters; ASME Paper Number 61-WA-37.

1. DATA OF CARDS 1, 3, 7, 1a, 2a AND THE LAST PARAMETER OF 12 MUST BE RIGHT ADJUSTED WITH NO DECIMAL POINT.
 2. DATA OF CARDS 7, 5, 6 MAY BE ANY ALPH. NUMERIC DATA.
 3. ALL REMAINING DATA REQUIRES A DECIMAL POINT.
 4. SEE ATTACHED SHEET FOR DETAILED EXPLANATION OF PARAMETERS DENOTED BY CIRCLED NUMBERS.

CARD 1: REQUIRED FOR EACH LOAD OF THE PROGRAM. GAS PROPERTIES: GAS CONSTANT, SPECIFIC HEAT RATIO, CONSTANT PRESSURE SPECIFIC HEAT, ABSOLUTE VISCOSITY. (Circled numbers 1, 2, 3, 4, 5, 6, 7)

CARD 2: START OF FIRST CASE.

CARD 3: CASE NUMBER.

CARD 4: APPLICATION.

CARD 5: CHARACTERISTICS.

CARD 6: OBJECTIVE.

CARD 7: INLET PLAS & NUMBER OF SPOOLS: PLAS. W. PLAS. KEYS, PLAS. KEYS, PLAS. KEYS, PLAS. KEYS. (Circled numbers 11, 12, 13, 14, 15, 16, 17, 18, 19, 20)

CARD 8: INLET MASS FLOW RATE.

CARD 9: SPOOL 1st ST. MEAN BLADE SP., EXH. FLANGE MACH NO., SPOOL RADIUS RATIO, INLET TOTAL TEMP., INLET TOTAL PRES., INLET WAKT. FLANGE AREA, WAKT. LOSS COEFFICIENT. (Circled numbers 21, 22, 23, 24, 25, 26, 27, 28, 29, 30)

CARD 10: INLET TANGENTIAL VELOCITY. (Circled number 31)

CARD 11: OVERSPEED FACTOR, OVERSPEED EXPONENT, DELTA. (Circled numbers 32, 33)

CARD 12: INLET SPEED, NUMBER OF STAGES. (Circled numbers 34, 35, 36, 37)

CARD 13: INLET CHARGED TIME. (Circled number 38)

CARD 14: INLET CHARGED TIME. (Circled number 39)

CARD 15: INLET CHARGED TIME. (Circled number 40)

CARD NO.	TEXT	CHARACTERS EACH	STAGES	OMIT IF M = 5	NEED AS MANY VALUES AS STAGES
CARD 15	SCALE FACTOR RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 16	MEAN RATIO RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 17	PERCENTAGE RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 18	PERCENTAGE RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 19	PERCENTAGE RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 20	PERCENTAGE RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 21	PERCENTAGE RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 22	PERCENTAGE RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 23	PERCENTAGE RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 24	PERCENTAGE RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES
CARD 25	PERCENTAGE RATIO (10 STAGES & CHARACTERS EACH)	10	10	(OMIT IF M = 5)	NEED AS MANY VALUES AS STAGES

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75

FOR A TWO SPOOL TURBINE (FLAG = 2) CARDS 11 TO 25 ARE TO BE REPEATED FOR THE SECOND SPOOL. ADDITIONAL CASES MAY BE STACKED BY REPEATING CARDS 3 TO 25
IF THIS OPTION IS SELECTED, THE LAST VARIABLE OF CARD 7 (INPAR) MUST BE 2. IF ONLY A FEM PARAMETERS ARE TO BE CHANGED FROM THE FIRST CASE IN SUCCESSIVE CASES,
A SECOND OPTION MAY BE SELECTED BY MAKING INPAR = 1 AND ADDING THE FOLLOWING CARDS;

CASE NUMBER
8

NUMBER OF PARAMETERS AND PARAMETER CODE NUMBERS (SEE ATTACHED SHEET FOR CODE NUMBERS)
53 54
(16 FIELDS, 5 CHARACTERS EACH)

PARAMETERS TO BE CHANGED FROM PREVIOUS CASE IN SAME ORDER AS CODE NUMBERS ON CARD 24.
ONE PARAMETER PER CARD EXCEPT STAGE PARAMETERS CODE NUMBERS 25 THRU 46.

CARD 24
CARD 25
CARD 26

SUBJECT

GAS TURBINE DESIGN PROGRAM.....
PARAMETER CHANGE CODE SHEET.....

DATE 2/8/68

WORK ORDER

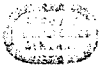
BY

K. KIRK

CHK. BY

DATE

CODE NO.	PARAMETER	FORTRAN SYMBOL
1	CHARACTERISTIC TITLE CARD.....	TITL2
2	OBJECTIVE TITLE CARD.....	TITL3
3	BLADE TYPE PARAMETER.....	IFLAG
4	STRESS CALCULATION PARAMETER.....	MI (M)
5	INDEX PAGE PRINT PARAMETER.....	JFLAG
6	PRESSURE RATIO PARAMETER.....	MFLAG
# 7	NUMBER OF SPOOLS.....	LFLAG
## 8	PRESSURE RATIO.....	PREQS; PREQT; PRQOS; PRQOT.
9	FLOW RATE.....	W
10	FIRST STAGE, FIRST SPOOL, MEAN BLADE SPEED.....	UM (1)
11	EXHAUST FLANGE MACH NUMBER.....	EMACH
12	SPOOL MEAN RADIUS RATIO.....	RFACT
13	INLET TOTAL TEMPERATURE.....	TTI (1)
14	INLET TOTAL PRESSURE.....	PTI (1)
15	FIRST SPOOL SHAFT HORSEPOWER.....	SHP (1)
16	SECOND SPOOL SHAFT HORSEPOWER.....	SHP (2)
17	FIRST SPOOL ROTATIVE SPEED.....	SP (1)
18	SECOND SPOOL ROTATIVE SPEED.....	SP (2)
19	FIRST SPOOL BLADE LOSS COEFFICIENTS.....	COE (1,1,I)
20	SECOND SPOOL BLADE LOSS COEFFICIENTS.....	COE (1,2,I)
21	FIRST SPOOL MANIFOLD LOSS COEFFICIENT.....	COE (2,1,I)
22	SECOND SPOOL MANIFOLD LOSS COEFF. (EXH. COLL.).....	COE (2,2,I)
#23	FIRST SPOOL NUMBER OF STAGES.....	COEM (1)
		COEM(2)
		N (1)



SUBJECT

GAS TURBINE DESIGN PROGRAM.....
PARAMETER CHANGE CODE SHEET.....CONTINUED

BY

K. KIRK

CHK. BY

CODE NO.	PARAMETER	FORTRAN SYMBOL
# 24	SECOND SPOOL NUMBER OF STAGES.....	N (2)
25	STAGE REACTIONS, FIRST SPOOL.....	REA (1,I)
26	STAGE REACTIONS, SECOND SPOOL.....	REA (2,I)
27	NOZZLE ANGLES, FIRST SPOOL.....	ADI (1,I)
28	NOZZLE ANGLES, SECOND SPOOL.....	ADI (2,I)
29	STAGE LOAD RATIOS, FIRST SPOOL.....	X (1,I)
30	STAGE LOAD RATIOS, SECOND SPOOL.....	X (2,I)
31	MEAN BLADE RATIOS, FIRST SPOOL.....	Y (1,I)
32	MEAN BLADE RATIOS, SECOND SPOOL.....	Y (2,I)
33	AXIAL VELOCITY RATIOS, FIRST SPOOL.....	Z (1,I)
34	AXIAL VELOCITY RATIOS, SECOND SPOOL.....	Z (2,I)
35	ROTOR TIP CLEARANCES, FIRST SPOOL.....	CLEAR (1,I)
36	ROTOR TIP CLEARANCES, SECOND SPOOL.....	CLEAR(2,I)
37	ROTOR ASPECT RATIOS, FIRST SPOOL.....	ARS (1,I)
38	ROTOR ASPECT RATIOS, SECOND SPOOL.....	ARS (2,I)
39	ROTOR THICKNESS/CHORD RATIO, FIRST SPOOL.....	TCRS (1,I)
40	ROTOR THICKNESS/CHORD RATIO, SECOND SPOOL.....	TCRS (2,I)
41	ROTOR SOLIDITIES, FIRST SPOOL.....	SOLID (1,I)
42	ROTOR SOLIDITIES, SECOND SPOOL.....	SOLID (2,I)
43	ROTOR SECTION MODULUS CONSTANT, FIRST SPOOL.....	SECON (1,I)
44	ROTOR SECTION MODULUS CONSTANT, SECOND SPOOL.....	SECON (2,I)
45	ROTOR BLADE AREA DISTRIBUTION, FIRST SPOOL.....	ARCON (1,I)
46	ROTOR BLADE AREA DISTRIBUTION, SECOND SPOOL.....	ARCON (2,I)
47	ROTOR MATERIAL DENSITY, FIRST SPOOL.....	RHO (1)
48	ROTOR MATERIAL DENSITY, SECOND SPOOL.....	RHO (2)



SUBJECT GAS TURBINE DESIGN PROGRAM.....
PARAMETER CHANGE CODE SHEET.....CONTINUED

BY K. KIRK

CHK BY

DATE

CODE NO.	PARAMETER	FORTRAN SYMBOL
49	STRESS LIMIT.....	STRL
50	OVERSPEED FACTOR, FIRST SPOOL.....	OSF (1)
51	OVERSPEED FACTOR, SECOND SPOOL.....	OSF (2)
52	OVERSPEED EXPONENT, FIRST SPOOL.....	CSEMP (1)
53	OVERSPEED EXPONENT, SECOND SPOOL.....	CSEXP (2)
54	ROTOR BLADE TAPER DEPTH, FIRST SPOOL.....	DELTA (1)
55	ROTOR BLADE TAPER DEPTH, SECOND SPOOL.....	DELTA (2)
56	INLET TANGENTIAL VELOCITY.....	VULIN
57	INLET FLANGE MACH NUMBER.....	BMACH
### 58	INPUT PARAMETER.....	INPAR



PROJECT NO.

SUBJECT

GAS TURBINE DESIGN PROGRAM.....
PARAMETER CHANGE CODE SHEET.....CONTINUED

BY

K. KIRK

CHK BY

DATE

NOTES:

THESE PARAMETERS MAY BE REDUCED FROM THE BASE CASE BUT MAY NOT BE INCREASED FROM THE BASE CASE.

THIS PARAMETER NUMBER REFERS TO THE FOLLOWING PARAMETER DEPENDING ON THE MOST RECENT VALUE OF MFLAG;

- PREQS FOR MFLAG = 1
- PREQT FOR MFLAG = 2
- PRQOS FOR MFLAG = 3
- PRQOT FOR MFLAG = 4

THIS PARAMETER MUST BE CHANGED TO 2 IF A NEW BASE CASE IS TO FOLLOW. (CODE NUMBER IS ALL THAT IS REQUIRED)

IF PARAMETERS 25 THROUGH 46 ARE TO BE CHANGED, THEY MUST BE RESPECIFIED FOR ALL STAGES OF A GIVEN SPOOL.

FOR PARAMETERS 19 AND 20, BOTH ROTOR AND STATOR LOSS COEFFICIENT OF THE SPOOL MUST BE RESPECIFIED.



SUBJECT

DATE

2/8/68

GAS TURBINE DESIGN PROGRAM.....CONTROL FLAGS FOR CARD SEVEN

WORK ORDER

BY

K. KIRK

CHK BY

DATE

GROUP ONE

- 1 = FREE VORTEX BLADES.
- 2 = NON TWISTED BLADES.

GROUP TWO

- 0 = STRESS CALCULATED.
- 1 = STRESS ADJUSTED BY U_m .
- 2 = STRESS ADJUSTED BY P_{t1} .
- 3 = STRESS ADJUSTED BY P_r .
- 4 = STRESS ADJUSTED BY N .
- 5 = STRESS NOT CALCULATED..... (OMIT CARD 11)

GROUP THREE

- 1 = PRINT INDEX PAGE.
- 2 = DO NOT PRINT INDEX PAGE.

GROUP FOUR

- 1 = TYPEWRITER OUTPUT.
- 2 = NO TYPEWRITER OUTPUT.

GROUP FIVE

- 1 = PRESSURE RATIO IS MAIN STATIC. } EXCLUDING EXHAUST COLLECTOR
- 2 = PRESSURE RATIO IS MAIN TOTAL. }
- 3 = PRESSURE RATIO IS OVERALL STATIC.
- 4 = PRESSURE RATIO IS OVERALL TOTAL.
- 5 = NO PRESSURE RATIO REQUIRED..... (OMIT CARD 8)

GROUP SIX

- 1 = SINGLE SPOOL.
- 2 = TWO SPOOL.

GROUP SEVEN

- 1 = NEXT CASE IS CHANGE ONLY.
- 2 = NEXT CASE IS A COMPLETE CASE.

GROUP EIGHT

- ~~ISW~~ ISW = 0 — STANDARD VELOCITY TRIANGLE
- ISW > 0 — VELOCITY TRIANGLE OPTION

GROUP NINE

- JSW = 0 — Inlet Tangential velocity = 0
- JSW > 0 — Inlet Tangential velocity Input ON CARD 10

GROUP TEN

- KSW = 0 — ROTOR MEAN LINE MAINTAINED AS INPUT
- KSW > 0 — ROTOR MEAN LINE ADJUSTED FOR constant h_{12}

GROUP ELEVEN

- LSW = 0 — Input Mach Number for Mach 2 and E.C.
- LSW > 0 — Input Areas " " " "



ASCS-0800-11

DATE 2/8/68

WORK ORDER

DATE

SUBJECT

GAS TURBINE DESIGN PROGRAM.....DATA SWITCHES

BY K. KIRK

CHK. BY

SWITCH ONE;

DOWN (STANDARD).....VELOCITY TRIANGLE, TYPE 1.

UP (OPTION).....VELOCITY TRIANGLE, TYPE 2.

SWITCH TWO;

DOWN (STANDARD).....INLET TANGENTIAL VELOCITY IS ASSUMED ZERO AND NOT TO BE SPECIFIED ON INPUT CARD NUMBER 10.

UP (OPTION).....INLET TANGENTIAL VELOCITY IS NOT ZERO AND IS TO BE SPECIFIED ON INPUT CARD NUMBER 10.

SWITCH THREE;

DOWN (STANDARD).....ROTOR BLADE MEAN LINE IS MAINTAINED AS SPECIFIED ON INPUT BY Y(I).

UP (OPTION).....ROTOR BLADE MEAN LINE IS ADJUSTED, USING THE INPUT VALUES OF Y(I) AS AN INITIAL GUESS, TO OBTAIN A CONSTANT RADIUS BLADE TIP LINE.

*Not Used ON 1108
SEE NEW FLAGS ISW, JSW, KSW, LSW*

PROGRAM

LISTING

// JOB T
// FOR

C MULTISTAGE AXIAL FLOW TURBINE DESIGN PERFORMANCE ANALYSIS PROGRAM
C K. G. KIRK, DEPT. 7740, NUCLEAR ROCKET OPERATIONS, AERONAUTICAL GENERAL CORP.
C 3/6/68

C SUBROUTINE INPT1
C SUBROUTINE READS IN DATE AND GAS PROPERTIES
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTTI(2), UMI(2),
ICOEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRITM(2), ETST, ETT, ETSTP,
ZETTT, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRIT(2), UMS, SUNHT(2),
3SUMHS(2), PREOS, PREOT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, NFLAG, LFLAG,
4PROOS, PROOT, PRSMH, PRTM,
5ETSM, ETTM, PTNE(2), AREAF, TCF, PECE, FFACT, IPAG, FMSCH
COMMON X(2,10), Y(2,10), RE(2,10), Z(2,10), AD1(2,10), PRSOL, PRICL,
1ETSOL, ETTOL, UCSOL, UCTH, UOBT, UOTM, AREAL
COMMON UP(10), PAF(10), JHS(10), ENACH, INPAR, IMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2V2(10), WU2(10), VD1(10), AD2(10), HD2(10), ETS(10), ETT(10), E(10),
3RR(10), TT1(10), TT2(10), PRT(10), PRS(10), PRN(10), PTT1(10), PT2(10),
4PT2(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VUIT(10), AD1T(10),
5V1T(10), WU1T(10), BD1T(10), W1T(10), WU2T(10), VU2T(10), V2T(10),
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10),
1, V1H(10), WU1H(10), SD1H(10), W1H(10), WU2H(10), VU2H(10), V2H(10),
2XU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4AC2T(10), I1H(10), I1T(10), I2H(10), P1H(10), P1T(10), R2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10),
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), P11H(10), T11L1(20), T11L2(20), T11L3(20),
2STRL(2), TUM1, TPTI, TPRST, ISP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCR5(2,10),
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
2 FORMAT (3A2/4F10.5)
READ (2,2) IM, ID, IY, R, GAM, CP, VIS
RETURN
END

// DUP
*STORE WS UA INPT1
*DUMP UA CD INPT1

// FOR SUBROUTINE INPT2 (VULIN)

C SUBROUTINE READS IN ALL DATA FOR BASE CASE
C EXCEPT DATE AND GAS PROPERTIES

```

COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1COEF(2), N(2), DHO(2), SP(2), PRSTM(2), PRITM(2), EIST, EITT, ETSTM,
2ETTMM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRIT(2), UMS, SUMHT(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRQOS, PROOT, PRSNM, PRITMM,
5ETSMM, ETTMM, PTME(2), AREAF, TECE, PECE, RFACI, IPAGL, EMACH
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRIOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TNANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3RM(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), RT1(10), PT2(10),
4PTD(10), ANI(10), HI(10), AN2(10), H2(10), UT(10), VUIT(10), AD1T(10),
5V1T(10), WU1T(10), BD1T(10), W1T(10), WU1T(10), VU2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VUIH(10), AD1H(10)
1, VIH(10), WUH(10), BD1H(10), W1H(10), W2H(10), WUH(10), VL2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VXT(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TT1L1(20), TT1L2(20), TT1L3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
3IC), STRS(10), STRI(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), CCF(2), OSEXP(2)
5, RT(10)
1 FORMAT (10F8.5)
2 FORMAT (20A4)
3 FORMAT (A4,A3)
4 FORMAT (2F10.5, I5)
5 FORMAT (7I5)
6 FORMAT (8F10.5)
READ (2,3) CASE1, CASE2
READ (2,2) TT1L1
READ (2,2) TT1L2
READ (2,2) TT1L3
READ (2,5) IFLAG, M, JFLAG, KFLAG, MFLAG, LFLAG, INPAR
GO TO (21,22,23,24,25), MFLAG

