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HELICOPTER ROTOR LOADS USING MATCHED ASYMPTOTIC EXPANSIONS:

USER'S MANUAL

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CONTENTS

SUMMARY

Computer programs have been developed to implement the computational scheme arising from Van Holten's asymptotic method for calculating airloads on a helicopter rotor blade in forward flight, and a similar technique which is based on a discretized version of the method. The basic outlines of the two programs are presented, followed by separate descriptions of the input requirements and output format. Two examples illustrating job entry with appropriate input data and corresponding output are included. Appendices contain a sample table of lift coefficient data for the NACA 0012 airfoil and listings of the two programs.

INTRODUCTION

The computer programs described in this report were developed during the course of an evaluation of Van Holten's asymptotic method (ref. 1) for the calculation of airloads on a helicopter rotor blade in forward flight. The validity and computational feasibility of the approach were investigated (ref. 2), and numerical results for specific flight conditions were compared with corresponding experimental data and computations based on other analytical methods. Program ASYMP1 was written to implement the computational scheme of reference 1 (the relevant equations and expressions are given in ref. 2). As an extension of this investigation, the above computational scheme was made more efficient by discretizing the variation of the doublet strength distribution, $g(r_b, \Psi_b)$, utilizing both piecewise constant and piecewise quadratic representations for the spanwise variation. The details of the discretized scheme are presented in reference 3 and the corresponding computational method is applied in Program ASYMP2.

The general organization is similar for both programs, since the two schemes differ only in the manner in which the velocity induced by the blade pressure field is calculated. The basic unknown to be determined is the doublet strength function, $g(r_b, \Psi_b)$. Its solution is effected by a collocation technique. In the original scheme (ref. 1) this unknown function appears as a continuous modal representation for the spanwise variation and a finite Fourier series for the azimuth variation. In the discretized scheme the unknowns are the values of g at the midpoints of the spanwise segments, with a finite Fourier series for the azimuth variation of each. In either case, the solution reduces to the determination of the coefficients in the collocation representations, which is accomplished by setting up a system of simultaneous equations.

The main programs and the various subprograms will be discussed in the next section, but the general sequence of program steps is as below.

(1) Read and write input; define auxiliary parameters required for the computation.

(2) Start loop for collocation points.

(3) Test the tangential velocity U_T; if $U_T \leq (U_T)_{min}$, set up the condition for zero lift and go to the end of the collocation loop.

(4) If airfoil data tables are used, determine the lift curve slope for the current collocation point.

(5) Start loop for the number of blades and define the first azimuth interval.

(6) Compute the induced velocity contributions for the current interval and add to the corresponding coefficient matrix elements in the system of equations.

(7) Increment the azimuth interval; if the azimuth limit has been reached, go to the the next step; if not, go to Step 6.

(8) End loop for number of blades.

(9) End loop for collocation points.

(10) Set up the extra equations for the blade motion parameters.

(11) Solve system of equations and write solution.

(12) Compute and write output.

Some mention must be made of the way in which the airfoil data are used in the computational scheme. The basic equation to be set up at any collocation point is of the form

$$w_b(r_{bo}, \Psi_{bo}) = w_{ind} \tag{1}$$

where w_{ind} is the velocity induced by the pressure fields of all the blades and w_b the normal velocity due to blade motion at a collocation point (r_{bo}, Ψ_{bo}). This is rewritten as

$$\begin{aligned} w_b(r_{bo}, \Psi_{bo}) &= (w_{ind})^{2D} + \left[w_{ind} - (w_{ind})^{2D}\right] \\ &= (w_{ind})^{2D} + \Delta w \end{aligned} \tag{2}$$

where $(w_{ind})^{2D}$ is the induced velocity corresponding to a steady, two-dimensional flow. Accordingly, corrections based on airfoil data are only applied to this term and, after modification, equation (2) becomes

$$\begin{aligned} w_b(r_{bo}, \Psi_{bo}) &= (w_{ind})^{2D}_{mod} + \Delta w \\ &= \left[(w_{ind})^{2D}_{mod} - (w_{ind})^{2D}\right] + w_{ind} \end{aligned} \tag{3}$$

For steady, locally two-dimensional flow,

$$(w_{ind})^{2D} = -g(r_{bo}, \Psi_{bo}) / \rho U_T \tag{4}$$

At the local incidence and Mach number corresponding to the collocation point, the airfoil data are interpolated in the form of a locally linear relation given by

$$C_\ell = a\alpha + C_{\ell o}$$

To account for such a relation, the expression in equation (4) is modified as

$$(w_{ind})^{2D}_{mod} = -\frac{2\pi}{a} \frac{g(r_{bo}, \Psi_{bo})}{\rho U_T} - U_T \frac{C_{\ell o}}{a} \qquad (5)$$

Using equations (4) and (5) in equation (3), the modified form of the boundary condition is obtained as

$$w_b(r_{bo}, \Psi_{bo}) = \left[-\frac{(2\pi - a)}{a} \frac{g(r_{bo}, \Psi_{bo})}{\rho U_T} - U_T \frac{C_{\ell o}}{a} \right] + w_{ind} \qquad (6)$$

Comparing equations (1) and (6), it can be seen that the modification due to the airfoil data is purely an additive term that is easily incorporated into the basic computational scheme.

The next section presents an outline of the main program and the various subprograms for ASYMP1 and ASYMP2, listing the input and output of each subprogram along with a brief description of its function. The sections following this deal with descriptions of the input and output for the two programs, and samples of job entry with the corresponding output.

PROGRAM OUTLINE

Program ASYMP1

Main Program. - The program steps listed in the previous section will now be discussed in more detail.

(1) The details regarding input data and the format in which they are to be entered are given in the next section. The data include parameters describing rotor geometry, the flight condition and blade motion. Specification of the blade motion parameters (collective pitch, coning angle and the two first harmonic flapping coefficients) is optional. If they are not specified, they will be calculated as part of the solution by generating additional equilibrium equations. The input also includes the five spanwise locations of the collocation points, the normal and reduced azimuth intervals to be used for the numerical integration, the minimum value of the local onset velocity below which the zero lift condition is to be used and an integer specifying whether airfoil data are to be used. The program then writes the input data as part of the output and defines auxiliary quantities such as the induced velocity from simple momentum theory and certain factors occurring in the induced velocity contribution from the trajectory segment immediately adjacent to the collocation point.

(2) The collocation loop consists of an outer loop for the eleven equally spaced azimuth locations and an inner loop for the five spanwise locations.

(3) For the current collocation point, the local onset velocity (UT) is compared with the specified minimum value (UTMIN). If UT> UTMIN, the next step is executed. If not, the zero lift condition is set up and the next collocation point is taken up.

(4) If airfoil data are not used, this step is skipped. If they are used, the local values of $a/2\pi$ and C_{ℓ_o} are interpolated from the tables. The local values of Mach number (MLOC) and incidence (ALOC) are first defined. Subroutine TABSCH is called to find the position of MLOC and ALOC in the arrays MCL and ACL that were read as part of the input. The required values of $a/2\pi$ (SLCR) and C_{ℓ_o} (CLØ) are then determined by linear interpolation.

(5) As mentioned in reference 2, the near field has a square root singularity

corresponding to the leading edge, and this is dealt with by stopping the numerical integration just in front of the leading edge and accounting for the remainder analytically. Before starting the numerical integration, therefore, this contribution is entered into the coefficient matrix, A. The system of equations is of the form

$$Ax = B$$

where x is the array of unknown coefficients (A_{ij}, B_{ij}, eq. (9) of ref. 2). If UT <UTMIN, the zero lift condition is set up at this point.

In order to start the numerical integration, a loop for the number of blades is set up. For the current blade, Subroutine DMIN is called to determine the positions along the fluid particle trajectory at which it is directly over the blade, within a distance DMAX. Around these locations (stored in array PMIN), the reduced azimuth interval DP2 will be used. The first azimuth interval is defined with its ends at PB1 and PB2.

(6) For the current azimuth interval, a loop is set up for the 5-point Gauss-Chebyschev integration (p. 12 of ref. 2). With 55 unknown coefficients, 4 blade motion parameters and one right-hand side, there are 60 integrations to be carried out over each interval of azimuth. The corresponding functional values are sequentially obtained from function FUN2.

(7) PB1 and PB2 are incremented for the next azimuth interval. If the azimuth limit PLIM has been reached, the integration is stopped and the next blade is taken up. If not, the interval is tested to check if it includes one of the "close" locations stored in PMIN. If it does, the reduced azimuth interval is used.

(8) At the end of the loop for the number of blades, the terms in the blade normal velocity, $w_b(r_{bo}, \Psi_{bo})$, are entered in the corresponding coefficient matrix elements.

(9) At the end of the loop for the collocation points, certain spanwise integrals required for the total blade lift and the moment about the hub due to the lift are calculated (p. 42 of ref. 2).

(10) To close the system of equations, four additional equations are set up (eqs. (E8), (E9), (E10), (E11) of ref. 2). If the four blade motion parameters are specified in the input, these equations are replaced by equations of the form

$$\theta_o = (\theta_o)_{input}$$

$$a_o = (a_o)_{input}, \text{ etc.}$$

(11) The completed system of equations is solved by calling Subroutine GELIM. This is a library-supplied routine that uses the LU decomposition. The solution is overwritten on the vector B and the program prints out the values of the collocation coefficients and the blade motion parameters.

(12) With the basic solution complete, the program computes and prints out various output quantities in tabular form. The output format is described separately in a later section.

Subroutine DMIN. -

Input: MU(μ), LAM(λ), DB($\Delta\Psi_j$), RBØ(r_{bo}), PBØ(Ψ_{bo}), PLIM, DMAX

Output: I, P

Comments: This subroutine locates those azimuth positions along the fluid particle trajectory at which the particle is "close" to the j^{th} blade. The x_b axis is fixed to the blade and rotates with it (fig. 1 of ref. 2) so that the x_b coordinate along the trajectory periodically goes to zero whenever there is an intersection with the z_b axis. At some of these locations the particle may be too close to the blade (within a specified distance DMAX). These are the locations (I in number) that are returned in the array P. The routine locates the positions by scanning the trajectory with small azimuth increments checking for a change in sign of the x_b coordinate. When such a position is located, the distance from the blade is compared with DMAX.

Subroutine TRAJ. -

Input: RØ(R_o/R_1), AR(A), MU, LAM, RBØ, PBØ, DB, PB(Ψ_b)

Output: R(r), SX($\sin \chi$), CX($\cos \chi$), SHP($\sinh \Psi$), CHP($\cosh \Psi$), ST($\sin \theta$), CT($\cos \theta$), SHE($\sinh \eta$), CHE($\cosh \eta$), SP($\sin \phi$), CP($\cos \phi$) - returned through common block TRAJ1

ZS(z_b/s)

Comments: Given a point Ψ_b on the trajectory relative to the j^{th} blade, the corresponding coordinates in various coordinate systems are calculated. The coordinates (r,χ, z_b), (Ψ,θ,χ) and (η,ϕ) are respectively of the point in cylindrical, prolate spheriodal and plane elliptic coordinate systems.

Function FUN1. -

Input: RØ, AR, I

N(n), PI(π) - through common block MAIN1

R, SX, CX, SHP, CHP, ST, CT, SHE, CHE, SP, CP - through common block TRAJ1

Comments: The values of various functions required in FUN2 are calculated. Specifically, the six derivative expressions D_1 to D_6 (Appendix C of ref. 2) are returned for values of I from 1 to 6 in the input.

Function FUN2. -

Input: RØ, AR, TW(ε), MU, LAM, RBØ, PBØ, DP($\Delta\Psi_b$), DB,

X(Ψ_{bi}, p. 12, ref. 2), I

N, PI - through common block MAIN1

Comments: As described in Step 6 of the main program, the coefficient matrix elements corresponding to the various unknowns and the right-hand side require numerical integration, for which the necessary functional values are returned by function FUN2. Given the azimuth position X, Subroutine TRAJ and Function FUN1 are used to set up the relevant expressions. The value, I = 1, corresponds to the function multiplying A_{oo}(eq. (9) of ref. 2). The value, I = 2, corresponds to the function multiplying A_{no} (n = 1,2,3,4). The values, I = 3,4,5,6,7, respectively correspond to the functions multiplying θ_o, a_o, a_1, b_1 and the right-hand side. The forms of these integrands are given in Appendix C of reference 2 as induced velocity coefficients. The nonintegral parts of these expressions are the result of analytical integration of the near field over a small interval $\Delta\Psi_b$ adjacent to the collocation point and are defined in the main program (Step 5). Over this interval, therefore, the near field contribution is skipped in Function FUN2.

Function FUN3. -

Input: RØ, AR, X, I

N, PI - through common block MAIN1

Comments: The expressions for the total blade lift and the moment about the hub due to the lift involve certain spanwise integrals (I_o^1, I_o^2, I_n^1, I_n^2 (n = 1,2,3,4) see p. 42 of ref.2) and the corresponding integrands are set up in FUN3. The radial position, r_b/R_1, is X. The notation, I = 1,2,3,4, corresponds respectively to the integrals I_o^1, I_o^2, I_n^1, I_n^2.

Function PNM. -

Input: N(n), M(m), X(x)

Comments: This function generates the associated Legendre function $P_n^m(x)$ over the ranges $0 \leq n \leq 4$, $0 \leq m \leq 3$, $|x|<1$. Although the relevant recursive relations could be used, the function defines P_n^m explicitly in terms of x for all the above values of n and m (Appendix D of ref. 2).

Function QNM. -

Input: N, M, X

Comments: The associated Legendre function $Q_n^m(x)$ is calculated over the ranges $1 \leq n \leq 4$, $1 \leq m \leq 2$, $|x| > 1$. As listed in Appendix D of reference 2, the exact definitions are used for $|x| \leq 3$ and asymptotic expansions are used for $|x| > 3$ to avoid the accumulation of roundoff error.

Subroutine TABSCH. -

Input: X, N, XT

Output: I1,I2, INT

Comments: This routine searches an array X, of dimension N, for the position of a value XT. If XT lies between X(I1) and X(I2), INT = 0. If XT is outside the range of X, the subroutine returns INT = -1 for XT < X(1) and INT = 1 for XT > X(N) (it is assumed that the elements in X are arranged in increasing order).

Program ASYMP2

Main Program. - Here again the previously listed program steps will be discussed in more detail.

(1) This step is similar to Step 1 of Program ASYMP1. There are some changes in the entry of input data (described in the next section). Instead of spanwise collocation point locations, the program reads the spanwise locations at which the blade is divided into segments for discretization. Collocation points are located at the center of each segment. The integer, ISEL, specifies whether a piecewise constant or piecewise quadratic representation is to be used for the computation. Following the reading and writing of input data, some arrays that will be required later are set up. Arrays FX1 and FX2 contain the average values of the factors

$$\sqrt{\frac{1-x}{1+x}} \text{ and } \left\{\frac{(R_1 - R_0)}{2R_1} \frac{\sqrt{1-x^2}}{A}\right\}$$

over each chordwise segment. These values will be used in the near field calculation. Array GF relates the endpoint and midpoint values for the spanwise segments in the piecewise quadratic representation. If $\rho_j (j = 1,..6)$ represent the ends of the 5 spanwise segments $(\rho_1 = R_0, \rho_6 = R_1)$ and $r_j (j = 1,..5)$ the midpoints, then

$$g(\rho_i) = \sum_{j=1}^{5} (GF)_{ij}\, g(r_j) \qquad (i = 2,3,4,5)$$

(2-5) These steps are generally the same as the corresponding steps in Program ASYMP1.

(6) For the current azimuth interval, the slopes and intercepts for the linear approximations to $x_b(\Psi_b)$, $y_b(\Psi_b)$ and $r_b(\Psi_b)$ are defined as XBI, XBS, YBS, RBI, RBS. The far field contribution is computed using Subroutine FFINT. For computing the common part and near field contributions (which are both dependent on the local spanwise dipole strength) it is necessary to divide that part of the interval (PB1, PB2) which has the trajectory within the blade span into subintervals such that each subinterval has a trajectory wholly within one spanwise segment. This is done by calling Subroutine SUBIVL. The common part and near field contributions are then computed respectively by calling Subroutines CPINT and NFINT, summing the contributions over each subinterval.

(7-12) Comments on these steps are the same as for Program ASYMP1.

<u>Subroutine SUBIVL</u>. -

Input: RB1(r_{b1}), RB2(r_{b2}), PB1(Ψ_{b1}), PB2(Ψ_{b2}), R(ρ_j, j = 1,..6)

Output: I, P1, P2

Comments: As explained in Step 6 for the main program, the azimuth interval must be subdivided so that the trajectory segments within each subinterval lie completely within one spanwise segment. This is done by comparing the endpoints for each segment (ρ_j, ρ_{j+1} for the j^{th} segment) successively with the spanwise coordinates at the ends of the interval, r_{b1} and r_{b2}. The terms I, P1 and P2 are all arrays of dimension 5, corresponding to the number of spanwise segments. For the segment J, I(J) = 1 or 0 depending on whether a portion of the trajectory does or does not lie within that segment. If I(J) = 1, the azimuth positions corresponding to the ends of that portion of the trajectory segment are stored in P1(J) and P2(J).

Subroutine NFINT. -

Input: P1, P2, X, ISEL

XI, XS, YS, RI, RS - through common block MAIN1

Output: T1, T2, T3

Comments: This subroutine computes various integral terms required for the near field contribution over the azimuth interval (P1, P2), with X being the chordwise location of a segment over which the surface pressure has been averaged. The terms T1, T2, T3 correspond to the terms n_o, n_1, n_2 in Appendix C of reference 3. For the piecewise constant representation, ISEL = 0, only T1 is used.

Subroutine CPINT. -

Input: P1, P2, ISEL

XI, XS, YS, RI, RS - through common block MAIN1

Output: T1, T2, T3

Comments: The terms required to set up the common part contribution over the azimuth interval (P1, P2) are calculated. The terms T1, T2, T3 correspond to C_1, C_2, C_3 in Appendix C of reference 3. For the case ISEL = 0, only the term T1 is relevant. The common part is singular at the collocation point, although the complete pressure field is regular due to the singularities in the far field and common part cancelling out in the limit. Since this has been established, when P2 = 0 (corresponding to the collocation point) the routine sets all the terms to zero.

Subroutine FFINT. -

Input: P1, P2, R, ISEL

XI, XS, YS, RI, RS - through common block MAIN1

Output: T1, T2, T3

Comments: This routine calculates the terms required for the far field contribution over the azimuth interval (P1, P2) with R being a boundary of one of the spanwise segments (ρ_j, j = 1, . . 6). The expressions for T1, T2, T3 are derived in Appendix C of reference 3. As pointed out above, the singularity in the far field gets cancelled out in the limit. However, unlike the common part, there is a finite residue left over after cancellation.

In addition to the subroutines listed in this section, both programs make use of Subroutine GELIM to solve the system of simultaneous equations. This routine uses direct Gaussian elimination with pivoting and details can be found in the Langley Computer Programming Manual.

DESCRIPTION OF INPUT

The input data required for the programs can be divided into two parts. The first consists of data pertaining to rotor geometry, flight condition, blade motion and some additional parameters relevant to the computational scheme. These are assumed to be a part of the INPUT file; that is, they must be entered after the job control statements when the job is submitted for execution. The second part consists of airfoil data (if required) and these are assumed to reside in a file called AFDATA which must therefore be available (if the data are to be used) when the job is executed. The format for the airfoil data is described separately following descriptions of the basic input for the two programs.

Program ASYMPI

The READ statements for the first part of the input are given below, followed by explanations of the data items.

```
READ (5,*) R , AR, NB, TW, MU, ALR, CT, MINF
READ (5,*) N1, N2, N3, N4
IF (N1. EQ. 1) READ (5,*) THC
IF (N2. EQ. 0) READ (5,*) GAMA
IF (N2. EQ. 1) READ (5,*) AØ
IF (N3. EQ. 1) READ (5,*) A1
IF (N4. EQ. 1) READ (5,*) B1
READ (5,*) (RBØ(I), I = 1, NSP)
READ (5,*) DP1D, DP2D, UTMIN, NAFD
```

Each READ statement corresponds to a line of data input. It may be noted that all the above statements specify free format for the data entry so that the different items in a single line of data can be entered in any convenient format, separated by commas.

RØ	=	root radius/tip radius
AR	=	aspect ratio
NB	=	number of blades (integer)
TW	=	built-in linear twist (ε , ref. 2)
	=	pitch angle at root minus pitch angle at tip
MU	=	forward speed/tip speed (floating point)
ALR	=	inclination of tip path plane to flight path, in degrees (forward tilt positive)
CT	=	rotor thrust coefficient = $T/\rho\,(\pi R_1^{\,2})\,(\Omega R_1)^2$

MINF = Mach number corresponding to forward speed (note: this is used only for interpolating from airfoil data; if airfoil data are not used, this item is not needed and can be set to zero)

N1,N2,N3,N4 = integers associated with the four blade motion parameters (THC, AØ, A1, B1 respectively) - if a blade motion parameter is to be specified in the data, the corresponding integer is set to 1; if it is to be calculated by the program, the integer is set to 0.

THC = pitch angle at blade root in degrees

GAMA = coefficient representing blade flapping inertia

= 2π(air density) (chord) $R_1^{\,4}$/(mass moment of inertia of blade about flapping hinge), to be specified if the coning angle is to be calculated

AØ = blade coning angle

A1 = first harmonic longitudinal flapping coefficient

B1 = first harmonic lateral flapping coefficient

Note: Flapping angle = AØ - A1 cos Ψ_b - B1 sin Ψ_b

RBØ = array (of dimension 5) containing the spanwise locations of the collocation points, as fractions of the tip radius, e.g., 0.3, 0.5, 0.75, 0.85, 0.95

DP1D, DP2D = normal and reduced azimuth intervals to be used for the numerical integration (step 6 of the main program) in degrees, e.g., 15.0, 5.0

UTMIN = minimum value of local onset velocity at a collocation point for using the normal velocity boundary condition (see step 3), as a fraction of the tip speed

Note: Local onset velocity at $(r_{bo}, \Psi_{bo}) = (r_{bo}/R_1 + \mu \sin \Psi_{bo})$

NAFD = integer related to use of airfoil data:
NAFD = 1 - airfoil data used
NAFD = 0 - airfoil data not used

Program ASYMP2

Much of the input is identical to that for ASYMP1, as can be seen from the READ statements below.

```
READ (5,*) RØ, AR, NB, TW, MU, ALR, CT, MINF
READ (5,*) N1, N2, N3, N4
IF (N1. EQ. 1) READ (5,*) THC
IF (N2. EQ. 0) READ (5,*) GAMA
IF (N2. EQ. 1) READ (5,*) AØ
IF (N3. EQ. 1) READ (5,*) A1
```

```
IF (N4. EQ. 1) READ (5,*) B1
READ (5,*) (R (I), I = 2, 6)
READ (5,*) DP1D, DP2D, UTMIN, ISEL, NAFD
```

R = array (of dimension 6) containing the spanwise locations (as fractions of the tip radius) marking the division into 5 spanwise segments

(R (1) = RØ, R (6) = 1.0)

e.g., R (I), I = 2, 6 ⟶ 0.5, 0.7, 0.8, 0.9, 1.0

ISEL = integer specifying choice of piecewise representation:

ISEL = 0 - piecewise constant representation

ISEL = 1 - piecewise quadratic representation

DP1D and DP2D are the normal and reduced azimuth intervals, in degrees, over which the induced velocity contributions are summed. Typical values are 30.0 and 10.0, respectively.

Airfoil Data

The data used in this case (if NAFD = 1) consist of lift coefficients, over a range of incidences and Mach numbers.

NXL = number of Mach numbers in the table

NZL = number of incidences in the table

MCL = array containing the NXL Mach numbers (ascending order)

ACL = array containing the NZL incidences (ascending order)

CL = two-dimensional array (of dimension at least (NZL, NXL)) containing the lift coefficients

The format for data entry is as below.

Line 1: NXL, NZL (30X, 2I2 format)

Col	31 - 32	NXL
	33 - 34	NZL

Lines 2(a),(b),. . . MCL (I), I = 1, NXL (7X, 9F7.0 format)

Col	8 - 14	MCL (1)
	15 - 21	MCL (2)
	.	
	.	
	.	
	64 - 70	MCL (9)

If NXL is greater than 9, additional lines are entered with the same format until all NXL entries have been made.

Lines 3(a), (b) . . . ACL (1), CL (1, I), I = 1, NXL (F7.0, 9F7.0 format)

Col	1 - 7	ACL (1)
	8 - 14	CL (1, 1)
	15 - 21	CL (1, 2)
	.	
	.	
	.	
	64 - 70	CL (1, 9)

If NXL is greater than 9, additional lines are entered as below (7X, 9F7.0 format).

Col	8 - 4	CL (1, 10)
	15 - 21	CL (1, 11)
	.	
	.	
	.	
	64 - 70	CL (1, 18)

Lines 4, 5, 6 . . . are identical in format to line 3 and contain the data with ACL (2), ACL (3) . . . ACL (NZL).

DESCRIPTION OF OUTPUT

The presentation of output is basically the same for Programs ASYMP1 and ASYMP2. Each page of output is formatted to fit within letter paper size (11" x 8.5"). Given below is a page-by-page description of the output.

Page 1 contains the input data and some auxiliary parameters, as well as the locations of the collocation points at which the normal velocity condition has been replaced by the zero lift condition. Page 2 contains the basic solution for the collocation coefficients used to express the variation of the dipole strength function $g(r_b, \Psi_b)$. These are 55 in number, corresponding to the coefficients in equation (9) of reference 2 for ASYMP1 and to the coefficients in equation (E3) of reference 3 for ASYMP2. Also presented on this page are the blade motion parameters (θ_o, a_o, a_1, b_1)

and the computed values of the rotor thrust coefficient and the moment coefficients about the rotor X - and Y - axes. Page 3 contains the distribution of sectional lift $/(\rho \Omega^2 R_1^3)$ in tabular form, at 5 radial and 24 azimuth locations. Page 4 contains a similar table of sectional lift*R_1/thrust per blade. Pages 5 and 6 contain tables of sectional pitching moment$/(\rho \Omega^2 R_1^4)$ and the center of pressure locations. Page 7 presents the variation with azimuth of the total blade lift, the moment due to lift about the hub and the radial location of the center of lift. Pages 8 - 15 present the distribution of surface pressure differential$/(\rho \Omega^2 R_1^2)$ at 5 spanwise and 10 chordwise locations, for every 15 degrees of azimuth.

EXAMPLES OF JOB ENTRY, INPUT DATA AND OUTPUT

The current versions of ASYMP1 and ASYMP2, written in Fortran IV, are intended to be run on the Cyber network at the Langley Research Center inasmuch as they use subroutine GELIM which is to be accessed from the subroutine library FTNMLIB. With appropriate changes, therefore, they can be run on any other system with a Fortran IV compiler. In order to compile and execute the programs, the basic sequence of job control statements would be as follows.

```
GET, ASYMP1 (or ASYMP2).
GET, AFDATA = airfoil datafile name. (if airfoil data are used)
MAP, OFF. (if load map is not required)
FTN, I = ASYMP1 (or ASYMP2), L = Ø.
ATTACH, FTNMLIB/UN = LIBRARY.
LIBRARY, FTNMLIB.
LGO.
```

The control statements must be followed by the relevant input data. Examples are given below for two conditions: (A) data for program ASYMP1, applied to Case 1, μ = 0.29 (see p. 16 of ref. 2) and (B) data for program ASYMP2, applied to Case 2, μ = 0.29 using the piecewise quadratic representation. In each case the input data is followed by the corresponding output listing.

Example A

Line 1: 0.17, 5.43, 2, 0., 0.29, 6.7, 0.00394, 0.

Line 2: 0, 1, 0, 0

Line 3: 0.