```

INPT2001
INPT2002
INPT2003
INPT2004
INPT2005
INPT2006
INPT2007
INPT2008
INPT2009
INPT2010
INPT2011
INPT2012
INPT2013
INPT2014
INPT2015
INPT2016
INPT2017
INPT2018
INPT2019
INPT2020
INPT2021
INPT2022
INPT2023
INPT2024
INPT2025
INPT2026
INPT2027
INPT2028
INPT2029
INPT2030
INPT2031
INPT2032
INPT2033
INPT2034
INPT2035
INPT2036
INPT2037
INPT2038
INPT2039
INPT2040
INPT2041
INPT2042
INPT2043

```

21 READ (2,4) PREQS          INPT2044
   GO TO 25                  INPT2045
22 READ (2,4) PREQT         INPT2046
   GO TO 25                  INPT2047
23 READ (2,4) PROQS         INPT2048
   GO TO 25                  INPT2049
24 READ (2,4) PROQT         INPT2050
   GO TO 25                  INPT2051
25 READ (2,6) W,UM1(1),EMACH,REACT,ITI(1),PTI(1),BMACH,COEM(1),COEM(2
   1),VULIN                 INPT2052
   DO 50 L=1,LFLAG          INPT2053
   IF (M-4) 30,30,35       INPT2054
30 READ (2,6) RHO(L),STRL(L),OSF(L),OSEXP(L),DELTA(L)  INPT2055
35 READ (2,4) SHP(L),SP(L),N(L)  INPT2056
   K=N(L)                   INPT2057
   READ (2,1) (REA(L,I),I=1,K)  INPT2058
   READ (2,1) (AD1(L,I),I=1,K)  INPT2059
   READ (2,1) (X(L,I),I=1,K)    INPT2060
   READ (2,1) (Y(L,I),I=1,K)    INPT2061
   READ (2,1) (Z(L,I),I=1,K)    INPT2062
   READ (2,1) (COF(L,I),I=1,K)  INPT2063
   READ (2,1) (COF(L,2,I),I=1,K) INPT2064
   READ (2,1) (CLEAR(L,I),I=1,K) INPT2065
   IF (M-4) 45,45,46          INPT2066
45 READ (2,1) (ARS(L,I),I=1,K)  INPT2067
   READ (2,1) (TCRS(L,I),I=1,K)  INPT2068
   READ (2,1) (SOLID(L,I),I=1,K) INPT2069
   READ (2,1) (SECON(L,I),I=1,K) INPT2070
   READ (2,1) (ARCON(L,I),I=1,3) INPT2071
   GO TO 50                  INPT2072
46 DO 47 I=1,3              INPT2073
47 ARCON(L,I)=0.0          INPT2074
   DO 48 I=1,K              INPT2075
   ARS(L,I)=0.0            INPT2076
   TCRS(L,I)=0.0          INPT2077
   SOLID(L,I)=0.0         INPT2078
   SECON(L,I)=0.0         INPT2079
48 SECON(L,I)=0.0         INPT2080
50 CONTINUE                INPT2081
   RETURN                   INPT2082
   END                       INPT2083

```

```

// CUP
*STORE WS UA INPT2
*DUMP UA CD INPT2

```

// FOR

```
C
C SUBROUTINE READS IN NEW PARAMETER VALUES FOR CHANGE CASE
C
SUBROUTINE INPT3(MI)
  DIMENSION ICODE(20)
  COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, ITI(2), PTI(2), UMI(2),
  1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRTTM(2), ETST, ETT, ETSTM,
  2ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTT(2), UMS, SUMHT(2),
  3SUMHS(2), PREGS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
  4PROOS, PRQOT, PRSNM, PRTTM,
  5ETSYM, ETTM, PTM(2), AREA, TECE, PECE, RFACT, IPAGE, EMACH
  COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRTOL,
  1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOFM, AREA1
  COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
  1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
  2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
  3RM(10), IT1(10), IT2(10), PRT(10), PRS(10), PRN(10), PT1(10), PT2(10),
  4PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VU1T(10), AD1T(10),
  5V1T(10), WU1T(10), BD1T(10), W1T(10), VU2T(10), AD2T(10), V2T(10)
  COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10)
  1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
  2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
  3ES(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
  4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
  5P2T(10), CGT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
  COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
  1P1T(10), PTH(10), TITL1(20), TITL2(20), TITL3(20)
  2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
  310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
  4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
  5, RT(10)
  2 FORMAT (20A4)
  3 FORMAT (A4,A3)
  4 FORMAT (16I5)
  5 FORMAT (F10.0)
  6 FORMAT (10F8.0)
  K1=N(1)
  K2=N(2)
  READ (2,3) CASE1,CASE2
  READ (2,4) NUMBER, (ICODE(J),J=1,NUMBER)
  DO 200 J=1,NUMBER
  KCODE=ICODE(J)
  GO TO (20,21,22,23,24,25,26,27,32,33,34,35,36,37,38,39,40,41,42,
```

143,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,	INPT3044
264,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81),KCODE	INPT3045
20 READ (2,2) TITL2	INPT3046
GO TO 200	INPT3047
21 READ (2,2) TITL3	INPT3048
GO TO 200	INPT3049
22 READ (2,4) IFLAG	INPT3050
GO TO 200	INPT3051
23 READ (2,4) MI	INPT3052
GO TO 200	INPT3053
24 READ (2,4) JFLAG	INPT3054
GO TO 200	INPT3055
25 READ (2,4) MFLAG	INPT3056
GO TO 200	INPT3057
26 READ (2,4) LFLAG	INPT3058
GO TO 200	INPT3059
27 GO TO (28,29,30,31),MFLAG	INPT3060
28 READ (2,5) PREGS	INPT3061
GO TO 200	INPT3062
29 READ (2,5) PREGT	INPT3063
GO TO 200	INPT3064
30 READ (2,5) PROOS	INPT3065
GO TO 200	INPT3066
31 READ (2,5) PROOT	INPT3067
GO TO 200	INPT3068
32 READ (2,5) W	INPT3069
GO TO 200	INPT3070
33 READ (2,5) UMI(1)	INPT3071
GO TO 200	INPT3072
34 READ (2,5) EMACH	INPT3073
GO TO 200	INPT3074
35 READ (2,5) RFACT	INPT3075
GO TO 200	INPT3076
36 READ (2,5) TTI(1)	INPT3077
GO TO 200	INPT3078
37 READ (2,5) PTI(1)	INPT3079
GO TO 200	INPT3080
38 READ (2,5) SHP(1)	INPT3081
GO TO 200	INPT3082
39 READ (2,5) SHP(2)	INPT3083
GO TO 200	INPT3084
40 READ (2,5) SP(1)	INPT3085
GO TO 200	INPT3086
41 READ (2,5) SP(2)	INPT3087

```

GO TO 200
42 READ(2,6) (COE(1,1,I),I=1,K1)
   READ(2,6) (COE(1,2,I),I=1,K1)
   GO TO 200
43 READ(2,6) (COE(2,1,I),I=1,K2)
   READ(2,6) (COE(2,2,I),I=1,K2)
   GO TO 200
44 READ (2,5) COEM(1)
   GO TO 200
45 READ (2,5) COEM(2)
   GO TO 200
46 READ (2,4) N(1)
   K1=N(1)
   GO TO 200
47 READ (2,4) N(2)
   K2=N(2)
   GO TO 200
48 READ (2,6) (REA(1,I),I=1,K1)
   GO TO 200
49 READ (2,6) (REA (2,I),I=1,K2)
   GO TO 200
50 READ (2,6) (AD1 (1,I),I=1,K1)
   GO TO 200
51 READ (2,6) (AD1 (2,I),I=1,K2)
   GO TO 200
52 READ (2,6) (X (1,I),I=1,K1)
   GO TO 200
53 READ (2,6) (X (2,I),I=1,K2)
   GO TO 200
54 READ (2,6) (Y (1,I),I=1,K1)
   GO TO 200
55 READ (2,6) (Y (2,I),I=1,K2)
   GO TO 200
56 READ (2,6) (Z (1,I),I=1,K1)
   GO TO 200
57 READ (2,6) (Z (2,I),I=2,K2)
   GO TO 200
58 READ (2,6) (CLEAR(1,I),I=1,K1)
   GO TO 200
59 READ (2,6) (CLEAR(2,I),I=1,K2)
   GO TO 200
60 READ (2,6) (ARS(1,I),I=1,K1)
   GO TO 200
61 READ (2,6) (ARS(2,I),I=1,K2)

```

```

INPT3088
INPT3089
INPT3090
INPT3091
INPT3092
INPT3093
INPT3094
INPT3095
INPT3096
INPT3097
INPT3098
INPT3099
INPT3100
INPT3101
INPT3102
INPT3103
INPT3104
INPT3105
INPT3106
INPT3107
INPT3108
INPT3109
INPT3110
INPT3111
INPT3112
INPT3113
INPT3114
INPT3115
INPT3116
INPT3117
INPT3118
INPT3119
INPT3120
INPT3121
INPT3122
INPT3123
INPT3124
INPT3125
INPT3126
INPT3127
INPT3128
INPT3129
INPT3130
INPT3131

```

```

62 GO TO 200
   READ (2,6) (TCRS(1,I),I=1,K1)
63 GO TO 200
   READ (2,6) (TCRS(2,I),I=1,K2)
64 GO TO 200
   READ (2,6) (SOLID(1,I),I=1,K1)
65 GO TO 200
   READ (2,6) (SOLID(2,I),I=1,K2)
66 GO TO 200
   READ (2,6) (SECON(1,I),I=1,K1)
67 GO TO 200
   READ (2,6) (SECON(2,I),I=1,K2)
68 GO TO 200
   READ (2,6) (ARCON(1,I),I=1,3)
69 GO TO 200
   READ (2,6) (ARCON(2,I),I=2,3)
70 GO TO 200
   READ (2,5) RHO(1)
71 GO TO 200
   READ (2,5) RHO(2)
72 GO TO 200
   READ (2,5) STRL(1)
73 GO TO 200
   READ (2,5) OSF(1)
74 GO TO 200
   READ (2,5) OSF(2)
75 GO TO 200
   READ (2,5) OSEXP(1)
76 GO TO 200
   READ (2,5) OSEXP(2)
77 GO TO 200
   READ (2,5) DELTA(1)
78 GO TO 200
   READ (2,5) DELTA(2)
79 GO TO 200
   READ (2,5) VULIN
80 GO TO 200
   READ (2,5) BMACH
81 GO TO 200
   INPAR=2
200 CONTINUE
   RETURN
   END

```

```

INPT3132
INPT3133
INPT3134
INPT3135
INPT3136
INPT3137
INPT3138
INPT3139
INPT3140
INPT3141
INPT3142
INPT3143
INPT3144
INPT3145
INPT3146
INPT3147
INPT3148
INPT3149
INPT3150
INPT3151
INPT3152
INPT3153
INPT3154
INPT3155
INPT3156
INPT3157
INPT3158
INPT3159
INPT3160
INPT3161
INPT3162
INPT3163
INPT3164
INPT3165
INPT3166
INPT3167
INPT3168
INPT3169
INPT3170
INPT3171
INPT3172
INPT3173
INPT3174

```

*STORE WS UA INPT3
*DUMP UA CD INPT3

```

// FOR SUBROUTINE LOA
C
C SUBROUTINE CALCULATES THE STAGE LOADING,SPEED AND LAMDA
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRSTM(2), ETST, EIT1, EISIM,
2ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTI(2), UMS, SUMHI(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PROOS, PROOT, PRSMM, PRTNM,
5ETSMM, ETTM, PTNE(2), AREAF, TFCE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRIOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREAI
COMMON UM(10), PAS(10), DHS(10), RMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), RD2(10), ETS(10), ETT(10), E(10),
3RM(10), TTL(10), TT2(10), PRT(10), PRS(10), PRN(10), PRT1(10), PRT2(10),
4PTO(10), ANI(10), H1(10), AN2(10), H2(10), UT(10), VUT(10), ADIT(10),
5V1T(10), WU1T(10), BD1T(10), W1T(10), WU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VUH(10), AD1H(10),
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), P11H(10), TITL1(20), TITL2(20), TITL3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), SIRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10),
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
K=N(L)
DHO(L)=550.*SHP(L)/(778.16*W)
PAO=UMI(L)**2/(32.174*778.16*DHO(L))
SUX=0.
DO 10 I=1,K
10 SUX=SUX+X(L,I)
DO 100 I=1,K
IF (I-1) 20,20,30
20 PAS(I)=PAO*SUX
30 PAS(I)=Y(L,I)**2*PAS(I)/X(L,I)
DHS(I)=UMI(L)**2*Y(L,I)**2/(32.174*778.16*PAS(I))
IF (I-1) 40,40,100
40 UM(I)=UMI(L)
LOA 001
LOA 002
LOA 003
LOA 004
LOA 005
LOA 006
LOA 007
LOA 008
LOA 009
LOA 010
LOA 011
LOA 012
LOA 013
LOA 014
LOA 015
LOA 016
LOA 017
LOA 018
LOA 019
LOA 020
LOA 021
LOA 022
LOA 023
LOA 024
LOA 025
LOA 026
LOA 027
LOA 028
LOA 029
LOA 030
LOA 031
LOA 032
LOA 033
LOA 034
LOA 035
LOA 036
LOA 037
LOA 038
LOA 039
LOA 040
LOA 041
LOA 042
LOA 043

```



```
100 UM(I)=Y(L,I)*UMI(L)
    RETURN
    END
```

```
LOA 044
LOA 045
LOA 046
```

```
// DUP
*STORE   WS   UA   LOA
*DUMP    UA   CD   LOA
```

```

// FOR SUBROUTINE CALC1
C SUBROUTINE CALCULATES VELOCITY PARAMETERS AND MEAN BLADE VELOCITIES
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UM1(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRSTM(2), ETST, ETT, ETSTM,
2ETTT, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRIT(2), UMS, SUMHT(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRQOS, PROQT, PRSMM, PRSTM,
5ETSMM, ETTMM, PTME(2), AREA, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRPTOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), RD2(10), ETS(10), ETT(10), E(10),
3RM(10), T1(10), T2(10), PR1(10), PRS(10), PRN(10), VU1(10), PT1(10), PT2(10),
4PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VU1(10), AD1T(10),
5V1T(10), WU1T(10), BD1T(10), W1T(10), WU2T(10), VU2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VUH(10), AD1H(10)
1, VIH(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TT1L(20), TT1L2(20), TT1L3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WFLAG, HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
K=N(L)
C DATA SWITCH 1 CONTROLS VELOCITY TRIANGLE BRANCH
C CALL DATSW (1,JSW)
C DO 100 I=1,K
C CALCULATION OF VELOCITY PARAMETERS
C AR1=AD1(L,I)/57.296
C COT(I)=COS(AR1)/SIN(AR1)
C DVU(I)=UM(I)/PAS(I)
C F=0.5*COT(I)**2*(1.-Z(L,I))*2
CALC1001
CALC1002
CALC1003
CALC1004
CALC1005
CALC1006
CALC1007
CALC1008
CALC1009
CALC1010
CALC1011
CALC1012
CALC1013
CALC1014
CALC1015
CALC1016
CALC1017
CALC1018
CALC1019
CALC1020
CALC1021
CALC1022
CALC1023
CALC1024
CALC1025
CALC1026
CALC1027
CALC1028
CALC1029
CALC1030
CALC1031
CALC1032
CALC1033
CALC1034
CALC1035
CALC1036
CALC1037
CALC1038
CALC1039
CALC1040
CALC1041
CALC1042
CALC1043

```

CALC1044
 CALC1045
 CALC1046
 CALC1047
 CALC1048
 CALC1049
 CALC1050
 CALC1051
 CALC1052
 CALC1053
 CALC1054
 CALC1055
 CALC1056
 CALC1057
 CALC1058
 CALC1059
 CALC1060
 CALC1061
 CALC1062
 CALC1063
 CALC1064
 CALC1065
 CALC1066
 CALC1067
 CALC1068
 CALC1069
 CALC1070
 CALC1071
 CALC1072
 CALC1073
 CALC1074
 CALC1075

```

G=-((1.-REA(L,I))*PAS(I)+0.5)
IF (F-0.) 30,20,30
20 VEP(I)=-G
GO TO 35

C VELOCITY TRIANGLE TYPE BRANCH
C
30 GO TO (32,31),JSW
31 VEP(I)=(SQRT(1.-4.*F*G)-1.)/(2.*F)
GO TO 35
32 VEP(I)=(-SQRT(1.-4.*F*G)-1.)/(2.*F)

C START CALCULATION OF MEAN BLADE VELOCITIES
C
35 VU1(I)=VEP(I)*DVU(I)
VX1(I)=VU1(I)*COT(I)
V1(I)=VU1(I)/SIN (AR1)
WU1(I)=VU1(I)-UM(I)
BR1=ATAN (WU1(I)/VX1(I))
BD1(I)=BR1*57.296
W1(I)=VX1(I)/COS (BR1)
VU2(I)=VU1(I)-DVU(I)
VX2(I)=VX1(I)*Z(L,I)
AR2=ATAN (VU2(I)/VX2(I))
AD2(I)=AR2*57.296
V2(I)=VX2(I)/COS (AR2)
WU2(I)=VU2(I)-UM(I)
BR2=ATAN (WU2(I)/VX2(I))
BD2(I)=BR2*57.296
100 W2(I)=VX2(I)/COS (BR2)
RETURN
END
  
```

// DUP WS UA CALC1
 *STORE UA CD CALC1
 *DUMP

```

// FOR SUBROUTINE CALC2 (KJ,VUJIN)
C
C SUBROUTINE DETERMINES STAGE LOSSES,MANIFOLD LOSSES,
C PRESSURES,TEMPERATURES,ANNULUS AREAS,BLADE HEIGHTS AND STAGE
C EFFICIENCIES
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTT(2), UMI(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRSTM(2), ETST, ETT, ETSTM,
2ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTT(2), UMS, SUMHT(2),
3SUMHS(2), PREOS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, NFLAG, LFLAG, L,
4PROOS, PROOT, PRSMV, PRSTM,
5ETSMN, ETTMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRTOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTH, AREA1
COMMON UM(10), PAS(10), DHS(10), EMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), ED1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3RM(10), TT1(10), TT2(10), PRT(10), PRS(10), PRN(10), PTT(10), PT2(10),
4PT0(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VU1T(10), AD1T(10),
5V1T(10), WU1T(10), BD1T(10), W1T(10), WU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10),
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), ACLT(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RVA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TT1L(20), TT1L2(20), TT1L3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
C
C DATA SWITCH 2 CONTROLS INPUT OF VUJIN
C DATA SWITCH 3 CONTROLS TIP RADIUS OPTION
C
CALL DATSW(2,JSW)
CALL DATSW(3,KSW)
KJ=1
J=N(L)
CON3=GAM/(GAM-1.)
DO 145 I=1,J
D=2.*COT(I)**2*VEP(I)**2+(VEP(I)-PAS(I))**2+(VEP(I)-PAS(I)-1.)**2
CALC2001
CALC2002
CALC2003
CALC2004
CALC2005
CALC2006
CALC2007
CALC2008
CALC2009
CALC2010
CALC2011
CALC2012
CALC2013
CALC2014
CALC2015
CALC2016
CALC2017
CALC2018
CALC2019
CALC2020
CALC2021
CALC2022
CALC2023
CALC2024
CALC2025
CALC2026
CALC2027
CALC2028
CALC2029
CALC2030
CALC2031
CALC2032
CALC2033
CALC2034
CALC2035
CALC2036
CALC2037
CALC2038
CALC2039
CALC2040
CALC2041
CALC2042
CALC2043

```

CALC2044
 CALC2045
 CALC2046
 CALC2047
 CALC2048
 CALC2049
 CALC2050
 CALC2051
 CALC2052
 CALC2053
 CALC2054
 CALC2055
 CALC2056
 CALC2057
 CALC2058
 CALC2059
 CALC2060
 CALC2061
 CALC2062
 CALC2063
 CALC2064
 CALC2065
 CALC2066
 CALC2067
 CALC2068
 CALC2069
 CALC2070
 CALC2071
 CALC2072
 CALC2073
 CALC2074
 CALC2075
 CALC2076
 CALC2077
 CALC2078
 CALC2079
 CALC2080
 CALC2081
 CALC2082
 CALC2083
 CALC2084
 CALC2085
 CALC2086
 CALC2087

```

GO TO (30,20),J5W
20 IF (L-1) 25,25,21
21 IF (I-1) 55,55,50
25 IF (I-1) 40,40,50
30 VU0=VU1IN
GO TO 55
40 VU0=0.
GO TO 55
50 VU0=VU2(I-1)
55 C=(1.+2.*COT(I)**2)*VEP(I)**2+(VU0/DVU(I))**2
FRO=2.
GO TO (70,56),J5K
56 IF (L-1) 57,57,70
57 IF (I-1) 90,90,70
70 IF (PAS(I)-0.5) 80,80,90
80 FST=2.*(1.-PAS(I))
GO TO 95
90 FST=1.
95 RM(I)=30.*QM(I)/(3.14159*SP(L))
RE=W/(RM(I)*VIS)
HSAVE=0.0
SLOSS=COE(L,1,I)
RLOSS=COE(L,2,I)
GO TO 97
96 RLOSS=COE(L,2,I)*(0.802+5.56*CLEAR(L,I)/H2(I))
SLOSS=COE(L,1,I)*(0.802+5.56*CLEAR(L,I)/H2(I))
HSAVE=H2(I)
97 STL=SLOSS / (2.*32.174*778.16*COT(I)*RE**0.2)*(FST*C*DVU(I)**2)
A=(FST*SLOSS*C+FRO*RLOSS*D)/(PE**0.2*COT(I))
ETT(I)=PAS(I)/(PAS(I)+0.5*A)
IF (I-1) 100,100,110
100 TTI(I)=TTI(L)
GO TO (101,102),L

C INLET MANIFOLD CONDITIONS DETERMINED
C
101 FMACH=1.+(GAM-1.)/2.*BMACH**2
TMANI=TTI(1)/FMACH
PMANI=PTI(1)/FMACH**CON3
PTME(1)=PTI(1)/(1.+COEM(1))*(1.-1./FMACH**CON3)
AREA=W/PTI(1)*SORT(R*TTI(1)/GAM/32.174)*FMACH**((GAM+1.)/(2.*
1(GAM-1.)))/BMACH
PTO(I)=PTML(1)
GO TO 100

```

CALC2088
 CALC2089
 CALC2090
 CALC2091
 CALC2092
 CALC2093
 CALC2094
 CALC2095
 CALC2096
 CALC2097
 CALC2098
 CALC2099
 CALC2100
 CALC2101
 CALC2102
 CALC2103
 CALC2104
 CALC2105
 CALC2106
 CALC2107
 CALC2108
 CALC2109
 CALC2110
 CALC2111
 CALC2112
 CALC2113
 CALC2114
 CALC2115
 CALC2116
 CALC2117
 CALC2118
 CALC2119
 CALC2120
 CALC2121
 CALC2122
 CALC2123
 CALC2124
 CALC2125
 CALC2126
 CALC2127
 CALC2128
 CALC2129
 CALC2130
 CALC2131

```

102 PTO(I)=PTI(2)
    GO TO 120
110 TT1(I)=TT2(I-1)
    PTO(I)=PT2(I-1)
120 TT2(I)=TT1(I)-DHS(I)/CP
    RMF(I)=12.*RM(I)

C TOTAL PRESSURE RATIO CALCULATED FROM EFFICIENCY AND STAGE SPECIFIC
C WORK
C
PRT(I)=1./((1.-DHS(I))/(EIT(I)*CP*TT1(I)))*CON3
CON1=2.*32.174*775.16*CP
T1(I)=TT1(I)-V1(I)**2/CON1
T2(I)=TT2(I)-V2(I)**2/CON1
PRN(I)=(1.-STL/(CP*V1(I)))*CON3
PT1(I)=PTO(I)*PRN(I)
PT2(I)=PTO(I)/PRT(I)
P1(I)=PT1(I)*(T1(I)/TT1(I))**CON3
P2(I)=PT2(I)*(T2(I)/TT2(I))**CON3
PRS(I)=PTO(I)/P2(I)
ETS(I)=DHS(I)/(CP*TT1(I))*(1.-((1./PRS(I))**((1./CON3))))
RO1=144.*P1(I)/(R*TT1(I))
RO2=144.*P2(I)/(R*TT2(I))
AN1(I)=144.*W/(RO1*VX1(I))
AN2(I)=144.*W/(RO2*VX2(I))
IF (N(L)-1) 123,123,124
122 RMA(1)=RMF(1)
    GO TO 129
124 IF (I-1) 127,125,126

C NOZZLE MEAN RADIUS FOR THE FIRST STAGE IS THAT OF THE FIRST STAGE
C ROTOR PLUS THE DIFFERENCE BETWEEN THE FIRST STAGE ROTOR AND
C SECOND STAGE NOZZLE MEAN RADII
125 RMA(1)=(3.*RMF(1)-RMF(2))/2.
    H1(1)=AN1(1)/(2.*3.14159*RMA(1))
    RMA(2)=(RMF(1)+RMF(2))/2.
    H1(2)=AN1(2)/(2.*3.14159*RMA(2))
    GO TO 127

C THE MEAN RADIUS OF ALL NOZZLES BUT THE FIRST IS THE AVERAGE OF
C THE MEAN RADII OF THE UPSTREAM AND DOWNSTREAM ROTORS
C
126 RMA(I)=(RMF(I)+RMF(I-1))/2.

```

CALC2132
CALC2133
CALC2134
CALC2135
CALC2136
CALC2137
CALC2138
CALC2139
CALC2140
CALC2141
CALC2142
CALC2143
CALC2144

```
134 H1(I)=C1(I)/I2.47.14159*PI*(I)
137 H2(I)=A2(I)/I3.47.14159*PI*(I)
139 R1(I)=RHF(I)+R2(I)/2.
139 GO TO (135,145),K58
145 IF (7.08*(R1(I)-R1(I))-9.001) 145,145,140
149 R3=2
149 Y(L,I)=(R1(I)+H2(I)/2.)/RHF(I)
149 CONTINUE
149 IF (LFLAG-1) 200,200,190
190 VUC=VU2(J)
200 RETURN
END
```

```
// CUP
*STIME MS UA CALC2
*DUMP UA CO CALC2
```

```

// FOR SUBROUTINE CALC9
C
C SUBROUTINE DETERMINES EXHAUST COLLECTOR LOSSES AND CONDITIONS
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1COEM(2), N(2), DHO(2), SP(2), FRSTM(2), PRSTM(2), E1S1, E1I1, E1SIM,
2ETTMM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), UMS, SUMHT(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRGOS, PROOT, PRSMM, PRTMM,
5ETSMM, ETTMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRIOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREAI
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3RM(10), TT1(10), TT2(10), PRT(10), PRS(10), PRN(10), PT1(10), PT2(10),
4PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VUT(10), ADIT(10),
5VIT(10), WUT(10), BDIT(10), WIT(10), VU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VUH(10), ADIH(10)
1, V1H(10), WU1H(10), BD1H(10), W1H(10), REAH(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TITL1(20), TITL2(20), TITL3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
J=N(L)
CON3=GAM/(GAM-1.)
GO TO (150,129), LFLAG
129 GO TO (200,150), L
150 FMACH=1.+(GAM-1.)/2.*EMACH**2
PTME(2)=PT2(J)/(1.+COEM(2))*(1.--1./FMACH**CON3)
AREAF=W/PTME(2)*SQRT(R*TT2(J)/GAM/32.174)*FMACH**((GAM+1.)/(2.*
1(GAM-1.)))/EMACH
PECE=PTME(2)/FMACH**CON3
TECE=TT2(J)/FMACH
200 RETURN
END
// DUP
CALC9001
CALC9002
CALC9003
CALC9004
CALC9005
CALC9006
CALC9007
CALC9008
CALC9009
CALC9010
CALC9011
CALC9012
CALC9013
CALC9014
CALC9015
CALC9016
CALC9017
CALC9018
CALC9019
CALC9020
CALC9021
CALC9022
CALC9023
CALC9024
CALC9025
CALC9026
CALC9027
CALC9028
CALC9029
CALC9030
CALC9031
CALC9032
CALC9033
CALC9034
CALC9035
CALC9036
CALC9037
CALC9038
CALC9039
CALC9040
CALC9041
CALC9042

```


*STORE
*DUMP

WS UA CALC9
UA CD CALC9

```

// FOR SUBROUTINE CALC3
C SUBROUTINE DETERMINES OVERALL TURBINE PERFORMANCE
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UM1(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRSTM(2), ETST, ETT, ETSTM,
2ETTTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTT(2), UMS, SUMHI(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRQOS, PRGOT, PRSMM, PRTMM,
5ETSMM, ETTMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH.
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRIOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BDI(10), AD2(10), BD2(10), EIS(10), EII(10), E(10),
3RM(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), P1(10), P12(10),
4PTO(10), AN1(10), H1(10), AN2(10), H2(10), U1(10), VU1(10), AD1(10),
5V1T(10), WU1T(10), BD1T(10), W1T(10), WU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10)
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), ACIT(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), I2I(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10),
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TITL1(20), TITL2(20), TITL3(20),
2STRL(2), TUM1, IPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), SIRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), ICRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
C
C CALCULATION OF OVERALL PERFORMANCE
C
CON4=(GAM-1.)/GAM
K=N(L)
DO 200 I=1,K
IF (I-N(L)) 140,130,130
130 PRST(L)=PRST(L)*PRS(I)
SUMHS(L)=SUMHS(L)+DHS(I)/ETS(I)
GO TO 150
140 PRST(L)=PRST(L)*PRT(I)
SUMHS(L)=SUMHS(L)+DHS(I)/ETT(I)
150 PRTT(L)=PRTT(L)*PRT(I)

```

CALC3001
CALC3002
CALC3003
CALC3004
CALC3005
CALC3006
CALC3007
CALC3008
CALC3009
CALC3010
CALC3011
CALC3012
CALC3013
CALC3014
CALC3015
CALC3016
CALC3017
CALC3018
CALC3019
CALC3020
CALC3021
CALC3022
CALC3023
CALC3024
CALC3025
CALC3026
CALC3027
CALC3028
CALC3029
CALC3030
CALC3031
CALC3032
CALC3033
CALC3034
CALC3035
CALC3036
CALC3037
CALC3038
CALC3039
CALC3040
CALC3041
CALC3042
CALC3043

```

SUMHT(L)=SUMHT(L)+DHS(I)/ETT(I)
CS(I)=SQRT (2.*32.174*DHS(I)*778.16/ETS(I))
UC(I)=UM(I)/CS(I)
200 UMS=UMS+UM(I)
DV=K
UMA(L)=UMS/DV
GO TO (210,220),L
210 PRSTM(1)=PTI(1)/P2(K)
PRTM(1)=PTI(1)/PT2(K)
GO TO (215,230),LFLAG
215 PRSOL=PTI(1)/PECE
PRTOL=PTI(1)/PTME(2)
DHSOL=CP*TTI(1)*(1.-(1./PRSOL)**CON4)
DHTOL=CP*TTI(1)*(1.-(1./PRTOL)**CON4)
ETSOL=DHO(1)/DHSOL
ETTOL=DHO(1)/DHTOL
UCSOL=UMA(1)/SQRT(2.*32.174*778.16*DHSOL)
UCTOL=UMA(1)/SQRT(2.*32.174*778.16*DHTOL)
PRSM=PRSOL
PRTM=PRTOL
ETSM=ETSOL
ETTM=ETTOL
GO TO 230
220 PRTM(2)=PTI(2)/PTME(2)
PRSTM(2)=PTI(2)/PECE
230 DHIS=CP*TTI(L)*(1.-(1./PRST(L))**CON4)
DHIT=CP*TTI(L)*(1.-(1./PRT(L))**CON4)
DHISM=CP*TTI(L)*(1.-(1./PRSTM(L))**CON4)
DHITM=CP*TTI(L)*(1.-(1./PRTM(L))**CON4)
ETST=DHO(L)/DHIS
ETTT=DHO(L)/DHIT
ETSTM=DHO(L)/DHISM
ETTTM=DHO(L)/DHITM
COS=2.*32.174*778.16*DHIS
CO=SQRT (COS)
UCO=UMA(L)/CO
UCOT=UMA(L)/SQRT(2.*32.174*778.16*DHIT)
COSM=2.*32.174*778.16*DHISM
COM=SQRT (COSM)
UCOM=UMA(L)/COM
UCOTM=UMA(L)/SQRT(2.*32.174*778.16*DHITM)
RET(L)=SUMHT(L)/DHIT
RES(L)=SUMHS(L)/DHIS
RETURN

```

```

CALC3044
CALC3045
CALC3046
CALC3047
CALC3048
CALC3049
CALC3050
CALC3051
CALC3052
CALC3053
CALC3054
CALC3055
CALC3056
CALC3057
CALC3058
CALC3059
CALC3060
CALC3061
CALC3062
CALC3063
CALC3064
CALC3065
CALC3066
CALC3067
CALC3068
CALC3069
CALC3070
CALC3071
CALC3072
CALC3073
CALC3074
CALC3075
CALC3076
CALC3077
CALC3078
CALC3079
CALC3080
CALC3081
CALC3082
CALC3083
CALC3084
CALC3085
CALC3086
CALC3087

```

END

CALC3088

// DUP
*STORE
*DUMP

WS UA CALC3
UA CD CALC3

```

// FOR
SUBROUTINE CALC4
C SURROUTINE CALCULATÉS RADIAL VELOCITY DISTRIBUTION FOR FREE VORTEX
C BLADING
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UM1(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRIM(2), EIS1, E11, E1S1M,
2ETT1M, UMA(2), UCO, UCOM, RET(2), RES(2), PRS1(2), PRI1(2), UMS, SUMHI(2),
3SUMHS(2), PRECS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRQOS, PROOT, PRSMM, PRTMM,
5ETSMM, ETTMM, PTME(2), AREA, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), Z(2,10), AD1(2,10), PRSOL, PRTOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), E1S(10), E11(10), E1(10),
3RM(10), TT1(10), TT2(10), PRT(10), PRS(10), PRN(10), PT1(10), PT2(10),
4PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VU1T(10), AD1T(10),
5V1T(10), WU1T(10), BD1T(10), W1T(10), W2T(10), VU2T(10), V21(10)
COMMON WU2T(10), BD2T(10), W2H(10), W1H(10), VU2H(10), AD2H(10), V2H(10),
1, V1H(10), WU1H(10), BD1H(10), W1H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
2WU2H(10), BD2H(10), W2H(10), W2H(10), W2H(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10),
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), TT2(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TT1L1(20), TT1L2(20), TT1L3(20),
2STRL(2), TUM1, TPT1, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
K=N(L)
DO 100 I=1,K
UT(I)=(RM(I)+H2(I)/24.)*UM(I)/RM(I)
VU1T(I)=VU1(I)*RMA(I)/(RMA(I)+H1(I)/2.)
VX1T(I)=VX1(I)
AR1T=ATAN (VU1T(I)/VX1T(I))
AD1T(I)=57.296*AR1T
V1T(I)=VU1T(I)/SIN (AR1T)
WU1T(I)=VU1T(I)-UT(I)
BR1T=ATAN (WU1T(I)/VX1T(I))
BD1T(I)=57.296*BR1T
W1T(I)=VX1T(I)/COS (BR1T)
CALC4001
CALC4002
CALC4003
CALC4004
CALC4005
CALC4006
CALC4007
CALC4008
CALC4009
CALC4010
CALC4011
CALC4012
CALC4013
CALC4014
CALC4015
CALC4016
CALC4017
CALC4018
CALC4019
CALC4020
CALC4021
CALC4022
CALC4023
CALC4024
CALC4025
CALC4026
CALC4027
CALC4028
CALC4029
CALC4030
CALC4031
CALC4032
CALC4033
CALC4034
CALC4035
CALC4036
CALC4037
CALC4038
CALC4039
CALC4040
CALC4041
CALC4042
CALC4043

```

CALC4044
CALC4045
CALC4046
CALC4047
CALC4048
CALC4049
CALC4050
CALC4051
CALC4052
CALC4053
CALC4054
CALC4055
CALC4056
CALC4057
CALC4058
CALC4059
CALC4060
CALC4061
CALC4062
CALC4063
CALC4064
CALC4065
CALC4066
CALC4067
CALC4068
CALC4069
CALC4070
CALC4071
CALC4072
CALC4073
CALC4074
CALC4075
CALC4076
CALC4077

```
VU2T(I)=VU2(I)*RM(I)/(RM(I)+H2(I)/24.)
VX2T(I)=VX2(I)
AR2T=ATAN (VU2T(I)/VX2T(I))
AD2T(I)=57.296*AR2T
V2T(I)=VX2T(I)/COS (AR2T)
WU2T(I)=VU2T(I)-UT(I)
BR2T=ATAN (WU2T(I)/VX2T(I))
BD2T(I)=57.296*BR2T
W2T(I)=VX2T(I)/COS (BR2T)
REAH(I)=1.-((VX1T(I)**2-VX2T(I)**2)/(2.*UT(I))*(VU1T(I)-VU2T(I)))
1-((VU1T(I)+VU2T(I))/(2.*UT(I))
UH(I)=(RM(I)-H2(I)/24.)*UM(I)/RM(I)
VU1H(I)=VU1(I)*RMA(I)/(RMA(I)-H1(I)/2.)
VX1H(I)=VX1(I)
AR1H=ATAN (VU1H(I)/VX1H(I))
AD1H(I)=57.296*AR1H
V1H(I)=VU1H(I)/SIN (AR1H)
WU1H(I)=VU1H(I)-UH(I)
BR1H=ATAN (WU1H(I)/VX1H(I))
BD1H(I)=57.296*BR1H
W1H(I)=VX1H(I)/COS (BR1H)
VU2H(I)=VU2(I)*RM(I)/(RM(I)-H2(I)/24.)
VX2H(I)=VX2(I)
AR2H=ATAN (VU2H(I)/VX2H(I))
AD2H(I)=57.296*AR2H
V2H(I)=VX2H(I)/COS (AR2H)
WU2H(I)=VU2H(I)-UH(I)
BR2H=ATAN (WU2H(I)/VX2H(I))
BD2H(I)=57.296*BR2H
W2H(I)=VX2H(I)/COS (BR2H)
100 REAH(I)=1.-((VX1H(I)**2-VX2H(I)**2)/(2.*UH(I))*(VU1H(I)-VU2H(I)))
1-((VU1H(I)+VU2H(I))/(2.*UH(I))
RETURN
END
// DUP
*STORE WS UA CALC4
*DUMP UA CD CALC4
```

```

// FOR SUBROUTINE CALC5
C SUBROUTINE CALCULATES HUB AND TIP PRESSURES AND TEMPERATURES FOR
C FREE VORTEX BLADING
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRTTM(2), ETST, ETT1, ETSTM,
2ETTTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTT(2), UMS, SUMHI(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRGOS, PRGOT, PRSMM, PRTTM,
5ETSMM, ETTMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRTOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UN(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), E11(10), E(10),
3RM(10), T1(10), TT2(10), PRT(10), PRS(10), PRN(10), P11(10), PT2(10),
4PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VUIT(10), ADIT(10),
5VIT(10), WUIT(10), BDI(10), WIT(10), VU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10)
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), P12H(10),
1PT1T(10), PT1H(10), TITL1(20), TITL2(20), TITL3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), ICRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
CON1=2.*32.174*778.16*CP
CON3=GAM/(GAM-1.)
K=N(L)
DO 100 I=1,K
TT2T(I)=TT2(I)
TT2H(I)=TT2(I)
PT1T(I)=PT1(I)
PT1H(I)=PT1(I)
PT2T(I)=PT2(I)
PT2H(I)=PT2(I)
T1H(I)=T1(I)-V1H(I)**2/CON1
T1T(I)=T1(I)-V1T(I)**2/CON1
CALC5001
CALC5002
CALC5003
CALC5004
CALC5005
CALC5006
CALC5007
CALC5008
CALC5009
CALC5010
CALC5011
CALC5012
CALC5013
CALC5014
CALC5015
CALC5016
CALC5017
CALC5018
CALC5019
CALC5020
CALC5021
CALC5022
CALC5023
CALC5024
CALC5025
CALC5026
CALC5027
CALC5028
CALC5029
CALC5030
CALC5031
CALC5032
CALC5033
CALC5034
CALC5035
CALC5036
CALC5037
CALC5038
CALC5039
CALC5040
CALC5041
CALC5042
CALC5043