Line 4: 0.3, 0.5, 0.75, 0.85, 0.95

Line 5: 15.0, 5.0, 0.1, 0

In the first line MINF has been set to zero since airfoil data are not going to be used. The second line specifies that θ_o, a_1 and b_1 are to be computed while a_o will be input. Since this example involves a teetering rotor with no coning angle, the third line specifies $a_o = 0$.

```
ROOT RADIUS/TIP RADIUS=     .17000

ASPECT RATIO=   5.43000

NUMBER OF BLADES= 2

LINEAR TWIST(ROOT TO TIP)=    0.00000 DEGREES

FORWARD SPEED/TIP SPEED=     .29000

ROTOR INCIDENCE(FORWARD TILT POSITIVE)=    5.70000 DEGREES

FREESTREAM MACH NUMBER=    0.00000

THRUST COEFFICIENT=     .00394

CONING ANGLE=   0.00000 DEGREES

TOTAL INFLOW RATIO=     .04070

MINIMUM UT=     .10000(ZERO LIFT CONDITION APPLIED BELOW THIS VALUE)

NORMAL AZIMUTH INTERVAL=  15.00000 DEGREES

REDUCED AZIMUTH INTERVAL=    5.00000 DEGREES

AIRFOIL DATA TABLES NOT USED

R=     .300 PSI= 229.091DEGREES UT=     .081 ZERO LIFT CONDITION APPLIED

R=     .300 PSI= 261.818DEGREES UT=     .013 ZERO LIFT CONDITION APPLIED

R=     .300 PSI= 294.545DEGREES UT=     .036 ZERO LIFT CONDITION APPLIED
```

SOLUTION FOR COEFFICIENTS

(GO(I),I=1,NSP)

-.2658E-02 -.4578E-02 -.7425E-02 -.1972E-02 -.4996E-03

(GC(I,J),J=1,NHM),I=1,NSP)

-.3422E-03	-.4419E-03	-.1377E-03	-.1375E-03	.6416E-04
.2011E-02	-.6358E-02	-.4901E-03	.1343E-02	-.2870E-03
-.4199E-05	-.1021E-02	-.3515E-03	-.4874E-03	-.9597E-04
.2913E-03	-.5772E-03	-.1344E-03	-.1949E-03	.3887E-03
.1011E-03	-.3411E-03	.1142E-03	.3015E-03	-.4662E-03

(GS(I,J),J=1,NHM),I=1,NSP)

.2957E-03	.1249E-03	.1927E-04	-.1278E-03	-.1251E-03
-.2556E-02	.6105E-03	-.3014E-02	.3499E-03	.7783E-03
-.4435E-03	.1166E-02	-.1548E-03	-.1594E-02	-.2098E-03
.9283E-03	-.3151E-03	-.1015E-03	.2088E-04	-.4070E-03
.5563E-03	.2649E-03	-.4271E-03	-.2013E-05	.3877E-03

PITCH ANGLE AT BLADE ROOT= 7.69346DEGREES

CONING ANGLE= 0.00000 DEGREES

FLAPPING COEFFICIENT, A1= 4.27211 DEGREES

FLAPPING COEFFICIENT, B1= .03698 DEGREES

COMPUTED THRUST COEFFICIENT= .3940E-02

COMPUTED MOMENT COEFFICIENT ABOUT ROTOR X-AXIS=-.3092E-16

COMPUTED MOMENT COEFFICIENT ABOUT ROTOR Y-AXIS= .3313E-17

TABLE 1 - SECTIONAL LIFT/(RHO*(OMEGA**2)*(R1**3))

PSI \ R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
0.0	.2249E-02	.8022E-02	.1818E-01	.2045E-01	.1620E-01
15.0	.1969E-02	.7424E-02	.1634E-01	.2047E-01	.1589E-01
30.0	.1864E-02	.6600E-02	.1565E-01	.1727E-01	.1319E-01
45.0	.1456E-02	.5512E-02	.1109E-01	.1213E-01	.9265E-02
60.0	.4532E-03	.3671E-02	.7571E-02	.8453E-02	.6733E-02
75.0	-.7856E-03	.1429E-02	.7249E-02	.8486E-02	.7113E-02
90.0	-.1522E-02	.4076E-03	.9650E-02	.1130E-01	.9429E-02
105.0	-.1247E-02	.1973E-02	.1257E-01	.1425E-01	.1159E-01
120.0	-.2901E-04	.5473E-02	.1451E-01	.1593E-01	.1270E-01
135.0	.1562E-02	.8591E-02	.1565E-01	.1692E-01	.1343E-01
150.0	.2731E-02	.9514E-02	.1663E-01	.1811E-01	.1448E-01
165.0	.2853E-02	.5504E-02	.1724E-01	.1914E-01	.1544E-01
180.0	.1906E-02	.6951E-02	.1672E-01	.1897E-01	.1542E-01
195.0	.5907E-03	.5653E-02	.1501E-01	.1744E-01	.1432E-01
210.0	-.1817E-03	.4394E-02	.1289E-01	.1548E-01	.1293E-01
225.0	-.1070E-03	.2997E-02	.1116E-01	.1392E-01	.1186E-01
240.0	.2586E-03	.1975E-02	.1005E-01	.1290E-01	.1118E-01
255.0	.1985E-03	.1867E-02	.9528E-02	.1240E-01	.1088E-01
270.0	-.2695E-03	.2456E-02	.9805E-02	.1274E-01	.1121E-01
285.0	-.3925E-03	.3135E-02	.1094E-01	.1397E-01	.1220E-01
300.0	.3837E-03	.3828E-02	.1244E-01	.1541E-01	.1328E-01
315.0	.1687E-02	.4965E-02	.1370E-01	.1639E-01	.1386E-01
330.0	.2600E-02	.6549E-02	.1485E-01	.1720E-01	.1428E-01
345.0	.2660E-02	.7798E-02	.1647E-01	.1869E-01	.1515E-01

TABLE 2 - SECTIONAL LIFT*R1/THRUST PER BLADE

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
PSI					
0.0	.3635E+00	.1296E+01	.2937E+01	.3304E+01	.2617E+01
15.0	.3162E+00	.1200E+01	.2963E+01	.3308E+01	.2567E+01
30.0	.3011E+00	.1066E+01	.2528E+01	.2790E+01	.2131E+01
45.0	.2352E+00	.8907E+00	.1792E+01	.1960E+01	.1497E+01
60.0	.7322E-01	.5931E+00	.1223E+01	.1366E+01	.1088E+01
75.0	-.1269E+00	.2309E+00	.1171E+01	.1371E+01	.1149E+01
90.0	-.2459E+00	.6536E-01	.1559E+01	.1826E+01	.1523E+01
105.0	-.2016E+00	.3188E+00	.2031E+01	.2303E+01	.1873E+01
120.0	-.4668E-02	.8843E+00	.2345E+01	.2573E+01	.2052E+01
135.0	.2524E+00	.1387E+01	.2529E+01	.2733E+01	.2170E+01
150.0	.4412E+00	.1537E+01	.2687E+01	.2927E+01	.2340E+01
165.0	.4609E+00	.1374E+01	.2785E+01	.3092E+01	.2495E+01
180.0	.3080E+00	.1123E+01	.2702E+01	.3064E+01	.2491E+01
195.0	.9544E-01	.9134E+00	.2425E+01	.2919E+01	.2314E+01
210.0	-.2936E-01	.7100E+00	.2082E+01	.2502E+01	.2089E+01
225.0	-.1729E-01	.4843E+00	.1804E+01	.2250E+01	.1917E+01
240.0	.4179E-01	.3191E+00	.1624E+01	.2084E+01	.1807E+01
255.0	.3207E-01	.3017E+00	.1540E+01	.2004E+01	.1758E+01
270.0	-.4355E-01	.3968E+00	.1584E+01	.2058E+01	.1811E+01
285.0	-.6342E-01	.5066E+00	.1768E+01	.2257E+01	.1971E+01
300.0	.6200E-01	.6135E+00	.2010E+01	.2490E+01	.2146E+01
315.0	.2726E+00	.8023E+00	.2213E+01	.2646E+01	.2243E+01
330.0	.4202E+00	.1053E+01	.2400E+01	.2779E+01	.2307E+01
345.0	.4298E+00	.1260E+01	.2660E+01	.3020E+01	.2448E+01

TABLE 3 - SECTIONAL PITCHING MOMENT/(RHO*(OMEGA**2)*(R1**4))

(ABOUT QUARTER-CHORD)

PSI \ R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
0.0	.3351E-04	.2642E-05	-.5538E-04	-.1002E-03	-.2298E-03
15.0	.1672E-04	-.7630E-05	-.7253E-04	-.1155E-03	-.2375E-03
30.0	.7246E-06	-.1930E-04	-.7620E-04	-.1124E-03	-.2154E-03
45.0	-.7096E-05	-.3003E-04	-.6516E-04	-.9244E-04	-.1738E-03
60.0	-.5719E-05	-.2723E-04	-.4886E-04	-.6794E-04	-.1352E-03
75.0	.1632E-05	-.7376E-05	-.3588E-04	-.4907E-04	-.1120E-03
90.0	.1282E-04	.1792E-04	-.2453E-04	-.3469E-04	-.9739E-04
105.0	.2607E-04	.3153E-04	-.3036E-05	-.1921E-04	-.8011E-04
120.0	.3549E-04	.2903E-04	.1265E-04	-.2037E-05	-.6118E-04
135.0	.3279E-04	.2079E-04	.2701E-04	.8561E-05	-.5242E-04
150.0	.1603E-04	.1620E-04	.2583E-04	.5792E-05	-.6087E-04
165.0	-.5481E-05	.1209E-04	.1147E-04	-.8223E-05	-.8076E-04
180.0	-.2433E-04	.2639E-06	-.5972E-05	-.2559E-04	-.1013E-03
195.0	-.3545E-04	-.1797E-04	-.1975E-04	-.4064E-04	-.1175E-03
210.0	-.4468E-04	-.3135E-04	-.2998E-04	-.5221E-04	-.1298E-03
225.0	-.5260E-04	-.3211E-04	-.3742E-04	-.5977E-04	-.1381E-03
240.0	-.5087E-04	-.2389E-04	-.3902E-04	-.6153E-04	-.1412E-03
255.0	-.3203E-04	-.1409E-04	-.3229E-04	-.5747E-04	-.1411E-03
270.0	-.1019E-05	-.3647E-05	-.2095E-04	-.5139E-04	-.1433E-03
285.0	.2748E-04	.1047E-04	-.1238E-04	-.4766E-04	-.1499E-03
300.0	.4311E-04	.2554E-04	-.1033E-04	-.4746E-04	-.1580E-03
315.0	.4753E-04	.3238E-04	-.1348E-04	-.5064E-04	-.1662E-03
330.0	.4733E-04	.2698E-04	-.2109E-04	-.5965E-04	-.1800E-03
345.0	.4383E-04	.1436E-04	-.3533E-04	-.7747E-04	-.2041E-03

TABLE 4 - CENTER OF PRESSURE LOCATION FROM LEADING EDGE(FRACTION OF CHORD)

PSI \ R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
0.0	.3475E+00	.2522E+00	.2301E+00	.2179E+00	.1572E+00
15.0	.3056E+00	.2433E+00	.2241E+00	.2131E+00	.1522E+00
30.0	.2525E+00	.2304E+00	.2181E+00	.2074E+00	.1432E+00
45.0	.2181E+00	.2144E+00	.2116E+00	.2001E+00	.1273E+00
60.0	.1674E+00	.2014E+00	.2078E+00	.1974E+00	.1136E+00
75.0	.2364E+00	.2162E+00	.2176E+00	.2122E+00	.1470E+00
90.0	.1949E+00	.5376E+00	.2334E+00	.2293E+00	.1324E+00
105.0	.1133E+00	.3545E+00	.2458E+00	.2412E+00	.2048E+00
120.0	-.7753E+01	.2847E+00	.2557E+00	.2492E+00	.2135E+00
135.0	.3873E+00	.2658E+00	.2613E+00	.2533E+00	.2245E+00
150.0	.2884E+00	.2611E+00	.2602E+00	.2521E+00	.2225E+00
165.0	.2351E+00	.2593E+00	.2544E+00	.2472E+00	.2158E+00
180.0	.1655E+00	.2502E+00	.2477E+00	.2412E+00	.2070E+00
195.0	-.1426E+00	.2292E+00	.2414E+00	.2348E+00	.1963E+00
210.0	.1859E+01	.2033E+00	.2348E+00	.2279E+00	.1843E+00
225.0	.3456E+01	.1799E+00	.2281E+00	.2219E+00	.1738E+00
240.0	-.1037E+01	.1708E+00	.2246E+00	.2188E+00	.1674E+00
255.0	-.8056E+00	.2006E+00	.2278E+00	.2197E+00	.1651E+00
270.0	.2747E+00	.2403E+00	.2360E+00	.2236E+00	.1664E+00
285.0	-.2080E+00	.2713E+00	.2426E+00	.2277E+00	.1696E+00
300.0	.9851E+00	.2936E+00	.2446E+00	.2298E+00	.1722E+00
315.0	.4343E+00	.2929E+00	.2436E+00	.2298E+00	.1717E+00
330.0	.3691E+00	.2770E+00	.2407E+00	.2273E+00	.1675E+00
345.0	.3578E+00	.2520E+00	.2360E+00	.2229E+00	.1619E+00

TABLE 5 - TOTAL BLADE LIFT, MOMENT ABOUT HUB AND RADIAL CENTER OF LIFT

TOTAL BLADE LIFT/(RHO*(OMEGA**2)*(R1**4))
TOTAL BLADE LIFT/THRUST PER BLADE
MOMENT ABOUT HUB/(RHO*(OMEGA**2)*(R1**5))
RADIAL CENTER OF LIFT/R1

PSI	TOTAL BLADE LIFT		MOMENT ABOUT HUB	CENTER OF LIFT
0.0	.8859E-02	.1431E+01	.6376E-02	.7198E+00
15.0	.8557E-02	.1399E+01	.6281E-02	.7256E+00
30.0	.7424E-02	.1200E+01	.5353E-02	.7210E+00
45.0	.5458E-02	.8819E+00	.3885E-02	.7118E+00
60.0	.3642E-02	.5885E+00	.2553E-02	.7283E+00
75.0	.2358E-02	.4513E+00	.2300E-02	.8049E+00
90.0	.3379E-02	.5461E+00	.2862E-02	.8468E+00
105.0	.4807E-02	.7757E+00	.3876E-02	.8063E+00
120.0	.6483E-02	.1048E+01	.4870E-02	.7512E+00
135.0	.7860E-02	.1273E+01	.5636E-02	.7152E+00
150.0	.8580E-02	.1403E+01	.6113E-02	.7043E+00
165.0	.8721E-02	.1409E+01	.6215E-02	.7126E+00
180.0	.8036E-02	.1298E+01	.5875E-02	.7311E+00
195.0	.6911E-02	.1117E+01	.5202E-02	.7526E+00
210.0	.5764E-02	.9313E+00	.4449E-02	.7720E+00
225.0	.4888E-02	.7898E+00	.3833E-02	.7842E+00
240.0	.4362E-02	.7047E+00	.3436E-02	.7879E+00
255.0	.4175E-02	.6746E+00	.3291E-02	.7882E+00
270.0	.4359E-02	.7044E+00	.3437E-02	.7884E+00
285.0	.4925E-02	.7959E+00	.3848E-02	.7812E+00
300.0	.5752E-02	.9295E+00	.4373E-02	.7602E+00
315.0	.6652E-02	.1075E+01	.4875E-02	.7328E+00
330.0	.7527E-02	.1216E+01	.5370E-02	.7135E+00
345.0	.8334E-02	.1347E+01	.5927E-02	.7112E+00

TABLE 6 -SURFACE PRESSURE DIFFERENTIAL/(RHO*(OMEGA**2)*(R1**2))

AZIMUTH ANGLE= 0.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.2681E-01	.1438E+00	.3514E+00	.4116E+00	.3868E+00
.10000	.2088E-01	.9940E-01	.2336E+00	.2772E+00	.2519E+00
.20000	.1698E-01	.6673E-01	.1547E+00	.1769E+00	.1493E+00
.30000	.1519E-01	.5121E-01	.1148E+00	.1291E+00	.9999E-01
.40000	.1390E-01	.4120E-01	.8925E-01	.9852E-01	.6887E-01
.50000	.1271E-01	.3370E-01	.7054E-01	.7644E-01	.4685E-01
.70000	.1008E-01	.2209E-01	.4296E-01	.4436E-01	.1775E-01
.90000	.6102E-02	.1126E-01	.2004E-01	.1922E-01	.1503E-02
.95000	.4398E-02	.7755E-02	.1344E-01	.1253E-01	-.5220E-03
.99000	.2016E-02	.3416E-02	.5745E-02	.5183E-02	-.9029E-03

AZIMUTH ANGLE= 15.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.2838E-01	.1366E+00	.3613E+00	.4182E+00	.3939E+00
.10000	.2079E-01	.9370E-01	.2442E+00	.2807E+00	.2493E+00
.20000	.1540E-01	.6188E-01	.1569E+00	.1778E+00	.1468E+00
.30000	.1286E-01	.4672E-01	.1154E+00	.1283E+00	.9742E-01
.40000	.1113E-01	.3698E-01	.8884E-01	.9760E-01	.6633E-01
.50000	.9739E-02	.2978E-01	.6950E-01	.7497E-01	.4440E-01
.70000	.7220E-02	.1895E-01	.4134E-01	.4256E-01	.1572E-01
.90000	.4168E-02	.9437E-02	.1871E-01	.1786E-01	.3215E-03
.95000	.2980E-02	.5487E-02	.1242E-01	.1150E-01	-.1345E-02
.99000	.1360E-02	.2855E-02	.5257E-02	.4699E-02	-.1259E-02

AZIMUTH ANGLE= 30.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.3292E-01	.1265E+00	.3139E+00	.3585E+00	.3257E+00
.10000	.2281E-01	.8587E-01	.2112E+00	.2397E+00	.2105E+00
.20000	.1532E-01	.5554E-01	.1345E+00	.1506E+00	.1226E+00
.30000	.1174E-01	.4106E-01	.9792E-01	.1081E+00	.8019E-01
.40000	.9406E-02	.3179E-01	.7463E-01	.8106E-01	.5352E-01
.50000	.7661E-02	.2503E-01	.5773E-01	.6156E-01	.3481E-01
.70000	.4987E-02	.1517E-01	.3345E-01	.3396E-01	.1068E-01
.90000	.2565E-02	.7177E-02	.1463E-01	.1366E-01	-.1452E-02
.95000	.1786E-02	.4670E-02	.9612E-02	.8663E-02	-.2384E-02
.99000	.7998E-03	.2122E-02	.4027E-02	.3482E-02	-.1630E-02

AZIMUTH ANGLE= 45.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.2851E-01	.1113E+00	.2265E+00	.2567E+00	.2376E+00
.10000	.1926E-01	.7471E-01	.1517E+00	.1708E+00	.1525E+00
.20000	.1221E-01	.4724E-01	.9564E-01	.1062E+00	.8719E-01
.30000	.8804E-02	.3410E-01	.6883E-01	.7526E-01	.5569E-01
.40000	.6627E-02	.2574E-01	.5179E-01	.5565E-01	.3591E-01
.50000	.5054E-02	.1970E-01	.3950E-01	.4158E-01	.2212E-01
.70000	.2559E-02	.1115E-01	.2214E-01	.2200E-01	.4709E-02
.90000	.1278E-02	.4790E-02	.9294E-02	.8295E-02	-.3110E-02
.95000	.8563E-03	.3145E-02	.6034E-02	.5143E-02	-.3237E-02
.99000	.3843E-03	.1327E-02	.2506E-02	.2021E-02	-.1877E-02

AZIMUTH ANGLE= 60.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.9764E-02	.7709E-01	.1562E+00	.1600E+00	.1757E+00
.10000	.6312E-02	.5129E-01	.1043E+00	.1195E+00	.1123E+00
.20000	.3506E-02	.3185E-01	.6532E-01	.7393E-01	.6347E-01
.30000	.2264E-02	.2253E-01	.4663E-01	.5210E-01	.3987E-01
.40000	.1417E-02	.1663E-01	.3485E-01	.3626E-01	.2508E-01
.50000	.6398E-03	.1240E-01	.2634E-01	.2637E-01	.1481E-01
.70000	.1572E-03	.5560E-02	.1446E-01	.1473E-01	.2082E-02
.90000	.2469E-05	.2530E-02	.5916E-02	.5420E-02	-.3143E-02
.95000	.1237E-04	.1597E-02	.3815E-02	.3339E-02	-.2979E-02
.99000	.2280E-04	.6471E-03	.1578E-02	.1308E-02	-.1637E-02

AZIMUTH ANGLE= 75.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	-.1566E-01	.2824E-01	.1459E+00	.1736E+00	.1725E+00
.10000	-.1075E-01	.1889E-01	.9809E-01	.1163E+00	.1115E+00
.20000	-.7196E-02	.1183E-01	.6236E-01	.7341E-01	.6467E-01
.30000	-.5548E-02	.8430E-02	.4535E-01	.5296E-01	.4207E-01
.40000	-.4489E-02	.6277E-02	.3454E-01	.3997E-01	.2787E-01
.50000	-.3682E-02	.4745E-02	.2670E-01	.3060E-01	.1796E-01
.70000	-.2351E-02	.2665E-02	.1547E-01	.1728E-01	.5415E-02
.90000	-.1040E-02	.1219E-02	.6765E-02	.7270E-02	-.5903E-03
.95000	-.6535E-03	.8392E-03	.4437E-02	.4702E-02	-.1016E-02
.99000	-.2468E-03	.3796E-03	.1854E-02	.1935E-02	-.6767E-03

AZIMUTH ANGLE= 90.0 DEGREES

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	-.3343E-01	-.7037E-03	.1859E+00	.2200E+00	.2085E+00
.10000	-.2228E-01	.5513E-03	.1264E+00	.1492E+00	.1371E+00
.20000	-.1395E-01	.1543E-02	.8239E-01	.9668E-01	.8295E-01
.30000	-.1000E-01	.2179E-02	.6153E-01	.7179E-01	.5691E-01
.40000	-.7494E-02	.2490E-02	.4624E-01	.5593E-01	.4046E-01
.50000	-.5568E-02	.2667E-02	.3847E-01	.4432E-01	.2582E-01
.70000	-.3018E-02	.2711E-02	.2387E-01	.2711E-01	.1334E-01
.90000	-.1027E-02	.2034E-02	.1128E-01	.1261E-01	.3937E-02
.95000	-.5757E-03	.1615E-02	.7550E-02	.8404E-02	.2207E-02
.99000	-.1847E-03	.6001E-03	.3203E-02	.3552E-02	.7842E-03

AZIMUTH ANGLE=105.0 DEGREES

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	-.3381E-01	.2258E-01	.2329E+00	.2682E+00	.2424E+00
.10000	-.2168E-01	.1743E-01	.1599E+00	.1835E+00	.1617E+00
.20000	-.1245E-01	.1414E-01	.1062E+00	.1210E+00	.1011E+00
.30000	-.8024E-02	.1254E-01	.8083E-01	.9152E-01	.7213E-01
.40000	-.5245E-02	.1162E-01	.6462E-01	.7267E-01	.5378E-01
.50000	-.3287E-02	.1072E-01	.5258E-01	.5873E-01	.4058E-01
.70000	-.7219E-03	.8759E-02	.3405E-01	.3747E-01	.2208E-01
.90000	.5616E-03	.5548E-02	.1691E-01	.1826E-01	.8734E-02
.95000	.6030E-03	.4062E-02	.1150E-01	.1234E-01	.5516E-02
.99000	.3684E-03	.1393E-02	.4951E-02	.5278E-02	.2211E-02

AZIMUTH ANGLE=120.0 DEGREES

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	-.1558E-01	.6798E-01	.2597E+00	.2920E+00	.2578E+00
.10000	-.8507E-02	.6244E-01	.1797E+00	.2010E+00	.1737E+00
.20000	-.2859E-02	.4410E-01	.1211E+00	.1343E+00	.1112E+00
.30000	-.1047E-03	.3555E-01	.9351E-01	.1028E+00	.8162E-01
.40000	.1573E-02	.3001E-01	.7581E-01	.8267E-01	.6279E-01
.50000	.2662E-02	.2574E-01	.6256E-01	.6764E-01	.4903E-01
.70000	.3686E-02	.1848E-01	.4173E-01	.4428E-01	.2881E-01
.90000	.3100E-02	.1029E-01	.2148E-01	.2221E-01	.1239E-01
.95000	.2412E-02	.7250E-02	.1478E-01	.1513E-01	.7960E-02
.99000	.1188E-02	.3242E-02	.6450E-02	.6528E-02	.3203E-02

AZIMUTH ANGLE=135.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1446E-01	.1483E+00	.2742E+00	.3059E+00	.2696E+00
.10000	.1205E-01	.1035E+00	.1906E+00	.2113E+00	.1827E+00
.20000	.1070E-01	.7098E-01	.1295E+00	.1421E+00	.1184E+00
.30000	.1014E-01	.5572E-01	.1008E+00	.1095E+00	.8808E-01
.40000	.9661E-02	.4537E-01	.8236E-01	.8853E-01	.6876E-01
.50000	.9185E-02	.3341E-01	.6847E-01	.7293E-01	.5451E-01
.70000	.7794E-02	.2634E-01	.4636E-01	.4632E-01	.3298E-01
.90000	.5069E-02	.1393E-01	.2432E-01	.2456E-01	.1449E-01
.95000	.3736E-02	.9653E-02	.1684E-01	.1681E-01	.9313E-02
.99000	.1753E-02	.4242E-02	.7407E-02	.7231E-02	.3717E-02

AZIMUTH ANGLE=150.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.4265E-01	.1567E+00	.2922E+00	.3287E+00	.2923E+00
.10000	.3046E-01	.1160E+00	.2030E+00	.2269E+00	.1978E+00
.20000	.2173E-01	.7893E-01	.1379E+00	.1523E+00	.1279E+00
.30000	.1761E-01	.6149E-01	.1071E+00	.1172E+00	.9490E-01
.40000	.1490E-01	.5025E-01	.8730E-01	.9468E-01	.7385E-01
.50000	.1279E-01	.4177E-01	.7245E-01	.7781E-01	.5335E-01
.70000	.9211E-02	.2824E-01	.4887E-01	.5134E-01	.3501E-01
.90000	.5168E-02	.1476E-01	.2554E-01	.2597E-01	.1519E-01
.95000	.3682E-02	.1020E-01	.1768E-01	.1774E-01	.9724E-02
.99000	.1666E-02	.4473E-02	.7770E-02	.7678E-02	.3862E-02

AZIMUTH ANGLE=165.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.5396E-01	.1492E+00	.3090E+00	.3529E+00	.3165E+00
.10000	.3692E-01	.1036E+00	.2137E+00	.2427E+00	.2132E+00
.20000	.2426E-01	.7029E-01	.1438E+00	.1613E+00	.1364E+00
.30000	.1821E-01	.5454E-01	.1108E+00	.1236E+00	.9996E-01
.40000	.1429E-01	.4436E-01	.8963E-01	.9913E-01	.7676E-01
.50000	.1138E-01	.3671E-01	.7376E-01	.8086E-01	.5978E-01
.70000	.7010E-02	.2463E-01	.4891E-01	.5253E-01	.3475E-01
.90000	.3300E-02	.1235E-01	.2506E-01	.2610E-01	.1454E-01
.95000	.2221E-02	.8912E-02	.1724E-01	.1773E-01	.9209E-02
.99000	.9555E-03	.3934E-02	.7534E-02	.7631E-02	.3628E-02

AZIMUTH ANGLE=180.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.4347E-01	.1250E+00	.3064E+00	.3554E+00	.3234E+00
.10000	.2862E-01	.8630E-01	.2108E+00	.2441E+00	.2167E+00
.20000	.1727E-01	.5773E-01	.1405E+00	.1613E+00	.1369E+00
.30000	.1172E-01	.4414E-01	.1072E+00	.1222E+00	.9899E-01
.40000	.8163E-02	.3336E-01	.8586E-01	.9706E-01	.7485E-01
.50000	.5604E-02	.2380E-01	.6994E-01	.7843E-01	.5729E-01
.70000	.2179E-02	.1873E-01	.4539E-01	.4992E-01	.3190E-01
.90000	.2841E-03	.9517E-02	.2271E-01	.2421E-01	.1249E-01
.95000	.4670E-04	.5570E-02	.1551E-01	.1633E-01	.7714E-02
.99000	-.3237E-04	.2905E-02	.6737E-02	.6930E-02	.2949E-02

AZIMUTH ANGLE=195.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.2331E-01	.1085E+00	.2600E+00	.3341E+00	.3099E+00
.10000	.1407E-01	.7382E-01	.1919E+00	.2279E+00	.2064E+00
.20000	.6612E-02	.4775E-01	.1267E+00	.1492E+00	.1289E+00
.30000	.2817E-02	.3554E-01	.9577E-01	.1120E+00	.9166E-01
.40000	.3845E-03	.2754E-01	.7591E-01	.8605E-01	.6834E-01
.50000	-.1278E-02	.2155E-01	.6118E-01	.7040E-01	.5130E-01
.70000	-.3009E-02	.1299E-01	.3893E-01	.4377E-01	.2704E-01
.90000	-.2564E-02	.5032E-02	.1897E-01	.2063E-01	.9476E-02
.95000	-.2020E-02	.4033E-02	.1288E-01	.1360E-01	.5526E-02
.99000	-.9423E-03	.1745E-02	.5568E-02	.5849E-02	.1944E-02

AZIMUTH ANGLE=210.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1260E-01	.9074E-01	.2450E+00	.3026E+00	.2892E+00
.10000	.6164E-02	.6083E-01	.1672E+00	.2055E+00	.1914E+00
.20000	.5031E-03	.3824E-01	.1094E+00	.1333E+00	.1179E+00
.30000	-.2363E-02	.2730E-01	.8183E-01	.9901E-01	.8271E-01
.40000	-.4259E-02	.2025E-01	.6415E-01	.7703E-01	.6038E-01
.50000	-.5460E-02	.1513E-01	.5111E-01	.6086E-01	.4428E-01
.70000	-.6321E-02	.7942E-02	.3160E-01	.3682E-01	.2172E-01
.90000	-.4639E-02	.2993E-02	.1500E-01	.1677E-01	.6369E-02
.95000	-.3426E-02	.1883E-02	.1011E-01	.1109E-01	.3315E-02
.99000	-.1573E-02	.7699E-03	.4347E-02	.4652E-02	.9490E-03

AZIMUTH ANGLE=225.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1736E-01	.6525E-01	.2155E+00	.2769E+00	.2721E+00
.10000	.9027E-02	.4328E-01	.1471E+00	.1873E+00	.1791E+00
.20000	.1984E-02	.2648E-01	.9543E-01	.1206E+00	.1089E+00
.30000	-.1708E-02	.1824E-01	.7073E-01	.8880E-01	.7515E-01
.40000	-.4068E-02	.1292E-01	.5487E-01	.6843E-01	.5375E-01
.50000	-.5616E-02	.9070E-02	.4320E-01	.5349E-01	.3841E-01
.70000	-.6861E-02	.3339E-02	.2598E-01	.3153E-01	.1733E-01
.90000	-.5233E-02	.9216E-03	.1189E-01	.1385E-01	.3975E-02
.95000	-.3913E-02	.4695E-03	.7928E-02	.9048E-02	.1675E-02
.99000	-.1824E-02	.1519E-03	.3375E-02	.3749E-02	.2516E-03