```

```
T2H(I)=TT2H(I)-V2H(I)**2/CON1
T2T(I)=TT2T(I)-V2T(I)**2/CON1
P1H(I)=PT1H(I)*(T1H(I)/TT1(I))**CON3
P1T(I)=PT1T(I)*(T1T(I)/TT1(I))**CON3
P2H(I)=PT2H(I)*(T2H(I)/TT2H(I))**CON3
P2T(I)=PT2T(I)*(T2T(I)/TT2T(I))**CON3
100 RETURN
END
```

```
// DUP
*STORE
*DUMP
```

```
WS UA CALC5
UA CD CALC5
```

```
CALC5044
CALC5045
CALC5046
CALC5047
CALC5048
CALC5049
CALC5050
CALC5051
```


SUBROUTINE CALC6

C SUBROUTINE CALCULATES STATOR EXIT RADIAL VELOCITY DISTRIBUTION FOR
 C NON-TWISTED BLADES USING THE RUNGE-KUTTA METHOD

CALC6001
 CALC6002
 CALC6003
 CALC6004
 CALC6005
 CALC6006
 CALC6007
 CALC6008
 CALC6009

COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTT(2), UMI(2),
 ICOEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRTM(2), ETST, ETT, ETSTM,
 ZETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTT(2), UMS, SUMHT(2),
 3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
 4PRGOS, PRGOT, PRSM, PRTM,
 5ETSM, ETM, PTM(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
 COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRTOL,
 1ETSOL, ETOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
 COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
 1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
 2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
 3RM(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), P11(10), PT2(10),
 4PT9(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VUIT(10), ADIT(10),
 5VIT(10), WUIT(10), BDIT(10), WIT(10), VU2T(10), AD2T(10), V2T(10)
 COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VUIH(10), ADIH(10)
 1, V1H(10), WU1H(10), BD1H(10), W1H(10), VU2H(10), AD2H(10), V2H(10),
 2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
 3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), ACIT(10),
 4AC2T(10), TH(10), TIT(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
 5P2T(10), COT(10), VEP(10), DVU(10), VXIT(10), VX2T(10), VX1H(10)
 COMMON VX2H(10), RMA(10), TIT2(10), TIT2H(10), PT2T(10), PT2H(10),
 1PT1T(10), PTH(10), TITL1(20), TITL2(20), TITL3(20),
 2STRLL(2), TUMI, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(

4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
 5, RT(10)
 DERVP(P, TTI, VU1, RADA, RMA) = P*VU1**2*(RMA/(RADA*12.))**2.*
 1SIN(ARI)**2)/(32.174*R*RADA*(TTI-VU1**2*(1.+(COS(ARI)/SIN(ARI)))**2CALC6031
 2)*(RMA/(RADA*12.))**2.*SIN(ARI)**2)/CON1))**2CALC6032
 CON1=2.*32.174*778.16*CP
 CON3=GAM/(GAM-1.)
 J=N(L)
 DO 100 I=1, J
 ARI=AD1(L,I)/57.296
 UT(I)=(RM(I)+H2(I)/24.)*UM(I)/RM(I)
 VU1(I)=VU1(I)*(RMA(I)/(RMA(I)+HI(I)/2.))**SIN(ARI)**2
 ADIT(I)=AD1(L,I)
 VXIT(I)=VUIT(I)*COT(I)

CALC6025
 CALC6026
 CALC6027
 CALC6028
 CALC6029
 CALC6030
 CALC6031
 CALC6032
 CALC6033
 CALC6034
 CALC6035
 CALC6036
 CALC6037
 CALC6038
 CALC6039
 CALC6040
 CALC6041
 CALC6042
 CALC6043

CALC6044
 CALC6045
 CALC6046
 CALC6047
 CALC6048
 CALC6049
 CALC6050
 CALC6051
 CALC6052
 CALC6053
 CALC6054
 CALC6055
 CALC6056
 CALC6057
 CALC6058
 CALC6059
 CALC6060
 CALC6061
 CALC6062
 CALC6063
 CALC6064
 CALC6065
 CALC6066
 CALC6067
 CALC6068
 CALC6069
 CALC6070
 CALC6071
 CALC6072
 CALC6073
 CALC6074
 CALC6075
 CALC6076
 CALC6077
 CALC6078
 CALC6079
 CALC6080
 CALC6081
 CALC6082
 CALC6083
 CALC6084
 CALC6085
 CALC6086
 CALC6087

```

V1T(I)=VUIT(I)/SIN(AR1)
WUIT(I)=VUIT(I)-UT(I)
BRIT=ATAN(WUIT(I)/VXIT(I))
BDIT(I)=57.296*BRIT
W1T(I)=VXIT(I)/COS(BRIT)
UH(I)=(RM(I)-H2(I)/24.)*UM(I)/RM(I)
VU1H(I)=VU1(I)*(RMA(I)/(RMA(I)-HI(I)/2.))*SIN(AR1)**2
AD1H(I)=AD1(L,I)
VX1H(I)=VUH(I)*COT(I)
V1H(I)=VUH(I)/SIN(AR1)
WUH(I)=VUH(I)-UH(I)
BR1H=ATAN(WUH(I)/VX1H(I))
BD1H(I)=57.296*BR1H
W1H(I)=VX1H(I)/COS(BR1H)
K=1
DELT1=H1(I)/(10.*12.)
PR=PI(I)
R1=RMA(I)/12.
GO TO 30
25 K=K+1
R1=R1+DELT1
30 RADA=R1
PRR=PR
CK1=DERVP(PRR,TT1(I),VU1(I),RADA,RMA(I))
RADA=R1+DELT1/2.
PRR=PR+DELT1*CK1/2.
CK2=DERVP(PRR,TT1(I),VU1(I),RADA,RMA(I))
PRR=PR+DELT1*CK2/2.
CK3=DERVP(PRR,TT1(I),VU1(I),RADA,RMA(I))
RADA=R1+DELT1
PRR=PR+DELT1*CK3
CK4=DERVP(PRR,TT1(I),VU1(I),RADA,RMA(I))
PR=PR+DELT1/6.*(CK1+2.*CK2+2.*CK3+CK4)
IF (K-5) 25,35,35
35 PIT(I)=PR
K=1
DELT1=-H1(I)/(10.*12.)
PR=PI(I)
R1=RMA(I)/12.
GO TO 45
40 K=K+1
R1=R1+DELT1
45 RADA=R1
PRR=PR

```

```

CK1=DERVP(PRR,TT1(I),VU1(I),RADA,RMA(I))
RADA=R1+DELT1/2.
PRR=PR+DELT1*CK1/2.
CK2=DERVP(PRR,TT1(I),VU1(I),RADA,RMA(I))
PRR=PR+DELT1*CK2/2.
CK3=DERVP(PRR,TT1(I),VU1(I),RADA,RMA(I))
RADA=R1+DELT1
PRR=PR+DELT1*CK3
CK4=DERVP(PRR,TT1(I),VU1(I),RADA,RMA(I))
PR=PR+DELT1/6.*(CK1+2.*CK2+2.*CK3+CK4)
IF (K-5) 40,50,50
50 PIH(I)=PR
TTT(I)=TT1(I)-VIT(I)**2/CON1
TIH(I)=TT1(I)-VIH(I)**2/CON1
PTIT(I)=PIH(I)*(TTT(I)/TIH(I))**CON3
100 PTIH(I)=PIH(I)*(TTT(I)/TIH(I))**CON3
RETURN
END

```

```

// DUP      WS  UA  CALC6
*STORE     UA  CD  CALC6
*DUMP

```

```

CALC6088
CALC6089
CALC6090
CALC6091
CALC6092
CALC6093
CALC6094
CALC6095
CALC6096
CALC6097
CALC6098
CALC6099
CALC6100
CALC6101
CALC6102
CALC6103
CALC6104
CALC6105

```

```

// FOR
SUBROUTINE CALC7
C SUBROUTINE CALCULATES ROTOR EXIT RADIAL VELOCITY DISTRIBUTION FOR
C NON-TWISTED BLADES USING THE RUNGE-KUTTA METHOD
C
COMMON IM, ID, IY, R, GAN, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRTM(2), ETST, ETTI, ETSTM,
2ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTT(2), UMS, SUMHT(2),
3SUMHS(2), PREOS, PREOT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PROOS, PROOT, PRSMH, PRTVM,
5ETSMM, ETTMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, FMACH
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRTOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BHACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2V2(10), WU2(10), BD1(10), AD2(10), SD2(10), ETS(10), ETT(10), E(10),
3RW(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), PTI(10), PT2(10),
4PTO(10), ANI(10), H1(10), AN2(10), H2(10), UT(10), VULT(10), ADIT(10),
5VIT(10), WUIT(10), EDT(10), WIT(10), VU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), SD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10)
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), SD2H(10), W2H(10), SEAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), ACIT(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TI2T(10), TI2H(10), TI2T(10), PI2H(10),
1PTIT(10), PT1H(10), TITL1(20), TITL2(20), FITL3(20),
2STRL(2), TUM1, TPI1, IPRST, TSP, M, RHC(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,2), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
DERV(VU2R, RAD, RADA, VU1, RMA) = OMEGA - ((VU2R/RAD)**2 + VU1*OMEGA*(RMA/(R
1ADA*12.))**SIN(ARI)**2*COS(ARI)**2 - RAD*OMEGA**2)/((1.+COTB**2)*(VU
2R-RAD*OMEGA))
VU1R(VU1, RMA) = VU1*(RMA/(RADA*12.))**5*IN(ARI)**2
TTR(TTI) = TTI - RAD*OMEGA*(VU1RR - VU2RR)/(32.174*778.16*CP)
TR(TTTR) = TTR - (VU2RR**2 + VX2RR**2)/(2.*32.174*778.16*CP)
VX2R(VU2RR) = (VU2RR - RAD*OMEGA)*COS(BF2)/SIN(BR2)
DERVP(PRR) = PRR*VU2RR**2/(32.174*RR*TRR#RAD)
OMEGA = 3.14159*SP(L)/30.
CON3 = GAM/(GAM-1.)
J = N(L)
DO 100 I=1, J

```

CALC7001
CALC7002
CALC7003
CALC7004
CALC7005
CALC7006
CALC7007
CALC7008
CALC7009
CALC7010
CALC7011
CALC7012
CALC7013
CALC7014
CALC7015
CALC7016
CALC7017
CALC7018
CALC7019
CALC7020
CALC7021
CALC7022
CALC7023
CALC7024
CALC7025
CALC7026
CALC7027
CALC7028
CALC7029
CALC7030
CALC7031
CALC7032
CALC7033
CALC7034
CALC7035
CALC7036
CALC7037
CALC7038
CALC7039
CALC7040
CALC7041
CALC7042
CALC7043

```

ARI=AD1(L,I)/57.296
BR2=BD2(I)/57.296
COTB=COS(BR2)/SIN(BR2)
DO 100 NDIR=1,2
K=1
GO TO (10,15),NDIR
10 DELT1=H1(I)/(10.*12.)
DELT2=U2(I)/(10.*12.)
GO TO 20
15 DELT1=-H1(I)/(10.*12.)
DELT2=-H2(I)/(10.*12.)
20 VU2R=VU2(I)
PR=P2(I)
R1=RMA(I)/12.
R2=RM(I)
GO TO 30
25 K=K+1
R1=R1+DELT1
R2=R2+DELT2
30 RADA=R1
RAD=R2
VU2RR=VU2R
CK1=DERV(VU2RR,RAD,RADA,VU1(I),RMA(I))
VUIRR=VUIR(VU1(I),RMA(I))
TTRR=TTR(TT1(I))
VX2RR=VX2R(VU2RR)
TTR=TR(TTRR)
PRR=PR
CKP1=DERVP(PRR)
RADA=R1+DELT1/2.
RAD=R2+DELT2/2.
VU2RR=VU2R+DELT2*CK1/2.
CK2=DERV(VU2RR,RAD,RADA,VU1(I),RMA(I))
VUIRR=VUIR(VU1(I),RMA(I))
TTRR=TTR(TT1(I))
VX2RR=VX2R(VU2RR)
TTR=TR(TTRR)
PRR=PR+DELT2*CKP1/2.
CKP2=DERVP(PRR)
VU2RR=VU2R+DELT2*CK2/2.
CK3=DERV(VU2RR,RAD,RADA,VU1(I),RMA(I))
VUIRR=VUIR(VU1(I),RMA(I))
TTRR=TTR(TT1(I))
VX2RR=VX2R(VU2RR)
CALC7044
CALC7045
CALC7046
CALC7047
CALC7048
CALC7049
CALC7050
CALC7051
CALC7052
CALC7053
CALC7054
CALC7055
CALC7056
CALC7057
CALC7058
CALC7059
CALC7060
CALC7061
CALC7062
CALC7063
CALC7064
CALC7065
CALC7066
CALC7067
CALC7068
CALC7069
CALC7070
CALC7071
CALC7072
CALC7073
CALC7074
CALC7075
CALC7076
CALC7077
CALC7078
CALC7079
CALC7080
CALC7081
CALC7082
CALC7083
CALC7084
CALC7085
CALC7086
CALC7087

```

```

TRR=TR(TTRR)
PRR=PR+DELT2*CKP2/2.
CKP3=DERVP(PRR)
RADA=R1+DELT1
RAD=R2+DELT2
VU2R=VU2R+DELT2*CK3
CK4=DERV(VU2R,RAD,RADA,VU1(I),RMA(I))
VU1R=VU1R(VU1(I),RMA(I))
TTRR=TTR(TT1(I))
VX2RR=VX2R(VU2RR)
TRR=TR(TTRR)
PRR=PR+DELT2*CKP3
CKP4=DERVP(PRR)
VU2R=VU2R+DELT2/6.*(CK1+2.*CK2+2.*CK3+CK4)
PR=PR+DELT2/6.*(CKP1+2.*CKP2+2.*CKP3+CKP4)
IF (K-5) 25,35,35
35 GO TO (36,50),NDIR
36 VU2T(I)=VU2R
P2T(I)=PR
T2T(I)=TTRR
TT2T(I)=TTRR
WU2T(I)=VU2T(I)-UT(I)
BD2T(I)=PD2(I)
VX2T(I)=WU2T(I)*COS(AR2)/SIN(ER2)
AR2T=ATAN(VU2T(I)/VX2T(I))
AD2T(I)=57.296*AR2T
V2T(I)=VX2T(I)/COS(AR2T)
W2T(I)=VX2T(I)/COS(AR2)
REAT(I)=1.-((VXIT(I)**2-VX2T(I)**2)/(2.*UT(I)*(VU1T(I)-VU2T(I)))
1-(VU1T(I)+VU2T(I))/(2.*UT(I)))
GO TO 100
50 VU2H(I)=VU2R
P2H(I)=FR
T2H(I)=TTRR
TT2H(I)=TTRR
WU2H(I)=VU2H(I)-UH(I)
VX2H(I)=WU2H(I)*COS(AR2)/SIN(ER2)
AR2H=ATAN(VU2H(I)/VX2H(I))
AD2H(I)=57.296*AR2H
V2H(I)=VX2H(I)/COS(AR2H)
BD2H(I)=PD2(I)
W2H(I)=VX2H(I)/COS(ER2)
PT2T(I)=P2T(I)*(TT2T(I)/T2T(I))**CON3
PT2H(I)=P2H(I)*(TT2H(I)/T2H(I))**CON3
CALC7093
CALC7089
CALC7090
CALC7091
CALC7092
CALC7093
CALC7094
CALC7095
CALC7096
CALC7097
CALC7098
CALC7099
CALC7100
CALC7101
CALC7102
CALC7103
CALC7104
CALC7105
CALC7106
CALC7107
CALC7108
CALC7109
CALC7110
CALC7111
CALC7112
CALC7113
CALC7114
CALC7115
CALC7116
CALC7117
CALC7118
CALC7119
CALC7120
CALC7121
CALC7122
CALC7123
CALC7124
CALC7125
CALC7126
CALC7127
CALC7128
CALC7129
CALC7130
CALC7131

```

CALC7132
CALC7133
CALC7134
CALC7135
CALC7136

REAH(I)=1.-((VX1H(I)**2-VX2H(I)**2)/(2.*UH(I))*(VU1H(I)-VU2H(I)))
1-(VU1H(I)+VU2H(I))/(2.*UH(I))

100 CONTINUE
RETURN
END

// DUP WS UA CALC7
*STORE UA CD CALC7
*DUP

```

// FOR SUBROUTINE CALC8
C SUBROUTINE CALCULATES MACH NUMBERS
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRITM(2), ETST, ETT, ETSTM,
2ETTMM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRIT(2), UMS, SUMHT(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRQOS, PRGOT, PRSM, PRITMM,
5ETSMM, ETTMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2, 10), Y(2, 10), REA(2, 10), Z(2, 10), AD1(2, 10), PRSOL, PRTOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3RM(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), PT1(10), PT2(10),
4PT0(10), ANI(10), HI(10), AN2(10), H2(10), UT(10), VUT(10), ADIT(10),
5VIT(10), WUIT(10), BDIT(10), WIT(10), VU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10)
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TITL1(20), TITL2(20), TITL3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2, 2, 10), CLEAR(2, 10), ARS(2, 10), TCRS(2, 10)
4, SECON(2, 10), ARCON(2, 3), SOLID(2, 10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
C
CALC8001
CALC8002
CALC8003
CALC8004
CALC8005
CALC8006
CALC8007
CALC8008
CALC8009
CALC8010
CALC8011
CALC8012
CALC8013
CALC8014
CALC8015
CALC8016
CALC8017
CALC8018
CALC8019
CALC8020
CALC8021
CALC8022
CALC8023
CALC8024
CALC8025
CALC8026
CALC8027
CALC8028
CALC8029
CALC8030
CALC8031
CALC8032
CALC8033
CALC8034
CALC8035
CALC8036
CALC8037
CALC8038
CALC8039
CALC8040
CALC8041
CALC8042
CALC8043
C
CALCULATION OF MACH NUMBERS
GON2=32.174*GAM*R
K=N(L)
DO 100 I=1,K
SQ1=SQRT (CON2*T1(I))
SQ2=SQRT (CON2*T2(I))
SQ1H=SQRT (CON2*T1H(I))
SQ1T=SQRT (CON2*T1T(I))
SQ2H=SQRT (CON2*T2H(I))
SQ2T=SQRT (CON2*T2T(I))
AC1(I)=V1(I)/SQ1

```



```
AC2(I)=W2(I)/SQ2
AC1H(I)=V1H(I)/SQ1H
AC1T(I)=V1T(I)/SQ1T
AC2H(I)=W2H(I)/SQ2H
100 AC2T(I)=W2T(I)/SQ2T
RETURN
END
```

```
CALC8044
CALC8045
CALC8046
CALC8047
CALC8048
CALC8049
CALC8050
```

```
// DUP
*STORE      WS  UA  CALC8
*DUMP       UA  CD  CALC8
```

```

// FOR
FUNCTION ROOT (A,B,C,D,X,STRES)
C
C FUNCTION SUBPROGRAM DETERMINES A NEW BLADE HEIGHT FOR STRESS
C PRESSURE AND PRESSURE RATIO ADJUSTING OPTIONS USING THE NEWTON RAPHSON
C METHOD
C
10 FORMAT (//IX,'NO SOLUTION FOR AVERAGE BLADE HEIGHT')
   NCONT=0
   ROOT=X
45 FH=B/ROOT+A*C*ROOT+A*D*ROOT**2-STRES
   DFH=-B/ROOT**2+A*C+2.*A*D*ROOT
   COR=FH/DFH
   ROOT=ROOT-COR
   NCONT=NCONT+1
   IF (ABS(COR/ROOT)-0.001) 100,100,50
50 IF (NCONT-30) 45,45,60
60 WRITE (3,10)
   STOP
100 RETURN
   END

// DUP
*STORE      WS  UA  ROOT
*DUMP       UA  CD  ROOT

```

```

ROOT0001
ROOT0002
ROOT0003
ROOT0004
ROOT0005
ROOT0006
ROOT0007
ROOT0008
ROOT0009
ROOT0010
ROOT0011
ROOT0012
RCOT0013
ROOT0014
ROOT0015
ROOT0016
RCOT0017
ROOT0018
ROOT0019
RCOT0020

```

```

// FOR SUBROUTINE STRES
C SUBROUTINE CALCULATES LAST STAGE BLADE ROOT STRESS, TESTS IT AGAINST
C STRESS LIMIT IF REQUIRED AND DETERMINES BRANCH TO CALCULATE OTHER
C BLADE ROOT STRESSES OR TO STRESS ADJUSTING SUBROUTINE
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UM1(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRITM(2), ETST, ETTI, ETSTM,
2ETTTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRIT(2), UMS, SUMHT(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRQOS, PRQOT, PRSMM, PRITM,
5ETSMM, ETTM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), Z(2,10), AD1(2,10), PRSOL, PRITOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREAI
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3RM(10), T11(10), T12(10), PRT(10), PRS(10), PRN(10), P11(10), P12(10),
4PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VUT(10), AD1T(10),
5V1T(10), WU1T(10), BD1T(10), W1T(10), VU1T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), LH(10), VUH(10), AD1H(10)
1, V1H(10), WU1H(10), BD1H(10), W1H(10), VU1H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), ACIT(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10),
COMMON VX2H(10), RMA(10), T12T(10), T12H(10), P12T(10), P12H(10),
1PT1T(10), PT1H(10), T1TL1(20), T1TL2(20), T1TL3(20),
2STRL(2), TUM1, TPTI, IPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
K=N(L)
SUMW=X(L,1)
IF (K-1) 11,11,9
9 DO 10 I=2,K
10 SUMW=SUMW+X(L,I)
11 WF(K)=X(L,K)/SUMW
RH=RMF(K)-HAVE(K)/2.0
F1=ARCON(L,1)/2.0*(1.-DELTA(L)**2)+ARCON(L,2)/3.0*(1.-DELTA(L)**3)+
1ARCON(L,3)/4.0*(1.-DELTA(L)**4)
F2=ARCON(L,1)*(1.-DELTA(L))+ARCON(L,2)/2.0*(1.-DELTA(L)**2)+ARCON(L,3)
STRES001
STRES002
STRES003
STRES004
STRES005
STRES006
STRES007
STRES008
STRES009
STRES010
STRES011
STRES012
STRES013
STRES014
STRES015
STRES016
STRES017
STRES018
STRES019
STRES020
STRES021
STRES022
STRES023
STRES024
STRES025
STRES026
STRES027
STRES028
STRES029
STRES030
STRES031
STRES032
STRES033
STRES034
STRES035
STRES036
STRES037
STRES038
STRES039
STRES040
STRES041
STRES042
STRES043

```

```

1L,3)/3.*(1.-DELTA(L)**3)
  STRC(K)=RHO(L)*HAVE(K)*(3.14159*SP(L)*OSF(L)/30.)**2/386.09*(RH*
1DELTA(L)+HAVE(K))*DELTA(L)**2/2.+HAVE(K)*F1+RH*F2)
  STRB(K)=33000.*SHP(L)*WF(L)*OSF(L)**OSEXP(L)*ARS(L,K)**2/(8.*3.14159*
159**2*OSF(L)*SP(L)*RMF(K)**2*SECON(L,K)*SOLID(L,K)*HAVE(K)/12.*TCRS
2S(L,K)**2)
  STRT(K)=STRC(K)+STRB(K)
  IF (M-1) 20,12,12
12 GO TO (15,15,14,15,15) ,NFLAG
14 NFLAG=4
  IF(STRT(K)-STRL(L))40,40,25
15 ERR=ABS(STRL(L)-STRT(K))
  IF(ERR-200.0)20,20,40
20 NFLAG=1
25 IF (K-1) 31,31,26
26 J=K-1
  DO 30 I=1,J
  WF(I)=X(L,I)/SUMW
  HAVE(I)=(H1(I)+H2(I))/2.0
  RH=RMF(I)-HAVE(I)/2.0
  STRC(I)=RHO(L)*HAVE(I)*(3.14159*SP(L)*OSF(L)/30.)**2/386.09*(RH*
1DELTA(L)+HAVE(I))*DELTA(L)**2/2.+HAVE(I)*F1+RH*F2)
  STRB(I)=33000.*SHP(L)*WF(I)*OSF(L)**OSEXP(L)*ARS(L,I)**2/(8.*3.14159*
159**2*OSF(L)*SP(L)*RMF(I)**2*SECON(L,I)*SOLID(L,I)*HAVE(I)/12.
2*TCRS(L,I)**2)
  WF(I)=WF(I)*100.0
30 STRT(I)=STRC(I)+STRB(I)
31 WF(K)=WF(K)*100.0
  GO TO 43
40 GO TO (41,41,41,42,42),NFLAG
41 NFLAG=2
  GO TO 43
42 NFLAG=5
43 RETURN
  END

```

```

// DUP
*STORE WS UA STRES
*DUMP UA CD STRES

```

```

STRES044
STRES045
STRES046
STRES047
STRES048
STRES049
STRES050
STRES051
STRES052
STRES053
STRES054
STRES055
STRES056
STRES057
STRES058
STRES059
STRES060
STRES061
STRES062
STRES063
STRES064
STRES065
STRES066
STRES067
STRES068
STRES069
STRES070
STRES071
STRES072
STRES073
STRES074
STRES075
STRES076
STRES077
STRES078

```



```

2**
31.5+HU*F1/UM(K)**1.5+F2*(RU/UM(K)-HU/2./UM(K)**1.5))-F3*SP(L)*WF STRS1044
4(K)*OSF(L)**USEXP(L)*UM(K)**3.5/(SP(L)*OSF(L)*RU**2*HU) STRS1045
DFU=RHO(L)*HU*(3.14159*SP(L)*OSF(L)/30.0)**2/386.09*(3./2./UM(K))* STRS1046
12.5*(DELTA(L)*(RU/UM(K)-HU/2./UM(K)**1.5)+HU*DELTA(L)**2/2./UM(K)) STRS1048
2**1.5+HU*F1/UM(K)**1.5+F2*(RU/UM(K)-HU/2./UM(K)**1.5))-1./UM(K)** STRS1049
33.5*(DELTA(L)*13.*HU/4./UM(K)**0.5-RU)-3.*HU*DELTA(L)**2/4./UM(K) STRS1050
4**0.5-3.*HU*F1/2./UM(K)**0.5+F2*(3.*HU/4./UM(K)**0.5-RU))-3.5*F3* STRS1051
5HP(L)*WF(K)*OSF(L)**USEXP(L)*UM(K)**2.5/(SP(L)*OSF(L)*RU**2*HU) STRS1052
COR=FU/DFU STRS1053
UM(K)=UM(K)-COR STRS1054
NCONT=NCONT+1 STRS1055
IF (ABS(COR/UM(K))-0.001) 53,53,52 STRS1056
52 IF(NCONT-30) 51,51,105 STRS1057
53 TUML=UM(K) STRS1058
TUM1=TUML/Y(L,K) STRS1059
GO TO 110 STRS1060
105 WRITE (3,5) STRS1061
STOP STRS1062
110 RETURN STRS1063
END STRS1064

```

```

// DUP
*STORE WS UA STRS1
*DUP UA CD STRS1

```

```

// F
SUBROUTINE STRS2
C SUBROUTINE ADJUSTS STRESS BY CHANGING INLET PRESSURE ,PRESSURE RATIO
C OR ROTATIVE SPEED
C
DIMENSION Q(4)
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TII(2), PTI(2), UMI(2),
1 COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRITM(2), ETST, ETT, ETSTM,
2 ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRIT(2), UMS, SUMHT(2),
3 SUMHS(2), PREQS, PREOT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4 PRQOS, PROOT, PRQMY, PRITM,
5 ETSMM, ETTMM, PTME(2), AREA, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), Z(2,10), AD1(2,10), PRSOL, PRITOL,
1 ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TVANI, PMANI,
1 V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2 W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3 RM(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), PTI(10), PT2(10),
4 PT0(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VU1T(10), ADIT(10),
5 V1T(10), WU1T(10), BD1T(10), W1T(10), WU1T(10), AD2T(10), VU1T(10),
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10),
1 V1H(10), WU1H(10), BD1H(10), W1H(10), WU1H(10), AD2H(10), V2H(10),
2 WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3 CS(10), UC(10), RMF(10), AC1(10), AC2(10), ACH(10), AC2H(10), ACIT(10),
4 AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5 P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10),
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1 PT1T(10), PT1H(10), TITL1(20), TITL2(20), TITL3(20),
2 STRL(2), TUM1, IPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
3 10), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4 , SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5 , RT(10)
K=N(L)
F1=ARCON(L,1)/2.*(1.-DELTA(L)**2)+ARCON(L,2)/3.*(1.-DELTA(L)**3)+
1 ARCON(L,3)/4.*(1.-DELTA(L)**4)
F2=ARCON(L,1)*(1.-DELTA(L))+ARCON(L,2)/2.*(1.-DELTA(L)**2)+ARCON(
1 L,3)/3.*(1.-DELTA(L)**3)
F3=33000.*ARS(L,K)**2/(8.*3.14159**2*SECON(L,K)*SOLID(L,K)*
1 TCRS(L,K)**2/12.)
GO TO (60,70,60,100),M
60 GO TO (110,65,70,70,70),NFLAG
65 NFLAG=3
GO TO 110
STRS2001
STRS2002
STRS2003
STRS2004
STRS2005
STRS2006
STRS2007
STRS2008
STRS2009
STRS2010
STRS2011
STRS2012
STRS2013
STRS2014
STRS2015
STRS2016
STRS2017
STRS2018
STRS2019
STRS2020
STRS2021
STRS2022
STRS2023
STRS2024
STRS2025
STRS2026
STRS2027
STRS2028
STRS2029
STRS2030
STRS2031
STRS2032
STRS2033
STRS2034
STRS2035
STRS2036
STRS2037
STRS2038
STRS2039
STRS2040
STRS2041
STRS2042
STRS2043

```

```

70 Q(1)=RHO(L)*(3.14159*SP(L)*OSF(L)/30.)*2/386.09
   Q(2)=F3*SHP(L)*WF(K)*OSF(L)**OSEXP(L)/(SP(L)*OSF(L)*RMF(K)**2)
   Q(3)=DELTA(L)*RMF(K)*(DELTA(L)+F2)
   Q(4)=DELTA(L)**2/2.-0.5*(DELTA(L)+F2)+F1
   THAVE=ROOT(Q(1),Q(2),Q(3),Q(4),HAVE(K),STRL(L))
   IF(M-3)80,140,140
80 TPTI=PTI(L)*HAVE(K)/THAVE
   GO TO 110
140 TPRST=PRSTM(L)
   FACI=1.3333333
   C=(1.-1./PRSTM(L))*((GAM-1.)/GAM))*(HAVE(K)/PRSTM(L)/THAVE)**FACI
IT
150 F=1.0-(1.0/TPRST)**((GAM-1.0)/GAM)-C*TPRST**FACT
   FP=(GAM-1.0)/GAM*(1.0/(TPRST**((2.0*GAM-1.0)/GAM)))-FACT *C*
   TPRST*(FACT-1.)
   IF (FP) 160,155,155
155 TPRST=TPRST+1.
   GO TO 150
160 CORR=F/FP
   TPRST=TPRST-CORR
   IF (ABS(CORR/TPRST)-0.001)110,110,150
100 ARA=2.*3.14159*RMF(K)*HAVE(K)
   F4=RHO(L)*ARA*(3.14159/30.)*2/60./386.09/UM(K)/OSF(L)
   F5=F4*(DELTA(L)*ARA*(DELTA(L)-1.)/120./UM(K)/OSF(L)+ARA*(F1-F2/2.))
   1/60./UM(K)/OSF(L))/144.
   F6=F4*30.*UM(K)*OSF(L)*(DELTA(L)+F2)/3.14159
   F7=F3*SHP(L)*OSF(L)**OSEXP(L)*WF(K)*2.*3.14159**2/30./UM(K)/OSF(L)
   1/ARA/12.-STRL(L)
   IF (ABS(ARCON(L,2))+ABS(ARCON(L,3))) 105,104,105
104 TSP=SQRT(-F7/F6)/OSF(L)
   GO TO 110
105 TSP=SQRT((-F6+SQRT(F6**2-4.*F5*F7))/2./F5)/OSF(L)
110 RETURN
   END

```

// DUP

*STORF WS UA STRS2

*DUMP UA CD STRS2

STRS2044
STRS2045
STRS2046
STRS2047
STRS2048
STRS2049
STRS2050
STRS2051
STRS2052
STRS2053
STRS2054
STRS2055
STRS2056
STRS2057
STRS2058
STRS2059
STRS2060
STRS2061
STRS2062
STRS2063
STRS2064
STRS2065
STRS2066
STRS2067
STRS2068
STRS2069
STRS2070
STRS2071
STRS2072
STRS2073
STRS2074
STRS2075
STRS2076
STRS2077


```

// FOR SUBROUTINE OVALL(J)
C SUBROUTINE CALCULATES OVERALL TWO-SPOOL PERFORMANCE AND PRINTS THIS
C INFORMATION
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UM1(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRSTM(2), ETST, ETT, ETSTM,
2ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRST(2), UMS, SUMHT(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRQOS, PRQOT, PRSMM, PRSTM,
5SETSMM, ETMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), Z(2,10), AD1(2,10), PRSOL, PRITOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOIM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3RM(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), PTL(10), PT2(10),
4PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VUIT(10), ADIT(10),
5V1T(10), WUIT(10), BDIT(10), WIT(10), VU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VUH(10), AD1H(10)
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), RD2H(10), W2H(10), REAH(10), TI(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10),
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TT1L(20), TT1L2(20), TT1L3(20),
2STRL(2), IUM1, TPT1, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
DH(PR) = CP * T * (1. - (1. / PR) ** CON4)
ET(DH) = (D1 + D2) / DH
UCOVL(DH) = UMAOL / SQRT(2. * 32.174 * 778.16 * DH)
K = N(2)
T = TTI(1)
D1 = DHO(1)
D2 = DHO(2)
DHOVL = DHO(1) + DHO(2)
10 FORMAT (//6H DATE , A2, 1H-, A2, 1H-, A2, 32X, 30H OVERT-ALL TWO-SPOOL PER
1FORMANCE, 38X, 4HPAGE, I3//)
15 FORMAT (41X, 38H FIRST SPOOL INLET TO SECOND SPOOL EXIT//)
20 FORMAT (42X, 35H MANIFOLD INLET TO SECOND SPOOL EXIT//)
OVALL001
OVALL002
OVALL003
OVALL004
OVALL005
OVALL006
OVALL007
OVALL008
OVALL009
OVALL010
OVALL011
OVALL012
OVALL013
OVALL014
OVALL015
OVALL016
OVALL017
OVALL018
OVALL019
OVALL020
OVALL021
OVALL022
OVALL023
OVALL024
OVALL025
OVALL026
OVALL027
OVALL028
OVALL029
OVALL030
OVALL031
OVALL032
OVALL033
OVALL034
OVALL035
OVALL036
OVALL037
OVALL038
OVALL039
OVALL040
OVALL041
OVALL042
OVALL043

```

OVALLO44
OVALLO45
OVALLO46
FTOVALLO47
OVALLO48
OVALLO49
SGOVALLO50
OVALLO51
OVALLO52
OVALLO53
OVALLO54
OVALLO55
OVALLO56
OVALLO57
OVALLO58
OVALLO59
OVALLO60
OVALLO61
OVALLO62
OVALLO63
OVALLO64
OVALLO65
OVALLO66
OVALLO67
OVALLO68
OVALLO69
OVALLO70
OVALLO71
OVALLO72
OVALLO73
OVALLO74
OVALLO75
OVALLO76
OVALLO77
OVALLO78
OVALLO79
OVALLO80
OVALLO81
OVALLO82
OVALLO83
OVALLO84
OVALLO85
OVALLO86
OVALLO87

25 FORMAT (4X,39HMANIFOLD EXIT TO EXHAUST COLLECTOR EXIT//)
30 FORMAT (40X,40HMANIFOLD INLET TO EXHAUST COLLECTOR EXIT//)
35 FORMAT (100H I DEL H UMA U/CO U/CO PRST
1 PRST E1ST E1TT RET RES /20H BIU/LB
2/SEC/2F10.1,8F10.3//)
40 FORMAT (40X,40HEXHAUST COLLECTOR EXIT FLANGE CONDITIONS//60H
IAREA MACH NUM PT P TI T /60H SGOVALLO50
2-IN PSIA PSIA DEG R DEG R /F10.2,F10.3OVALLO51
3,4F10.1)
45 FORMAT (1H1)

CON4=(GAM-1.)/GAM
PRSOL=PRST(1)*PRST(2)
PRDOM=PRST(1)*PRST(2)
PRSM=PRST(1)*PRST(2)
PR10L=PRST(1)*PRST(2)
PR10M=PRST(1)*PRST(2)
PR1ML=PRST(1)*PRST(2)
PR1TM=PRST(1)*PRST(2)
DHSOL=DH(PRSOL)
DHSOM=DH(PRSOM)
DHSML=DH(PRSML)
DHSMM=DH(PRSMM)
DH10L=DH(PR10L)
DH10M=DH(PR10M)
DH1ML=DH(PR1ML)
DH1TM=DH(PR1TM)
ET10L=ET(DH10L)
ET10M=ET(DH10M)
ET1ML=ET(DH1ML)
ET1TM=ET(DH1TM)
UMAOL=(UMA(1)+UMA(2))/2.
UCSOL=UCOVL(DHSOL)
UCSOM=UCOVL(DHSOM)
UCSML=UCOVL(DHSML)
UCSMM=UCOVL(DHSMM)
UCTOL=UCOVL(DH10L)
UCTOM=UCOVL(DH10M)
UCTML=UCOVL(DH1ML)
UCTMM=UCOVL(DH1TM)

```

DHOOL=DHO(1)+DHO(2)
SUHTO=SUMHT(1)+SUMHT(2)
SUHSO=SUMHS(1)+SUMHS(2)
RESOL=SUHSO/DHSOL
RESOM=SUHSO/DHSOM
RESML=SUHSO/DHSML
RESMM=SUHSO/DHSMM
RETOL=SUHTO/DHTOL
RETOM=SUHTO/DHTOM
RETML=SUHTO/DHTML
RETMM=SUHTO/DHTMM
IF (J-1) 200,200,100
100 IPAGE=IPAGE+1
WRITE (3,45)
WRITE (3,10) IM, ID, IY, IPAGE
WRITE (3,15)
WRITE (3,35) DHOVL,UMAOL,UCSOL,UCTOL,PRSOL,PRTOL,ETSOL,ETTOL,
1RESOL,RETOL
WRITE (3,20)
WRITE (3,35) DHOVL,UMAOL,UCSOM,UCTOM,PRSOM,PRTOM,ETSOM,ETTOM,
1RESOM,RETOM
WRITE (3,25)
WRITE (3,35) DHOVL,UMAOL,UCSML,UCTML,PRSMML,PRTML,ETSML,ETTML,
1RESML,RETML
WRITE (3,30)
WRITE (3,35) DHOVL,UMAOL,UCSMM,UCTMM,PRSMML,PRTMM,ETSMM,ETTMM,
1RESMM,RETMM
WRITE (3,40) AREAF,EMACH,PTME(2),PECE,TT2(K),TECE
200 RETURN
END