AZIMUTH ANGLE=240.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.2374E-01	.4311E-01	.1969E+00	.2587E+00	.2599E+00
.10000	.1362E-01	.2951E-01	.1336E+00	.1748E+00	.1705E+00
.20000	.5343E-02	.1740E-01	.8634E-01	.1121E+00	.1027E+00
.30000	.1089E-02	.1131E-01	.6373E-01	.8221E-01	.7011E-01
.40000	-.1548E-02	.8149E-02	.4920E-01	.6305E-01	.4941E-01
.50000	-.3514E-02	.5495E-02	.3851E-01	.4902E-01	.3462E-01
.70000	-.5379E-02	.1980E-02	.2281E-01	.2848E-01	.1461E-01
.90000	-.4509E-02	.2151E-03	.1019E-01	.1223E-01	.2600E-02
.95000	-.3442E-02	.4432E-04	.6740E-02	.7930E-02	.7710E-03
.99000	-.1536E-02	.5244E-05	.2846E-02	.3259E-02	-.1080E-03

AZIMUTH ANGLE=255.0 DEGREES

R/R1: X/C	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1521E-01	.3753E-01	.1847E+00	.2480E+00	.2544E+00
.10000	.6996E-02	.2544E-01	.1256E+00	.1677E+00	.1668E+00
.20000	.3893E-02	.1621E-01	.8164E-01	.1078E+00	.1003E+00
.30000	.1210E-02	.1159E-01	.6058E-01	.7914E-01	.6827E-01
.40000	-.5749E-03	.8529E-02	.4702E-01	.6079E-01	.4796E-01
.50000	-.1842E-02	.6247E-02	.3701E-01	.4733E-01	.3345E-01
.70000	-.3233E-02	.3027E-02	.2219E-01	.2758E-01	.1384E-01
.90000	-.2852E-02	.1003E-02	.1008E-01	.1190E-01	.2185E-02
.95000	-.2195E-02	.6235E-03	.6702E-02	.7730E-02	.4779E-03
.99000	-.1049E-02	.2590E-03	.2847E-02	.3184E-02	-.2406E-03

AZIMUTH ANGLE=270.0 DEGREES

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	-.5900E-02	.4472E-01	.1851E+00	.2517E+00	.2621E+00
.10000	-.3552E-02	.3112E-01	.1266E+00	.1706E+00	.1720E+00
.20000	-.1909E-02	.2101E-01	.8325E-01	.1102E+00	.1038E+00
.30000	-.1301E-02	.1605E-01	.6252E-01	.8142E-01	.7100E-01
.40000	-.1055E-02	.1274E-01	.4913E-01	.6293E-01	.5019E-01
.50000	-.9711E-03	.1019E-01	.3920E-01	.4932E-01	.3528E-01
.70000	-.9386E-03	.6227E-02	.2425E-01	.2923E-01	.1496E-01
.90000	-.6851E-03	.2869E-02	.1149E-01	.1292E-01	.2566E-02
.95000	-.4964E-03	.1928E-02	.7750E-02	.8471E-02	.6641E-03
.99000	-.2146E-03	.8363E-03	.3339E-02	.3524E-02	-.2071E-03

AZIMUTH ANGLE=285.0 DEGREES

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	-.1952E-01	.5190E-01	.2025E+00	.2726E+00	.2833E+00
.10000	-.1111E-01	.3699E-01	.1391E+00	.1852E+00	.1862E+00
.20000	-.4583E-02	.2617E-01	.9231E-01	.1203E+00	.1128E+00
.30000	-.1557E-02	.2097E-01	.6999E-01	.8937E-01	.7752E-01
.40000	.1710E-03	.1747E-01	.5557E-01	.6951E-01	.5515E-01
.50000	.1210E-02	.1469E-01	.4482E-01	.5437E-01	.3911E-01
.70000	.2091E-02	.9990E-02	.2842E-01	.3308E-01	.1712E-01
.90000	.1762E-02	.5175E-02	.1388E-01	.1499E-01	.3403E-02
.95000	.1368E-02	.3573E-02	.9439E-02	.9903E-02	.1169E-02
.99000	.6780E-03	.1573E-02	.4097E-02	.4157E-02	-.2384E-04

AZIMUTH ANGLE=300.0 DEGREES

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	-.1118E-01	.5853E-01	.2292E+00	.2989E+00	.3055E+00
.10000	-.4376E-02	.4249E-01	.1576E+00	.2033E+00	.2009E+00
.20000	.1265E-02	.3103E-01	.1048E+00	.1324E+00	.1217E+00
.30000	.3960E-02	.2565E-01	.7973E-01	.9861E-01	.8372E-01
.40000	.5445E-02	.2198E-01	.6352E-01	.7695E-01	.5961E-01
.50000	.6214E-02	.1900E-01	.5143E-01	.6097E-01	.4234E-01
.70000	.6277E-02	.1367E-01	.3289E-01	.3710E-01	.1876E-01
.90000	.4342E-02	.7532E-02	.1619E-01	.1704E-01	.4078E-02
.95000	.3216E-02	.5290E-02	.1103E-01	.1131E-01	.1629E-02
.99000	.1510E-02	.2365E-02	.4784E-02	.4766E-02	.1869E-03

AZIMUTH ANGLE=315.0 DEGREES

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	.1133E-01	.7637E-01	.2536E+00	.3178E+00	.3188E+00
.10000	.1139E-01	.5515E-01	.1742E+00	.2161E+00	.2094E+00
.20000	.1219E-01	.4004E-01	.1156E+00	.1406E+00	.1265E+00
.30000	.1266E-01	.3290E-01	.8775E-01	.1046E+00	.8561E-01
.40000	.1271E-01	.2912E-01	.6982E-01	.8161E-01	.6134E-01
.50000	.1239E-01	.2431E-01	.5647E-01	.6463E-01	.4331E-01
.70000	.1061E-01	.1755E-01	.3604E-01	.3934E-01	.1891E-01
.90000	.5542E-02	.9750E-02	.1769E-01	.1810E-01	.4038E-02
.95000	.4796E-02	.6377E-02	.1203E-01	.1203E-01	.1618E-02
.99000	.2191E-02	.3383E-02	.5207E-02	.5075E-02	.2055E-03

AZIMUTH ANGLE=330.0 DEGREES

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	.2818E-01	.1075E+00	.2776E+00	.3362E+00	.3313E+00
.10000	.2292E-01	.7618E-01	.1901E+00	.2281E+00	.2171E+00
.20000	.1981E-01	.5353E-01	.1255E+00	.1477E+00	.1303E+00
.30000	.1845E-01	.4283E-01	.9478E-01	.1095E+00	.8850E-01
.40000	.1735E-01	.3580E-01	.7503E-01	.8497E-01	.6220E-01
.50000	.1618E-01	.3035E-01	.6039E-01	.6699E-01	.4341E-01
.70000	.1311E-01	.2122E-01	.3820E-01	.4039E-01	.1821E-01
.90000	.7921E-02	.1147E-01	.1859E-01	.1840E-01	.3305E-02
.95000	.5674E-02	.8019E-02	.1262E-01	.1220E-01	.1048E-02
.99000	.2572E-02	.3558E-02	.5454E-02	.5137E-02	-.6754E-04

AZIMUTH ANGLE=345.0 DEGREES

R/R1:	.3000E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	.3043E-01	.1353E+00	.3123E+00	.3704E+00	.3573E+00
.10000	.2414E-01	.9443E-01	.2131E+00	.2504E+00	.2333E+00
.20000	.2018E-01	.6456E-01	.1395E+00	.1610E+00	.1391E+00
.30000	.1841E-01	.5041E-01	.1044E+00	.1164E+00	.9387E-01
.40000	.1707E-01	.4122E-01	.8201E-01	.9121E-01	.6525E-01
.50000	.1577E-01	.3425E-01	.6547E-01	.7133E-01	.4495E-01
.70000	.1266E-01	.2310E-01	.4074E-01	.4225E-01	.1791E-01
.90000	.7653E-02	.1206E-01	.1950E-01	.1884E-01	.2378E-02
.95000	.5497E-02	.8355E-02	.1318E-01	.1240E-01	.2410E-03
.99000	.2504E-02	.3635E-02	.5677E-02	.5187E-02	-.4990E-03

Example B

Line 1:	0.16, 17.2, 4, 7., 0.29, 6.1, 0.0057, 0.
Line 2:	0, 0, 0, 0
Line 3:	9.6
Line 4:	0.5, 0.7, 0.8, 0.9, 1.0
Line 5:	30.0, 10.0, 0.1, 1, 0

ROOT RADIUS/TIP RADIUS= R0/R1 =   .16000

ASPECT RATIO= 17.20000

NUMBER OF BLADES= 4

LINEAR TWIST (ROOT TO TIP) =   7.00000 DEGREES

FORWARD SPEED/TIP SPEED=   .29000

ROTOR INCIDENCE (FORWARD TILT POSITIVE) =   6.10000 DEGREES

FREESTREAM MACH NUMBER=   0.00000

THRUST COEFFICIENT=   .00570

FLAPPING INERTIA COEFFICIENT=   9.60000

TOTAL INFLOW RATIO=   .04070

MINIMUM UT=   .10000(ZERO LIFT CONDITION APPLIED BELOW THIS VALUE)

NORMAL AZIMUTH SPACING= 30.00000 DEGREES

REDUCED AZIMUTH SPACING= 10.00000 DEGREES

PIECEWISE QUADRATIC APPROXIMATION OF SPANWISE DIPOLE STRENGTH VARIATION
****

AIRFOIL DATA TABLES NOT USED

R=   .330 PSI= 261.818DEGREES UT=   .043 ZERO LIFT CONDITION APPLIED

R=   .330 PSI= 294.545DEGREES UT=   .066 ZERO LIFT CONDITION APPLIED

SOLUTION FOR COEFFICIENTS

```
(G0(I),I=1,NSP)

-.1030E-01 -.3620E-01 -.5546E-01 -.6555E-01 -.6185E-01

((GC(I,J),J=1,NHM),I=1,NSP)

 .2862E-02 -.1508E-02 -.1917E-03  .6273E-04  .1313E-02
 .3552E-02 -.1179E-01 -.3967E-03 -.2030E-02  .3574E-03
-.7379E-03 -.1748E-01 -.6217E-02 -.3336E-02 -.3559E-02
-.4820E-02 -.1986E-01 -.5994E-02 -.4791E-02 -.2886E-02
-.9984E-02 -.1884E-01 -.7201E-02 -.5393E-02 -.9666E-03

((GS(I,J),J=1,NHM),I=1,NSP)

-.1085E-01  .1015E-02 -.2362E-02 -.5882E-03 -.4870E-03
-.9381E-02  .1593E-02  .5553E-03  .2258E-02 -.8259E-03
-.3426E-03  .5535E-02  .3046E-03  .3133E-02  .2034E-02
 .9840E-02  .5338E-02  .2388E-02  .3525E-02  .1809E-02
 .1839E-01  .6391E-02  .4011E-02  .2664E-02  .6377E-03

PITCH ANGLE AT BLADE ROOT=  15.36381 DEGREES
CONING ANGLE=   5.82645 DEGREES
FLAPPING COEFFICIENT, A1=   6.28243 DEGREES
FLAPPING COEFFICIENT, B1=   1.79994 DEGREES
COMPUTED THRUST COEFFICIENT= .5700E-02
COMPUTED MOMENT COEFFICIENT ABOUT ROTOR X-AXIS=-.1988E-16
COMPUTED MOMENT COEFFICIENT ABOUT ROTOR Y-AXIS= .3755E-16
```

TABLE 1 - SECTIONAL LIFT/(RHO*(OMEGA**2)*(R1**3))

PSI	R/R1: .3300E+00	.5000E+00	.7500E+00	.8500E+00	.9500E+00
0.0	.1364E-02	.7153E-02	.1326E-01	.1599E-01	.1583E-01
15.0	.2196E-02	.6746E-02	.1068E-01	.1269E-01	.1238E-01
30.0	.2733E-02	.5973E-02	.7605E-02	.8833E-02	.3190E-02
45.0	.2654E-02	.5331E-02	.6193E-02	.6638E-02	.5290E-02
60.0	.2307E-02	.5305E-02	.6192E-02	.6257E-02	.4364E-02
75.0	.2311E-02	.5599E-02	.6376E-02	.6428E-02	.4689E-02
90.0	.2814E-02	.5344E-02	.6333E-02	.6463E-02	.5267E-02
105.0	.3383E-02	.5924E-02	.6890E-02	.6687E-02	.5779E-02
120.0	.3602E-02	.6213E-02	.8553E-02	.8250E-02	.6504E-02
135.0	.3519E-02	.7100E-02	.1046E-01	.1008E-01	.7570E-02
150.0	.3271E-02	.8295E-02	.1136E-01	.1144E-01	.9094E-02
165.0	.3100E-02	.8950E-02	.1110E-01	.1199E-01	.1033E-01
180.0	.2433E-02	.8483E-02	.1050E-01	.1208E-01	.1101E-01
195.0	.1399E-02	.7107E-02	.1001E-01	.1192E-01	.1102E-01
210.0	.4668E-03	.5625E-02	.9294E-02	.1135E-01	.1059E-01
225.0	.5559E-04	.4559E-02	.8104E-02	.1041E-01	.1015E-01
240.0	.5088E-04	.3806E-02	.6999E-02	.9638E-02	.9987E-02
255.0	.5183E-04	.3070E-02	.6574E-02	.9385E-02	.9998E-02
270.0	-.7825E-04	.2429E-02	.6561E-02	.9284E-02	.9878E-02
285.0	-.1126E-03	.2313E-02	.6379E-02	.8974E-02	.9737E-02
300.0	.1002E-03	.3033E-02	.6406E-02	.9100E-02	.1032E-01
315.0	.3820E-03	.4385E-02	.7803E-02	.1081E-01	.1226E-01
330.0	.5496E-03	.5841E-02	.1070E-01	.1394E-01	.1499E-01
345.0	.7773E-03	.6867E-02	.1325E-01	.1642E-01	.1673E-01

TABLE 2 - SECTIONAL LIFT*R1/THRUST PER BLADE

R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
PSI					
0.0	.3048E+00	.1500E+01	.2963E+01	.3572E+01	.3537E+01
15.0	.4906E+00	.1507E+01	.2386E+01	.2834E+01	.2765E+01
30.0	.6105E+00	.1334E+01	.1712E+01	.1973E+01	.1930E+01
45.0	.5929E+00	.1202E+01	.1383E+01	.1483E+01	.1182E+01
60.0	.5154E+00	.1139E+01	.1383E+01	.1398E+01	.9748E+00
75.0	.5161E+00	.1251E+01	.1425E+01	.1436E+01	.1047E+01
90.0	.6286E+00	.1306E+01	.1415E+01	.1444E+01	.1177E+01
105.0	.7557E+00	.1323E+01	.1539E+01	.1538E+01	.1291E+01
120.0	.8046E+00	.1339E+01	.1911E+01	.1643E+01	.1453E+01
135.0	.7860E+00	.1586E+01	.2336E+01	.2253E+01	.1713E+01
150.0	.7529E+00	.1853E+01	.2537E+01	.2556E+01	.2031E+01
165.0	.6925E+00	.2001E+01	.2479E+01	.2679E+01	.2308E+01
180.0	.5435E+00	.1895E+01	.2345E+01	.2699E+01	.2459E+01
195.0	.3124E+00	.1588E+01	.2237E+01	.2664E+01	.2462E+01
210.0	.1047E+00	.1256E+01	.2076E+01	.2535E+01	.2366E+01
225.0	.1242E-01	.1019E+01	.1810E+01	.2325E+01	.2267E+01
240.0	.1137E-01	.8502E+00	.1563E+01	.2153E+01	.2231E+01
255.0	.1158E-01	.6859E+00	.1468E+01	.2096E+01	.2233E+01
270.0	-.1748E-01	.5425E+00	.1466E+01	.2074E+01	.2206E+01
285.0	-.2514E-01	.5177E+00	.1425E+01	.2005E+01	.2175E+01
300.0	.2239E-01	.6775E+00	.1431E+01	.2033E+01	.2305E+01
315.0	.8533E-01	.9797E+00	.1743E+01	.2414E+01	.2736E+01
330.0	.1228E+00	.1305E+01	.2390E+01	.3115E+01	.3349E+01
345.0	.1736E+00	.1534E+01	.2959E+01	.3667E+01	.3737E+01

TABLE 3 - SECTIONAL PITCHING MOMENT/(RHO*(OMEGA**2)*(R1**4))

(ABOUT QUARTER-CHORD)

PSI \ R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
0.0	-.2121E-05	-.3533E-06	.6289E-06	.1284E-05	.1939E-05
15.0	-.1393E-05	.3939E-06	.1387E-05	.2048E-05	.2710E-05
30.0	-.7230E-06	.9181E-06	.1830E-05	.2438E-05	.3045E-05
45.0	-.3145E-06	.1325E-05	.1771E-05	.2268E-05	.2764E-05
60.0	-.2834E-06	.6227E-06	.1126E-05	.1462E-05	.1797E-05
75.0	-.6270E-06	-.2500E-06	-.5616E-07	.7975E-07	.2157E-06
90.0	-.1226E-05	-.1465E-05	-.1599E-05	-.1688E-05	-.1777E-05
105.0	-.1876E-05	-.2749E-05	-.3235E-05	-.3558E-05	-.3882E-05
120.0	-.2350E-05	-.3840E-05	-.4668E-05	-.5220E-05	-.5771E-05
135.0	-.2458E-05	-.4505E-05	-.5543E-05	-.6402E-05	-.7160E-05
150.0	-.2103E-05	-.4612E-05	-.6006E-05	-.6936E-05	-.7865E-05
165.0	-.1317E-05	-.4159E-05	-.5737E-05	-.6790E-05	-.7843E-05
180.0	-.2470E-06	-.3271E-05	-.4951E-05	-.6071E-05	-.7191E-05
195.0	.8704E-06	-.2172E-05	-.3863E-05	-.4990E-05	-.6117E-05
210.0	.1775E-05	-.1122E-05	-.2731E-05	-.3804E-05	-.4877E-05
225.0	.2248E-05	-.3485E-06	-.1791E-05	-.2753E-05	-.3714E-05
240.0	.2169E-05	.6958E-08	-.1194E-05	-.1995E-05	-.2796E-05
255.0	.1548E-05	-.7483E-07	-.9764E-06	-.1577E-05	-.2179E-05
270.0	.5240E-06	-.4920E-06	-.1056E-05	-.1433E-05	-.1809E-05
285.0	-.6714E-06	-.1054E-05	-.1266E-05	-.1408E-05	-.1550E-05
300.0	-.1772E-05	-.1538E-05	-.1408E-05	-.1321E-05	-.1235E-05
315.0	-.2546E-05	-.1734E-05	-.1314E-05	-.1021E-05	-.7274E-06
330.0	-.2652E-05	-.1599E-05	-.9028E-06	-.4387E-06	.2540E-07
345.0	-.2674E-05	-.1088E-05	-.2073E-06	.3802E-05	.9576E-06

TABLE 4 - CENTER OF PRESSURE LOCATION FROM LEADING EDGE(FRACTION OF CHORD)

R/RTI	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
PSI					
0.0	.2162E+00	.2490E+00	.2510E+00	.2516E+00	.2525E+00
15.0	.2370E+00	.2512E+00	.2527E+00	.2533E+00	.2545E+00
30.0	.2446E+00	.2531E+00	.2549E+00	.2557E+00	.2576E+00
45.0	.2476E+00	.2539E+00	.2559E+00	.2570E+00	.2607E+00
60.0	.2475E+00	.2524E+00	.2537E+00	.2548E+00	.2584E+00
75.0	.2444E+00	.2490E+00	.2498E+00	.2503E+00	.2509E+00
90.0	.2411E+00	.2449E+00	.2448E+00	.2447E+00	.2431E+00
105.0	.2386E+00	.2405E+00	.2404E+00	.2394E+00	.2362E+00
120.0	.2366E+00	.2374E+00	.2388E+00	.2370E+00	.2318E+00
135.0	.2357E+00	.2370E+00	.2390E+00	.2370E+00	.2309E+00
150.0	.2372E+00	.2335E+00	.2392E+00	.2376E+00	.2323E+00
165.0	.2413E+00	.2405E+00	.2394E+00	.2384E+00	.2345E+00
180.0	.2479E+00	.2421E+00	.2403E+00	.2397E+00	.2366E+00
195.0	.2627E+00	.2437E+00	.2421E+00	.2414E+00	.2386E+00
210.0	.3275E+00	.2459E+00	.2440E+00	.2431E+00	.2405E+00
225.0	.1078E+01	.2484E+00	.2455E+00	.2446E+00	.2425E+00
240.0	.1123E+01	.2500E+00	.2465E+00	.2458E+00	.2443E+00
255.0	.8615E+00	.2495E+00	.2470E+00	.2466E+00	.2455E+00
270.0	.1129E+00	.2459E+00	.2467E+00	.2468E+00	.2463E+00
285.0	.3721E+00	.2407E+00	.2459E+00	.2468E+00	.2467E+00
300.0	-.1121E+00	.2396E+00	.2455E+00	.2470E+00	.2476E+00
315.0	.1135E+00	.2413E+00	.2466E+00	.2481E+00	.2488E+00
330.0	.1437E+00	.2444E+00	.2483E+00	.2494E+00	.2500E+00
345.0	.1795E+00	.2463E+00	.2497E+00	.2505E+00	.2512E+00

TABLE 5 - TOTAL BLADE LIFT, MOMENT ABOUT HUB AND RADIAL CENTER OF LIFT

TOTAL BLADE LIFT/(RHO*(OMEGA**2)*(R1**4))
TOTAL BLADE LIFT/THRUST PER BLADE
MOMENT ABOUT HUB/(RHO*(OMEGA**2)*(R1**5))
RADIAL CENTER OF LIFT/R1

PSI	TOTAL BLADE LIFT		MOMENT ABOUT HUB	CENTER OF LIFT
0.0	.6342E-02	.1417E+01	.4785E-02	.7545E+00
15.0	.5565E-02	.1243E+01	.4034E-02	.7250E+00
30.0	.4464E-02	.9971E+00	.3067E-02	.6871E+00
45.0	.3682E-02	.8225E+00	.2439E-02	.6625E+00
60.0	.3453E-02	.7713E+00	.2289E-02	.6630E+00
75.0	.3585E-02	.8007E+00	.2385E-02	.6652E+00
90.0	.3826E-02	.8546E+00	.2512E-02	.6567E+00
105.0	.4146E-02	.9262E+00	.2703E-02	.6519E+00
120.0	.4649E-02	.1038E+01	.3076E-02	.6616E+00
135.0	.5310E-02	.1186E+01	.3590E-02	.6751E+00
150.0	.5886E-02	.1315E+01	.4033E-02	.6853E+00
165.0	.6089E-02	.1360E+01	.4218E-02	.6926E+00
180.0	.5804E-02	.1296E+01	.4106E-02	.7075E+00
195.0	.5152E-02	.1151E+01	.3780E-02	.7337E+00
210.0	.4401E-02	.9832E+00	.3360E-02	.7633E+00
225.0	.3794E-02	.8476E+00	.2970E-02	.7827E+00
240.0	.3419E-02	.7638E+00	.2703E-02	.7907E+00
255.0	.3192E-02	.7129E+00	.2555E-02	.8004E+00
270.0	.2999E-02	.6699E+00	.2442E-02	.8142E+00
285.0	.2908E-02	.6496E+00	.2372E-02	.8155E+00
300.0	.3193E-02	.7133E+00	.2543E-02	.7963E+00
315.0	.4058E-02	.9064E+00	.3159E-02	.7786E+00
330.0	.5285E-02	.1180E+01	.4088E-02	.7736E+00
345.0	.6241E-02	.1394E+01	.4801E-02	.7593E+00

TABLE 6 - SURFACE PRESSURE DIFFERENTIAL/(RHO*(OMEGA**2)*(R1**2))

AZIMUTH ANGLE= 0.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.6963E-01	.4057E+00	.7561E+00	.9133E+00	.9069E+00
.10000	.4928E-01	.2794E+00	.5200E+00	.6278E+00	.6229E+00
.20000	.3467E-01	.1665E+00	.3461E+00	.4174E+00	.4136E+00
.30000	.2786E-01	.1427E+00	.2639E+00	.3180E+00	.3146E+00
.40000	.2345E-01	.1145E+00	.2113E+00	.2543E+00	.2513E+00
.50000	.2005E-01	.9374E-01	.1722E+00	.2071E+00	.2043E+00
.70000	.1431E-01	.6157E-01	.1124E+00	.1348E+00	.1327E+00
.90000	.7892E-02	.3145E-01	.5706E-01	.6829E-01	.6700E-01
.95000	.5535E-02	.2166E-01	.3924E-01	.4694E-01	.4602E-01
.99000	.2461E-02	.9496E-02	.1718E-01	.2054E-01	.2013E-01

AZIMUTH ANGLE= 15.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1196E+00	.3848E+00	.6122E+00	.7286E+00	.7135E+00
.10000	.8321E-01	.2646E+00	.4205E+00	.5001E+00	.4893E+00
.20000	.5566E-01	.1751E+00	.2791E+00	.3317E+00	.3239E+00
.30000	.4419E-01	.1342E+00	.2123E+00	.2520E+00	.2456E+00
.40000	.3616E-01	.1074E+00	.1695E+00	.2010E+00	.1955E+00
.50000	.3012E-01	.8752E-01	.1378E+00	.1632E+00	.1595E+00
.70000	.2049E-01	.5708E-01	.8943E-01	.1057E+00	.1022E+00
.90000	.1083E-01	.2895E-01	.4514E-01	.5324E-01	.5128E-01
.95000	.7523E-02	.1990E-01	.3100E-01	.3654E-01	.3516E-01
.99000	.3320E-02	.8713E-02	.1356E-01	.1597E-01	.1536E-01

AZIMUTH ANGLE= 30.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1526E+00	.3423E+00	.4423E+00	.5110E+00	.4767E+00
.10000	.1055E+00	.2354E+00	.3033E+00	.3501E+00	.3262E+00
.20000	.7094E-01	.1561E+00	.2006E+00	.2313E+00	.2148E+00
.30000	.5465E-01	.1185E+00	.1520E+00	.1751E+00	.1621E+00
.40000	.4420E-01	.9454E-01	.1209E+00	.1391E+00	.1284E+00
.50000	.3640E-01	.7688E-01	.9796E-01	.1125E+00	.1035E+00
.70000	.2423E-01	.4982E-01	.6311E-01	.7231E-01	.6606E-01
.90000	.1254E-01	.2511E-01	.3161E-01	.3613E-01	.3277E-01
.95000	.8659E-02	.1723E-01	.2167E-01	.2474E-01	.2241E-01
.99000	.3810E-02	.7534E-02	.9460E-02	.1080E-01	.9763E-02

AZIMUTH ANGLE= 45.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1496E+00	.3096E+00	.3585E+00	.3856E+00	.3109E+00
.10000	.1032E+00	.2124E+00	.2456E+00	.2640E+00	.2122E+00
.20000	.6906E-01	.1407E+00	.1622E+00	.1740E+00	.1391E+00
.30000	.5295E-01	.1068E+00	.1227E+00	.1314E+00	.1044E+00
.40000	.4262E-01	.8511E-01	.9748E-01	.1042E+00	.8229E-01
.50000	.3493E-01	.6905E-01	.7884E-01	.8411E-01	.6601E-01
.70000	.2305E-01	.4463E-01	.5062E-01	.5360E-01	.4167E-01
.90000	.1182E-01	.2243E-01	.2527E-01	.2675E-01	.2043E-01
.95000	.8153E-02	.1539E-01	.1731E-01	.1830E-01	.1392E-01
.99000	.3577E-02	.6724E-02	.7551E-02	.7977E-02	.6053E-02

AZIMUTH ANGLE= 60.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1300E+00	.3038E+00	.3550E+00	.3610E+00	.2547E+00
.10000	.8968E-01	.2087E+00	.2443E+00	.2475E+00	.1741E+00
.20000	.6003E-01	.1336E+00	.1619E+00	.1637E+00	.1145E+00
.30000	.4603E-01	.1055E+00	.1229E+00	.1241E+00	.8631E-01
.40000	.3706E-01	.8422E-01	.9797E-01	.9874E-01	.6826E-01
.50000	.3038E-01	.6850E-01	.7951E-01	.8000E-01	.5497E-01
.70000	.2005E-01	.4450E-01	.5142E-01	.5156E-01	.3498E-01
.90000	.1029E-01	.2248E-01	.2586E-01	.2583E-01	.1730E-01
.95000	.7094E-02	.1544E-01	.1775E-01	.1771E-01	.1182E-01
.99000	.3113E-02	.6754E-02	.7755E-02	.7733E-02	.5147E-02