```

```

OVALL088
OVALL089
OVALL090
OVALL091
OVALL092
OVALL093
OVALL094
OVALL095
OVALL096
OVALL097
OVALL098
OVALL099
OVALL100
OVALL101
OVALL102
OVALL103
OVALL104
OVALL105
OVALL106
OVALL107
OVALL108
OVALL109
OVALL110
OVALL111
OVALL112
OVALL113
OVALL114
OVALL115
OVALL116
OVALL117

```

```

// DUP
*STORE      WS  UA  OVALL
*DUMP       UA  CD  OVALL

```

```

// FOR SUBROUTINE OUTPT
C SUBROUTINE PRINTS INPUT INFORMATION FOR BOTH SPOOLS
C
DIMENSION NSW(16)
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRTIM(2), EIST, EITI, EISTM,
2ETTTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTT(2), UMS, SUMHT(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRQOS, PROOT, PRSMM, PRTMM,
5ETSM, ETTM, PTME(2), AREAF, TECE, PFCE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), Z(2,10), AD1(2,10), PRSOL, PRITOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), ED1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3RM(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), PTT(10), PT2(10),
4PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VU1T(10), AD1T(10),
5V1T(10), WU1T(10), BD1T(10), W1T(10), VU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), RD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10),
1, V1H(10), WU1H(10), RD1H(10), W1H(10), VU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), ACH(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), PH(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TT1L1(20), TT1L2(20), TT1L3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), CSEXP(2)
5, RT(10)
3 FORMAT (1H1)
5 FORMAT (//5H DATE, A2, 1H-, A2, 1H-, A2, 43X, I2, 6H STAGE, 48X, 4HPAGE, I3, OUTPT033
1/51X, 18HGAS TURBINE DESIGN/56X, 8HANALYSIS//)
6 FORMAT (//52X, 15HCASE CONDITIONS//3X, 5HSHAFT, 10X, 4HFLOW, 7X, 11HINLET, OUTPT035
1T TOTAL, 6X, 11HINLET TOTAL, 6X, 10HMEAN BLADE, 6X, 8HROTATIVE, 7X, OUTPT036
2 9HE.C. LOSS/1X, 10HHORSEPOWER, 7X, 4HRATE, 7X, 11HTEMPERATURE, OUTPT037
3E, 7X, 8HPRESSURE, 10X, 5HSPEED, 10X, 5HSPEED, 8X, 11HCOEFFICIENT OUTPT038
4 /17X, 6HLR/SEC, 8X, 5HDEG R, 13X, 4HPSIA, 12X, 6HFT/SEC, 10X, 3HRPOUT, OUTPT039
5M)
7 FORMAT (//52X, 15HCASE CONDITIONS//3X, 5HSHAFT, 8X, 4HFLOW, 5X, 11HINLET, OUTPT041
1 TOTAL, 4X, 11HINLET TOTAL, 4X, 10HMEAN BLADE, 4X, 8HROTATIVE, 5X OUTPT042
2 , 9HMAN. LOSS, 5X, 9HE.C. LOSS/1X, 10HHORSEPOWER, 5X, 4HRATE, 5X, OUTPT043

```



```

K=N(L)
JFLAG=JFLAG
KSW=0
DO 165 ISW=1,16
LSW=ISW-1
CALL DATSW (LSW,JSW)
GO TO (160,165),JSW
160 KSW=KSW+1
NSW(KSW)=LSW
165 CONTINUE
GO TO (200,210),L
200 IPAGE=1
GO TO 230
210 JFLAG=2
IF (M-4) 215,215,220
215 IPAGE=8
GO TO 230
220 IPAGE=7
230 WRITE (3,3)
GO TO (115,135),JFLAG
115 WRITE (3,37) IM,ID,IY,K
GO TO 136
134 JFLAG=2
WRITE (3,3)
135 WRITE (3,5) IM,ID,IY,K,IPAGE
136 WRITE (3,10) L,LFLAG
WRITE (3,32)
WRITE (3,31) TITL1
WRITE (3,33) CASE1,CASE2
WRITE (3,35) TITL2
WRITE (3,36) TITL3
WRITE (3,34)
WRITE (3,13) R,GAM,CP,VIS
GO TO (118,117),LFLAG
117 GO TO (137,138),L
137 WRITE (3,14)
GO TO 139
138 WRITE (3,6)
139 WRITE (3,17) SHP(L),W,TTI(L),PTI(L),UMI(L),SP(L),COEM(L)
GO TO 119
118 WRITE (3,7)
WRITE (3,8) SHP(L),W,TTI(L),PTI(L),UMI(L),SP(L),COEM(L),COEM(2)
119 IF (M-4) 120,120,130
120 WRITE (3,20) (ARCON(L,I),I=1,3),DELTA(L),OSF(L),OSEXP(L)
OUTPUT088
OUTPUT089
OUTPUT090
OUTPUT091
OUTPUT092
OUTPUT093
OUTPUT094
OUTPUT095
OUTPUT096
OUTPUT097
OUTPUT098
OUTPUT099
OUTPUT100
OUTPUT101
OUTPUT102
OUTPUT103
OUTPUT104
OUTPUT105
OUTPUT106
OUTPUT107
OUTPUT108
OUTPUT109
OUTPUT110
OUTPUT111
OUTPUT112
OUTPUT113
OUTPUT114
OUTPUT115
OUTPUT116
OUTPUT117
OUTPUT118
OUTPUT119
OUTPUT120
OUTPUT121
OUTPUT122
OUTPUT123
OUTPUT124
OUTPUT125
OUTPUT126
OUTPUT127
OUTPUT128
OUTPUT129
OUTPUT130
OUTPUT131

```

```

WRITE (3,38) STRL(L),RHO(L),M
GO TO 155
130 WRITE (3,42)
155 IF (KSW) 128,128,125
125 WRITE (3,40) (NSW(I),I=1,KSW)
GO TO 131
128 WRITE (3,41)
131 WRITE (3,18)
WRITE (3,21)
WRITE (3,19) (I,REA(L,I),AD1(L,I),X(L,I),Y(L,I),Z(L,I),COE(L,I),I),
1COE(L,2,I),CLEAR(L,I),ARS(L,I),TCRS(L,I),SECON(L,I),SOLID(L,I),I=1,
2,K)
GO TO (134,150),JFLG
150 RETURN
END
// DUP
*STORE WS UA OUTPUT
*DUMP UA CD OUTPUT

```

```

OUTPT132
OUTPT133
OUTPT134
OUTPT135
OUTPT136
OUTPT137
OUTPT138
OUTPT139
OUTPT140
OUTPT141
OUTPT142
OUTPT143
OUTPT144
OUTPT145
OUTPT146

```

// FOR SUBROUTINE OUTP1

C SUBROUTINE PRINTS ALL CALCULATED INFORMATION EXCEPT STRESS AND
C PERFORMANCE INFORMATION

C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UM1(2),
1 COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRITM(2), ETST, ETTI, ETSTM,
2 ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTT(2), UMS, SUMHT(2),
3 SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4 PRQOS, PRQOT, PRSMM, PRITMM,
5 ETSMM, ETTMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2, 10), Y(2, 10), REA(2, 10), Z(2, 10), AD1(2, 10), PRSQL, PRITOL,
1 ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1 V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2 W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3 RM(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), PTT(10), PT2(10),
4 PTO(10), ANI(10), HI(10), AN2(10), H2(10), UT(10), VUT(10), ADIT(10),
5 VIT(10), WUIT(10), BDI(10), WIT(10), VU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VJ1H(10), AD1H(10),
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2 WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3 CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), ACIT(10),
4 AC2T(10), TH(10), TIT(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5 P2T(10), COT(10), VEP(10), DVU(10), VXIT(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1 PTT(10), PTH(10), TITL1(20), TITL2(20), TITL2(20),
2 STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
3 10), STRB(10), STRT(10), COE(2, 2, 10), CLEAR(2, 10), ARS(2, 10), TCRS(2, 10),
4, SECON(2, 10), ARCON(2, 3), SOLID(2, 10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
3 FORMAT (1H1)
6 FORMAT (///5H DATE, A2, 1H-, A2, 1H-, A2, 1H-, A2, 39X, 16HSTAGE VELOCITIES, 45X,
14HPAGE, I3 //)
27 FORMAT (
2V1 WU1 W1 VX2 STAGE U VU1 V2 WU2 W2
3 REACTION /113H FT/SEC FT/SEC FT/SEC FT/SEC FT/SEC FT/SEC FT/SEC FT/SEC
4T/SEC FT/SEC FT/SEC FT/SEC FT/SEC FT/SEC FT/SEC FT/SEC
19 FORMAT (5X, I2, 1X, 11F9.1, F9.3/8X, 11F9.1, F9.3/8X, 11F9.1, F9.3//)
7 FORMAT (///5H DATE, A2, 1H-, A2, 1H-, A2, 40X, 14HSTAGE GEOMETRY, 46X,
14HPAGE, I3//)
29 FORMAT (120H STAGE ANNULUS ALPHA1 MEAN BETA1 BLADE ALPHA2 BETA2
2 ANNULUS ANNULUS ALPHA1 BETA1 ALPHA2 BETA2)


```

3TA2)
21 FORMAT (
3      72H
41     AREA 2/120H
5      SQ-IN      SQ-IN      DEG
6      DEG )
22 FORMAT (9X,I2,1X,F12.4,F10.3,2X,F10.3,2X,2F12.3,4F12.2/72X,
14F12.2/72X,4F12.2//)
8  FORMAT (///5H DATE,A2,1H-,A2,1H-,A2,17X,9HPRESSURES,55X,
112HTEMPERATURES,7X,4HPAGE,I3//)
30 FORMAT (
2      PT2      P2      PRS      120H      STAGE      PT1      P1
3      TT2      T2      )
23 FORMAT (
3      PSIA      120H      PSIA      PSIA      DEG R      DEG R
4A     DEG R      DEG R/(7X,I2,1X,4F10.1,30X,4F10.1/10X,4F10.1,2F10.3,
5     610X,4F10.1/10X,4F10.1,30X,4F10.1//)
6     11 FORMAT (///5H DATE,A2,1H-,A2,1H-,A2,38X,18HSTAGE MACH NUMBERS,44X,OUTP1062
14HPAGE,I3//)
28 FORMAT (
2     2NOZZLE EXIT      40H      STAGE      ABSOLUTE      RELATIVE /10X,30H
3     317X,F5.3,F15.3//)
25 FORMAT (54X,11HFREE VORTEX//)
26 FORMAT (51X,18HNON TWISTED BLADES//)
K=N(L)
WRITE (3,3)
IPAGE=IPAGE+1
WRITE (3,6) IM, ID, IY, IPAGE
IF (IFLAG-2) 40,50,50
40 WRITE (3,25)
GO TO 60
50 WRITE (3,26)
60 WRITE (3,27)
WRITE (3,19) (I,UH(I),VU1H(I),VX1H(I),V1H(I),WU1H(I),WIH(I),
1VU2H(I),VX2H(I),V2H(I),WU2H(I),W2H(I),REAH(I),UM(I),VU1(I),VX1(I),
2V1(I),WU1(I),W1(I),VU2(I),VX2(I),V2(I),WU2(I),W2(I),REA(L,I),UT(I),
3,VU1T(I),VX1T(I),V1T(I),WU1T(I),W1T(I),VU2T(I),VX2T(I),V2T(I),
4WU2T(I),W2T(I),REAT(I),I=1,K)
WRITE (3,3)
IPAGE=IPAGE+1
WRITE (3,11) IM, ID, IY, IPAGE
IF (IFLAG-2) 65,70,70
65 WRITE (3,25)

```

```

OUTP1044
OUTP1045
OUTP1046
OUTP1047
OUTP1048
OUTP1049
OUTP1050
OUTP1051
OUTP1052
OUTP1053
OUTP1054
T1OUTP1055
OUTP1056
OUTP1057
OUTP1058
OUTP1059
OUTP1060
OUTP1061
OUTP1062
OUTP1063
OUTP1064
OUTP1065
OUTP1066
OUTP1067
OUTP1068
OUTP1069
OUTP1070
OUTP1071
OUTP1072
OUTP1073
OUTP1074
OUTP1075
OUTP1076
OUTP1077
OUTP1078
OUTP1079
OUTP1080
OUTP1081
OUTP1082
OUTP1083
OUTP1084
OUTP1085
OUTP1086
OUTP1087

```

```

GO TO 75
70 WRITE (3,26)
75 WRITE (3,28)
   IAC1(I),AC2T(I),I=1,K)
   WRITE (3,3)
   IPAGE=IPAGE+1
   WRITE (3,7) IM, ID, IY, IPAGE
   IF (IFLAG-2) 80,85,85
80 WRITE (3,25)
   GO TO 90
85 WRITE (3,26)
90 WRITE (3,29)
   WRITE (3,21)
   WRITE (3,22)
   IAD1H(I),BD1H(I),
   IAD2H(I),BD2H(I),AD1(L,I),BD1(I),AD2(I),BD2(I),AD1T(I),BD1T(I),
   2AD2T(I),BD2T(I),I=1,K)
   WRITE (3,3)
   IPAGE=IPAGE+1
   WRITE (3,8) IM, ID, IY, IPAGE
   IF (IFLAG-2) 95,100,100
95 WRITE (3,25)
   GO TO 105
100 WRITE (3,26)
105 WRITE (3,30)
   WRITE (3,23)
   IT1H(I),TT2H(I),T2H(I),PT1(I),P1(I),PT2(I),P2(I),PRS(I),PRT(I),
   2TT1(I),T1(I),TT2(I),T2(I),PT1(I),P1T(I),P2T(I),TT1(I),
   3TTT(I),TT2T(I),T2T(I),I=1,K)
   RETURN
END
// DUP
*STORE WS UA OUTPI
*DUMP UA CD OUTPI
(I,AC1H(I),AC2H(I),AC1(I),AC2(I),
(I,RMF(I),H1(I),H2(I),AN1(I),AN2(I),

```

```

OUTP1088
OUTP1089
OUTP1090
OUTP1091
OUTP1092
OUTP1093
OUTP1094
OUTP1095
OUTP1096
OUTP1097
OUTP1098
OUTP1099
OUTP1100
OUTP1101
OUTP1102
OUTP1103
OUTP1104
OUTP1105
OUTP1106
OUTP1107
OUTP1108
OUTP1109
OUTP1110
OUTP1111
OUTP1112
OUTP1113
OUTP1114
OUTP1115
OUTP1116
OUTP1117
OUTP1118

```

// FOR SUBROUTINE OUTP2

C SUBROUTINE PRINTS CALCULATED STRESS DATA

C

```
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRITM(2), ETST, ETT, ETSTM,
2ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRIT(2), UMS, SUMHT(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PRCOS, PROOT, PRSMM, PRITM,
5ETSMM, ETMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2, 10), Y(2, 10), REA(2, 10), Z(2, 10), AD1(2, 10), PRSOL, PRITOL,
1ETCOL, ETOL, UCSOL, UCTOL, UCOT, UCOTM, AREAI
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3RM(10), T1(10), TT2(10), PRT(10), PRS(10), PRN(10), PT1(10), PT2(10),
4PTO(10), ANI(10), HI(10), AN2(10), H2(10), UT(10), VU1T(10), ADIT(10),
5V1T(10), VU1T(10), BDIT(10), W1T(10), VU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VUH(10), ADIH(10)
1, VIH(10), WU1H(10), BD1H(10), W1H(10), VU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), ACIH(10), AC2H(10), AC1T(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TT1L1(20), TT1L2(20), TT1L3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2, 2, 10), CLEAR(2, 10), ARS(2, 10), TCRS(2, 10)
4, SECON(2, 10), ARCON(2, 3), SOLID(2, 10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
1 FORMAT(//5H DATE, A2, IH-, A2, IH-, A2, 35X, 23H ROTOR BLADE ROOT STRESS, OUTP2031
142X, 4HPAGE, I3 //)
2 FORMAT (2X, STAGE, 11X, MEAN, 14X, AVERAGE, 13X, STAGE, 11X,
1 CENTRIPETAL, 10X, BENDING, 10X, TOTAL, /17X, RADIUS, 10X,
2 BLADE HEIGHT, 11X, LOAD, 15X, STRESS, 13X, STRESS, 10X,
3 STRESS, /19X, IN, 17X, IN, 15X, PERCENT, 14X, PSI, 16X, PSI, 13X,
4 PSI //)
3 FORMAT (3X, I2, 11X, F7.4, 15X, F5.3, 13X, F5.1, 13X, F8.1, 12X, F7.1, 8X, F8.1,
1 //)
4 FORMAT (//2X, 80HNOTE, TURBINE PRESSURE RATIO CANNOT BE ADJUSTED TO
10 ARRIVE AT A STRESS VALUE OF, F7.1, 22H PSI IN THE LAST ROTOR/9X, 10UTP2041
202HBLADE. THE ABOVE STRESS VALUES ARE AT A PRESSURE RATIO OF 4.0, 10UTP2042
3 MINIMUM STRESS IS AT A PRESSURE RATIO/9X, 21HOF APPROXIMATELY 4.0, 10UTP2043
```

```

4*)
6 FORMAT (//2X,103HNOTE, NUMBER OF ITERATIONS THROUGH THE STRESS SUBROUTINE EXCEEDED 15 WITHOUT REACHING THE STRESS LIMIT.)
15 FORMAT (1H1)
K=N(L)
WRITE (3,15)
IPAGE=IPAGE+1
WRITE (3,1) IM,ID,IY,IPAGE
WRITE (3,2)
WRITE (3,3) (I,RMF(I),HAVE(I) ,WF(I),STRC(I),STRB(I),
1 STRT(I),I=1,K)
GO TO (10,10,10,5,10,7),NFLAG
5 WRITE (3,4) STRL(L)
GO TO 10
7 WRITE (3,6)
10 RETURN
END

```

```

// DUP
*STORE
*DUMP

```

```

WS UA OUTP2
UA CD OUTP2

```

```

OUTP2044
OUTP2045
OUTP2046
OUTP2047
OUTP2048
OUTP2049
OUTP2050
OUTP2051
OUTP2052
OUTP2053
OUTP2054
OUTP2055
OUTP2056
OUTP2057
OUTP2058
OUTP2059
OUTP2060