AZIMUTH ANGLE= 75.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1290E+00	.3172E+00	.3622E+00	.3655E+00	.2672E+00
.10000	.8916E-01	.2194E+00	.2493E+00	.2515E+00	.1838E+00
.20000	.5997E-01	.1459E+00	.1662E+00	.1676E+00	.1223E+00
.30000	.4621E-01	.1116E+00	.1270E+00	.1280E+00	.9329E-01
.40000	.3738E-01	.8959E-01	.1019E+00	.1026E+00	.7468E-01
.50000	.3079E-01	.7326E-01	.8319E-01	.8371E-01	.6089E-01
.70000	.2051E-01	.4811E-01	.5450E-01	.5475E-01	.3974E-01
.90000	.1062E-01	.2457E-01	.2776E-01	.2786E-01	.2017E-01
.95000	.7340E-02	.1692E-01	.1911E-01	.1917E-01	.1387E-01
.99000	.3226E-02	.7418E-02	.8373E-02	.8396E-02	.6074E-02

AZIMUTH ANGLE= 90.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1553E+00	.3265E+00	.3539E+00	.3609E+00	.2927E+00
.10000	.1077E+00	.2257E+00	.2446E+00	.2495E+00	.2026E+00
.20000	.7284E-01	.1517E+00	.1644E+00	.1678E+00	.1366E+00
.30000	.5643E-01	.1169E+00	.1266E+00	.1292E+00	.1055E+00
.40000	.4589E-01	.9446E-01	.1024E+00	.1045E+00	.8549E-01
.50000	.3799E-01	.7775E-01	.8426E-01	.8605E-01	.7056E-01
.70000	.2556E-01	.5172E-01	.5606E-01	.5728E-01	.4718E-01
.90000	.1336E-01	.2575E-01	.2900E-01	.2964E-01	.2453E-01
.95000	.9256E-02	.1848E-01	.2004E-01	.2049E-01	.1697E-01
.99000	.4076E-02	.8122E-02	.8805E-02	.9003E-02	.7465E-02

AZIMUTH ANGLE=105.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1852E+00	.3264E+00	.3795E+00	.3781E+00	.3139E+00
.10000	.1267E+00	.2264E+00	.2632E+00	.2625E+00	.2185E+00
.20000	.8740E-01	.1533E+00	.1782E+00	.1780E+00	.1490E+00
.30000	.6798E-01	.1189E+00	.1383E+00	.1383E+00	.1163E+00
.40000	.5548E-01	.9574E-01	.1125E+00	.1128E+00	.9531E-01
.50000	.4610E-01	.8015E-01	.9327E-01	.9358E-01	.7948E-01
.70000	.3123E-01	.5401E-01	.6287E-01	.6325E-01	.5420E-01
.90000	.1644E-01	.2329E-01	.3293E-01	.3322E-01	.2870E-01
.95000	.1140E-01	.1960E-01	.2282E-01	.2304E-01	.1994E-01
.99000	.5028E-02	.8535E-02	.1005E-01	.1015E-01	.8804E-02

AZIMUTH ANGLE=120.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1959E+00	.3390E+00	.4686E+00	.4493E+00	.3480E+00
.10000	.1363E+00	.2358E+00	.3255E+00	.3126E+00	.2432E+00
.20000	.9290E-01	.1605E+00	.2210E+00	.2128E+00	.1671E+00
.30000	.7249E-01	.1251E+00	.1718E+00	.1660E+00	.1314E+00
.40000	.5935E-01	.1023E+00	.1402E+00	.1358E+00	.1084E+00
.50000	.4946E-01	.8515E-01	.1165E+00	.1131E+00	.9094E-01
.70000	.3369E-01	.5789E-01	.7886E-01	.7697E-01	.6276E-01
.90000	.1782E-01	.3057E-01	.4148E-01	.4068E-01	.3360E-01
.95000	.1238E-01	.2123E-01	.2878E-01	.2825E-01	.2341E-01
.99000	.5465E-02	.9366E-02	.1269E-01	.1247E-01	.1035E-01

AZIMUTH ANGLE=135.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1908E+00	.3367E+00	.5733E+00	.5492E+00	.4092E+00
.10000	.1329E+00	.2690E+00	.3982E+00	.3821E+00	.2862E+00
.20000	.9068E-01	.1832E+00	.2703E+00	.2602E+00	.1969E+00
.30000	.7066E-01	.1428E+00	.2101E+00	.2029E+00	.1551E+00
.40000	.5810E-01	.1159E+00	.1714E+00	.1660E+00	.1281E+00
.50000	.4849E-01	.9736E-01	.1424E+00	.1363E+00	.1076E+00
.70000	.3312E-01	.6525E-01	.9036E-01	.9411E-01	.7447E-01
.90000	.1756E-01	.3502E-01	.5067E-01	.4974E-01	.3995E-01
.95000	.1221E-01	.2432E-01	.3515E-01	.3455E-01	.2785E-01
.99000	.5390E-02	.1073E-01	.1550E-01	.1524E-01	.1232E-01

AZIMUTH ANGLE=150.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1837E+00	.4542E+00	.6231E+00	.6243E+00	.4875E+00
.10000	.1278E+00	.3155E+00	.4327E+00	.4341E+00	.3405E+00
.20000	.8698E-01	.2143E+00	.2936E+00	.2953E+00	.2337E+00
.30000	.6781E-01	.1667E+00	.2282E+00	.2301E+00	.1837E+00
.40000	.5547E-01	.1361E+00	.1861E+00	.1881E+00	.1514E+00
.50000	.4619E-01	.1131E+00	.1545E+00	.1566E+00	.1269E+00
.70000	.3141E-01	.7660E-01	.1045E+00	.1064E+00	.8751E-01
.90000	.1659E-01	.4032E-01	.5492E-01	.5614E-01	.4679E-01
.95000	.1152E-01	.2797E-01	.3809E-01	.3898E-01	.3259E-01
.99000	.5084E-02	.1233E-01	.1679E-01	.1719E-01	.1441E-01

AZIMUTH ANGLE=165.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1713E+00	.4936E+00	.6093E+00	.6561E+00	.5579E+00
.10000	.1187E+00	.3424E+00	.4230E+00	.4559E+00	.3890E+00
.20000	.8026E-01	.2313E+00	.2869E+00	.3098E+00	.2560E+00
.30000	.6216E-01	.1798E+00	.2229E+00	.2410E+00	.2083E+00
.40000	.5053E-01	.1463E+00	.1817E+00	.1968E+00	.1711E+00
.50000	.4162E-01	.1212E+00	.1508E+00	.1636E+00	.1431E+00
.70000	.2811E-01	.8169E-01	.1019E+00	.1109E+00	.9804E-01
.90000	.1469E-01	.4273E-01	.5354E-01	.5839E-01	.5215E-01
.95000	.1017E-01	.2965E-01	.3713E-01	.4052E-01	.3628E-01
.99000	.4480E-02	.1306E-01	.1636E-01	.1787E-01	.1603E-01

AZIMUTH ANGLE=180.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.1373E+00	.4698E+00	.5730E+00	.6639E+00	.5988E+00
.10000	.9468E-01	.3254E+00	.4009E+00	.4608E+00	.4167E+00
.20000	.6333E-01	.2198E+00	.2715E+00	.3124E+00	.2840E+00
.30000	.4853E-01	.1700E+00	.2106E+00	.2425E+00	.2216E+00
.40000	.3904E-01	.1380E+00	.1715E+00	.1976E+00	.1814E+00
.50000	.3198E-01	.1141E+00	.1421E+00	.1640E+00	.1512E+00
.70000	.2108E-01	.7550E-01	.9580E-01	.1107E+00	.1030E+00
.90000	.1080E-01	.3983E-01	.5019E-01	.5811E-01	.5449E-01
.95000	.7446E-02	.2761E-01	.3478E-01	.4029E-01	.3786E-01
.99000	.3266E-02	.1215E-01	.1532E-01	.1776E-01	.1671E-01

AZIMUTH ANGLE=195.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.8270E-01	.3957E+00	.5546E+00	.6590E+00	.6036E+00
.10000	.5636E-01	.2738E+00	.3842E+00	.4567E+00	.4193E+00
.20000	.3683E-01	.1844E+00	.2594E+00	.3088E+00	.2848E+00
.30000	.2756E-01	.1422E+00	.2007E+00	.2391E+00	.2215E+00
.40000	.2164E-01	.1152E+00	.1629E+00	.1943E+00	.1808E+00
.50000	.1730E-01	.9496E-01	.1347E+00	.1608E+00	.1502E+00
.70000	.1084E-01	.6338E-01	.9031E-01	.1080E+00	.1018E+00
.90000	.5271E-02	.3289E-01	.4708E-01	.5643E-01	.5356E-01
.95000	.3585E-02	.2274E-01	.3260E-01	.3903E-01	.3716E-01
.99000	.1556E-02	.1000E-01	.1435E-01	.1721E-01	.1638E-01

AZIMUTH ANGLE=210.0 DEGREES

R/R1: X/C	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	.3325E-01	.3154E+00	.5179E+00	.6308E+00	.5838E+00
.10000	.2174E-01	.2178E+00	.3582E+00	.4366E+00	.4049E+00
.20000	.1298E-01	.1452E+00	.2411E+00	.2943E+00	.2741E+00
.30000	.8756E-02	.1124E+00	.1860E+00	.2272E+00	.2125E+00
.40000	.6092E-02	.9068E-01	.1505E+00	.1842E+00	.1730E+00
.50000	.4216E-02	.7452E-01	.1241E+00	.1520E+00	.1433E+00
.70000	.1767E-02	.4941E-01	.8275E-01	.1016E+00	.9654E-01
.90000	.3945E-03	.2548E-01	.4291E-01	.5284E-01	.5055E-01
.95000	.1845E-03	.1759E-01	.2967E-01	.3655E-01	.3503E-01
.99000	.5036E-04	.7726E-02	.1304E-01	.1608E-01	.1543E-01

AZIMUTH ANGLE=225.0 DEGREES

R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	.1153E-01	.2578E+00	.4538E+00	.5811E+00	.5629E+00
.10000	.5494E-02	.1776E+00	.3135E+00	.4017E+00	.3898E+00
.20000	.2409E-02	.1187E+00	.2105E+00	.2702E+00	.2630E+00
.30000	.3737E-03	.9089E-01	.1620E+00	.2081E+00	.2033E+00
.40000	-.8762E-03	.7306E-01	.1308E+00	.1683E+00	.1550E+00
.50000	-.1575E-02	.5980E-01	.1076E+00	.1386E+00	.1363E+00
.70000	-.2354E-02	.3934E-01	.7141E-01	.9228E-01	.9129E-01
.90000	-.1839E-02	.2013E-01	.3687E-01	.4777E-01	.4754E-01
.95000	-.1376E-02	.1387E-01	.2547E-01	.3301E-01	.3290E-01
.99000	-.6412E-03	.6084E-02	.1119E-01	.1451E-01	.1448E-01

AZIMUTH ANGLE=240.0 DEGREES

R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	.1097E-01	.2153E+00	.3932E+00	.5402E+00	.5571E+00
.10000	.6158E-02	.1489E+00	.2714E+00	.3731E+00	.3852E+00
.20000	.2253E-02	.9924E-01	.1820E+00	.2504E+00	.2592E+00
.30000	.3058E-03	.7579E-01	.1398E+00	.1926E+00	.1998E+00
.40000	-.8893E-03	.6076E-01	.1127E+00	.1554E+00	.1616E+00
.50000	-.1652E-02	.4951E-01	.9251E-01	.1278E+00	.1332E+00
.70000	-.2295E-02	.3247E-01	.6123E-01	.8476E-01	.8874E-01
.90000	-.1786E-02	.1653E-01	.3152E-01	.4372E-01	.4598E-01
.95000	-.1335E-02	.1133E-01	.2175E-01	.3019E-01	.3178E-01
.99000	-.6222E-03	.4935E-02	.9549E-02	.1326E-01	.1397E-01

AZIMUTH ANGLE=255.0 DEGREES

R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	.8709E-02	.1742E+00	.3699E+00	.5274E+00	.5600E+00
.10000	.5002E-02	.1199E+00	.2552E+00	.3640E+00	.3868E+00
.20000	.2012E-02	.8002E-01	.1710E+00	.2440E+00	.2597E+00
.30000	.5272E-03	.6116E-01	.1312E+00	.1874E+00	.1998E+00
.40000	-.3870E-03	.4908E-01	.1057E+00	.1511E+00	.1613E+00
.50000	-.9771E-03	.4010E-01	.8674E-01	.1240E+00	.1327E+00
.70000	-.1505E-02	.2630E-01	.5733E-01	.8207E-01	.8806E-01
.90000	-.1207E-02	.1341E-01	.2947E-01	.4224E-01	.4546E-01
.95000	-.9067E-03	.9233E-02	.2033E-01	.2915E-01	.3139E-01
.99000	-.4238E-03	.4046E-02	.8923E-02	.1280E-01	.1379E-01

AZIMUTH ANGLE=270.0 DEGREES

X/C \ R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	-.2495E-02	.1362E+00	.3689E+00	.5222E+00	.5545E+00
.10000	-.2053E-02	.9403E-01	.2545E+00	.3603E+00	.3828E+00
.20000	-.1816E-02	.6311E-01	.1706E+00	.2414E+00	.2568E+00
.30000	-.1729E-02	.4852E-01	.1310E+00	.1853E+00	.1973E+00
.40000	-.1660E-02	.3916E-01	.1056E+00	.1493E+00	.1591E+00
.50000	-.1579E-02	.3213E-01	.8665E-01	.1225E+00	.1307E+00
.70000	-.1327E-02	.2134E-01	.5732E-01	.8103E-01	.8657E-01
.90000	-.9248E-03	.1101E-01	.2949E-01	.4166E-01	.4460E-01
.95000	-.5934E-03	.7600E-02	.2034E-01	.2875E-01	.3078E-01
.99000	-.2689E-03	.3333E-02	.8931E-02	.1262E-01	.1352E-01

AZIMUTH ANGLE=285.0 DEGREES

X/C \ R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	-.8895E-02	.1273E+00	.3577E+00	.5047E+00	.5475E+00
.10000	-.5692E-02	.8861E-01	.2470E+00	.3482E+00	.3778E+00
.20000	-.3221E-02	.5997E-01	.1658E+00	.2334E+00	.2532E+00
.30000	-.2022E-02	.4549E-01	.1274E+00	.1791E+00	.1944E+00
.40000	-.1270E-02	.3783E-01	.1028E+00	.1444E+00	.1567E+00
.50000	-.7504E-03	.3134E-01	.8450E-01	.1185E+00	.1286E+00
.70000	-.1158E-03	.2110E-01	.5603E-01	.7835E-01	.8504E-01
.90000	.1322E-03	.1105E-01	.2889E-01	.4030E-01	.4374E-01
.95000	.1239E-03	.7654E-02	.1994E-01	.2780E-01	.3018E-01
.99000	.6579E-04	.3371E-02	.8759E-02	.1220E-01	.1325E-01

AZIMUTH ANGLE=300.0 DEGREES

X/C \ R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
.05000	-.9034E-03	.1556E+00	.3588E+00	.5122E+00	.5818E+00
.10000	.5135E-03	.1156E+00	.2478E+00	.3534E+00	.4012E+00
.20000	.1656E-02	.7841E-01	.1664E+00	.2367E+00	.2685E+00
.30000	.2574E-02	.6089E-01	.1280E+00	.1816E+00	.2059E+00
.40000	.2990E-02	.4963E-01	.1034E+00	.1463E+00	.1657E+00
.50000	.3198E-02	.4118E-01	.8501E-01	.1200E+00	.1359E+00
.70000	.3085E-02	.2782E-01	.5644E-01	.7932E-01	.8963E-01
.90000	.2075E-02	.1460E-01	.2914E-01	.4077E-01	.4599E-01
.95000	.1515E-02	.1012E-01	.2012E-01	.2812E-01	.3171E-01
.99000	.6942E-03	.4462E-02	.8840E-02	.1234E-01	.1391E-01

AZIMUTH ANGLE=315.0 DEGREES

R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	.1223E-01	.2427E+00	.4385E+00	.6102E+00	.6939E+00
.10000	.1005E-01	.1681E+00	.3026E+00	.4206E+00	.4780E+00
.20000	.8672E-02	.1136E+00	.2029E+00	.2813E+00	.3193E+00
.30000	.8437E-02	.8790E-01	.1558E+00	.2155E+00	.2443E+00
.40000	.8096E-02	.7140E-01	.1256E+00	.1733E+00	.1963E+00
.50000	.7698E-02	.5904E-01	.1031E+00	.1420E+00	.1606E+00
.70000	.6463E-02	.3963E-01	.6824E-01	.9350E-01	.1055E+00
.90000	.4016E-02	.2063E-01	.3512E-01	.4790E-01	.5394E-01
.95000	.2889E-02	.1432E-01	.2424E-01	.3302E-01	.3716E-01
.99000	.1309E-02	.6303E-02	.1054E-01	.1448E-01	.1629E-01

AZIMUTH ANGLE=330.0 DEGREES

R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	.2061E-01	.3259E+00	.6045E+00	.7907E+00	.8521E+00
.10000	.1601E-01	.2253E+00	.4167E+00	.5445E+00	.5864E+00
.20000	.1311E-01	.1516E+00	.2785E+00	.3633E+00	.3909E+00
.30000	.1187E-01	.1163E+00	.2133E+00	.2778E+00	.2986E+00
.40000	.1101E-01	.9451E-01	.1715E+00	.2230E+00	.2394E+00
.50000	.1021E-01	.7785E-01	.1404E+00	.1822E+00	.1954E+00
.70000	.8279E-02	.5136E-01	.9244E-01	.1195E+00	.1279E+00
.90000	.5027E-02	.2585E-01	.4732E-01	.6099E-01	.6513E-01
.95000	.3600E-02	.1856E-01	.3261E-01	.4200E-01	.4482E-01
.99000	.1626E-02	.8160E-02	.1430E-01	.1841E-01	.1964E-01

AZIMUTH ANGLE=345.0 DEGREES

R/R1:	.3300E+00	.6000E+00	.7500E+00	.8500E+00	.9500E+00
X/C					
.05000	.3421E-01	.3361E+00	.7519E+00	.9342E+00	.9542E+00
.10000	.2526E-01	.2664E+00	.5176E+00	.6427E+00	.6561E+00
.20000	.1912E-01	.1786E+00	.3453E+00	.4281E+00	.4366E+00
.30000	.1635E-01	.1371E+00	.2638E+00	.3268E+00	.3328E+00
.40000	.1451E-01	.1105E+00	.2116E+00	.2618E+00	.2663E+00
.50000	.1299E-01	.9067E-01	.1729E+00	.2136E+00	.2170E+00
.70000	.9998E-02	.5997E-01	.1133E+00	.1396E+00	.1416E+00
.90000	.5852E-02	.3084E-01	.5775E-01	.7098E-01	.7180E-01
.95000	.4159E-02	.2128E-01	.3976E-01	.4883E-01	.4937E-01
.99000	.1868E-02	.9342E-02	.1742E-01	.2139E-01	.2161E-01

Sample Airfoil Data

Printed below is a sample print of typical airfoil data to illustrate the previously described input format.

1127

	0.	.2	.3	.4	.5	.6	.7	.75	.8	.9	1.
-39.	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18
-21.	-.8	-.8	-.81	-.83	-.85	-.85	-.85	-.71	-.68	-.64	-.64
-16.5	-1.007	-1.007	-.944	-.960	-.965	-.965	-.965	-.795	-.760	-.70	-.70
-15.	-1.19	-1.19	-1.09	-1.055	-.99	-.98	-.98	-.83	-.79	-.72	-.72
-14.	-1.333	-1.333	-1.22	-1.096	-1.	-.97	-.97	-.84	-.805	-.73	-.73
-13.	-1.334	-1.334	-1.28	-1.12	-1.	-.96	-.96	-.85	-.815	-.735	-.735
-12.	-1.255	-1.255	-1.26	-1.13	-1.	-.947	-.94	-.85	-.82	-.74	-.74
-11.	-1.161	-1.161	-1.19	-1.12	-.994	-.930	-.923	-.85	-.81	-.74	-.74
-10.	-1.055	-1.055	-1.01	-1.082	-.985	-.910	-.900	-.845	-.805	-.73	-.73
-8.	-.844	-.844	-.88	-.907	-.922	-.87	-.84	-.82	-.77	-.695	-.695
-6.	-.633	-.633	-.66	-.684	-.741	-.77	-.75	-.77	-.72	-.593	-.593
-4.	-.46	-.46	-.46	-.4805	-.52	-.5657	-.6401	-.7244	-.53	-.396	-.396
-2.	-.25	-.25	-.25	-.2399	-.27	-.282	-.3274	-.3605	-.3469	-.1399	-.1399
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2.	.23	.23	.23	.2403	.25	.271	.3245	.3417	.3676	.1245	.1245
4.	.45	.45	.45	.4916	.51	.5731	.6252	.6368	.5428	.45	.45
6.	.70	.70	.70	.7224	.75	.7967	.7367	.7169	.6430	.593	.593
8.	.89	.89	.89	.9416	.89	.8711	.7513	.7071	.70	.695	.695
10.	1.08	1.08	1.08	1.0333	.93	.8802	.8600	.845	.805	.73	.73
11.	1.161	1.161	1.19	1.1200	.994	.93	.923	.85	.81	.74	.74
12.	1.255	1.255	1.26	1.1305	1.0000	.947	.940	.85	.82	.74	.74
13.	1.334	1.334	1.28	1.12	1.	.96	.96	.85	.815	.735	.735
14.	1.33	1.33	1.22	1.096	1.	.97	.97	.84	.805	.73	.73
15.	1.19	1.19	1.09	1.055	.99	.98	.98	.83	.79	.72	.72
16.5	1.007	1.007	.944	.96	.965	.965	.965	.795	.76	.7	.7
21.	.8	.8	.81	.83	.85	.85	.85	.71	.68	.64	.64
39.	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18

REFERENCES

1. Van Holten, Th.: The Computation of Aerodynamic Loads on Helicopter Blades in Forward Flight, Using the Method of the Acceleration Potential. Report VTH-189, Technische Hogeschool Delft, Netherlands, March 1975.

2. Pierce, G. Alvin and Vaidyanathan, Anand R.: Helicopter Rotor Loads Using a Matched Asymptotic Expansion Technique, NASA CR-165742, May 1981.

3. Pierce, G. Alvin and Vaidyanathan, Anand R.: Helicopter Rotor Loads Using Discretized Matched Asymptotic Expansions, NASA CR-166092, May 1983.

APPENDIX A

LISTING OF PROGRAM ASYMP1

```
      PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     1AFDATA,TAPE1=AFDATA)
C
C     CALCULATION OF THE UNSTEADY AIRLOADS ON A HELICOPTER ROTOR BLADE IN
C     FORWARD FLIGHT. THE METHOD USES AN ACCELERATION POTENTIAL DESCRIPTION
C     OF THE FLOW FIELD AND A MATCHED ASYMPTOTIC EXPANSION TECHNIQUE TO
C     OBTAIN A SOLUTION CORRECT TO O(1/(AR*AR)).
C     REF.1 - TH. VAN HOLTEN, REPORT VTH-189,TECHNISCHE HOGESCHOOL,DELFT,
C     NETHERLANDS.
C     REF.2 - G.A.PIERCE ET AL, NASA CR 165742, MAY 1981.
C     FOR IDENTIFICATION OF PROGRAM STEPS, REFER USER'S MANUAL.
C
      REAL MU,LAM,MCL,MINF,MLOC
      DIMENSION RBO(5),XOUT(10),PBOD(24),A(59,59),B(59,1),
     1IPIVOT(59),PMIN(20),FI1(5),FI2(5),GO(5),GC(5,5),GS(5,5),F1(24),
     2F2(24),F3(24),FLT1(24),FLT2(24),FMT(24),COL(24),GST(24,5),WK(59),
     3DGS2(24,5),FL1(24,5),FL2(24,5),FM(24,5),XCP(24,5),
     4POUT(5,10),PDIP(24,5)
      DIMENSION CL(50,20),MCL(20),ACL(50)
      COMMON/MAIN1/NL,PI
      YL(XL,XL1,XL2,YL1,YL2)=YL1+(XL-XL1)*(YL2-YL1)/(XL2-XL1)
      DATA NSP,NHM,NAZ,NCOF,NCOFP,DMAX/5,5,11,59,60,0.5/
      DATA XOUT/.05,.1,.2,.3,.4,.5,.7,.9,.95,.99/
      PI=4.*ATAN(1.)
C
C     PROGRAM STEP 1.
C     READ AND WRITE INPUT DATA AND ASSOCIATED QUANTITIES.
C
      READ(5,*)RO,AR,NB,TW,MU,ALR,CT,MINF
      READ(5,*)N1,N2,N3,N4
      IF(N1 .EQ. 1)READ(5,*)THC
      IF(N2 .EQ. 0)READ(5,*)GAMA
      IF(N2 .EQ. 1)READ(5,*)A0
      IF(N3 .EQ. 1)READ(5,*)A1
      IF(N4 .EQ. 1)READ(5,*)B1
      READ(5,*)(RBO(I),I=1,NSP)
      READ(5,*)DP1D,DP2D,UTMIN,NAFD
C
C     NAFD=0 -- AIRFOIL TABLES NOT USED.
C     NAFD=1 -- AIRFOIL TABLES USED.
C
      IF(NAFD .EQ. 0)GO TO 8
      READ(1,1)NXL,NZL
    1 FORMAT(30X,2I2)
      READ(1,2)(MCL(I),I=1,NXL)
    2 FORMAT(7X,9F7.0)
      NL1=NXL/9
      NL2=NL1+1
      DO 3 I=1,NZL
      DO 3 J=1,NL2
      J1=(J-1)*9+1
      J2=J*9
      IF(J1 .GT. NXL)GO TO 3
      IF(J2 .GT. NXL)J2=NXL
      IF(J .EQ. 1)READ(1,4)ACL(I),(CL(I,J3),J3=J1,J2)
    4 FORMAT(F7.0,9F7.0)
      IF(J .GT. 1)READ(1,5)(CL(I,J3),J3=J1,J2)
    5 FORMAT(7X,9F7.0)
    3 CONTINUE
```

```
    8  CONTINUE
       DP1=DP1D*PI/180.
       DP2=DP2D*PI/180.
       WRITE(6,10)
   10  FORMAT(1H1)
       WRITE(6,20)RO,AR,NB,TW,MU,ALR,MINF
   20  FORMAT(//6X,"ROOT RADIUS/TIP RADIUS=",F10.5//6X,"ASPECT RATIO=",
      1F10.5//6X,"NUMBER OF BLADES=",I2//6X,
      2"LINEAR TWIST(ROOT TO TIP)=",F10.5,1X,"DEGREES"//6X,
      3"FORWARD SPEED/TIP SPEED=",F10.5//6X,
      4"ROTOR INCIDENCE(FORWARD TILT POSITIVE)=",F10.5,1X,"DEGREES"//6X,
      5"FREESTREAM MACH NUMBER=",F10.5)
       TW=TW*PI/180.
       ALR=ALR*PI/180.
       IF(N1 .EQ. 0)THC=0.
       IF(N2 .EQ. 0)A0=0.
       IF(N3 .EQ. 0)A1=0.
       IF(N4 .EQ. 0)B1=0.
       WRITE(6,30)CT
   30  FORMAT(/6X,"THRUST COEFFICIENT=",F10.5)
       IF(N1 .EQ. 1)WRITE(6,40)THC
   40  FORMAT(/6X,"PITCH ANGLE AT BLADE ROOT=",F10.5,1X,"DEGREES")
       IF(N2 .EQ. 0)WRITE(6,50)GAMA
   50  FORMAT(/6X,"FLAPPING INERTIA COEFFICIENT=",F10.5)
       IF(N2 .EQ. 1)WRITE(6,60)A0
   60  FORMAT(/6X,"CONING ANGLE=",F10.5,1X,"DEGREES")
       IF(N3 .EQ. 1)WRITE(6,70)A1
   70  FORMAT(/6X,"FLAPPING COEFFICIENT, A1=",F10.5,1X,"DEGREES")
       IF(N4 .EQ. 1)WRITE(6,80)B1
   80  FORMAT(/6X,"FLAPPING COEFFICIENT, B1=",F10.5,1X,"DEGREES")
       THC=THC*PI/180.
       A0=A0*PI/180.
       A1=A1*PI/180.
       B1=B1*PI/180.
       LAM=MU*ALR+SQRT(.5*(-MU*MU+SQRT(MU*MU*MU*MU+CT*CT)))
       WRITE(6,90)LAM,UTMIN,DP1D,DP2D
   90  FORMAT(/6X,"TOTAL INFLOW RATIO=",F10.5//6X,"MINIMUM UT=",F10.5,
      1"(ZERO LIFT CONDITION APPLIED BELOW THIS VALUE)"//6X,
      2"NORMAL AZIMUTH INTERVAL=",F10.5,1X,"DEGREES"//6X,
      3"REDUCED AZIMUTH INTERVAL=",F10.5,1X,"DEGREES")
       SLCR=1.
       CL0=0.
       IF(NAFD .EQ. 0)WRITE(6,91)
   91  FORMAT(/6X,"AIRFOIL DATA TABLES NOT USED")
       IF(NAFD .EQ. 1)WRITE(6,92)
   92  FORMAT(/6X,"AIRFOIL DATA TABLES USED")
C
C   CALCULATE QUANTITIES NEEDED FOR TRAJECTORY SEGMENT ADJACENT TO THE
C   COLLOCATION POINT.
C
       ETA1P=ALOG((3.+SQRT(5.))/2.)
       CF1=COSH(.5*ETA1P)/SINH(.5*ETA1P)
       CF2=.5*CF1-ETA1P
       CF3=.25*CF1-SINH(ETA1P)
       EX1=EXP(-ETA1P)
       CF4=.5-EX1
       CF5=-.5*ETA1P-.5*EX1+.25*EX1*EX1+3./8.
       L=1
C
C   PROGRAM STEP 2.
```

```
C   START OUTER LOOP FOR COLLOCATION. THIS LOOP SETS THE CURRENT AZIMUTH
C   STATION.
C
      DO 100 J=1,NAZ
      PBO=2.*J*PI/NAZ
      PBOD(J)=360.*J/NAZ
      CP1=COS(PBO)
      SP1=SIN(PBO)
      CP2=COS(2.*PBO)
      SP2=SIN(2.*PBO)
C
C   START INNER LOOP FOR COLLOCATION. THIS LOOP SETS THE CURRENT RADIAL
C   LOCATION.
C
      DO 100 I=1,NSP
      DO 110 M=1,NCOF
      A(L,M)=0.
 110  CONTINUE
      B(L,1)=0.
      ZBO=2.*(RBO(I)-.5*(1.+RO))/(1.-RO)
      SQZ=SQRT(1.-ZBO*ZBO)
      UT=RBO(I)+MU*SP1
C
C   PROGRAM STEP 3.
C   TEST THE TANGENTIAL VELOCITY AT THE COLLOCATION POINT, TO DECIDE
C   WHETHER NORMAL VELOCITY BOUNDARY CONDITION OR ZERO LIFT CONDITION
C   SHOULD BE APPLIED.
C
      IF(UT .GT. UTMIN)GO TO 120
      WRITE(6,130)RBO(I),PBOD(J),UT
 130  FORMAT(/6X,"R=",F8.3,1X,"PSI=",F8.3,"DEGREES",1X,"UT=",
     1F8.3,1X,"ZERO LIFT CONDITION APPLIED")
      GO TO 140
 120  DP=(1.-RO)/(2.*AR*UT)
      PLIM=PBO-(2.+RBO(I)*CP1)/SQRT(MU*MU+LAM*LAM)
      IF(NAFD .EQ. 0)GO TO 133
C
C   PROGRAM STEP 4.
C   CALCULATE LIFT CURVE SLOPE FROM DATA TABLES FOR THE CURRENT
C   COLLOCATION POINT, USING THE LOCAL INCIDENCE AND MACH NUMBER.
C
      MLOC=UT*MINF/MU
      ALOC=THC-TW*(RBO(I)-RO)/(1.-RO)+B1*CP1-A1*SP1
     1-(MU*AO*CP1+LAM)/UT
      ALOC=ALOC*180./PI
      CALL TABSCH(MCL,NXL,MLOC,IMCL1,IMCL2,INT)
      IF(INT .EQ. -1)IMCL1=IMCL2=1
      IF(INT .EQ. 1)IMCL1=IMCL2=NXL
      CALL TABSCH(ACL,NZL,ALOC,IACL1,IACL2,INT)
      IF(INT .EQ. 0)GO TO 131
      IF(INT .EQ. -1)GO TO 132
      IACL1=NXL-1
      IACL2=NXL
      GO TO 131
 132  IACL1=1
      IACL2=2
 131  SLC1=(CL(IACL2,IMCL1)-CL(IACL1,IMCL1))/(ACL(IACL2)
     1-ACL(IACL1))
      CL01=CL(IACL1,IMCL1)-SLC1*ACL(IACL1)
      SLC1=SLC1*180./PI
```

```
      SLC2=(CL(IACL2,IMCL2)-CL(IACL1,IMCL2))/(ACL(IACL2)
     1-ACL(IACL1))
      CLO2=CL(IACL1,IMCL2)-SLC2*ACL(IACL1)
      SLC2=SLC2*180./PI
      IF(IMCL1 .EQ. IMCL2)SLCR=SLC1/(2.*PI)
      IF(IMCL1 .NE. IMCL2)SLCR=YL(MLOC,MCL(IMCL1),MCL(IMCL2),
     1SLC1,SLC2)/(2.*PI)
      IF(IMCL1 .EQ. IMCL2)CLO=CLO1
      IF(IMCL1 .NE. IMCL2)CLO=YL(MLOC,MCL(IMCL1),MCL(IMCL2),
     1CLO1,CLO2)
 133  CONTINUE
C
C   CALCULATE THE CONTRIBUTION TO THE INDUCED VELOCITY FROM THE
C   TRAJECTORY SEGMENT ADJACENT TO THE COLLOCATION POINT, AND ADD TO
C   COEFFICIENT MATRIX ELEMENT. ALTERNATIVELY, SET UP THE ZERO LIFT
C   CONDITION.
C
 140  DO 150 I1=1,NSP
      IF(I1 .GT. 1)GO TO 160
      IF(UT .LE. UTMIN)GO TO 170
      IF(SLCR .EQ. 0.)GO TO 151
      W1=-AR*(1.+ZBO)*CF1/UT+MU*CP1*CF2/(UT*UT)-(2.*AR*(1.+ZBO)-
     1FUN3(RO,AR,RBO(I),1))/UT
      W2=(1.-RO)*(1.+ZBO)*CF2/(2.*UT*UT)-(1.-RO)*MU*CP1*CF3/(2.*AR*
     1UT*UT*UT)
      W3=(1.-RO)*(1.-RO)*(1.+ZBO)*CF3/(8.*AR*UT*UT*UT)
      W1=W1-AR*(1.+ZBO)*(1.-SLCR)/(SLCR*UT)
      GO TO 180
 151  W1=AR*(1.+ZBO)
      W2=W3=0.
      GO TO 180
 170  W1=AR*(1.+ZBO)-FUN3(RO,AR,RBO(I),1)
      W2=0.
      W3=0.
      GO TO 180
 160  NL=I1-1
      IF(UT .LE. UTMIN)GO TO 190
      POS=PNM(I1-1,0,ZBO)
      P1S=PNM(I1-1,1,ZBO)
      PO=FUN3(RO,AR,RBO(I),3)
      IF(SLCR .EQ. 0.)GO TO 152
      W1=-AR*SQZ*P1S*CF1/(2.*PI*UT)-MU*CP1*NL*(NL+1.)*POS*CF2/(2.*PI
     1*UT*UT)+MU*MU*CP1*CP1*NL*(NL+1.)*P1S*CF3/(4.*PI*AR*SQZ*UT
     2*UT*UT)-(AR*SQZ*P1S+PO/2.)/(PI*UT)
      W2=(1.-RO)*SQZ*P1S*CF2/(4.*PI*UT*UT)+(1.-RO)*MU*CP1*NL*(NL+1.)
     1*POS*CF3/(4.*PI*AR*UT*UT*UT)
      W3=(1.-RO)*(1.-RO)*SQZ*P1S*CF3/(16.*PI*AR*UT*UT*UT)
      W1=W1-AR*SQZ*P1S*(1.-SLCR)/(2.*PI*SLCR*UT)
      GO TO 180
 152  W1=AR*SQZ*P1S/(2.*PI)
      W2=W3=0.
      GO TO 180
 190  W1=(AR*SQZ*PNM(I1-1,1,ZBO)+FUN3(RO,AR,RBO(I),3))/(2.*PI)
      W2=0.
      W3=0.
 180  M=(I1-1)*NAZ+1
      A(L,M)=A(L,M)+W1
      DO 150 I2=1,NHM
      M=M+1
      A(L,M)=A(L,M)+(W1+I2*I2*W3)*COS(I2*PBO)-I2*W2*SIN(I2*PBO)
```

```
      M=M+1
      A(L,M)=A(L,M)+(W1+I2*I2*W3)*SIN(I2*PBO)+I2*W2*COS(I2*PBO)
  150 CONTINUE
      IF(UT .GT. UTMIN)GO TO 200
      M=NSP*NAZ+1
      A(L,M)=A(L,M)+(1.-RO)*(2.*MU*CP1)/(4.*AR)+(1.-RO)*(1.-RO)
     1*(-1.)/(16.*AR*AR)
      M=M+1
      A(L,M)=A(L,M)+(1.-RO)*(2.*MU*SP1+RBO(I))/(4.*AR)
      M=M+1
      A(L,M)=A(L,M)+(1.-RO)*(-2.*MU*SP2-2.*RBO(I)*CP1)/(4.*AR)+(1.-RO)
     1*(1.-RO)*(2.*SP1)/(16.*AR*AR)
      M=M+1
      A(L,M)=A(L,M)+(1.-RO)*(2.*MU*CP2-2.*RBO(I)*SP1)/(4.*AR)+(1.-RO)
     1*(1.-RO)*(-2.*CP1)/(16.*AR*AR)
      B(L,1)=B(L,1)-TW*(2.*MU*RO*CP1-MU*MU*SP2-4.*MU*RBO(I)*CP1)/(4.*AR)
     1-(1.-RO)*(-RO+4.*RBO(I)+4.*MU*SP1)*TW/(16.*AR*AR)
      L=L+1
      GO TO 100
  200 CONTINUE
      IF(SLCR .NE. 0.)GO TO 201
      B(L,1)=B(L,1)-UT*UT*CLO/(2.*PI)
      L=L+1
      GO TO 100
  201 B(L,1)=B(L,1)+UT*CLO/(2.*PI*SLCR)
C
C     PROGRAM STEP 5.
C     START CALCULATION OF THE INDUCED VELOCITY CONTRIBUTION THAT REQUIRES
C     INTEGRATION WITH AZIMUTH.
C     START LOOP FOR NUMBER OF BLADES.
C
      DO 210 IBL=1,NB
      DB=2.*PI*(IBL-1)/NB
C
C     CALL SUBROUTINE TO DETERMINE AZIMUTH POSITIONS AT WHICH TRAJECTORY
C     IS CLOSE TO A BLADE.
C
      IF(DP1 .NE. DP2)CALL DMIN(MU,LAM,DB,RBO(I),PBO,PLIM,DMAX,IMIN,
     1PMIN)
      J1=1
      K1=0
C
C     SET LOWER AND UPPER LIMITS FOR AZIMUTH SUB-INTERVAL.
C
      PB2=PBO
      IF(IBL .EQ. 1)PB1=PBO-DP
      IF(IBL .GT. 1)PB1=PBO-DP1
  220 CONTINUE
      G1=.5*(PB2+PB1)
      G2=.5*(PB2-PB1)
C
C     PROGRAM STEP 6.
C     START LOOP FOR 5-POINT GAUSS-CHEBYSCHEV INTEGRATION.
C
      DO 230 I1=1,5
      G=G1+G2*COS((2.*I1-1.)*PI/10.)
      FACT=SQRT((G-PB1)*(PB2-G))
      DO 230 M=1,NCOFP
      M1=(M-1)/NAZ+1
      M2=M-(M1-1)*NAZ
```

```
      IF(M1 .GT. NSP)GO TO 240
      M3=M2/2
      M4=M2-M3*2
      IF(M1 .GT. 1)GO TO 250
      IF(M2 .EQ. 1)FN=FUN2(RO,AR,TW,MU,LAM,RBO(I),PBO,DP,DB,G,1)
      GO TO 260
  250 NL=M1-1
      IF(M2 .EQ. 1)FN=FUN2(RO,AR,TW,MU,LAM,RBO(I),PBO,DP,DB,G,2)
  260 IF(M2 .EQ. 1)A(L,M)=A(L,M)+FN*FACT*PI/5.
      IF(M2 .GT. 1 .AND. M4 .EQ. 0)A(L,M)=A(L,M)+FN*COS(M3*(G+DB))
     1*FACT*PI/5.
      IF(M2 .GT. 1 .AND. M4 .GT. 0)A(L,M)=A(L,M)+FN*SIN(M3*(G+DB))
     1*FACT*PI/5.
      GO TO 230
  240 I2=M+2-(NSP*NAZ)
      FN=FUN2(RO,AR,TW,MU,LAM,RBO(I),PBO,DP,DB,G,I2)
      IF(M .LE. NCOF)A(L,M)=A(L,M)+FN*FACT*PI/5.
      IF(M .EQ. NCOFP)B(L,1)=B(L,1)+FN*FACT*PI/5.
  230 CONTINUE
C
C   PROGRAM STEP 7.
C   END OF LOOP FOR GAUSS-CHEBYSCHEV INTEGRATION.
C   REDEFINE UPPER AND LOWER LIMITS FOR THE NEXT AZIMUTH SUB-INTERVAL.
C   TEST TO SEE IF THE AZIMUTH LIMIT HAS BEEN REACHED. ALSO TEST TO SEE
C   IF THE TRAJECTORY IN THE NEXT SEGMENT IS CLOSE TO A BLADE, IN WHICH
C   CASE REDUCED SPACING MUST BE USED.
C
      PB2=PB1
      IF(PB2 .LE. PLIM)GO TO 210
      IF(DP1 .EQ. DP2)GO TO 270
      IF(J1 .GT. IMIN)GO TO 270
      IF(K1 .EQ. 0 .AND. PB2 .LE. (PMIN(J1)+PI/6.))GO TO 280
      IF(K1 .EQ. 1 .AND. PB2 .GT. (PMIN(J1)-PI/6.))GO TO 280
      IF(K1 .EQ. 1 .AND. PB2 .LE. (PMIN(J1)-PI/6.))GO TO 290
      IF(PB2 .GT. (PBO-PI/6.) .AND. IBL .EQ. 1)PB1=PB1-DP2
      IF(PB2 .LE. (PBO-PI/6.) .OR. IBL .GT. 1)PB1=PB1-DP1
      IF(K1 .EQ. 0 .AND. PB1 .LT. (PMIN(J1)+DP1))PB1=PMIN(J1)+DP1
      GO TO 220
  270 PB1=PB1-DP1
      GO TO 220
  280 PB1=PB1-DP2
      K1=1
      GO TO 220
  290 PB1=PB1-DP1
      K1=0
      J1=J1+1
      GO TO 220
  210 CONTINUE
C
C   PROGRAM STEP 8.
C   END OF LOOP FOR NUMBER OF BLADES.
C   SET UP THE COEFFICIENT MATRIX ELEMENTS CORRESPONDING TO THE
C   4 AUXILIARY UNKNOWNS, AND THE RIGHT HAND SIDE.
C
      M=NSP*NAZ+1
      A(L,M)=A(L,M)-UT-(1.-RO)*(2.*MU*CP1)*CF4/(2.*AR*UT)-
     1(1.-RO)*(1.-RO)*(-2.*MU*SP1)*CF5/(4.*AR*AR*UT*UT)
      M=M+1
      A(L,M)=A(L,M)+MU*CP1-(1.-RO)*(2.*MU*SP1+RBO(I))*CF4/(2.*AR*UT)
     1-(1.-RO)*(1.-RO)*(3.*MU*CP1)*CF5/(4.*AR*AR*UT*UT)
```

```
      M=M+1
      A(L,M)=A(L,M)+.5*MU*(1.-CP2)+RBO(I)*SP1-(1.-RO)*(-2.*MU*SP2
     1-2.*RBO(I)*CP1)*CF4/(2.*AR*UT)-(1.-RO)*(1.-RO)*(-4.*MU*CP2
     2+2.*RBO(I)*SP1-2.*MU*CP1*CP1)*CF5/(4.*AR*AR*UT*UT)
      M=M+1
      A(L,M)=A(L,M)-RBO(I)*CP1-.5*MU*SP2-(1.-RO)*(2.*MU*CP2-2.*RBO(I)
     1*SP1)*CF4/(2.*AR*UT)-(1.-RO)*(1.-RO)*(-4.*MU*SP2-2.*RBO(I)
     2*CP1-2.*MU*CP1*SP1)*CF5/(4.*AR*AR*UT*UT)
      B(L,1)=B(L,1)-MU*ALR-TW*(RBO(I)-RO)*UT/(1.-RO)-TW*(-2.*MU*RO*CP1
     1+MU*MU*SP2+4.*MU*RBO(I)*CP1)*CF4/(2.*AR*UT)-(1.-RO)*TW*
     2(2.*MU*RO*SP1+2.*MU*MU*CP2-4.*MU*RBO(I)*SP1+4.*MU*MU
     3*CP1*CP1)*CF5/(4.*AR*AR*UT*UT)
      L=L+1
  100 CONTINUE
C
C   PROGRAM STEP 9.
C   END OF COLLOCATION LOOP.
C   CALCULATE SPANWISE INTEGRALS NEEDED IN SUBSEQUENT STEPS.
C
      DO 300 I=1,NSP
      FI1(I)=0.
      FI2(I)=0.
  300 CONTINUE
      G1=.5*(1.+RO)
      G2=.5*(1.-RO)
      DO 310 I=1,10
      G=G1+G2*COS((2.*I-1.)*PI/20.)
      FACT=SQRT((G-RO)*(1.-G))
      DO 310 I1=1,NSP
      NL=I1-1
      IF(I1 .GT. 1)GO TO 320
      FI1(I1)=FI1(I1)+FACT*FUN3(RO,AR,G,1)*PI/10.
      FI2(I1)=FI2(I1)+FACT*FUN3(RO,AR,G,2)*PI/10.
      GO TO 310
  320 FI1(I1)=FI1(I1)+FACT*FUN3(RO,AR,G,3)*PI/10.
      FI2(I1)=FI2(I1)+FACT*FUN3(RO,AR,G,4)*PI/10.
  310 CONTINUE
C
C   PROGRAM STEP 10.
C   SET UP THE EXTRA 4 EQUATIONS NEEDED TO CLOSE THE SYSTEM.
C
      DO 330 I=1,4
      DO 340 M=1,NCOF
      A(L,M)=0.
  340 CONTINUE
      B(L,1)=0.
      IF(I .EQ. 1 .AND. N1 .EQ. 1)GO TO 350
      IF(I .EQ. 2 .AND. N2 .EQ. 1)GO TO 360
      IF(I .EQ. 3 .AND. N3 .EQ. 1)GO TO 370
      IF(I .EQ. 4 .AND. N4 .EQ. 1)GO TO 380
      IF(I .LE. 2)I1=1
      IF(I .GT. 2)I1=I-1
      IF(I .GT. 1)GO TO 390
C
C   THE FOLLOWING EQUATION SETS THE TOTAL BLADE LIFT,AVERAGED OVER
C   THE AZIMUTH, EQUAL TO THE THRUST COEFFICIENT.
C
      M=1
      A(L,M)=A(L,M)+(1.-RO)*(1.-RO)-(1.-RO)*FI1(1)/AR
      M=M+NAZ
```

```
      A(L,M)=A(L,M)+(1.-RO)*(1.-RO)/(3.*PI)
      DO 400 I2=2,NSP
      M=(I2-1)*NAZ+I1
      A(L,M)=A(L,M)+(1.-RO)*FI1(I2)/(2.*PI*AR)
  400 CONTINUE
      M=NSP*NAZ+1
      A(L,M)=A(L,M)-(1.-RO)*(1.-RO)*(1.-RO)*(1.-RO)/(16.*AR*AR*AR)
      M=M+1
      A(L,M)=A(L,M)+(1.-RO)*(1.-RO)*(1.-RO)*(1.+RO)/(8.*AR*AR)
      B(L,1)=B(L,1)+CT/NB-(1.-RO)*(1.-RO)*(1.-RO)*(2.+RO)*TW/(16.*AR*AR*
     1AR)
      L=L+1
      GO TO 330
C
C  THE NEXT THREE EQUATIONS (I=2,3,4) REPRESENT MOMENT EQUILIBRIUM
C  ABOUT THE HUB (ZEROTH HARMONIC, FIRST HARMONIC COSINE AND FIRST
C  HARMONIC SINE COMPONENTS).
  390 M=I1
      A(L,M)=A(L,M)-FI2(1)+AR*(.5*(1.-RO*RO)+(1.-RO)*(1.-RO)/6.)
      M=M+NAZ
      A(L,M)=A(L,M)+AR*(1.-RO*RO)/(6.*PI)
      M=M+NAZ
      A(L,M)=A(L,M)+AR*(1.-RO)*(1.-RO)/(10.*PI)
      DO 410 I2=2,NSP
      M=(I2-1)*NAZ+I1
      A(L,M)=A(L,M)+FI2(I2)/(2.*PI)
  410 CONTINUE
      M=NSP*NAZ+1
      IF(I .EQ. 2)A(L,M)=A(L,M)-(1.-RO)*(1.-RO)*(1.-RO)*(1.+RO)/(32.*
     1AR*AR)
      IF(I .EQ. 3)A(L,M)=A(L,M)+MU*(1.-RO)*(1.-RO*RO)/(4.*AR)
      M=M+1
      IF(I .EQ. 2)A(L,M)=A(L,M)+(1.-RO)*(1.-RO*RO*RO)/(12.*AR)
     1-2./GAMA
      IF(I .EQ. 4)A(L,M)=A(L,M)+(1.-RO)*(1.-RO*RO)*MU/(4.*AR)
      M=M+1
      IF(I .EQ. 3)A(L,M)=A(L,M)-(1.-RO)*(1.-RO*RO*RO)/(6.*AR)
      IF(I .EQ. 4)A(L,M)=A(L,M)+(1.-RO)*(1.-RO)*(1.-RO*RO)/(16.*AR*AR)
      M=M+1
      IF(I .EQ. 3)A(L,M)=A(L,M)-(1.-RO)*(1.-RO)*(1.-RO*RO)/(16.*AR*AR)
      IF(I .EQ. 4)A(L,M)=A(L,M)-(1.-RO)*(1.-RO*RO*RO)/(6.*AR)
      IF(I .EQ. 2)B(L,1)=B(L,1)-(1.-RO)*(1.-RO)*(1.-RO)*(1.-RO)*TW/(12.
     1*AR*AR)+RO*(1.-RO)*(1.-RO)*(1.+RO)*TW/(32.*AR*AR)
      IF(I .EQ. 3)B(L,1)=B(L,1)+MU*TW*(-RO*(1.-RO*RO)/4.+(1.-RO*RO*RO)/
     13.)/AR
      IF(I .EQ. 4)B(L,1)=B(L,1)-MU*TW*(1.-RO)*(1.-RO*RO)/(8.*AR*AR)
      L=L+1
      GO TO 330
C
C  THE FOLLOWING EQUATION SETS THE COLLECTIVE PITCH EQUAL TO THE
C  GIVEN VALUE.
C
  350 M=NSP*NAZ+1
      A(L,M)=1.
      B(L,1)=THC
      L=L+1
      GO TO 330
C
C  THE FOLLOWING EQUATION SETS THE CONING ANGLE EQUAL TO THE GIVEN
C  VALUE.
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```
C
  360  M=NSP*NAZ+2
       A(L,M)=1.
       B(L,1)=A0
       L=L+1
       GO TO 330
C
C  THE FOLLOWING EQUATION SETS THE CYCLIC PITCH COEFFICIENT, A1,EQUAL
C  TO THE GIVEN VALUE.
C
  370  M=NSP*NAZ+3
       A(L,M)=1.
       B(L,1)=A1
       L=L+1
       GO TO 330
C
C  THE FOLLOWING EQUATION SETS THE CYCLIC PITCH COEFFICIENT, B1, EQUAL
C  TO THE GIVEN VALUE.
C
  360  M=NSP*NAZ+4
       A(L,M)=1.
       B(L,1)=31
       L=L+1
  330  CONTINUE
C
C  PROGRAM STEP 11.
C  SOLVE THE SYSTEM OF SIMULTANEOUS EQUATIONS AND PRINT THE SOLUTION.
C
       CALL GELIM(NCOF,NCOF,A,1,B,IPIVOT,0,WK,IERR)
       IF(IERR .EQ. 1)GO TO 420
       L=1
       DO 430 I1=1,NSP
       GO(I1)=B(L,1)
       L=L+1
       DO 430 I2=1,NHM
       GC(I1,I2)=B(L,1)
       L=L+1
       GS(I1,I2)=B(L,1)
       L=L+1
  430  CONTINUE
       THC=B(NSP*NAZ+1,1)
       THCD=THC*180./PI
       A0=B(NSP*NAZ+2,1)
       A0D=A0*180./PI
       A1=B(NSP*NAZ+3,1)
       A1D=A1*180./PI
       B1=B(NSP*NAZ+4,1)
       B1D=B1*180./PI
       WRITE(6,10)
       WRITE(6,440)