```

// FOR SUBROUTINE OUTP3

C SUBROUTINE PRINTS CALCULATED PERFORMANCE DATA FOR EACH STAGE AND
C EACH SPOOL
C

COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, ITI(2), PTI(2), UM1(2),
1 COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRTIM(2), ETSI, ETTI, ETSTM,
2 ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRTI(2), UMS, SUMHT(2),
3 SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLA5, KFLAG, MFLAG, LFLAG, L,
4 PRQS, PRQOT, PRSMM, PRTMM,
5 ETSMM, ETTMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), ADI(2,10), PRSOL, PRTOL,
1 ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1 V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2 W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3 RM(10), TT1(10), TT2(10), PRT(10), PRS(10), PRN(10), PT1(10), PT2(10),
4 PT0(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VU1T(10), AD1T(10),
5 V1T(10), WU1T(10), BD1T(10), W1T(10), WU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VUH(10), AD1H(10)
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2 WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3 CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1T(10),
4 AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5 P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1 PT1T(10), PT1H(10), TT1L1(20), TT1L2(20), TT1L3(20),
2 STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
3 10), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
3 FORMAT (1H1)
1 FORMAT (//47X, 25HINLET MANIFOLD CONDITIONS//50H AREA MACH AOUTP3033
1NUM P T PTME /50H SQ-IN PSIA OUTP3034
2 DEG-R PSIA / F10.2, F10.3, 3F10.1) AOUTP3035
2 FORMAT (40X, 40HEXHAUST COLLECTOR EXIT FLANGE CONDITIONS//60H SQ-OUTP3037
1REA MACH NUM PT PSIA DEG R TT /60H T /60H SQ-OUTP3038
2IN PSIA PSIA DEG R DEG R//F10.2, F10.3, OUTP3039
34F10.1)
4 FORMAT (//26X, 68HOVERALL TURBINE PERFORMANCE INCLUDING MANIFOLD ANOUTP3040
1D EXHAUST COLLECTOR//60H U/CO U/CO PRST PRTT OUTP3041
2 ETST ETT /6F10.3) OUTP3042
5 FORMAT (//32X, 55HOVERALL TURBINE PERFORMANCE INCLUDING EXHAUST COLOURP3043

```

1LECTOR//60H      U/CO      U/CO      PRST      PRTT      ETST      OUTP3044
2 ETTT /6F10.3)                                     OUTP3045
9 FORMAT (///5H DATE,A2,IH-,A2,38X,17HSTAGE PERFORMANCE,45X,  OUTP3046
14HPAGE,I3//60H  STAGE      LAMDA      DEL H      ETS      ETT      OUTP3047
2 U/CO /24X,6HBTU/LB/(7X,I2,I1X,F10.3,F10.1,3F10.3/)      OUTP3048
10 FORMAT (//47X,25HOVERALL BLADE PERFORMANCE//100H DEL H      UMOUPT3049
1A U/CO U/CO PRST PRTT ETST ETST OUTP3050
2 RET RES /20H BTU/LB FT/SEC/2F10.1,8F10.3) OUTP3051
12 FORMAT (//37X,46HOVERALL TURBINE PERFORMANCE INCLUDING MANIFOLD//OUTP3052
160H U/CO U/CO PRST PRTT ETSI ETTT / OUTP3053
26F10.3) OUTP3054
K=N(L) OUTP3055
WRITE (3,3) OUTP3056
IPAGE=IPAGE+1 OUTP3057
WRITE (3,9) IM,ID,IY,IPAGE,(I,PAS(I),DHS(I),ETS(I),ETT(I),UC(I), OUTP3058
1I=1,K) OUTP3059
WRITE (3,10) DHO(L),UMA(L),UCO,UCOT,PRST(L),PRTT(L),ETST,ETT, OUTP3060
1RET(L),RES(L) OUTP3061
GO TO (130,135) ,L OUTP3062
130 WRITE (3,12) UCOM,UCOTM,PRSTM(L),PRTTM(L),ETSTM,ETTTM OUTP3063
GO TO 140 OUTP3064
135 WRITE (3,5) UCOM,UCOTM,PRSTM(L),PRTTM(L),ETSTM,ETTTM OUTP3065
140 GO TO (125,150),LFLAG OUTP3066
125 WRITE (3,4) UCSOL,UCTOL,PRSOL,PRTOL,ETSOL,ETTOL OUTP3067
150 GO TO (151,152),L OUTP3068
151 WRITE (3,1) AREA1,BMACH,PMANI,TMANI,PTIME(1) OUTP3069
152 GO TO (155,160),LFLAG OUTP3070
155 WRITE (3,2) AREA2,EMACH,PTIME(2),PECE,TT2(K),TECE OUTP3071
160 RETURN OUTP3072
END OUTP3073

```

```

// DUP
*STORE WS UA OUTP3
*DUMP UA CD OUTP3

```

```

// FOR SUBROUTINE PRATO (MFLG,JK,K)
C SUBROUTINE CALCULATES NEW FLOW RATE TO SATISFY PRESSURE RATIO
C REQUIREMENT
C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRITM(2), EIST, ETT, EISTM,
2ETTT, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRIT(2), UMS, SUMHT(2),
3SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4PROOS, PROOT, PRSM, PRITM,
5ETSM, ETMM, PTME(2), AREAF, TECE, PECE, RFACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), REA(2,10), Z(2,10), AD1(2,10), PRSOL, PRITOL,
1ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOIM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2W2(10), WU2(10), BD1(10), AD2(10), BD2(10), ETS(10), ETT(10), E(10),
3RM(10), TTI(10), TT2(10), PRT(10), PRS(10), PRN(10), PI1(10), PI2(10),
4PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VU1T(10), ADIT(10),
5V1T(10), WU1T(10), BDIT(10), W1T(10), WU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10)
1, V1H(10), WU1H(10), BD1H(10), W1H(10), WU2H(10), AD2H(10), V2H(10),
2WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3CS(10), UC(10), RMF(10), AC1(10), AC2(10), ACIH(10), AC2H(10), ACIT(10),
4AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10)
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1PT1T(10), PT1H(10), TITL1(20), TITL2(20), TITL3(20),
2STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
310), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), TCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
CON4=(GAM-1.)/GAM
IF (LFLAG-1) 50,50,40
40 GO TO (60,70,80,90,100),MFLG
50 GO TO (60,70,82,92,100),MFLG
60 IF (ABS(PRSTM(1)-PREQS)-0.01) 100,100,65
65 W=550.*SHP(1)/(ETSTM*778.16*CP*TTI(1)*(1.-(1./PREQS)**CON4))
JK=1
GO TO 150
70 IF (ABS(PRTM(1)-PREQT)-0.01) 100,100,75
75 W=550.*SHP(1)/(ETTM*778.16*CP*TTI(1)*(1.-(1./PREQT)**CON4))
JK=1
GO TO 150
PRAT0001
PRAT0002
PRAT0003
PRAT0004
PRAT0005
PRAT0006
PRAT0007
PRAT0008
PRAT0009
PRAT0010
PRAT0011
PRAT0012
PRAT0013
PRAT0014
PRAT0015
PRAT0016
PRAT0017
PRAT0018
PRAT0019
PRAT0020
PRAT0021
PRAT0022
PRAT0023
PRAT0024
PRAT0025
PRAT0026
PRAT0027
PRAT0028
PRAT0029
PRAT0030
PRAT0031
PRAT0032
PRAT0033
PRAT0034
PRAT0035
PRAT0036
PRAT0037
PRAT0038
PRAT0039
PRAT0040
PRAT0041
PRAT0042
PRAT0043

```

PRAT0044
PRAT0045
PRAT0046
PRAT0047
PRAT0048
PRAT0049
PRAT0050
PRAT0051
PRAT0052
PRAT0053
PRAT0054
PRAT0055
PRAT0056
PRAT0057
PRAT0058
PRAT0059
PRAT0060
PRAT0061
PRAT0062
PRAT0063
PRAT0064
PRAT0065
PRAT0066
PRAT0067
PRAT0068
PRAT0069
PRAT0070
PRAT0071
PRAT0072
PRAT0073
PRAT0074
PRAT0075
PRAT0076
PRAT0077

```
80 IF(L-1) 81,81,82
81 L=2
   TTI(2)=TT2(K)
   PTI(2)=PT2(K)
   UM1(2)=SP(2)*3.14159*RM(K)*RFACT/30.
   JK=1
   GO TO 150
82 IF (ABS(PRSMM-PRQOS)-0.01) 96,96,85
85 W=550.*(SHP(1)+SHP(2))/(ETSMM*778.16*CP*TTI(1))*(1.--(1./PRQOS)
   1**CON4))
   L=1
   JK=1
   GO TO 150
90 IF (L-1) 91,91,92
91 L=2
   TTI(2)=TT2(K)
   PTI(2)=PT2(K)
   UM1(2)=SP(2)*3.14159*RM(K)*RFACT/30.
   JK=1
   GO TO 150
92 IF (ABS(PRTMM-PROOT)-0.01) 96, 96,95
95 W=550.*(SHP(1)+SHP(2))/(ETTMM*778.16*CP*TTI(1))*(1.--(1./PROOT)
   1**CON4))
   L=1
   JK=1
   GO TO 150
96 IF (LFLAG-1) 100,100,97
97 MFLG=5
   L=1
   JK=1
   GO TO 150
100 JK=2
150 RETURN
END
```

// DUP
*STORE WS UA PRATO
*DUMP UA CD PRATO

// FOR *IOCS)CARD,TYPEWRITER,KEYBOARD,1132 PRINTER,DISK*

C MAIN PROGRAM FOR CONTROL OF SUBROUTINES

C
COMMON IM, ID, IY, R, GAM, CP, VIS, SHP(2), W, TTI(2), PTI(2), UMI(2),
1 COEM(2), N(2), DHO(2), SP(2), PRSTM(2), PRSTM(2), ETST, ETT, ETSTM,
2 ETTM, UMA(2), UCO, UCOM, RET(2), RES(2), PRST(2), PRST(2), UMS, SUMHI(2),
3 SUMHS(2), PREQS, PREQT, IFLAG, CASE1, CASE2, JFLAG, KFLAG, MFLAG, LFLAG, L,
4 PRGOS, PROOT, PRSMM, PRITM,
5 ETSMM, ETTMM, PTIME(2), AREAF, TECE, PECE, REACT, IPAGE, EMACH
COMMON X(2,10), Y(2,10), Z(2,10), AD1(2,10), PRSOL, PRTOI,
1 ETSOL, ETTOL, UCSOL, UCTOL, UCOT, UCOTM, AREA1
COMMON UM(10), PAS(10), DHS(10), BMACH, INPAR, TMANI, PMANI,
1 V1(10), VU1(10), VX1(10), W1(10), WU1(10), V2(10), VU2(10), VX2(10),
2 W2(10), WU2(10), BD1(10), AD2(10), BD2(10), EIS(10), EIT(10), E(10),
3 RM(10), T1(10), T2(10), PRT(10), PRS(10), PRN(10), PT1(10), PT2(10),
4 PTO(10), AN1(10), H1(10), AN2(10), H2(10), UT(10), VU1T(10), AD1T(10),
5 V1T(10), WU1T(10), BD1T(10), W1T(10), VU2T(10), AD2T(10), V2T(10)
COMMON WU2T(10), BD2T(10), W2T(10), REAT(10), UH(10), VU1H(10), AD1H(10),
1, V1H(10), WU1H(10), BD1H(10), W1H(10), VU2H(10), AD2H(10), V2H(10),
2 WU2H(10), BD2H(10), W2H(10), REAH(10), T1(10), T2(10), P1(10), P2(10),
3 CS(10), UC(10), RMF(10), AC1(10), AC2(10), AC1H(10), AC2H(10), AC1I(10),
4 AC2T(10), T1H(10), T1T(10), T2H(10), P1H(10), P1T(10), P2H(10), T2T(10),
5 P2T(10), COT(10), VEP(10), DVU(10), VX1T(10), VX2T(10), VX1H(10),
COMMON VX2H(10), RMA(10), TT2T(10), TT2H(10), PT2T(10), PT2H(10),
1 PTTT(10), PTH(10), TITL1(20), TITL2(20), TITL3(20),
2 STRL(2), TUM1, TPTI, TPRST, TSP, M, RHO(2), NFLAG, WF(10), HAVE(10), STRC(
3 IO), STRB(10), STRT(10), COE(2,2,10), CLEAR(2,10), ARS(2,10), FCRS(2,10)
4, SECON(2,10), ARCON(2,3), SOLID(2,10), DELTA(2), OSF(2), OSEXP(2)
5, RT(10)
5 FORMAT (5X,4HITER,10X,2HUM,10X,3HPTI,10X,5HPREQS,10X,2HSP,10X,
16HSTRESS/)
10 FORMAT (7X,I2,F15.1,F11.1,F14.2,F15.1,F15.1)
11 FORMAT (' NO SOLUTION FOR CONSTANT TIP RADIUS ADJUSTMENT,KJ=',I1)
CALL INPT1
GO TO 18
15 GO TO (12,18), INPAR
12 CALL INPT3 (MI)
GO TO 19
18 CALL INPT2 (VU1IN)
MI=M
19 JOVAL=1
MFLAG=MFLAG

MAIN 001
MAIN 002
MAIN 003
MAIN 004
MAIN 005
MAIN 006
MAIN 007
MAIN 008
MAIN 009
MAIN 010
MAIN 011
MAIN 012
MAIN 013
MAIN 014
MAIN 015
MAIN 016
MAIN 017
MAIN 018
MAIN 019
MAIN 020
MAIN 021
MAIN 022
MAIN 023
MAIN 024
MAIN 025
MAIN 026
MAIN 027
MAIN 028
MAIN 029
MAIN 030
MAIN 031
MAIN 032
MAIN 033
MAIN 034
MAIN 035
MAIN 036
MAIN 037
MAIN 038
MAIN 039
MAIN 040
MAIN 041
MAIN 042

```

M=MI
L=1
ITER=0
NFLAG=1
K=N(1)
IF (M-4) 13,13,16
13 GO TO (17,16),KFLAG
17 WRITE (1,5)
14 GO TO (7,8),KFLAG
7 WRITE (1,10) ITER,UM1(1),PTI(1),PREQS,SP(1),STRT(K)
8 MFLG=MFLAG
16 KCONT=0
25 UMS=0.
SUMHS(L)=0.
SUMHT(L)=0.
PRTT(L)=1.
PRST(L)=1.
CALL LOA
CALL CALC1
CALL CALC2(KJ,VU1IN)
KCONT=KCONT+1
IF(KCONT-10) 49,48,48
48 WRITE (3,11) KJ
GO TO 15
49 GO TO (50,25),KJ
50 CALL CALC9
CALL CALC3
GO TO (65,65,55,55,100),MFLG
55 GO TO (65,60),L
60 CALL OVALL(JOVAL)
65 CALL PRATO(MFLG,JK,K)
GO TO (16,100),JK
100 IF (IFLAG-2) 20,30,30
20 CALL CALC4
CALL CALC5
GO TO 40
30 CALL CALC6
CALL CALC7
40 CALL CALC8
IF (M-4) 105,105,150
105 IF (L-1) 110,110,106
106 M=0
NFLAG=1
110 CALL STRES

```

```

MAIN 043
MAIN 044
MAIN 045
MAIN 046
MAIN 047
MAIN 048
MAIN 049
MAIN 050
MAIN 051
MAIN 052
MAIN 053
MAIN 054
MAIN 055
MAIN 056
MAIN 057
MAIN 058
MAIN 059
MAIN 060
MAIN 061
MAIN 062
MAIN 063
MAIN 064
MAIN 065
MAIN 066
MAIN 067
MAIN 068
MAIN 069
MAIN 070
MAIN 071
MAIN 072
MAIN 073
MAIN 074
MAIN 075
MAIN 076
MAIN 077
MAIN 078
MAIN 079
MAIN 080
MAIN 081
MAIN 082
MAIN 083
MAIN 084
MAIN 085
MAIN 086

```

```

111 IF (M-1) 150,111,111
112 GO TO (150,112,112,150,112) ,NFLAG
113 IF (M-1) 113,113,114
113 CALL STRS1
GO TO 115
114 CALL STRS2
115 GO TO (150,120,117,150,136) ,NFLAG
117 PREQS=4.0
ITER=ITER+1
MFLAG=1
GO TO 14
120 ITER=ITER+1
IF (ITER-15) 121,121,141
121 IF (M-2) 125,130,135
125 UM1(L)=TUM1
GO TO 14
130 PT1(L)=TPT1
GO TO 14
135 IF (M-4) 136,140,150
136 PREQS=TPRST
ITER=ITER+1
IF (ITER-15) 137,137,141
137 MFLAG=1
GO TO 14
140 SP(L)=TSP
GO TO 14
141 NFLAG=5
150 CALL OUTP1
CALL OUTP1
CALL OUTP3
IF (M-4) 160,160,170
160 CALL OUTP2
170 IF (LFLAG-1) 15,15,180
180 IF (L-1) 190,190,200
190 L=2
MFLG=5
TT1(2)=TT2(K)
PT1(2)=PT2(K)
UM1(2)=SP(2)*3.14159*RM(K)*REACT/30.
GO TO 16
200 JOVAL=2
CALL OVALL(JOVAL)
GO TO 15
END

```

```

MAIN 087
MAIN 088
MAIN 089
MAIN 090
MAIN 091
MAIN 092
MAIN 093
MAIN 094
MAIN 095
MAIN 096
MAIN 097
MAIN 098
MAIN 099
MAIN 100
MAIN 101
MAIN 102
MAIN 103
MAIN 104
MAIN 105
MAIN 106
MAIN 107
MAIN 108
MAIN 109
MAIN 110
MAIN 111
MAIN 112
MAIN 113
MAIN 114
MAIN 115
MAIN 116
MAIN 117
MAIN 118
MAIN 119
MAIN 120
MAIN 121
MAIN 122
MAIN 123
MAIN 124
MAIN 125
MAIN 126
MAIN 127
MAIN 128
MAIN 129
MAIN 130

```

// DUP
*STORE
*DUMP

WS UA MAIN
UA CD MAIN

```

// XEO MAIN 03
*LOCAL1AIN,LOA,INPT1,INPT2,INPT3,CALC1,CALC2,CALC3,CALC4,CALC5,CALC6,
*LOCALCALC7,CALC8,CALC9,STRES,STRS1,STRS2,OUTP1,OUTP2,OUTP3,
*LOCALPRATO,OVALL
030668
766.3700001.391000003.50400000.00001340
9999-99
EXAMPLE CASE.....
TWO SPOOL-7STAGES, FIRST SPOOL-3 STAGES, SECOND SPOOL.....
TO DEMONSTRATE COMPUTER PROGRAM.....

```

	1	0	1	2	3	2	1	1660.	300.	0.2	0.5
10.0											
10.		1400.	0.3	1.	3.			1660.	300.	0.2	0.5
1.0		50000.	1.	7				1.			
40000.		20000.									
.0	.02	.04		.06	.08		.10	.12			
75.	73.	71.		69.	67.		65.	63.			
1.	.9	.8		.7	.6		.5	.5			
1.	1.	1.		1.	1.		1.	1.			
1.	1.	1.		1.	1.		1.	1.			
.4	.4	.4		.4	.4		.4	.4			
.4	.4	.4		.4	.4		.4	.4			
.01	.01	.01		.01	.01		.01	.01			
1.	1.	1.		1.	1.		1.	1.			
.3	.3	.3		.3	.3		.3	.3			
1.5	1.5	1.5		1.5	1.5		1.5	1.5			
.09	.09	.09		.09	.09		.09	.09			
1.	.0	.0		.0	.0		.0	.0			
.300	50000.	15000.		1.	3.		1.	1.			
10000.											
.0	.0	.0		.0	.0		.0	.0			
60.	58.	56.		56.	56.		56.	56.			
1.	1.	1.		1.	1.		1.	1.			
1.	1.	1.		1.	1.		1.	1.			
1.	1.	1.		1.	1.		1.	1.			
.4	.4	.4		.4	.4		.4	.4			
0.4	0.4	0.4		0.4	0.4		0.4	0.4			
.01	.01	.01		.01	.01		.01	.01			
1.	1.	1.		1.	1.		1.	1.			
.3	.3	.3		.3	.3		.3	.3			
1.5	1.5	1.5		1.5	1.5		1.5	1.5			
.09	.09	.09		.09	.09		.09	.09			
1.	.0	.0		.0	.0		.0	.0			

EXAMPLE CASE

COMPUTER PRINTED OUTPUT

DATE03-01-68

7 STAGE
GAS TURBINE DESIGN
ANALYSIS

SPOOL NUMBER 1 OF 2

CASE NUMBER 9999-99

APPLICATION-----EXAMPLE CASE.....
CHARACTERISTICS---TWO SPOOL-7STAGES, FIRST SPOOL--3 STAGES, SECOND SPOOL.....
OBJECTIVE-----TO DEMONSTRATE COMPUTER PROGRAM.....