  440  FORMAT(//6X,"SOLUTION FOR COEFFICIENTS"/6X,25(1H-)//6X,
      1"(GO(I),I=1,NSP)")
       WRITE(6,450)(GO(I),I=1,NSP)
  450  FORMAT(/6X,5(E10.4,1X))
       WRITE(6,460)
  460  FORMAT(//6X,"(GC(I,J),J=1,NHM),I=1,NSP)"//)
       DO 470 I=1,NSP
       WRITE(6,450)(GC(I,J),J=1,NHM)
  470  CONTINUE
       WRITE(6,480)
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 480  FORMAT(//6X,"(GS(I,J),J=1,NHM),I=1,NSP)"//)
      DO 490 I=1,NSP
      WRITE(6,450)(GS(I,J),J=1,NHM)
 490  CONTINUE
      WRITE(6,500)THCD,A0D,A1D,B1D
 500  FORMAT(//6X,"PITCH ANGLE AT BLADE ROOT=",F10.5,"DEGREES"//6X,
     1"CONING ANGLE=",F10.5,1X,"DEGREES"//6X,
     2"FLAPPING COEFFICIENT, A1=",F10.5,1X,"DEGREES"//6X,
     3"FLAPPING COEFFICIENT, B1=",F10.5,1X,"DEGREES")
C
C  PROGRAM STEP 12.
C  START LOOP FOR AZIMUTH STATIONS AT WHICH OUTPUT QUANTITIES ARE
C  CALCULATED.
C
      CTCAL=0.
      CMXCAL=0.
      CMYCAL=0.
      DO 510 I=1,24
      PBOD(I)=15.*(I-1.)
      PBO=(I-1.)*PI/12.
      CP1=COS(PBO)
      SP1=SIN(PBO)
      CP2=COS(2.*PBO)
      SP2=SIN(2.*PBO)
      F1(I)=-THC-TW*RO/(1.-RO)-2.*B1*CP1+(2.*A1+4.*MU*TW/(1.-RO))*SP1
      F2(I)=CP1*(2.*MU*TW*RO/(1.-RO)+2.*MU*THC)+2.*MU*A0*SP1
     1+2.*MU*B1*CP2-(2.*MU*A1+MU*MU*TW/(1.-RO))*SP2
      F3(I)=A0-CP1*(4.*MU*TW/(1.-RO)+2.*A1)-2.*B1*SP1
      FG1=G0(1)
      FG2=G0(2)
      FG3=G0(3)
      FN1=0.
      FN2=0.
      DO 520 I1=2,5
      FN1=FN1+FI1(I1)*G0(I1)
      FN2=FN2+FI2(I1)*G0(I1)
      DO 520 I2=1,NHM
      CI2=COS(I2*PBO)
      SI2=SIN(I2*PBO)
      IF(I1 .GT. 2)GO TO 530
      FG1=FG1+GC(1,I2)*CI2+GS(1,I2)*SI2
      FG2=FG2+GC(2,I2)*CI2+GS(2,I2)*SI2
      FG3=FG3+GC(3,I2)*CI2+GS(3,I2)*SI2
 530  FN1=FN1+FI1(I1)*(GC(I1,I2)*CI2+GS(I1,I2)*SI2)
      FN2=FN2+FI2(I1)*(GC(I1,I2)*CI2+GS(I1,I2)*SI2)
 520  CONTINUE
      FLT1(I)=-PI*(1.-RO)*FI1(1)*FG1/AR+PI*(1.-RO)*(1.-RO)*FG1+(1.-RO)*
     1(1.-RO)*FG2/3.+(1.-RO)*FN1/(2.*AR)+PI*(1.-RO)*(1.-RO)*(1.-RO)
     2*F2(I)/(4.*AR*AR)+PI*(1.-RO)*(1.-RO)*(1.-RO*RO)*F3(I)/(8.*
     3AR*AR)+PI*(1.-RO)*(1.-RO)*(1.-RO)*(1.-RO)*(F1(I)+2.*TW*(1.+RO)
     4/(1.-RO))/(16.*AR*AR*AR)
      FLT2(I)=FLT1(I)/(CT*PI/NB)
      FMT(I)=-PI*(1.-RO)*FI2(1)*FG1/AR+PI*(1.-RO)*(.5*(1.-RO*RO)+(1.-RO)
     1*(1.-RO)/6.)*FG1+(1.-RO)*(1.-RO*RO)*FG2/6.+(1.-RO)*(1.-RO)
     2*(1.-RO)*FG3/10.+(1.-RO)*FN2/(2.*AR)+PI*(1.-RO)*(1.-RO)*
     3(1.-RO*RO)*F2(I)/(8.*AR*AR)+PI*(1.-RO)*(1.-RO)*(1.-RO*RO*RO)
     4*F3(I)/(12.*AR*AR)+PI*(1.-RO)*(1.-RO)*(1.-RO)*(1.-RO*RO)*F1(I)
     5/(32.*AR*AR*AR)+PI*TW*(1.-RO)*(1.-RO)*(1.-RO*RO*RO)/(12.*AR
     6*AR*AR)
      COL(I)=FMT(I)/FLT1(I)
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      CTCAL=CTCAL+FLT1(I)/24.
      CMXCAL=CMXCAL+FMT(I)*SP1/24.
      CMYCAL=CMYCAL-FMT(I)*CP1/24.
C
C  START LOOP FOR RADIAL STATIONS AT WHICH OUTPUT QUANTITIES ARE
C  CALCULATED.
C
      DO 510 I1=1,NSP
      F23=F2(I)+RBO(I1)*F3(I)
      ZB=2.*(RBO(I1)-.5*(1.+RO))/(1.-RO)
      UT=RBO(I1)+MU*SP1
      SQZ=SQRT(1.-ZB*ZB)
      FNO=FUN3(RO,AR,RBO(I1),1)
      FN1=0.
      FN2=0.
      FN3=0.
      DO 540 I2=2,5
      NL=I2-1
      PN1=PNM(I2-1,1,ZB)
      PN2=FUN3(RO,AR,RBO(I1),3)
      FN1=FN1+GC(I2)*PN1
      FN2=FN2+GO(I2)*PN2
      FN3=FN3+GC(I2)*NL*(NL+1.)*PN1
      DO 540 I3=1,NHM
      CI3=COS(I3*PBO)
      SI3=SIN(I3*PBO)
      FN1=FN1+PN1*(GC(I2,I3)*CI3+GS(I2,I3)*SI3)
      FN2=FN2+PN2*(GC(I2,I3)*CI3+GS(I2,I3)*SI3)
      FN3=FN3+NL*(NL+1.)*PN1*(GC(I2,I3)*CI3+GS(I2,I3)*SI3)
  540 CONTINUE
      GST(I,I1)=AR*((1.+ZB)*FG1+SQZ*FN1/(2.*PI))
      PDIP(I,I1)=-FNO*FG1+FN2/(2.*PI)
      DGS2(I,I1)=-AR*FN3/(2.*PI*SQZ)
      FL1(I,I1)=(1.-RO)*PI*(PDIP(I,I1)+GST(I,I1)+(1.-RO)*F23/
     1(4.*AR)+(1.-RO)*(1.-RO)*(F1(I)+4.*TW*RBO(I1)/(1.-RO))/
     2(16.*AR*AR))/AR
      FL2(I,I1)=FL1(I,I1)/(CT*PI/NB)
      FM(I,I1)=GST(I,I1)+(2.*DGS2(I,I1)+(1.-RO)*(1.-RO)*(F1(I)+4.*TW
     1*RBO(I1)/(1.-RO)))/(32.*AR*AR)
      FM(I,I1)=FM(I,I1)*PI*(1.-RO)*(1.-RO)/(4.*AR*AR)
      FM(I,I1)=FM(I,I1)+(1.-RO)*FL1(I,I1)/(4.*AR)
      XCP(I,I1)=.25+FM(I,I1)*AR/(FL1(I,I1)*(1.-RO))
  510 CONTINUE
      CTCAL=CTCAL*NB/PI
      CMXCAL=CMXCAL*NB/PI
      CMYCAL=CMYCAL*NB/PI
      WRITE(6,541)CTCAL,CMXCAL,CMYCAL
  541 FORMAT(/6X,"COMPUTED THRUST COEFFICIENT=",E10.4//6X,
     1"COMPUTED MOMENT COEFFICIENT ABOUT ROTOR X-AXIS=",E10.4//6X,
     2"COMPUTED MOMENT COEFFICIENT ABOUT ROTOR Y-AXIS=",E10.4)
C
C  PRINT OUTPUT IN TABULAR FORM.
C
      WRITE(6,10)
      WRITE(6,550)
  550 FORMAT(//6X,"TABLE 1 - SECTIONAL LIFT/(RHO*(OMEGA**2)*(R1**3))"/6X
     1,49(1H-)//)
      WRITE(6,560)(RBO(I),I=1,NSP)
  560 FORMAT(/12X,"R/R1:  ",5(E10.4,1X))
      WRITE(6,570)
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570  FORMAT(/7X,"PSI")
     DO 580 I=1,24
     WRITE(6,590)PBOD(I),(FL1(I,I1),I1=1,NSP)
590  FORMAT(/6X,F5.1,8X,5(E10.4,1X))
580  CONTINUE
     WRITE(6,10)
     WRITE(6,600)
600  FORMAT(//6X,"TABLE 2 - SECTIONAL LIFT*R1/THRUST PER BLADE"/6X,
    144(1H-)//)
     WRITE(6,560)(RBO(I),I=1,NSP)
     WRITE(6,570)
     DO 610 I=1,24
     WRITE(6,590)PBOD(I),(FL2(I,I1),I1=1,NSP)
610  CONTINUE
     WRITE(6,10)
     WRITE(6,620)
620  FORMAT(//6X,"TABLE 3 - SECTIONAL PITCHING MOMENT/(RHO*(OMEGA**2)*(
    1R1**4))"/6X,60(1H-)/16X,"(ABOUT QUARTER-CHORD)"//)
     WRITE(6,560)(RBO(I),I=1,NSP)
     WRITE(6,570)
     DO 630 I=1,24
     WRITE(6,590)PBOD(I),(FM(I,I1),I1=1,NSP)
630  CONTINUE
     WRITE(6,10)
     WRITE(6,640)
640  FORMAT(//6X,"TABLE 4 - CENTER OF PRESSURE LOCATION FROM LEADING ED
    1GE(FRACTION OF CHORD)"/6X,74(1H-)//)
     WRITE(6,560)(RBO(I),I=1,NSP)
     WRITE(6,570)
     DO 650 I=1,24
     WRITE(6,590)PBOD(I),(XCP(I,I1),I1=1,NSP)
650  CONTINUE
     WRITE(6,10)
     WRITE(6,660)
660  FORMAT(//6X,"TABLE 5 - TOTAL BLADE LIFT, MOMENT ABOUT HUB AND RADI
    1AL CENTER OF LIFT"/6X,70(1H-)//6X,
    2"TOTAL BLADE LIFT/(RHO*(OMEGA**2)*(R1**4))"/6X,
    3"TOTAL BLADE LIFT/THRUST PER BLADE"/6X,
    4"MOMENT ABOUT HUB/(RHO*(OMEGA**2)*(R1**5))"/6X,
    5"RADIAL CENTER OF LIFT/R1"//7X,"PSI",8X,"TOTAL BLADE LIFT",
    65X,"MOMENT",5X,"CENTER"/38X,"ABOUT HUB",4X,"OF LIFT")
     DO 670 I=1,24
     WRITE(6,680)PBOD(I),FLT1(I),FLT2(I),FMT(I),COL(I)
680  FORMAT(/6X,F5.1,5X,4(E10.4,1X))
670  CONTINUE
     WRITE(6,10)
     WRITE(6,690)
690  FORMAT(//6X,"TABLE 6 -SURFACE PRESSURE DIFFERENTIAL/(RHO*(OMEGA**2
    1)*(R1**2))"/6X,64(1H-)//)
     DO 700 I=1,24
     WRITE(6,710)PBOD(I)
710  FORMAT(/6X,"AZIMUTH ANGLE=",F5.1,1X,"DEGREES"/6X,27(1H-))
     WRITE(6,560)(RBO(I1),I1=1,NSP)
     WRITE(6,720)
720  FORMAT(11X,"X/C")
     DO 730 I1=1,NSP
     F23=F2(I)+RBO(I1)*F3(I)
     DO 740 I2=1,10
     CCH=2.*XOUT(I2)-1.
     SCH=SQRT(1.-CCH*CCH)
```

```
      POUT(I1,I2)=-GST(I,I1)*SCH/(1.+CCH)+2.*SCH*(PDIP(I,I1)+2.*GST
     1(I,I1))+DGS2(I,I1)*SCH*SCH/(4.*AR*AR)+F23*(1.-RO)*SCH/(2.*AR)
     2+(F1(I)+4.*TW*RBO(I1)/(1.-RO))*(1.-RO)*(1.-RO)*(1.-RO)*
     3SCH*(1.+CCH)/(8.*AR*AR)
      POUT(I1,I2)=2.*POUT(I1,I2)
  740 CONTINUE
  730 CONTINUE
      DO 750 I2=1,10
      WRITE(6,755)XOUT(I2),(POUT(I1,I2),I1=1,NSP)
  755 FORMAT(6X,F8.5,5X,5(E10.4,1X))
  750 CONTINUE
      IPG=3
      IREM=I-(I/IPG)*IPG
      IF(IREM .EQ. 0)WRITE(6,10)
  700 CONTINUE
      STOP
C
C  PRINT ERROR MESSAGE IF COEFFICIENT MATRIX IS SINGULAR.
C
  420 WRITE(6,760)
  760 FORMAT(/6X,"COEFFICIENT MATRIX IS SINGULAR")
      STOP
      END
      SUBROUTINE DMIN(MU,LAM,DB,RBO,PBO,PLIM,DMAX,I,P)
C
C  CALCULATION OF AZIMUTH POSITIONS AT WHICH TRAJECTORY IS DIRECTLY
C  OVER A BLADE, WITHIN A DISTANCE DMAX.
C
      REAL MU,LAM
      DIMENSION P(20)
      Y(X,X1,X2,Y1,Y2)=Y1+(Y2-Y1)*(X-X1)/(X2-X1)
      I=0
      P1=0.
      XB1=0.
      P2=-0.2
   10 XB2=RBO*SIN(P2+DB)+MU*SIN(P2+PBO+DB)*P2
      IF(P1 .NE. 0.)GO TO 20
   30 P1=P2
      IF(P1 .LE. PLIM)RETURN
      P2=P2-0.2
      XB1=XB2
      GO TO 10
   20 TEST=XB1*XB2
      IF(TEST .GT. 0.)GO TO 30
      PC=Y(0.,XB1,XB2,P1,P2)
      XBC=RBO*SIN(PC+DB)+MU*SIN(PC+PBO+DB)*PC
      RBC=RBO*COS(PC+DB)+MU*COS(PC+PBO+DB)*PC
      D=SQRT(XBC*XBC+LAM*LAM*PC*PC+(RBC-RBO)*(RBC-RBO))
      IF(D .GT. DMAX)GO TO 30
      I=I+1
      P(I)=PC
      GO TO 30
      END
      SUBROUTINE TRAJ(RO,AR,MU,LAM,RBO,PBO,DB,PB,ZS)
C  THIS SUBROUTINE CALCULATES THE PARAMETERS FOR THE LINEARISED
C  TRAJECTORY CORRESPONDING TO A GIVEN COLLOCATION POINT.
      REAL MU,LAM
      COMMON/TRAJ1/R,SX,CX,SHP,CHP,ST,CT,SHE,CHE,SP,CP
      XB=RBO*SIN(PB+DB-PBO)+MU*(PB-PBO)*SIN(PB+DB)
      YB=LAM*(PB-PBO)
```

```
      Z3=-.5*(1.+RO)+RBO*COS(PB+DB-PBO)+MU*(PB-PBO)*COS(PB+DB)
      R=SQRT(XB*XB+YB*YB)
      SX=YB/R
      CX=XB/R
      XS=2.*XB/(1.-RO)
      YS=2.*YB/(1.-RO)
      ZS=2.*ZB/(1.-RO)
      RS=2.*R/(1.-RO)
      R1=SQRT(RS*RS+(1.+ZS)*(1.+ZS))
      R2=SQRT(RS*RS+(1.-ZS)*(1.-ZS))
      CHP=(R1+R2)/2.
      SHP=SQRT(CHP*CHP-1.)
      CT=ZS/CHP
      ST=RS/SHP
      R3=SQRT((XS*AR-1.5)*(XS*AR-1.5)+YS*YS*AR*AR)
      R4=SQRT((XS*AR+.5)*(XS*AR+.5)+YS*YS*AR*AR)
      CHE=(R3+R4)/2.
      IF(CHE .LE. 1.)CHE=ABS((R4-R3)/2.)
      SHE=SQRT(CHE*CHE-1.)
      CP=(XS*AR-.5)/CHE
      SP=AR*YS/SHE
      RETURN
      END
      FUNCTION FUN1(RO,AR,I)
C   THIS SUBPROGRAM RETURNS THE VALUES OF VARIOUS FUNCTIONS REQUIRED
C   IN FUNCTION FUN2.
      COMMON/MAIN1/N,PI
      COMMON/TRAJ1/R,SX,CX,SHP,CHP,ST,CT,SHE,CHE,SP,CP
      GO TO (10,20,30,40,50,60),I
   10 F1=SHP*SHP*(CHP-CT)
      F2=(CHP-CT)*(CHP-CT)
      F3=(CHP-CT)*(CHP+CT)
      F4=(SHP*SHP*CT*CT-CHP*CHP*ST*ST)/F1-ST*ST*(CHP+CT)/F2
      FUN1=-2.*(SX*SX*F4/F3+CX*CX/F1)/(1.-RO)
      RETURN
   20 PN1=PNM(N,1,CT)
      PN2=PNM(N,2,CT)
      QN1=QNM(N,1,CHP)
      QN2=QNM(N,2,CHP)
      F1=1./(ST*SHP)
      F2=SX*SX/(SHP*SHP+ST*ST)
      FUN1=(F1*PN1*QN1+F2*(ST*CHP*PN1*QN2-CT*SHP*PN2*QN1))/(PI*(1.-RO))
      RETURN
   30 F1=SHP*SHP+ST*ST
      F2=F1*SHP*SHP
      F3=CHP/F1-CHP*CHP*CHP*ST*ST/F2
      F3=F3-2.*CHP*ST*ST*(CHP*CHP+CT*CT)/(F1*F1)
      F3=F3*SX*SX/F1
      FUN1=2.*(F3+CX*CX*CHP/F2)/(1.-RO)
      RETURN
   40 FUN1=(1.-RO)*(CX*CX-SX*SX)/(R*R)
      RETURN
   50 F1=SHE*SHE*CP*CP+CHE*CHE*SP*SP
      F2=(CHE+CP)*(CHE+CP)
      FUN1=2.*AR*(SHE*CP+SHE*CHE*(CP*CP-SP*SP))/((1.-RO)*F1*F2)
      RETURN
   60 F1=SHE*SHE*CP*CP+CHE*CHE*SP*SP
      F2=SHE*CP*CP-CHE*SP*SP
      FUN1=2.*AR*(CHE-SHE)*F2/((1.-RO)*F1)
      RETURN
```

```
      END
      FUNCTION FUN2(RO,AR,TW,MU,LAM,RBO,PBO,DP,DB,X,I)
C  THIS SUBPROGRAM SETS UP THE INTEGRAND FOR THE INTEGRATION REQUIRED
C  FOR THE INDUCED VELOCITY IN THE MAIN PROGRAM.
      REAL MU,LAM
      COMMON/MAIN1/N,PI
      COMMON/FUN21/F1,F2,F3,F4,F5,F6,ZBS
      P=X+DB
      IF(I .EQ. 2)GO TO 20
      IF(I .GT. 2)GO TO 40
      CALL TRAJ(RO,AR,MU,LAM,RBO,PBO,DB,X,ZS)
      ZBS=ZS
      F1=FUN1(RO,AR,1)
      F3=FUN1(RO,AR,3)
      F4=FUN1(RO,AR,4)
      F5=FUN1(RO,AR,5)
      F6=FUN1(RO,AR,6)
      FUN2=-F1
      IF(ABS(ZBS) .GT. 1.)GO TO 10
      FUN2=FUN2-(1.+ZBS)*F4/2.
   10 IF(DB .EQ. 0. .AND. X .GT. (PBO-DP))RETURN
      IF(ABS(ZBS) .GT. 1.)RETURN
      FUN2=FUN2+AR*(1.+ZBS)*F5
      RETURN
   20 F2=FUN1(RO,AR,2)
      FUN2=-F2
      IF(ABS(ZBS) .GT. 1.)GO TO 30
      PN1=PNM(N,1,ZBS)
      FUN2=FUN2-PN1*SQRT(1.-ZBS*ZBS)*F4/(4.*PI)
   30 IF(DB .EQ. 0. .AND. X .GT. (PBO-DP))RETURN
      IF(ABS(ZBS) .GT. 1.)RETURN
      FUN2=FUN2+AR*SQRT(1.-ZBS*ZBS)*PN1*F5/(2.*PI)
      RETURN
   40 ITEST=I-2
      ZB=(1.-RO)*ZBS/2.
      RB=ZB+.5*(1.+RO)
      GO TO (50,60,70,80,90),ITEST
   50 FN2=2.*MU*COS(P)
      FN3=0.
      GO TO 100
   60 FN2=2.*MU*SIN(P)
      FN3=1.
      GO TO 100
   70 FN2=-2.*MU*SIN(2.*P)
      FN3=-2.*COS(P)
      GO TO 100
   80 FN2=2.*MU*COS(2.*P)
      FN3=-2.*SIN(P)
      GO TO 100
   90 FN2=-TW*(2.*MU*COS(P)+MU*MU*SIN(2.*P))/(1.-RO)
      FN3=4.*MU*TW*COS(P)/(1.-RO)
  100 FUN2=-(1.-RO)*F3*(FN2+RO*FN3)/(4.*AR*AR)
      FUN2=FUN2+(1.-RO)*(1.-RO)*FN3*F1/(8.*AR*AR)
      IF(ABS(ZBS) .GT. 1.)GO TO 110
      FUN2=FUN2+(1.-RO)*(FN2+RB*FN3)*F4/(8.*AR*AR)
  110 IF(DB .EQ. 0. .AND. X .GT. (PBO-DP))RETURN
      IF(ABS(ZBS) .GT. 1.)RETURN
      FUN2=FUN2-(1.-RO)*(FN2+RB*FN3)*F6/(2.*AR)
      RETURN
      END
```

```
      FUNCTION FUN3(RO,AR,X,I)
C     THIS SUBPROGRAM SETS UP THE INTEGRAND FOR SOME SPANWISE INTEGRALS
C     REQUIRED IN THE MAIN PROGRAM.
      COMMON/MAIN1/N,PI
      ZBS=2.*(X-.5*(1.+RO))/(1.-RO)
      R1=SQRT(1./(16.*AR*AR)+.25*(1.+ZBS)*(1.+ZBS))
      R2=SQRT(1./(16.*AR*AR)+.25*(1.-ZBS)*(1.-ZBS))
      CHP1=R1+R2
      SHP1=SQRT(CHP1*CHP1-1.)
      CT1=ZBS/CHP1
      ST1=1./(2.*AR*SHP1)
      IF(I .LE. 2)GO TO 10
      PN1=PNM(N,1,CT1)
      QN1=QNM(N,1,CHP1)
      GO TO 20
   10 F1=ST1/(SHP1*(CHP1-CT1))
      IF(I .EQ. 1)FUN3=F1
      IF(I .EQ. 2)FUN3=X*F1
      RETURN
   20 F2=PN1*QN1
      IF(I .EQ. 3)FUN3=F2
      IF(I .EQ. 4)FUN3=X*F2
      RETURN
      END
      FUNCTION PNM(N,M,X)
C     CALCULATION OF ASSOCIATED LEGENDRE FUNCTIONS PNM.
C     RANGE: 0 .LE. N .LE. 4, 0 .LE. M .LE. 3, ABS(X) .LT. 1.
      IF(N .LT. 1 .OR. N .GT. 4)GO TO 10
      IF(M .LT. 0 .OR. M .GT. 3)GO TO 20
      IF(ABS(X) .GE. 1.)GO TO 30
      SX=SQRT(1.-X*X)
      IF(M .EQ. 1)GO TO 40
      IF(M .EQ. 2)GO TO 50
      IF(M .EQ. 3)GO TO 180
      GO TO (60,70,80,90),N
   60 PNM=X
      RETURN
   70 PNM=.5*(3.*X*X-1.)
      RETURN
   80 PNM=.5*(5.*X*X*X-3.*X)
      RETURN
   90 PNM=(35.*X*X*X*X-30.*X*X+3.)/8.
      RETURN
   40 GO TO (100,110,120,130),N
  100 PNM=SX
      RETURN
  110 PNM=3.*X*SX
      RETURN
  120 PNM=.5*SX*(15.*X*X-3.)
      RETURN
  130 PNM=.5*SX*(35.*X*X*X-15.*X)
      RETURN
   50 GO TO (140,150,160,170),N
  140 PNM=0.
      RETURN
  150 PNM=3.*SX*SX
      RETURN
  160 PNM=15.*X*SX*SX
      RETURN
  170 PNM=.5*SX*SX*(105.*X*X-15.)
```

```
      RETURN
  160 GO TO (190,200,210,220),N
  190 PNM=0.
      RETURN
  200 PNM=0.
      RETURN
  210 PNM=15.*SX*SX*SX
      RETURN
  220 PNM=105.*X*SX*SX*SX
      RETURN
   10 WRITE(6,11)N
   11 FORMAT(6X,*N=*,I5,1X,*INVALID N IN PNM*)
      STOP
   20 WRITE(6,21)M
   21 FORMAT(6X,*M=*,I5,1X,*INVALID M IN PNM*)
      STOP
   30 WRITE(6,31)X
   31 FORMAT(6X,*X=*,E10.4,1X,*INVALID X IN PNM*)
      STOP
      END
      FUNCTION QNM(N,M,X)
C     CALCULATION OF ASSOCIATED LEGENDRE FUNCTIONS QNM.
C     RANGE: 1 .LE. N .LE. 4, 1 .LE. M .LE. 2, ABS(X) .GT. 1.
C     ASYMPTOTIC EXPANSIONS USED FOR X .GT. 3.
      IF(N .LT. 1 .OR. N .GT. 4)GO TO 10
      IF(M .LT. 1 .OR. M .GT. 2)GO TO 20
      IF(ABS(X) .LE. 1.)GO TO 30
      SX=SQRT(X*X-1.)
      ALX=ALOG((X+1.)/(X-1.))
      X2=X*X
      X3=X2*X
      X4=X3*X
      X5=X4*X
      X6=X5*X
      X7=X6*X
      X8=X7*X
      X9=X8*X
      X10=X9*X
      X11=X10*X
      X12=X11*X
      IF(M .EQ. 2)GO TO 40
      GO TO (50,60,70,80),N
   50 IF(X .GT. 3.)GO TO 51
      QNM=SX*(.5*ALX-X/(SX*SX))
      RETURN
   51 QNM=-SX*(2./(3.*X3)+4./(5.*X5)+6./(7.*X7)+8./(9.*X9))
      RETURN
   60 IF(X .GT. 3.)GO TO 61
      QNM=SX*(1.5*X*ALX-(3.*X2-1.)/(2.*SX*SX)-1.5)
      RETURN
   61 QNM=-SX*(2./(5.*X4)+4./(7.*X6)+2./(3.*X8)+8./(11.*X10))
      RETURN
   70 IF(X .GT. 3.)GO TO 71
      QNM=SX*((15.*X2-3.)*ALX/4.-(5.*X3-3.*X)/(2.*SX*SX)-5.*X)
      RETURN
   71 QNM=-SX*(8./(35.*X5)+8./(21.*X7)+16./(33.*X9)+10./(13.*X11))
      RETURN
   80 IF(X .GT. 3.)GO TO 81
      QNM=SX*((35.*X3-15.*X)*ALX/4.-(35.*X4-30.*X2+3.)/(8.*SX*SX)
     1-105.*X2/8.+55./24.)
```

```
      RETURN
   81 QNM=-SX*(8./(63.*X6)+8./(33.*X8)+48./(143.*X10))
      RETURN
   40 GO TO (90,100,110,120),N
   90 IF(X .GT. 3.)GO TO 91
      QNM=2./(SX*SX)
      RETURN
   91 QNM=SX*SX*(2./X4+4./X6+6./X8+8./X10)
      RETURN
  100 IF(X .GT. 3.)GO TO 101
      QNM=SX*SX*(1.5*ALX-6.*X/(SX*SX)+X*(3.*X2-1.)/(SX*SX*SX*SX))
      RETURN
  101 QNM=SX*SX*(8./(5.*X5)+24./(7.*X7)+16./(3.*X9)+80./(11.*X11))
      RETURN
  110 IF(X .GT. 3.)GO TO 111
      QNM=SX*SX*(15.*X*ALX/2.-(15.*X2-3.)/(SX*SX)+X*(5.*X3-3.*X)
     1/(SX*SX*SX*SX)-5.)
      RETURN
  111 QNM=SX*SX*(8./(7.*X6)+8./(3.*X8)+48./(11.*X10)+110./(13.*X12))
      RETURN
  120 IF(X .GT. 3.)GO TO 121
      QNM=SX*SX*((105.*X2-15.)*ALX/4.-(35.*X3-15.*X)/(SX*SX)
     1+X*(35.*X4-30.*X2+3.)/(4.*SX*SX*SX*SX)-105.*X/4.)
      RETURN
  121 QNM=SX*SX*(16./(21.*X7)+64./(33.*X9)+480./(143.*X11))
      RETURN
   10 WRITE(6,11)N
   11 FORMAT(6X,*N=*,I5,1X,*INVALID N IN QNM*)
      STOP
   20 WRITE(6,21)M
   21 FORMAT(6X,*M=*,I5,1X,*INVALID M IN QNM*)
      STOP
   30 WRITE(6,31)X
   31 FORMAT(6X,*X=*,E10.4,1X,*INVALID X IN QNM*)
      STOP
      END
      SUBROUTINE TABSCH(X,N,XT,I1,I2,INT)
C
C  GIVEN AN ARRAY X, TO LOCATE THE POSITION OF A VALUE XT.
C  IF INT=0, XT LIES BETWEEN X(I1) AND X(I2).
C  IF INT=1, XT IS GREATER THAN X(N).
C  IF INT=-1, XT IS LESS THAN X(1).
C
      DIMENSION X(N)
      I1=0
      I2=0
      NM=N-1
      DO 10 I=1,NM
      IF(XT .GE. X(I) .AND. XT .LE. X(I+1))GO TO 20
   10 CONTINUE
      IF(XT .LT. X(1))GO TO 30
      IF(XT .GT. X(N))GO TO 40
   20 INT=0
      IF(XT .EQ. X(I))GO TO 21
      IF(XT .EQ. X(I+1))GO TO 22
      I1=I
      I2=I+1
      RETURN
   21 I1=I2=I
      RETURN
```

```
22   I1=I2=I+1
     RETURN
30   INT=-1
     RETURN
40   INT=1
     RETURN
     END
```

APPENDIX B

LISTING OF PROGRAM ASYMP2

```
      PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     1AFDATA,TAPE1=AFDATA)
C
C  COMPUTATION OF THE UNSTEADY AIRLOADS ON A HELICOPTER ROTOR BLADE IN
C  FORWARD FLIGHT, USING A SIMPLIFIED VERSION OF THE ASYMPTOTIC APPROACH
C  PROPOSED BY VAN HOLTEN. THE DIPOLE STRENGTH DISTRIBUTION ALONG THE
C  BLADE IS APPROXIMATED BY A PIECEWISE CONSTANT OR PIECEWISE QUADRATIC
C  REPRESENTATION. THE HELICAL TRAJECTORY OF THE FREESTREAM FLUID
C  PARTICLE RELATIVE TO THE BLADE IS APPROXIMATED BY SUCCESSIVE STRAIGHT
C  LINE SEGMENTS.
C  FOR IDENTIFICATION OF PROGRAM STEPS, REFER USER'S MANUAL.
C
      REAL MU,LAM,MCL,MINF,MLOC
      DIMENSION R(6),RBO(5),DR(5),X(6),FX1(5),FX2(5),P1(5),P2(5),IP(5),
     1FG(5),WK(59),BT(4),GF(4,5),PMIN(20),GO(5),GC(5,5),GS(5,5),G(24,5),
     2A(59,59),B(59,1),IPIVOT(59),PGOD(24),FLT1(24),FLT2(24),
     3FMT(24),COL(24),GL(5),GR(5),FL1(24,5),FL2(24,5),FM(24,5),
     4XCP(24,5),XOUT(10),F23(24,5),POUT(5,10)
      DIMENSION CL(50,20),MCL(20),ACL(50)
      COMMON/MAIN1/XBI,XBS,YBS,RBI,RBS
      YL(XL,XL1,XL2,YL1,YL2)=YL1+(XL-XL1)*(YL2-YL1)/(XL2-XL1)
      DATA X/-1.,-.9,-.6,0.,.5,1./
      DATA NSP,NHM,NAZ,NCOF,DMAX/5,5,11,59,0.5/
      DATA XOUT/.05,.1,.2,.3,.4,.5,.7,.9,.95,.99/
      PI=4.*ATAN(1.)
C
C  PROGRAM STEP 1.
C  READ AND WRITE INPUT DATA AND ASSOCIATED QUANTITIES.
C
      READ(5,*)RO,AR,NB,TW,MU,ALR,CT,MINF
      READ(5,*)N1,N2,N3,N4
      IF(N1 .EQ. 1)READ(5,*)THC
      IF(N2 .EQ. 0)READ(5,*)GAMA
      IF(N2 .EQ. 1)READ(5,*)AO
      IF(N3 .EQ. 1)READ(5,*)A1
      IF(N4 .EQ. 1)READ(5,*)B1
      READ(5,*)(R(I),I=2,6)
C
C  ISEL .EQ. 0 -- PIECEWISE CONSTANT REPRESENTATION.
C  ISEL .EQ. 1 -- PIECEWISE QUADRATIC REPRESENTATION.
C
      READ(5,*)DP1D,DP2D,UTMIN,ISEL,NAFD
C
C  NAFD=0 -- AIRFOIL TABLES NOT USED.
C  NAFD=1 -- AIRFOIL TABLES USED.
C
      IF(NAFD .EQ. 0)GO TO 8
      READ(1,1)NXL,NZL
    1 FORMAT(30X,2I2)
      READ(1,2)(MCL(I),I=1,NXL)
    2 FORMAT(7X,9F7.0)
      NL1=NXL/9
      NL2=NL1+1
      DO 3 I=1,NZL
      DO 3 J=1,NL2
      J1=(J-1)*9+1
      J2=J*9
      IF(J1 .GT. NXL)GO TO 3
      IF(J2 .GT. NXL)J2=NXL
```

```
      IF(J .EQ. 1)READ(1,4)ACL(I),(CL(I,J3),J3=J1,J2)
    4 FORMAT(F7.0,9F7.0)
      IF(J .GT. 1)READ(1,5)(CL(I,J3),J3=J1,J2)
    5 FORMAT(7X,9F7.0)
    3 CONTINUE
    6 CONTINUE
      DP1=DP1D*PI/180.
      DP2=DP2D*PI/180.
      WRITE(6,9)
    9 FORMAT(1H1)
      WRITE(6,10)RO,AR,NB,TW,MU,ALR,MINF
   10 FORMAT(//6X,"ROOT RADIUS/TIP RADIUS= RO/R1 =",F10.5//6X,
     1"ASPECT RATIO=",F10.5//6X,"NUMBER OF BLADES=",I2//6X,
     2"LINEAR TWIST (ROOT TO TIP) =",F10.5,1X,"DEGREES"//6X,
     3"FORWARD SPEED/TIP SPEED=",F10.5//6X,
     4"ROTOR INCIDENCE (FORWARD TILT POSITIVE) =",F10.5,1X,
     5"DEGREES"//6X,"FREESTREAM MACH NUMBER=",F10.5)
      R(1)=RO
      TW=TW*PI/180.
      ALR=ALR*PI/180.
      IF(N1 .EQ. 0)THC=0.
      IF(N2 .EQ. 0)A0=0.
      IF(N3 .EQ. 0)A1=0.
      IF(N4 .EQ. 0)B1=0.
      WRITE(6,11)CT
   11 FORMAT(/6X,"THRUST COEFFICIENT=",F10.5)
      IF(N1 .EQ. 1)WRITE(6,12)THC
   12 FORMAT(/6X,"PITCH ANGLE AT BLADE ROOT=",F10.5,1X,"DEGREES")
      IF(N2 .EQ. 0)WRITE(6,13)GAMA
   13 FORMAT(/6X,"FLAPPING INERTIA COEFFICIENT=",F10.5)
      IF(N2 .EQ. 1)WRITE(6,14)A0
   14 FORMAT(/6X,"CONING ANGLE=",F10.5,1X,"DEGREES")
      IF(N3 .EQ. 1)WRITE(6,15)A1
   15 FORMAT(/6X,"FLAPPING COEFFICIENT, A1=",F10.5,1X,"DEGREES")
      IF(N4 .EQ. 1)WRITE(6,16)B1
   16 FORMAT(/6X,"FLAPPING COEFFICIENT, B1=",F10.5,1X,"DEGREES")
      THC=THC*PI/180.
      A0=A0*PI/180.
      A1=A1*PI/180.
      B1=B1*PI/180.
      LAM=MU*ALR+SQRT(.5*(-MU*MU+SQRT(MU*MU*MU*MU+CT*CT)))
      WRITE(6,20)LAM,UTMIN,DP1D,DP2D
   20 FORMAT(/6X,"TOTAL INFLOW RATIO=",F10.5//6X,
     1"MINIMUM UT=",F10.5,"(ZERO LIFT CONDITION APPLIED BELOW THIS VALUE
     2)"//6X,"NORMAL AZIMUTH SPACING=",F10.5,1X,"DEGREES"//6X,
     3"REDUCED AZIMUTH SPACING=",F10.5,1X,"DEGREES")
      IF(ISEL .EQ. 0)WRITE(6,30)
   30 FORMAT(/6X,"PIECEWISE CONSTANT APPROXIMATION OF SPANWISE DIPOLE ST
     1RENGTH VARIATION"/6X,70(1H*)/)
      IF(ISEL .NE. 0)WRITE(6,40)
   40 FORMAT(/6X,"PIECEWISE QUADRATIC APPROXIMATION OF SPANWISE DIPOLE S
     1TRENGTH VARIATION"/6X,71(1H*)/)
      SLCR=1.
      CL0=0.
      IF(NAFD .EQ. 0)WRITE(6,41)
   41 FORMAT(/6X,"AIRFOIL DATA TABLES NOT USED")
      IF(NAFD .EQ. 1)WRITE(6,42)
   42 FORMAT(/6X,"AIRFOIL DATA TABLES USED")
C
C  CALCULATE QUANTITIES NEEDED FOR TRAJECTORY SEGMENT ADJACENT TO
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C  THE BLADE AT THE COLLOCATION POINT.
C
      ETA1P=ALOG((3.+SQRT(5.))/2.)
      CF1=COSH(.5*ETA1P)/SINH(.5*ETA1P)
      CF2=.5-EXP(-ETA1P)
      CF3=ETA1P-.5*CF1
C
C  CALCULATE QUANTITIES NEEDED FOR NEAR FIELD REPRESENTATION.
C
      DO 50 I=1,5
      T1=ACOS(X(I))
      T2=ACOS(X(I+1))
      FX1(I)=(T2-T1-(SIN(T2)-SIN(T1)))/(X(I+1)-X(I))
      FX2(I)=-((T2-T1)/2.-(SIN(2.*T2)-SIN(2.*T1))/4.)/(X(I+1)-X(I))
      FX2(I)=FX2(I)*(1.-RO)/(2.*AR)
   50 CONTINUE
      DO 60 I=1,NSP
      RBO(I)=(R(I)+R(I+1))/2.
      DR(I)=R(I+1)-R(I)
   60 CONTINUE
      IF(ISEL .EQ. 0)GO TO 70
C
C  FOR PIECEWISE QUADRATIC REPRESENTATION, DETERMINE VALUES AT THE ENDS
C  OF THE SEGMENTS IN TERMS OF THE CENTRAL VALUES.
C
      NSPM=NSP-1
      DO 80 I=1,NSPM
      BT(I)=3.*(1./DR(I)+1./DR(I+1))
      IF(I .EQ. 1)GO TO 80
      BT(I)=BT(I)-1./(BT(I-1)*DR(I)*DR(I))
   80 CONTINUE
      DO 90 I=1,NSPM
      DO 90 J=1,NSP
      GF(I,J)=0.
      IF(J .EQ. I .OR. J .EQ. (I+1))GF(I,J)=GF(I,J)+4./BT(I)
      IF(I .EQ. 1)GO TO 90
      GF(I,J)=GF(I,J)-GF(I-1,J)/(BT(I)*DR(I))
   90 CONTINUE
      DO 100 I=2,NSPM
      I1=NSP-I
      DO 100 J=1,NSP
      GF(I1,J)=GF(I1,J)-GF(I1+1,J)/(BT(I1)*DR(I1+1))
  100 CONTINUE
C
C  PROGRAM STEP 2.
C  BEGIN SETTING UP THE SYSTEM OF SIMULTANEOUS EQUATIONS.
C
   70 L=1
      DO 110 J=1,NAZ
C
C  SET THE AZIMUTH STATION FOR THE CURRENT COLLOCATION POINT.
C
      PBO=2.*J*PI/NAZ
      PBOD(J)=360.*J/NAZ
      CP1=COS(PBO)
      SP1=SIN(PBO)
      CP2=COS(2.*PBO)
      SP2=SIN(2.*PBO)
      DO 110 I=1,NSP
C
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C  SET THE RADIAL STATION FOR THE CURRENT COLLOCATION POINT.
C
      UT=RBO(I)+MU*SP1
      DO 115 M=1,NCOF
      A(L,M)=0.
 115  CONTINUE
C
C  PROGRAM STEP 3.
C  TEST THE TANGENTIAL VELOCITY AT THE COLLOCATION POINT, TO DECIDE
C  WHETHER NORMAL VELOCITY BOUNDARY CONDITION OR ZERO LIFT CONDITION
C  SHOULD BE APPLIED.
C
      IF(UT .GT. UTMIN)GO TO 120
      WRITE(6,130)RBO(I),PBOD(J),UT
 130  FORMAT(/6X,"R=",F8.3,1X,"PSI=",F8.3,"DEGREES",1X,
     1"UT=",F8.3,1X,"ZERO LIFT CONDITION APPLIED")
      B(L,1)=0.
      GO TO 140
 120  DP=1.5*(1.-RO)/(2.*AR*UT)
      PLIM=-(2.+RBO(I)*CP1)/SQRT(MU*MU+LAM*LAM)
      IF(NAFD .EQ. 0)GO TO 133
C
C  PROGRAM STEP 4.
C  CALCULATE LIFT CURVE SLOPE FROM DATA TABLES FOR THE CURRENT
C  COLLOCATION POINT, USING THE LOCAL INCIDENCE AND MACH NUMBER.
C
      MLOC=UT*MINF/MU
      ALOC=THC-TW*(RBO(I)-RO)/(1.-RO)+B1*CP1-A1*SP1
     1-(MU*AO*CP1+LAM)/UT
      ALOC=ALOC*180./PI
      CALL TABSCH(MCL,NXL,MLOC,IMCL1,IMCL2,INT)
      IF(INT .EQ. -1)IMCL1=IMCL2=1
      IF(INT .EQ. 1)IMCL1=IMCL2=NXL
      CALL TABSCH(ACL,NZL,ALOC,IACL1,IACL2,INT)
      IF(INT .EQ. 0)GO TO 131
      IF(INT .EQ. -1)GO TO 132
      IACL1=NXL-1
      IACL2=NXL
      GO TO 131
 132  IACL1=1
      IACL2=2
 131  SLC1=(CL(IACL2,IMCL1)-CL(IACL1,IMCL1))/(ACL(IACL2)
     1-ACL(IACL1))
      CLO1=CL(IACL1,IMCL1)-SLC1*ACL(IACL1)
      SLC1=SLC1*180./PI
      SLC2=(CL(IACL2,IMCL2)-CL(IACL1,IMCL2))/(ACL(IACL2)
     1-ACL(IACL1))
      CLO2=CL(IACL1,IMCL2)-SLC2*ACL(IACL1)
      SLC2=SLC2*180./PI
      IF(IMCL1 .EQ. IMCL2)SLCR=SLC1/(2.*PI)
      IF(IMCL1 .NE. IMCL2)SLCR=YL(MLOC,MCL(IMCL1),MCL(IMCL2),
     1SLC1,SLC2)/(2.*PI)
      IF(IMCL1 .EQ. IMCL2)CLO=CLO1
      IF(IMCL1 .NE. IMCL2)CLO=YL(MLOC,MCL(IMCL1),MCL(IMCL2),
     1CLO1,CLO2)
 133  CONTINUE
      IF(SLCR .EQ. 0.)GO TO 134
      T1=-(CF1+(1.-SLCR)/SLCR)/UT
      T2=MU*CP1*CF3*(1.-RO)/(2.*AR*UT*UT*DR(I))
      T3=-(1.-RO)*CF3/(2.*AR*UT*UT)
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      B(L,1)=-MU*ALR-UT*TW*(RBO(I)-RO)/(1.-RO)+UT*CLO/(2.*PI*SLCR)
      GO TO 140
  134 T1=1.
      T2=T3=0.
      B(L,1)=-UT*UT*CLO/(2.*PI)
  140 CONTINUE
C
C  SET UP THE CONTRIBUTION TO THE COEFFICIENT MATRIX OF THE TRAJECTORY
C  SEGMENT ADJACENT TO THE BLADE. ALTERNATIVELY, SET UP THE ZERO LIFT
C  CONDITION.
C
      DO 150 M=1,NCOF
      M1=(M-1)/NAZ+1
      M2=M-(M1-1)*NAZ
      IF(M1 .EQ. (NSP+1))GO TO 160
      M3=M2/2
      M4=M2-M3*2
      WT1=0.
      WT2=0.
      WT3=0.
      IF(UT .LE. UTMIN)GO TO 170
      IF(M1 .EQ. I)WT1=T1
      IF(M1 .EQ. I)WT3=T3
      IF(ISEL .EQ. 0)GO TO 180
      IF(I .LT. NSP)WT2=WT2+T2*GF(I,M1)/DR(M1)
      IF(I .GT. 1)WT2=WT2-T2*GF(I-1,M1)/DR(M1)
      GO TO 180
  170 IF(M1 .EQ. I)WT1=1.
  180 IF(M2 .EQ. 1)A(L,M)=WT1+WT2
      IF(M2 .GT. 1 .AND. M4 .EQ. 0)A(L,M)=(WT1+WT2)*COS(M3*PBO)
     1-M3*WT3*SIN(M3*PBO)
      IF(M2 .GT. 1 .AND. M4 .GT. 0)A(L,M)=(WT1+WT2)*SIN(M3*PBO)
     1+M3*WT3*COS(M3*PBO)
      GO TO 150
  160 IF(SLCR .EQ. 0.)GO TO 150
      IF(UT .GT. UTMIN)WT=-(1.-RO)*CF2/(2.*AR*UT)
      IF(UT .LE. UTMIN)WT=-(1.-RO)/(4.*AR)
      IF(M2 .EQ. 1)A(L,M)=WT*(2.*MU*CP1)
      IF(M2 .EQ. 2)A(L,M)=WT*(2.*MU*SP1+RBO(I))
      IF(M2 .EQ. 3)A(L,M)=WT*(-2.*MU*SP2-2.*RBO(I)*CP1)
      IF(M2 .EQ. 4)A(L,M)=WT*(2.*MU*CP2-2.*RBO(I)*SP1)
  150 CONTINUE
      IF(SLCR .EQ. 0.)GO TO 191
      B(L,1)=B(L,1)-WT*TW*(2.*MU*RO*CP1-MU*MU*SP2-4.*MU*CP1*RBO(I))/
     1(1.-RO)
      IF(UT .GT. UTMIN)GO TO 190
  191 L=L+1
      GO TO 110
C
C  PROGRAM STEP 5.
C  START LOOP FOR NUMBER OF BLADES.
C
  190 DO 200 IBL=1,NB
      IBLO=IBL
      DB=2.*PI*(IBL-1)/NB
C
C  CALL SUBROUTINE TO DETERMINE AZIMUTH POSITIONS ALONG THE TRAJECTORY
C  AT WHICH THE TRAJECTORY IS CLOSE TO A BLADE.
C
      IF(DP1 .NE. DP2)CALL DMIN(MU,LAM,DB,RBO(I),PBO,PLIM,DMAX,
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```
     1IMIN,PMIN)
C
C   DEFINE THE AZIMUTH INTERVAL FOR THE FIRST TRAJECTORY SEGMENT.
C
      J1=1
      K1=0
      PB2=0.
      IF(IBL .EQ. 1)PB1=-DP
      IF(IBL .GT. 1)PB1=-DP1
  210 CONTINUE
      DO 220 I1=1,5
      FG(I1)=0.
  220 CONTINUE
      FCNF=0.
      FTHNF=0.
      FAONF=0.
      FA1NF=0.
      FB1NF=0.
C
C   PROGRAM STEP 6.
C   CALCULATE SLOPE AND INTERCEPT COMPONENTS FOR CURRENT TRAJECTORY
C   SEGMENT.
C
      XB1=RBO(I)*SIN(PB1+DB)+MU*PB1*SIN(PB1+PBO+DB)
      XB2=RBO(I)*SIN(PB2+DB)+MU*PB2*SIN(PB2+PBO+DB)
      RB1=RBO(I)*COS(PB1+DB)+MU*PB1*COS(PB1+PBO+DB)
      RB2=RBO(I)*COS(PB2+DB)+MU*PB2*COS(PB2+PBO+DB)
      XBS=(XB2-XB1)/(PB2-PB1)
      XBI=XB1-XBS*PB1
      IF(PB2 .EQ. 0. .AND. (DB .EQ. 0. .OR. DB .EQ. PI))XBI=0.
      RBS=(RB2-RB1)/(PB2-PB1)
      RBI=RB1-RBS*PB1
      YBS=LAM
      NSPP=NSP+1
C
C   START CALCULATION OF FAR FIELD CONTRIBUTION.
C
      DO 230 I1=1,NSPP
      I2=I1-1
      CALL FFINT(PB1,PB2,R(I1),ISEL,FG1,FG2,FG3)
      IF(I1 .EQ. 1)GO TO 240
      IF(ISEL .EQ. 0)GO TO 250
      FF1=-(1.-RO)*(FG1-FG1M)/(4.*AR*DR(I2)*DR(I2))
      FF2=-(1.-RO)*(R(I1)*FG1-R(I2)*FG1M)/(4.*AR*DR(I2)*DR(I2))
      FF3=-(1.-RO)*(FG2-FG2M)/(4.*AR*DR(I2)*DR(I2))
      FF4=-(1.-RO)*(FG3-FG3M)/(4.*AR*DR(I2)*DR(I2))
      T1M=(-2.*(RBO(I2)+R(I1))+2.*RBI)*FF1+2.*FF2+2.*RBS*FF3-2.*FF4
      T1=(8.*RBO(I2)-4.*RBI)*FF1-4.*FF2-4.*RBS*FF3+4.*FF4
      T1P=(-2.*(RBO(I2)+R(I2))+2.*RBI)*FF1+2.*FF2+2.*RBS*FF3-2.*FF4
      DO 260 I3=1,NSP
      IF(I2 .NE. 1)FG(I3)=FG(I3)+T1M*GF(I2-1,I3)/DR(I3)
      IF(I3 .EQ. I2)FG(I3)=FG(I3)+T1
      IF(I2 .NE. NSP)FG(I3)=FG(I3)+T1P*GF(I2,I3)/DR(I3)
  260 CONTINUE
      GO TO 240
  250 FG(I2)=FG(I2)-(1.-RO)*(FG1-FG1M)/(4.*AR)
  240 FG1M=FG1
      FG2M=FG2
      FG3M=FG3
  230 CONTINUE
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C
C  END CALCULATION OF FAR FIELD CONTRIBUTION.
C  CALL SUBROUTINE TO DIVIDE CURRENT TRAJECTORY SEGMENT INTO SUB-
C  SEGMENTS ALIGNED WITH SPANWISE SEGMENTS ALONG THE BLADE.
C
      CALL SUBIVL(RB1,RB2,PB1,PB2,R,IP,P1,P2)
      CB1=COS(PB2+PB0+DB)
      CB2=COS(2.*(PB2+PB0+DB))
      SB1=SIN(PB2+PB0+DB)
      SB2=SIN(2.*(PB2+PB0+DB))
      FC=TW*(2.*MU*RO*CB1-MU*MU*SB2-4.*MU*RB2*CB1)/(1.-RO)
      FTH=2.*MU*CB1
      FA0=2.*MU*SB1+RB2
      FA1=-2.*MU*SB2-2.*RB2*CB1
      FB1=2.*MU*CB2-2.*RB2*SB1
C
C  START CALCULATION OF COMMON PART AND NEAR FIELD CONTRIBUTIONS. IN
C  THE FOLLOWING LOOP, THE FIRST PASS CALCULATES THE COMMON PART, AND
C  THE SECOND PASS THE NEAR FIELD.
C
      DO 270 I1=1,2
      IF(I1 .EQ. 2 .AND. IBL .EQ. 1 .AND. PB2 .EQ. 0.)GO TO 280
      DO 270 I2=1,NSP
      FG1=0.
      FG2=0.
      FG3=0.
      FG4=0.
      IF(IP(I2) .EQ. 0)GO TO 270
      IF(I1 .EQ. 2)GO TO 290
      CALL CPINT(P1(I2),P2(I2),ISEL,FG1,FG2,FG3)
      IF(ISEL .EQ. 0)GO TO 300
      FG1=-(1.-RO)*FG1/(2.*AR*DR(I2)*DR(I2))
      FG2=-(1.-RO)*FG2/(2.*AR*DR(I2)*DR(I2))
      FG3=-(1.-RO)*FG3/(2.*AR*DR(I2)*DR(I2))
      GO TO 310
 300  FG(I2)=FG(I2)-(1.-RO)*FG1/(2.*AR)
      GO TO 270
 290  DO 320 I3=1,6
      CALL NFINT(P1(I2),P2(I2),(1.-RO)*X(I3)/(2.*AR),ISEL,FN1,FN2,FN3)
      IF(I3 .EQ. 1)GO TO 330
      FG4=FG4+FX2(I3-1)*(FN1-FN1M)/PI
      IF(ISEL .EQ. 0)GO TO 340
      FG1=FG1+FX1(I3-1)*(FN1-FN1M)/(PI*DR(I2)*DR(I2))
      FG2=FG2+FX1(I3-1)*(FN2-FN2M)/(PI*DR(I2)*DR(I2))
      FG3=FG3+FX1(I3-1)*(FN3-FN3M)/(PI*DR(I2)*DR(I2))
      GO TO 330
 340  FG(I2)=FG(I2)+FX1(I3-1)*(FN1-FN1M)/PI
 330  FN1M=FN1
      FN2M=FN2
      FN3M=FN3
 320  CONTINUE
      IF(ISEL .EQ. 0)GO TO 270
 310  T1M=2.*((RBI-R(I2+1))*(RBI-RBO(I2))*FG1+(2.*RBI-RBO(I2)
     1-R(I2+1))*RBS*FG2+RBS*RBS*FG3)
      T1=-4.*((RBI-R(I2))*(RBI-R(I2+1))*FG1+(2.*RBI-R(I2)-R(I2+1))
     1*RBS*FG2+RBS*RBS*FG3)
      T1P=2.*((RBI-R(I2))*(RBI-RBO(I2))*FG1+(2.*RBI-RBO(I2)-R(I2))
     1*RBS*FG2+RBS*RBS*FG3)
      DO 350 I3=1,NSP
      IF(I2 .GT. 1)FG(I3)=FG(I3)+T1M*GF(I2-1,I3)/DR(I3)
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```
      IF(I3 .EQ. I2)FG(I3)=FG(I3)+T1
      IF(I2 .NE. NSP)FG(I3)=FG(I3)+T1P*GF(I2,I3)/DR(I3)
  350 CONTINUE
      IF(I1 .EQ. 1)GO TO 270
      FCNF=FCNF+FG4*FC
      FTHNF=FTHNF+FG4*FTH
      FAONF=FAONF+FG4*FAO
      FA1NF=FA1NF+FG4*FA1
      FB1NF=FB1NF+FG4*FB1
  270 CONTINUE
  280 CONTINUE
C
C  ADD THE CONTRIBUTIONS, CALCULATED FOR THE CURRENT TRAJECTORY SEGMENT,
C  TO THE COEFFICIENT MATRIX ELEMENTS
C
      DO 360 M=1,NCOF
      M1=(M-1)/NAZ+1
      M2=M-(M1-1)*NAZ
      IF(M1 .EQ. (NSP+1))GO TO 370
      M3=M2/2
      M4=M2-M3*2
      IF(M2 .EQ. 1)A(L,M)=A(L,M)+FG(M1)
      IF(M2 .GT. 1 .AND. M4 .EQ. 0)A(L,M)=A(L,M)+FG(M1)
     1*COS(M3*(PB2+PB0+DB))
      IF(M2 .GT. 1 .AND. M4 .GT. 0)A(L,M)=A(L,M)+FG(M1)
     1*SIN(M3*(PB2+PB0+DB))
      GO TO 360
  370 IF(M2 .EQ. 1)A(L,M)=A(L,M)+FTHNF
      IF(M2 .EQ. 2)A(L,M)=A(L,M)+FAONF
      IF(M2 .EQ. 3)A(L,M)=A(L,M)+FA1NF
      IF(M2 .EQ. 4)A(L,M)=A(L,M)+FB1NF
  360 CONTINUE
      B(L,1)=B(L,1)-FCNF
C
C  PROGRAM STEP 7.
C  REDEFINE THE AZIMUTH INTERVAL, FOR THE NEXT TRAJECTORY SEGMENT.
C  TEST TO SEE IF THE FINAL SEGMENT HAS BEEN CALCULATED. ALSO TEST
C  TO SEE IF THE NEXT SEGMENT IS CLOSE TO A BLADE, IN WHICH CASE
C  REDUCED SPACING IS TO BE USED.
C
      PB2=PB1
      IF(PB2 .LE. PLIM)GO TO 200
      IF(DP1 .EQ. DP2)GO TO 380
      IF(J1 .GT. IMIN)GO TO 380
      IF(K1 .EQ. 0 .AND. PB2 .LE. (PMIN(J1)+DP1))GO TO 390
      IF(K1 .EQ. 1 .AND. PB2 .GT. (PMIN(J1)-DP1))GO TO 390
      IF(K1 .EQ. 1 .AND. PB2 .LE. (PMIN(J1)-DP1))GO TO 400
      IF(PB2 .GT. (-3.*DP1) .AND. IBL .EQ. 1)PB1=PB1-DP2
      IF(PB2 .LE. (-3.*DP1) .OR. IBL .GT. 1)PB1=PB1-DP1
      IF(K1 .EQ. 0 .AND. PB1 .LT. (PMIN(J1)+DP1))PB1=PMIN(J1)+DP1
      GO TO 210
  380 PB1=PB1-DP1
      GO TO 210
  390 PB1=PB1-DP2
      K1=1
      GO TO 210
  400 PB1=PB1-DP1
      K1=0
      J1=J1+1
      GO TO 210
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C
C  PROGRAM STEP 8. END OF LOOP FOR NUMBER OF BLADES.
C
 200  CONTINUE
C
C  SET UP THE ELEMENTS CORRESPONDING TO THE 4 AUXILIARY UNKNOWNS.
C
      M=NSP*NAZ+1
      A(L,M)=A(L,M)-UT
      M=M+1
      A(L,M)=A(L,M)+MU*CP1
      M=M+1
      A(L,M)=A(L,M)+RBO(I)*SP1+.5*MU*(1.-CP2)
      M=M+1
      A(L,M)=A(L,M)-RBO(I)*CP1-.5*MU*SP2
      L=L+1
C
C  PROGRAM STEP 9. END OF COLLOCATION LOOP.
C
 110  CONTINUE
C
C  PROGRAM STEP 10.
C  SET UP THE EXTRA 4 EQUATIONS NEEDED TO CLOSE THE SYSTEM.
C
      DO 410 I=1,4
      DO 420 M=1,NCOF
      A(L,M)=0.
 420  CONTINUE
      B(L,1)=C.
      IF(I .EQ. 1 .AND. N1 .EQ. 1)GO TO 430
      IF(I .EQ. 2 .AND. N2 .EQ. 1)GO TO 440
      IF(I .EQ. 3 .AND. N3 .EQ. 1)GO TO 450
      IF(I .EQ. 4 .AND. N4 .EQ. 1)GO TO 460
      IF(I .LE. 2)I1=1
      IF(I .GT. 2)I1=I-1
      DO 470 M1=1,NSP
      IF(I .GT. 1)GO TO 480
      DO 490 M2=1,NSP
      M=(M2-1)*NAZ+I1
      IF(ISEL .EQ. 0)GO TO 500
      IF(M1 .NE. 1)A(L,M)=A(L,M)-DR(M1)*GF(M1-1,M2)/(6.*DR(M2))
      IF(M2 .EQ. M1)A(L,M)=A(L,M)-4.*DR(M1)/6.
      IF(M1 .LT. NSP)A(L,M)=A(L,M)-DR(M1)*GF(M1,M2)/(6.*DR(M2))
      GO TO 490
 500  IF(M2 .EQ. M1)A(L,M)=A(L,M)-DR(M1)
 490  CONTINUE
      GO TO 470
 480  DO 510 M2=1,NSP
      M=(M2-1)*NAZ+I1
      IF(ISEL .EQ. 0)GO TO 520
      IF(M1 .NE. 1)A(L,M)=A(L,M)-R(M1)*DR(M1)*GF(M1-1,M2)/(6.*DR(M2))
      IF(M2 .EQ. M1)A(L,M)=A(L,M)-4.*RBO(M1)*DR(M1)/6.
      IF(M1 .LT. NSP)A(L,M)=A(L,M)-R(M1+1)*DR(M1)*GF(M1,M2)/(6.*DR(M2))
      GO TO 510
 520  IF(M2 .EQ. M1)A(L,M)=A(L,M)-RBO(M1)*DR(M1)
 510  CONTINUE
 470  CONTINUE
      GO TO (530,540,550,560),I
 530  M=NSP*NAZ+2
      A(L,M)=(1.-RO)*(1.-RO*RO)/(8.*AR)
```