GAS PROPERTIES

GAS	CONSTANT	766.37
FT/DEG R		
SPECIFIC HEAT	RATIO	1.391
SPECIFIC HEAT	BTU/LB-DEG R	3.504
CONSTANT PRESSURE		
ABSOLUTE	LB/FT-SEC	0.1340E-04
VISCOSITY		

CASE CONDITIONS

SHAFT	FLOW	INLET TOTAL	INLET TOTAL	MEAN BLADE	ROTATIVE	MAN. LOSS
HORSEPOWER	RATE	TEMPERATURE	PSIA	SPEED	SPEED	COEFFICIENT
40000.0	15.45	1660.0	300.0	1400.0	20000.0	0.500
	LB/SEC	DEG R		FT/SEC	RPM	

BLADE CROSS SECTION AREA DISTRIBUTION	DELTA	OVERSPEED FACTOR	OVERSPEED EXPONENT
0.10000E 01	0.00000E 00	1.000	3.000

STRESS LIMIT	MATERIAL DENSITY	PARAMETER INDEX	DATA SWITCHES ON
50000.0	0.300	0	NONE

STAGE INPUT PARAMETERS

STAGE	REACTION	NOZZLE	STAGE	MEAN	AXIAL	NOZZLE	ROTOR	ROTOR	ASPECT	TH/CD	SECTION	SOLIDITY
7	0.120	63.00	0.500	1.000	1.000	0.400	0.400	0.010	1.00	0.30	0.090	1.500
6	0.100	65.00	0.500	1.000	1.000	0.400	0.400	0.010	1.00	0.30	0.090	1.500
5	0.080	67.00	0.600	1.000	1.000	0.400	0.400	0.010	1.00	0.30	0.090	1.500
4	0.060	69.00	0.700	1.000	1.000	0.400	0.400	0.010	1.00	0.30	0.090	1.500
3	0.040	71.00	0.800	1.000	1.000	0.400	0.400	0.010	1.00	0.30	0.090	1.500
2	0.020	73.00	0.900	1.000	1.000	0.400	0.400	0.010	1.00	0.30	0.090	1.500
1	0.000	75.00	1.000	1.000	1.000	0.400	0.400	0.010	1.00	0.30	0.090	1.500
	DEG	LOAD	RATIO	RADIUS	RATIO	LOSS	LOSS	IN	CONST.			
	ANGLE				VELOCITY	COEFF.	COEFF.	COEFF.				

INDEX PAGE

DATE03-01-68

7 STAGE
GAS TURBINE DESIGN
ANALYSIS

SPOOL NUMBER 1 OF 2

CASE NUMBER

9999-99

APPLICATION-----EXAMPLE CASE.....
CHARACTERISTICS---TWO SPOOL-TSTAGES, FIRST SPOOL--3 STAGES, SECOND SPOOL.....
OBJECTIVE-----TO DEMONSTRATE COMPUTER PROGRAM.....
GAS PROPERTIES

GAS CONSTANT 766.37 FT/DEG R
SPECIFIC HEAT RATIO 1.391
CONSTANT PRESSURE SPECIFIC HEAT BTU/LB-DEG R 3.504
ABSOLUTE VISCOSITY LB/FT-SEC 0.134E-04

CASE CONDITIONS
SHAFT FLOW INLET TOTAL 40000.0
HORSEPOWER RATE 15.45 LB/SEC
INLET TOTAL TEMPERATURE 1660.0 DEG R
INLET TOTAL PRESSURE 300.0 PSIA
MEAN BLADE SPEED 1400.0 FT/SEC
ROTATIVE SPEED 20000.0 RPM
MAN. LOSS COEFFICIENT 0.500

BLADE CROSS SECTION AREA DISTRIBUTION DELTA OVERSPEED FACTOR OVERSPEED EXPONENT

0.1000E 01 0.0000E 00 0.0000E 00 1.000 3.000

STRESS LIMIT 50000.0 PSI
MATERIAL DENSITY 0.300 LB/CU-IN
PARAMETER INDEX 0
DATA SWITCHES ON NONE

STAGE INPUT PARAMETERS

STAGE	REACTION	NOZZLE	STAGE	MEAN	RADIUS	LOAD	RATIO	AXIAL	VELOCITY	NOZZLE	LOSS	ROTOR	ROTOR	ASPECT	TH/CD	SECTION	SOLIDITY
1	0.000	75.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.400	0.010	1.000	1.000	1.00	0.30	0.090	1.500
2	0.020	73.00	0.900	1.000	1.000	1.000	1.000	1.000	1.000	0.400	0.010	1.000	1.000	1.00	0.30	0.090	1.500
3	0.040	71.00	0.800	1.000	1.000	1.000	1.000	1.000	1.000	0.400	0.010	1.000	1.000	1.00	0.30	0.090	1.500
4	0.060	69.00	0.700	1.000	1.000	1.000	1.000	1.000	1.000	0.400	0.010	1.000	1.000	1.00	0.30	0.090	1.500
5	0.080	67.00	0.600	1.000	1.000	1.000	1.000	1.000	1.000	0.400	0.010	1.000	1.000	1.00	0.30	0.090	1.500
6	0.100	65.00	0.500	1.000	1.000	1.000	1.000	1.000	1.000	0.400	0.010	1.000	1.000	1.00	0.30	0.090	1.500
7	0.120	63.00	0.500	1.000	1.000	1.000	1.000	1.000	1.000	0.400	0.010	1.000	1.000	1.00	0.30	0.090	1.500

DATE 03-01-68

STAGE MACH NUMBERS

PAGE 2

FREE VORTEX

STAGE	ABSOLUTE NOZZLE EXIT	RELATIVE ROTOR EXIT
1	0.730 0.668 0.616	0.492 0.484 0.480
2	0.713 0.642 0.585	0.468 0.463 0.462
3	0.693 0.613 0.552	0.441 0.439 0.443
4	0.669 0.580 0.515	0.408 0.413 0.423
5	0.640 0.542 0.476	0.371 0.383 0.401
6	0.606 0.501 0.434	0.328 0.350 0.377
7	0.630 0.516 0.446	0.351 0.373 0.401

DATE03-01-68

STAGE GEOMETRY

PAGE 4

FREE VORTEX

STAGE	MEAN RADIUS IN	BLADE HEIGHT 1 IN	BLADE HEIGHT 2 IN	ANNULUS AREA 1 SQ-IN	ANNULUS AREA 2 SQ-IN	ALPHA1 DEG	BETA1 DEG	ALPHA2 DEG	BETA2 DEG
1	8.0214	1.335	1.397	67.302	70.448	76.19 75.00 73.81	71.84 69.06 69.84	-50.59 -56.22 -53.98	-69.38 -69.06 -68.89
2	8.0214	1.594	1.658	80.378	83.584	74.60 73.00 71.42	69.54 65.65 61.00	-53.04 -49.99 -47.20	-66.31 -66.06 -66.04
3	8.0214	1.892	1.958	95.390	98.719	73.10 71.00 68.94	67.30 61.96 55.33	-46.76 -43.03 -39.76	-63.02 -62.96 -63.24
4	8.0214	2.232	2.301	112.504	115.978	71.71 69.00 66.38	65.15 57.89 48.50	-39.41 -35.13 -31.61	-59.35 -59.75 -60.56
5	8.0214	2.616	2.688	131.874	135.477	70.44 67.00 63.72	63.09 53.29 40.06	-30.44 -26.07 -22.73	-55.07 -56.37 -58.05
6	8.0214	3.049	3.122	153.717	157.382	69.31 65.00 60.97	61.11 47.92 29.39	-19.07 -15.55 -13.11	-49.73 -52.75 -55.80
7	8.0214	3.238	3.326	163.234	167.660	67.87 63.00 58.51	59.52 49.13 25.46	-19.22 -15.45 -12.89	-47.93 -50.99 -54.18

DATE03-01-68

PRESSURES

TEMPERATURES

PAGE 5

FREE VORTEX

STAGE	PT1 PSIA	P1 PSIA	PT2 PSIA	P2 PSIA	PRS	PRT	TT1 DEG R	T1 DEG R	TT2 DEG R	T2 DEG R
1	289.0	202.9	219.1	203.0	1.443	1.350	1660.0	1503.0	1555.5	1522.5
	289.0	214.5	219.1	204.9			1660.0	1526.6	1555.5	1526.6
	289.0	223.9	219.1	206.4			1660.0	1545.0	1555.5	1529.7
2	211.7	151.0	163.6	153.0	1.420	1.338	1555.5	1414.6	1461.5	1434.1
	211.7	160.6	163.6	154.3			1555.5	1439.4	1461.5	1437.5
	211.7	168.0	163.6	155.2			1555.5	1457.7	1461.5	1440.0
3	159.4	115.8	125.7	118.5	1.370	1.301	1461.5	1335.9	1378.0	1355.4
	159.4	123.9	125.7	119.4			1461.5	1361.5	1378.0	1356.1
	159.4	129.7	125.7	120.0			1461.5	1379.4	1378.0	1360.0
4	123.3	91.4	99.3	94.5	1.323	1.265	1378.0	1267.0	1304.9	1286.6
	123.3	98.3	99.3	95.0			1378.0	1292.9	1304.9	1286.5
	123.3	102.9	99.3	95.3			1378.0	1309.9	1304.9	1289.5
5	97.9	74.4	80.9	77.5	1.277	1.228	1304.9	1208.0	1242.2	1227.0
	97.9	80.2	80.9	77.8			1304.9	1233.8	1242.2	1226.5
	97.9	83.9	80.9	77.9			1304.9	1249.5	1242.2	1229.5
6	80.1	62.5	67.9	65.5	1.231	1.190	1242.2	1159.0	1190.0	1176.4
	80.1	67.5	67.9	65.6			1242.2	1184.0	1190.0	1176.5
	80.1	70.4	67.9	65.7			1242.2	1198.1	1190.0	1179.0
7	67.2	51.5	56.6	54.2	1.249	1.199	1190.0	1104.2	1137.8	1124.1
	67.2	56.1	56.6	54.3			1190.0	1131.0	1137.8	1124.7
	67.2	58.7	56.6	54.4			1190.0	1145.4	1137.8	1125.0

DATE03-01-68

ROTOR BLADE ROOT STRESS

PAGE 7

STAGE	MEAN RADIUS IN	AVERAGE BLADE HEIGHT IN	STAGE LOAD PERCENT	CENTRIPETAL STRESS PSI	BENDING STRESS PSI	TOTAL STRESS PSI
1	8.0214	1.366	20.0	37362.2	1877.8	39240.0
2	8.0214	1.626	18.0	44471.6	1419.8	45891.4
3	8.0214	1.925	16.0	52648.5	1066.0	53714.6
4	8.0214	2.266	14.0	61971.4	792.4	62763.9
5	8.0214	2.652	12.0	72513.9	580.5	73094.4
6	8.0214	3.086	10.0	84379.9	415.7	84795.6
7	8.0214	3.282	10.0	89749.1	390.8	90139.9

DATE03-01-68

3 STAGE
GAS TURBINE DESIGN
ANALYSIS

SPOOL NUMBER 2 OF 2

CASE NUMBER

99999-99

APPLICATION-----EXAMPLE CASE.....
CHARACTERISTICS---TWO SPOOL-1STAGES, FIRST SPOOL--3 STAGES, SECOND SPOOL.....
OBJECTIVE-----TO DEMONSTRATE COMPUTER PROGRAM.....
GAS PROPERTIES

GAS
CONSTANT FT/DEG R 766.37
SPECIFIC HEAT RATIO 1.391
CONSTANT PRESSURE SPECIFIC HEAT BTU/LB-DEG R 3.504
ABSOLUTE VISCOSITY LB/FT-SEC 0.134GE-04

CASE CONDITIONS

SHAFT HORSEPOWER 10000.0
FLOW RATE LB/SEC 15.45
TEMPERATURE DEG R 1137.8
INLET TOTAL PRESSURE PSIA 56.6
MEAN BLADE SPEED FT/SEC 1050.0
ROTATIVE SPEED RPM 15000.0
E.C. LOSS COEFFICIENT 1.000

BLADE CROSS SECTION AREA DISTRIBUTION DELTA OVERSPEED FACTOR OVERSPEED EXPONENT
0.10000E 01 0.00000E 00 0.00000E 00 1.000 3.000

STRESS LIMIT PSI 50000.0
MATERIAL DENSITY LB/CU-IN 0.300
PARAMETER INDEX 0
DATA SWITCHES ON NONE

STAGE INPUT PARAMETERS

STAGE REACTION ANGLE DEG 0.000
NOZZLE LOAD RATIO 1.000
STAGE MEAN RADIUS 1.000
AXIAL VELOCITY 1.000
NOZZLE LOSS COEFF. 0.400
ROTOR CLEAR IN LOSS COEFF. 0.400
ASPECT RATIO 1.00
TH/CD RATIO 0.30
SECTION MODULUS CONST. 1.500
SOLIDITY 1.500

DATE03-01-68

STAGE VELOCITIES

PAGE 9

FREE VORTEX

STAGE	U FT/SEC	VU1 FT/SEC	VX1 FT/SEC	V1 FT/SEC	WU1 FT/SEC	W1 FT/SEC	VU2 FT/SEC	VX2 FT/SEC	V2 FT/SEC	WU2 FT/SEC	W2 FT/SEC	REACTION
1	828.7	3619.6	1655.7	3980.3	2790.9	3245.1	-972.7	1655.7	1920.3	-1801.4	2446.7	-0.596
	1050.0	2867.7	1655.7	3311.4	1817.7	2458.7	-767.7	1655.7	1825.0	-1817.7	2458.7	0.000
	1271.2	2374.5	1655.7	2894.7	1103.2	1989.6	-634.1	1655.7	1773.0	-1905.3	2524.2	0.315
2	814.9	3679.4	1791.9	4092.6	2864.5	3378.8	-989.2	1791.9	2046.9	-1804.1	2542.8	-0.650
	1050.0	2867.7	1791.9	3381.6	1817.7	2552.5	-767.7	1791.9	1949.5	-1817.7	2552.5	0.000
	1285.0	2349.4	1791.9	2954.8	1064.4	2084.2	-627.3	1791.9	1898.6	-1912.3	2620.7	0.329
3	797.8	3756.2	1934.3	4225.0	2958.4	3534.6	-1010.4	1934.3	2182.3	-1808.2	2647.9	-0.720
	1050.0	2867.7	1934.3	3459.1	1817.7	2654.4	-767.7	1934.3	2081.1	-1817.7	2654.4	0.000
	1302.1	2319.1	1934.3	3019.9	1017.0	2485.4	-619.0	1934.3	2030.9	-1921.2	2726.3	0.347

DATE03-01-68

STAGE MACH NUMBERS

PAGE 10

FREE VORTEX

STAGE	ABSOLUTE NOZZLE EXIT	RELATIVE ROTOR EXIT
1	0.664 0.545 0.473	0.403 0.404 0.415
2	0.699 0.569 0.493	0.428 0.429 0.440
3	0.740 0.595 0.515	0.456 0.457 0.469

DATE03-01-68

STAGE GEOMETRY

FREE VORTEX

STAGE	MEAN RADIUS IN	BLADE HEIGHT 1 IN	BLADE HEIGHT 2 IN	ANNULUS AREA 1 SQ-IN	ANNULUS AREA 2 SQ-IN	ALPHA1 DEG	BETA1 DEG	ALPHA2 DEG	BETA2 DEG
1	8.0214	3.332	3.380	167.961	170.371	55.11	59.32	-30.43	-47.41
2	8.0214	3.539	3.591	178.367	181.011	64.03	57.97	-28.89	-45.19
3	8.0214	3.794	3.853	191.252	194.203	62.75	56.82	-27.58	-43.07

DATE03-01-68

PRESSURES

TEMPERATURES

PAGE 12

FREE VORTEX

STAGE	PT1 PSIA	P1 PSIA	PT2 PSIA	P2 PSIA	PRS	PRT	TT1 DEG R	T1 DEG R	TT2 DEG R	T2 DEG R
1	55.9	41.7	48.0	44.8	1.254	1.179	1137.8	1047.5	1094.3	1073.3
	55.9	45.7	48.0	45.1			1137.8	1075.3	1094.3	1075.3
	55.9	48.0	48.0	45.3			1137.8	1090.0	1094.3	1076.4
2	47.4	34.2	40.4	37.2	1.278	1.187	1094.3	998.8	1050.8	1026.9
	47.4	38.1	40.4	37.5			1094.3	1029.1	1050.8	1029.1
	47.4	40.1	40.4	37.7			1094.3	1044.5	1050.8	1030.2
3	39.9	27.7	33.8	30.7	1.306	1.195	1050.8	949.0	1007.3	980.1
	39.9	31.4	33.8	30.9			1050.8	982.6	1007.3	982.6
	39.9	33.3	33.8	31.1			1050.8	998.8	1007.3	983.7

DATE03-01-68

STAGE PERFORMANCE

PAGE 13

STAGE	LAMDA	DEL H BTU/LB	ETS	ETT	U/CO
1	0.288	152.4	0.618	0.844	0.298
2	0.288	152.4	0.595	0.843	0.293
3	0.288	152.4	0.572	0.844	0.287

OVERALL BLADE PERFORMANCE

DEL H BTU/LB	UMA FT/SEC	U/CO	U/CO'	PRST	PRTT	ETST	ETTT	RET	RES
457.4	1050.0	0.188	0.202	1.828	1.674	0.735	0.850	1.007	1.008

OVERALL TURBINE PERFORMANCE INCLUDING EXHAUST COLLECTOR

U/CO	U/CO'	PRST	PRTT	ETST	ETTT
0.183	0.192	1.888	1.775	0.700	0.770

DATE03-01-68

ROTOR BLADE ROOT STRESS

PAGE 14

STAGE	MEAN RADIUS IN	AVERAGE BLADE HEIGHT IN	STAGE LOAD PERCENT	CENTRIPETAL STRESS PSI	BENDING STRESS PSI	TOTAL STRESS PSI
1	8.0214	3.356	33.3	51618.6	424.7	52043.3
2	8.0214	3.565	33.3	54829.4	399.8	55229.3
3	8.0214	3.823	33.3	58807.9	372.8	59180.8

DATE 03-01-68

OVER-ALL TWO-SPOOL PERFORMANCE

PAGE 15

FIRST SPOOL INLET TO SECOND SPOOL EXIT

DEL H BTU/LB	UMA FT/SEC	U/CO	U/CO*	PRST	PRTT	ETST	ETTT	RET	RES
2287.0	1225.0	0.104	0.106	9.554	8.747	0.837	0.861	1.069	1.050

MANIFOLD INLET TO SECOND SPOOL EXIT

DEL H BTU/LB	UMA FT/SEC	U/CO	U/CO*	PRST	PRTT	ETST	ETTT	RET	RES
2287.0	1225.0	0.104	0.106	9.685	8.866	0.833	0.857	1.064	1.046

MANIFOLD EXIT TO EXHAUST COLLECTOR EXIT

DEL H BTU/LB	UMA FT/SEC	U/CO	U/CO*	PRST	PRTT	ETST	ETTT	RET	RES
2287.0	1225.0	0.104	0.105	9.867	9.273	0.828	0.845	1.058	1.030

MANIFOLD INLET TO EXHAUST COLLECTOR EXIT

DEL H BTU/LB	UMA FT/SEC	U/CO	U/CO*	PRST	PRTT	ETST	ETTT	RET	RES
2287.0	1225.0	0.103	0.104	10.002	9.400	0.825	0.841	1.053	1.026

EXHAUST COLLECTOR EXIT FLANGE CONDITIONS

AREA SQ-IN	MACH NUM	PT PSIA	P PSIA	1T DEG R	T DEG R
223.57	0.300	21.9	29.9	1007.3	989.8