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      B(L,1)=AR*CT/(NB*(1.-RO))
C
C   THE ABOVE EQUATION EQUATES THE TOTAL LIFT DUE TO ALL THE BLADES,
C   AVERAGED OVER THE AZIMUTH, TO THE THRUST COEFFICIENT.
C
      L=L+1
      GO TO 410
 430  M=NSP*NAZ+1
      A(L,M)=1.
      B(L,1)=THC
C
C   THE ABOVE EQUATION SETS THE COLLECTIVE PITCH TO THE GIVEN VALUE.
C
      L=L+1
      GO TO 410
 540  M=NSP*NAZ+2
      A(L,M)=(1.-RO)*(1.-RO*RO*RO)/(12.*AR)-2./GAMA
      B(L,1)=0.
C
C   THE ABOVE EQUATION REPRESENTS THE ZEROTH HARMONIC COMPONENT OF
C   MOMENT EQUILIBRIUM ABOUT THE HUB.
C
      L=L+1
      GO TO 410
 440  M=NSP*NAZ+2
      A(L,M)=1.
      B(L,1)=A0
C
C   THE ABOVE EQUATION SETS THE CONING ANGLE TO THE GIVEN VALUE.
C
      L=L+1
      GO TO 410
 550  M=NSP*NAZ+1
      A(L,M)=MU*(1.-RO)*(1.-RO*RO)/(4.*AR)
      M=M+2
      A(L,M)=-(1.-RO)*(1.-RO*RO*RO)/(6.*AR)
      B(L,1)=-TW*MU*(RO*(1.-RO*RO)-4.*(1.-RO*RO*RO)/3.)/(4.*AR)
C
C   THE ABOVE EQUATION REPRESENTS THE FIRST HARMONIC COSINE COMPONENT
C   OF MOMENT EQUILIBRIUM ABOUT THE HUB.
C
      L=L+1
      GO TO 410
 450  M=NSP*NAZ+3
      A(L,M)=1.
      B(L,1)=A1
C
C   THE ABOVE EQUATION SETS THE CYCLIC PITCH COEFFICIENT, A1, TO THE
C   GIVEN VALUE.
C
      L=L+1
      GO TO 410
 560  M=NSP*NAZ+2
      A(L,M)=MU*(1.-RO)*(1.-RO*RO)/(4.*AR)
      M=M+2
      A(L,M)=-(1.-RO)*(1.-RO*RO*RO)/(6.*AR)
      B(L,1)=0.
C
C   THE ABOVE EQUATION REPRESENTS THE FIRST HARMONIC SINE COMPONENT OF
C   MOMENT EQUILIBRIUM ABOUT THE HUB.
```

```
C
      L=L+1
      GO TO 410
 460  M=NSP*NAZ+4
      A(L,M)=1.
      B(L,1)=B1
C
C  THE ABOVE EQUATION SETS THE CYCLIC PITCH COEFFICIENT, B1, TO THE
C  GIVEN VALUE.
C
      L=L+1
 410  CONTINUE
C
C  PROGRAM STEP 11.
C  SOLVE THE SYSTEM OF SIMULTANEOUS EQUATIONS AND PRINT THE SOLUTION.
C
      CALL GELIM(NCOF,NCOF,A,1,B,IPIVOT,0,WK,IERR)
      IF(IERR .EQ. 1)GO TO 570
      L=1
      DO 580 I=1,NSP
      GO(I)=B(L,1)
      L=L+1
      DO 580 J=1,NHM
      GC(I,J)=B(L,1)
      L=L+1
      GS(I,J)=B(L,1)
      L=L+1
 580  CONTINUE
      THC=B(NSP*NAZ+1,1)
      THCD=THC*180./PI
      A0=B(NSP*NAZ+2,1)
      A0D=A0*180./PI
      A1=B(NSP*NAZ+3,1)
      A1D=A1*180./PI
      B1=B(NSP*NAZ+4,1)
      B1D=B1*180./PI
      WRITE(6,9)
      WRITE(6,590)
 590  FORMAT(6X,"SOLUTION FOR COEFFICIENTS"/6X,25(1H-)//6X,
     1"(GO(I),I=1,NSP)")
      WRITE(6,600)(GO(I),I=1,NSP)
 600  FORMAT(/6X,5(E10.4,1X))
      WRITE(6,610)
 610  FORMAT(//6X,"((GC(I,J),J=1,NHM),I=1,NSP)"//)
      DO 620 I=1,NSP
      WRITE(6,600)(GC(I,J),J=1,NHM)
 620  CONTINUE
      WRITE(6,630)
 630  FORMAT(//6X,"((GS(I,J),J=1,NHM),I=1,NSP)"//)
      DO 640 I=1,NSP
      WRITE(6,600)(GS(I,J),J=1,NHM)
 640  CONTINUE
      WRITE(6,650)THCD,A0D,A1D,B1D
 650  FORMAT(//6X,"PITCH ANGLE AT BLADE ROOT=",F10.5,1X,"DEGREES"//6X,
     1"CONING ANGLE=",F10.5,1X,"DEGREES"//6X,
     2"FLAPPING COEFFICIENT, A1=",F10.5,1X,"DEGREES"//6X,
     3"FLAPPING COEFFICIENT, B1=",F10.5,1X,"DEGREES")
C
C  PROGRAM STEP 12.
C  START LOOP FOR AZIMUTH STATIONS AT WHICH OUTPUT QUANTITIES ARE
```

```
C  CALCULATED.
C
      CTCAL=0.
      CMXCAL=0.
      CMYCAL=0.
      DO 670 I=1,24
      PBOD(I)=15.*(I-1)
      PBO=PBOD(I)*PI/180.
      CP1=COS(PBO)
      SP1=SIN(PBO)
      CP2=COS(2.*PBO)
      SP2=SIN(2.*PBO)
      F2=CP1*(2.*MU*TW*RO/(1.-RO)+2.*MU*THC)+2.*MU*A0*SP1+2.*MU*B1*CP2
     1-SP2*(MU*MU*TW/(1.-RO)+2.*MU*A1)
      F3=A0-CP1*(4.*MU*TW/(1.-RO)+2.*A1)-2.*B1*SP1
      GI1=0.
      GI2=0.
      DO 690 I1=1,NSP
      G(I,I1)=G0(I1)
      DO 690 I2=1,NHM
      G(I,I1)=G(I,I1)+GC(I1,I2)*COS(I2*PBO)+GS(I1,I2)*SIN(I2*PBO)
  690 CONTINUE
      DO 700 I1=1,NSP
      IF(ISEL .NE. 0)GO TO 710
      GI1=GI1+DR(I1)*G(I,I1)
      GI2=GI2+DR(I1)*RBO(I1)*G(I,I1)
      GO TO 700
  710 GI1=GI1+4.*DR(I1)*G(I,I1)/6.
      GI2=GI2+4.*DR(I1)*RBO(I1)*G(I,I1)/6.
      IF(I1 .EQ. 1)GL(I1)=0.
      IF(I1 .GT. 1)GL(I1)=GR(I1-1)
      GR(I1)=0.
      IF(I1 .EQ. NSP)GO TO 720
      DO 730 I2=1,NSP
      GR(I1)=GR(I1)+GF(I1,I2)*G(I,I2)/DR(I2)
  730 CONTINUE
  720 GI1=GI1+DR(I1)*(GL(I1)+GR(I1))/6.
      GI2=GI2+DR(I1)*(R(I1)*GL(I1)+R(I1+1)*GR(I1))/6.
  700 CONTINUE
      FLT1(I)=(1.-RO*RO)*A0/2.+CP1*(2.*MU*THC*(1.-RO)-2.*MU*TW
     1-A1*(1.-RO*RO))+SP1*(1.-RO)*(2.*MU*A0-B1*(1.+RO))
     2+2.*MU*B1*(1.-RO)*CP2-SP2*(2.*MU*A1*(1.-RO)+MU*MU*TW)
      FLT1(I)=-FLT1(I)*(1.-RO)/(4.*AR)
      FLT1(I)=-(FLT1(I)+GI1)*PI*(1.-RO)/AR
      FLT2(I)=FLT1(I)/(CT*PI/NB)
      FMT(I)=(1.-RO*RO*RO)*A0/3.+CP1*(MU*THC*(1.-RO*RO)-2.*A1*
     1(1.-RO*RO*RO)/3.+MU*TW*RO*(1.+RO)-4.*MU*TW*(1.+RO+RO*RO)/3.)
     2+SP1*(MU*A0*(1.-RO*RO)-2.*B1*(1.-RO*RO*RO)/3.)+CP2*MU*B1*
     3(1.-RO*RO)-SP2*(MU*A1*(1.-RO*RO)+MU*MU*TW*(1.+RO)/2.)
      FMT(I)=-FMT(I)*(1.-RO)/(4.*AR)
      FMT(I)=-(FMT(I)+GI2)*PI*(1.-RO)/AR
      COL(I)=FMT(I)/FLT1(I)
      CTCAL=CTCAL+FLT1(I)/24.
      CMXCAL=CMXCAL+FMT(I)*SP1/24.
      CMYCAL=CMYCAL-FMT(I)*CP1/24.
C
C  START LOOP FOR RADIAL STATIONS AT WHICH OUTPUT QUANTITIES ARE
C  CALCULATED.
C
      DO 740 I1=1,NSP
```

```
      IF(ISEL .EQ. 0)GO TO 780
      QC=2.*(GR(I1)+GL(I1)-2.*G(I,I1))/(DR(I1)*DR(I1))
      QB=(GR(I1)-GL(I1))/DR(I1)-2.*QC*RBO(I1)
      QA=G(I,I1)-RBO(I1)*QB-RBO(I1)*RBO(I1)*QC
      GOUT=QA+QB*RBO(I1)+QC*RBO(I1)*RBO(I1)
      GO TO 790
780   GOUT=G(I,I1)
790   F23(I,I1)=F2+RBO(I1)*F3
      FL1(I,I1)=-PI*(1.-RO)*(GOUT-(1.-RO)*F23(I,I1)/(4.*AR))/AR
      FL2(I,I1)=FL1(I,I1)/(CT*PI/NB)
      FM(I,I1)=-PI*(1.-RO)*(1.-RO)*(1.-RO)*F23(I,I1)/(16.*AR*AR*AR)
      XCP(I,I1)=.25+FM(I,I1)*AR/(FL1(I,I1)*(1.-RO))
740   CONTINUE
670   CONTINUE
      CTCAL=CTCAL*NB/PI
      CMXCAL=CMXCAL*NB/PI
      CMYCAL=CMYCAL*NB/PI
      WRITE(6,791)CTCAL,CMXCAL,CMYCAL
791   FORMAT(/6X,"COMPUTED THRUST COEFFICIENT=",E10.4//6X,
     1"COMPUTED MOMENT COEFFICIENT ABOUT ROTOR X-AXIS=",E10.4//6X,
     2"COMPUTED MOMENT COEFFICIENT ABOUT ROTOR Y-AXIS=",E10.4)
C
C  PRINT ALL OUTPUT QUANTITIES IN TABULAR FORM.
C
      WRITE(6,9)
      WRITE(6,800)
800   FORMAT(//6X,"TABLE 1 - SECTIONAL LIFT/(RHO*(OMEGA**2)*(R1**3))"/6X
     1,49(1H-)//)
      WRITE(6,810)(RBO(I),I=1,NSP)
810   FORMAT(/12X,"R/R1:   ",5(E10.4,1X))
      WRITE(6,811)
811   FORMAT(/7X,"PSI")
      DO 820 I=1,24
      WRITE(6,830)PBOD(I),(FL1(I,I1),I1=1,NSP)
830   FORMAT(/6X,F5.1,8X,5(E10.4,1X))
820   CONTINUE
      WRITE(6,9)
      WRITE(6,840)
840   FORMAT(//6X,"TABLE 2 - SECTIONAL LIFT*R1/THRUST PER BLADE"/6X,
     144(1H-)//)
      WRITE(6,810)(RBO(I),I=1,NSP)
      WRITE(6,811)
      DO 850 I=1,24
      WRITE(6,830)PBOD(I),(FL2(I,I1),I1=1,NSP)
850   CONTINUE
      WRITE(6,9)
      WRITE(6,860)
860   FORMAT(//6X,"TABLE 3 - SECTIONAL PITCHING MOMENT/(RHO*(OMEGA**2)*(
     1R1**4))"/6X,60(1H-)/16X,"(ABOUT QUARTER-CHORD)"//)
      WRITE(6,810)(RBO(I),I=1,NSP)
      WRITE(6,811)
      DO 870 I=1,24
      WRITE(6,830)PBOD(I),(FM(I,I1),I1=1,NSP)
870   CONTINUE
      WRITE(6,9)
      WRITE(6,880)
880   FORMAT(//6X,"TABLE 4 - CENTER OF PRESSURE LOCATION FROM LEADING ED
     1GE(FRACTION OF CHORD)"/6X,74(1H-)//)
      WRITE(6,910)(RBO(I),I=1,NSP)
      WRITE(6,811)
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      DO 890 I=1,24
      WRITE(6,830)PBOD(I),(XCP(I,I1),I1=1,NSP)
 890  CONTINUE
      WRITE(6,9)
      WRITE(6,900)
 900  FORMAT(//6X,"TABLE 5 - TOTAL BLADE LIFT, MOMENT ABOUT HUB AND RADI
     1AL CENTER OF LIFT"/6X,70(1H-)//6X,
     2"TOTAL BLADE LIFT/(RHO*(OMEGA**2)*(R1**4))"/6X,
     3"TOTAL BLADE LIFT/THRUST PER BLADE"/6X,
     4"MOMENT ABOUT HUB/(RHO*(OMEGA**2)*(R1**5))"/6X,
     5"RADIAL CENTER OF LIFT/R1"//7X,"PSI",8X,"TOTAL BLADE LIFT",
     655X,"MOMENT",5X,"CENTER"/38X,"ABOUT HUB",4X,"OF LIFT")
      DO 910 I=1,24
      WRITE(6,920)PBOD(I),FLT1(I),FLT2(I),FMT(I),COL(I)
 920  FORMAT(/6X,F5.1,5X,4(E10.4,1X))
 910  CONTINUE
      WRITE(6,9)
      WRITE(6,940)
 940  FORMAT(//6X,"TABLE 6 - SURFACE PRESSURE DIFFERENTIAL/(RHO*(OMEGA**
     12)*(R1**2))"/6X,64(1H-)//)
      DO 950 I=1,24
      WRITE(6,960)PBOD(I)
 960  FORMAT(/5X,"AZIMUTH ANGLE=",F5.1,1X,"DEGREES"/6X,27(1H-))
      WRITE(6,810)(RBO(I1),I1=1,NSP)
      WRITE(6,970)
 970  FORMAT(11X,"X/C")
      DO 980 I1=1,NSP
      DO 980 I2=1,10
      CCH=2.*XOUT(I2)-1.
      SCH=SQRT(1.-CCH*CCH)
      POUT(I1,I2)=-G(I,I1)*SCH/(1.+CCH)+F23(I,I1)*(1.-RO)*SCH/(2.*AR)
      POUT(I1,I2)=2.*POUT(I1,I2)
 980  CONTINUE
      DO 990 I2=1,10
      WRITE(6,991)XOUT(I2),(POUT(I1,I2),I1=1,NSP)
 991  FORMAT(6X,F8.5,5X,5(E10.4,1X))
 990  CONTINUE
      IREM=I-(I/3)*3
      IF(IREM .EQ. 0)WRITE(6,9)
 950  CONTINUE
      STOP
C
C  PRINT ERROR MESSAGE IF COEFFICIENT MATRIX IS SINGULAR.
C
 570  WRITE(6,930)
 930  FORMAT(6X,"COEFFICIENT MATRIX SINGULAR")
      STOP
      END
      SUBROUTINE DMIN(MU,LAM,DB,RBO,PBO,PLIM,DMAX,I,P)
C
C  CALCULATION OF AZIMUTH POSITIONS AT WHICH TRAJECTORY IS DIRECTLY
C  OVER A BLADE, WITHIN A DISTANCE DMAX.
C
      REAL MU,LAM
      DIMENSION P(20)
      Y(X,X1,X2,Y1,Y2)=Y1+(Y2-Y1)*(X-X1)/(X2-X1)
      I=0
      P1=0.
      XB1=0.
      P2=-0.2
```

```
10   XB2=RBO*SIN(P2+DB)+MU*SIN(P2+PBO+DB)*P2
     IF(P1 .NE. 0.)GO TO 20
30   P1=P2
     IF(P1 .LE. PLIM)RETURN
     P2=P2-0.2
     XB1=XB2
     GO TO 10
20   TEST=XB1*XB2
     IF(TEST .GT. 0.)GO TO 30
     PC=Y(0.,XB1,XB2,P1,P2)
     XBC=RBO*SIN(PC+DB)+MU*SIN(PC+PBO+DB)*PC
     RBC=RBO*COS(PC+DB)+MU*COS(PC+PBO+DB)*PC
     D=SQRT(XBC*XBC+LAM*LAM*PC*PC+(RBC-RBO)*(RBC-RBO))
     IF(D .GT. DMAX)GO TO 30
     I=I+1
     P(I)=PC
     GO TO 30
     END
     SUBROUTINE SUBIVL(RB1,RB2,PB1,PB2,R,I,P1,P2)
C
C  DIVISION OF TRAJECTORY SEGMENT INTO SUB-SEGMENTS ALIGNED WITH BLADE
C  SPANWISE SEGMENTS.
C
     DIMENSION R(6),I(5),P1(5),P2(5)
     Y(X,X1,X2,Y1,Y2)=Y1+(Y2-Y1)*(X-X1)/(X2-X1)
     DO 10 J=1,5
     I(J)=0
     P1(J)=0.
     P2(J)=0.
10   CONTINUE
     DO 20 J=1,5
     R1=R(J)
     R2=R(J+1)
     IF(RB1 .LE. R1 .AND. RB2 .LE. R1)GO TO 20
     IF(RB1 .GE. R2 .AND. RB2 .GE. R2)GO TO 20
     IF(RB1 .GE. R1 .AND. RB1 .LE. R2 .AND. RB2 .GE. R1
    1.AND. RB2 .LE. R2)GO TO 30
     IF(RB1 .LE. R2 .AND. RB2 .GT. R1)GO TO 40
     IF(RB1 .LT. R2 .AND. RB2 .GE. R2)GO TO 50
     IF(RB1 .GT. R1 .AND. RB2 .LE. R1)GO TO 60
     IF(RB1 .GE. R2 .AND. RB2 .LT. R2)GO TO 70
30   I(J)=1
     P1(J)=PB1
     P2(J)=PB2
     RETURN
40   I(J)=1
     P1(J)=Y(R1,RB1,RB2,PB1,PB2)
     IF(RB2 .GT. R2)P2(J)=Y(R2,RB1,RB2,PB1,PB2)
     IF(RB2 .LE. R2)P2(J)=PB2
     GO TO 20
50   I(J)=1
     P2(J)=Y(R2,RB1,RB2,PB1,PB2)
     IF(RB1 .LT. R1)P1(J)=Y(R1,RB1,RB2,PB1,PB2)
     IF(RB1 .GE. R1)P1(J)=PB1
     GO TO 20
60   I(J)=1
     P2(J)=Y(R1,RB1,RB2,PB1,PB2)
     IF(RB1 .GT. R2)P1(J)=Y(R2,RB1,RB2,PB1,PB2)
     IF(RB1 .LE. R2)P1(J)=PB1
     GO TO 20
```

```
   70  I(J)=1
       P1(J)=Y(R2,RB1,RB2,PB1,PB2)
       IF(RB2 .LT. R1)P2(J)=Y(R1,RB1,RB2,PB1,PB2)
       IF(RB2 .GE. R1)P2(J)=PB2
   20  CONTINUE
       RETURN
       END
       SUBROUTINE NFINT(P1,P2,X,ISEL,T1,T2,T3)
C
C  INTEGRATION OF NEAR FIELD PRESSURE GRADIENT.
C
       DIMENSION F0(2),F1(2),F2(2),F3(2)
       COMMON/MAIN1/XI,XS,YS,RI,RS
       D0=(X-XI)*(X-XI)
       D1=-2.*(X-XI)*XS
       D2=XS*XS+YS*YS
       Q=4.*D0*D2-D1*D1
       IF(Q .NE. 0.)SQ=SQRT(Q)
       DO 10 I=1,2
       IF(I .EQ. 1)P=P1
       IF(I .EQ. 2)P=P2
       DD=D0+D1*P+D2*P*P
       IF(Q .NE. 0.)F0(I)=2.*ATAN((D1+2.*D2*P)/SQ)/SQ
       IF(Q .EQ. 0.)F0(I)=-1./(D2*P)
       F1(I)=(ALOG(DD)-D1*F0(I))/(2.*D2)
       IF(ISEL .EQ. 0)GO TO 20
       F2(I)=(P-D1*F1(I)-D0*F0(I))/D2
       F3(I)=(P*P/2.-D1*F2(I)-D0*F1(I))/D2
       GO TO 10
   20  F2(I)=0.
       F3(I)=0.
   10  CONTINUE
       T1=(X-XI)*(F0(2)-F0(1))-XS*(F1(2)-F1(1))
       T2=(X-XI)*(F1(2)-F1(1))-XS*(F2(2)-F2(1))
       T3=(X-XI)*(F2(2)-F2(1))-XS*(F3(2)-F3(1))
       RETURN
       END
       SUBROUTINE CPINT(P1,P2,ISEL,T1,T2,T3)
C
C  INTEGRATION OF COMMON PART PRESSURE GRADIENT.
C
       DIMENSION F0(2),F1(2),F2(2),F3(2),F4(2)
       COMMON/MAIN1/XI,XS,YS,RI,RS
       R0=XI*XI
       R1=XI*XS
       R2=XS*XS+YS*YS
       Q=4.*XI*XI*YS*YS
       IF(Q .NE. 0.)SQ=SQRT(Q)
       DO 10 I=1,2
       IF(I .EQ. 1)P=P1
       IF(I .EQ. 2)P=P2
       RR=R0+2.*R1*P+R2*P*P
       IF(Q .EQ. 0. .AND. P .EQ. 0.)GO TO 20
       IF(Q .NE. 0.)T=2.*ATAN((2.*R1+2.*R2*P)/SQ)/SQ
       IF(Q .EQ. 0.)T=0.
       IF(Q .NE. 0.)F0(I)=2.*(R1+R2*P)/(Q*RR)+2.*R2*T/Q
       IF(Q .EQ. 0.)F0(I)=-1./(3.*R2*R2*P*P*P)
       F1(I)=(-1./(2.*RR)-R1*F0(I))/R2
       F2(I)=(-P/RR+R0*F0(I))/R2
       IF(ISEL .EQ. 0)GO TO 30
```

```
      F3(I)=(-R0*F1(I)-2.*R1*F2(I))/R2+(ALOG(RR)/2.-R1*T)/(R2*R2)
      IF(Q .EQ. 0.)F3(I)=ALOG(P*P)/(2.*R2*R2)
      F4(I)=(P*P*P/RR-4.*R1*F3(I)-3.*R0*F2(I))/R2
      GO TO 10
   20 F0(I)=0.
      F1(I)=0.
      F2(I)=0.
   30 F3(I)=0.
      F4(I)=0.
   10 CONTINUE
      DF0=F0(2)-F0(1)
      DF1=F1(2)-F1(1)
      DF2=F2(2)-F2(1)
      DF3=F3(2)-F3(1)
      DF4=F4(2)-F4(1)
      T1=R0*DF0+2.*R1*DF1+(XS*XS-YS*YS)*DF2
      T2=R0*DF1+2.*R1*DF2+(XS*XS-YS*YS)*DF3
      T3=R0*DF2+2.*R1*DF3+(XS*XS-YS*YS)*DF4
      RETURN
      END
      SUBROUTINE FFINT(P1,P2,R,ISEL,T1,T2,T3)
C
C  INTEGRATION OF FAR FIELD PRESSURE GRADIENT.
C
      DIMENSION F1(2),F2(2),F3(2)
      COMMON/MAIN1/XI,XS,YS,RI,RS
      R0=XI*XI
      R1=XI*XS
      R2=XS*XS+YS*YS
      D0=R0+(R-RI)*(R-RI)
      D1=R1-(R-RI)*RS
      D2=R2+RS*RS
      SD2=SQRT(D2)
      FN1=ABS(XI*YS)
      FN2=(R-RI)*R2+RS*R1
      FN3=D1*D1-D0*D2
      Q=4.*D2*FN1*FN1
      IF(Q .NE. 0.)SQ=SQRT(Q)
      DO 10 I=1,2
      IF(I .EQ. 1)P=P1
      IF(I .EQ. 2)P=P2
      F1(I)=0.
      F2(I)=0.
      F3(I)=0.
      XB=XI+XS*P
      YB=YS*P
      RB=RI+RS*P
      RR=XB*XB+YB*YB
      U=R-RB
      D=SQRT(RR+U*U)
      T=D1+D2*P+SD2*D
      G1=ALOG(T*T)/(2.*SD2)
      G2=(D-D1*G1)/D2
      IF(XI .EQ. 0. .AND. P .EQ. 0.)GO TO 20
      IF(XI .EQ. 0.)GO TO 30
      IF(ISEL .EQ. 0)GO TO 40
      G3=ATAN(2.*(T*(SD2+RS)-FN2)/SQ)-ATAN(2.*(T*(SD2-RS)+FN2)/SQ)
      G3=4.*SD2*G3/SQ
      G4=(ALOG((D-U)/(D+U))-2.*RS*G1-R1*G3)/R2
      G5=(-R0*G3-2.*R1*G4+2.*(R-RI)*G1-2.*RS*G2)/R2
```

```
      G6=(8.*SD2*FN3*(SD2*D-RS*U)/(T*RR)+8.*SD2*FN2*U/RR
     1+4.*D2*FN2*G3)/Q
      G7=(-2.*D/RR-R1*G6-RS*G3)/R2
      G8=(-R0*G5-2.*R1*G7+2.*G1+2.*(R-RI)*G3-2.*RS*G4)/R2
      G9=(-R0*G7-2.*R1*G8+2.*G2+2.*(R-RI)*G4-2.*RS*G5)/R2
      F1(I)=(2.*G1+(R-RI)*G3-RS*G4-YS*YS*G8)/2.
      F2(I)=(2.*G2+(R-RI)*G4-RS*G5-YS*YS*G9)/2.
      G10=2.*ATAN((2.*(SD2-RS)*T+2.*FN2)/SQ)/SQ
      G11=ALOG(ABS((SD2-RS)*T*T+2.*FN2*T-(SD2+RS)*FN3))
      G12=(-2.*R1*SD2*G10+G11-(SD2-RS)*G1)/R2
      G13=(P+2.*R0*(XS*XS-YS*YS)*SD2*G10/R2-2.*R1*G11/R2
     1+(2.*R1*D2-(SD2+RS)*FN2)*G1/(D2*(SD2+RS))+RS*D/D2)/R2
      F3(I)=P*ALOG(D+U)-R1*G12-XS*XS*G13+RS*G2
      GO TO 10
   40 F1(I)=RS*YS*(YS*D+SD2*YB)/(R2*SD2*T*D)-XS*XB*
     1(RS*D-SD2*U)/(R2*T*RR)-YS*YB*U*(1.-R1/T)/(D*R2*RR)
      F2(I)=0.
      F3(I)=0.
      GO TO 10
   30 IF(ISEL .EQ. 0)GO TO 50
      G14=(T-D1-SD2*ABS(R-RI))/(T-D1+SD2*ABS(R-RI))
      G14=ALOG(G14*G14)/2.
      F1(I)=(XS*XS-YS*YS)*(-D/P+D2*G1+D1*G14/ABS(R-RI))/(R2*R2)
     1+YS*YS*G1/R2
      F2(I)=(XS*XS-YS*YS)*(D+ABS(R-RI)*G14+D1*G1)/(R2*R2)
     1+YS*YS*G2/R2
      G15=(P+RS*D/D2)/R2-(R-RI)*G1/D2
      F3(I)=P*ALOG(D+U)-XS*XS*G15+RS*G2
      GO TO 10
   50 F1(I)=(XS*XS-YS*YS)*D/(R2*R2*(R-RI)*P)
     1+YS*YS*P/(R2*(R-RI)*D)
      F2(I)=0.
      F3(I)=0.
      GO TO 10
   20 IF(ISEL .EQ. 0)GO TO 60
      G16=ALOG(T/(2.*U*U))
      F1(I)=(XS*XS-YS*YS)*(D2*G1-D1*(1.-G16)/ABS(U))/(R2*R2)
     1+YS*YS*G1/R2
      F2(I)=(XS*XS-YS*YS)*(D1*G1+ABS(U)*(1.+G16))/(R2*R2)
     1+YS*YS*G2/R2
      G17=RS*D/(R2*D2)-U*G1/D2
      F3(I)=-XS*XS*G17+RS*G2
      GO TO 10
   60 F1(I)=-(XS*XS-YS*YS)*RS/(R2*R2*ABS(U))
      F2(I)=0.
      F3(I)=0.
   10 CONTINUE
      T1=F1(2)-F1(1)
      T2=F2(2)-F2(1)
      T3=F3(2)-F3(1)
      RETURN
      END
      SUBROUTINE TABSCH(X,N,XT,I1,I2,INT)
C
C  GIVEN AN ARRAY X, TO LOCATE THE POSITION OF A VALUE XT.
C  IF INT=0, XT LIES BETWEEN X(I1) AND X(I2).
C  IF INT=1, XT IS GREATER THAN X(N).
C  IF INT=-1, XT IS LESS THAN X(1).
C
      DIMENSION X(N)
```

```
      I1=0
      I2=0
      NM=N-1
      DO 10 I=1,NM
      IF(XT .GE. X(I) .AND. XT .LE. X(I+1))GO TO 20
   10 CONTINUE
      IF(XT .LT. X(1))GO TO 30
      IF(XT .GT. X(N))GO TO 40
   20 INT=0
      IF(XT .EQ. X(I))GO TO 21
      IF(XT .EQ. X(I+1))GO TO 22
      I1=I
      I2=I+1
      RETURN
   21 I1=I2=I
      RETURN
   22 I1=I2=I+1
      RETURN
   30 INT=-1
      RETURN
   40 INT=1
      RETURN
      END
```

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16. Abstract

Computer programs have been developed to implement the computational scheme arising from Van Holten's asymptotic method for calculating airloads on a helicopter rotor blade in forward flight, and a similar technique which is based on a discretized version of the method. The basic outlines of the two programs are presented, followed by separate descriptions of the input requirements and output format. Two examples illustrating job entry with appropriate input data and corresponding output are included. Appendices contain a sample table of lift coefficient data for the NACA 0012 airfoil and listings of the two programs.

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